Institution:
University of Cambridge

Unit of Assessment:
UoA1

Title of case study:
Evidence based imaging – Impact of Body CT and MRI in clinical practice.

1. Summary of the impact (indicative maximum 100 words)

Computed tomography (CT) and Magnetic Resonance Imaging (MRI) have revolutionised the practice of medicine by providing improved diagnostic accuracy resulting in improved clinical management and outcome. The evidence-based medicine approach developed by Professor Dixon and his team contributed to the timely evaluation of these technologies. Several of his studies proved improved outcome measures, including reduced mortality, shorter in-patient stay and enhanced diagnostic confidence. Examples include: CT of patients with acute abdominal problems and possible large bowel disease; CT for suspected pulmonary embolism; MRI for lumbar spine disease; MRI for knee and shoulder problems. These informed radiological guidelines adopted across Europe.

2. Underpinning research (indicative maximum 500 words)

Professor Adrian K Dixon (Department of Radiology, University of Cambridge, UGC Funded, tenured since 1979, Professor since 1994) and his team have been at the forefront of introducing new Body CT and MRI techniques into the UK for the last three decades. His main research contribution has been to pioneer the rigorous evaluation of evolving imaging techniques in patients, wherever possible by randomised trials comparing the effectiveness and cost effectiveness of the novel imaging against the existing conventional management pathway. He also pioneered the development of image guided interventional techniques.

Technology Assessment

In 1995 Dixon developed templates for assessing technical efficacy, diagnostic impact, clinical impact, therapeutic impact and impact on health outcome of imaging technology using MRI of the knee as the exemplar (1). This framework facilitated further work by Dixon into the cost effectiveness of CT and MRI in 1997 (2). In 1998 Dixon reported a large clinical trial demonstrating the superiority of CT over nuclear medicine techniques for the diagnosis of pulmonary embolism (3). In the area of abdominal pain, Dixons randomized controlled trials demonstrated the effectiveness of early CT imaging in patients presenting with acute abdominal pain (4) Working with W Hollingworth (Department of Public Health and Primary Care, now at Bristol), an MRC funded research fellow, Dixon showed that MRI improved diagnostic accuracy and confidence in patients with knee, cervical and lumbar spine problems and multiple sclerosis and then assessed the health outcomes for a variety of MRI indications (in 2017 patients) (5).

Novel applications of CT

In 1993 with KA Miles (radiology trainee at Cambridge, now Professor of Radiology, Brisbane and honorary appointment, UCL) he developed a dynamic contrast CT method for quantifying arterial and portal blood perfusion of the liver in 24 patients (some with cirrhosis); producing a high resolution functional map of the liver (6). Rapidly acquired data using CT allowed Dixon with his physics team to develop software to quantify contrast enhancement in tissues. In 1993 Dixon pioneered the use of image guided biopsies to replace open surgical biopsy in children, demonstrating the importance of guided needle placement to accurately obtain diagnostic specimens safely (7) leading onto development by Dixon of CT guided drainage procedures. In 1994, in collaboration with M Fink (Radiology trainee at Cambridge, now paediatric radiologist, University of Melbourne) Dixon developed CT colonography and showed that this was a safe effective technique in frail, elderly patients (8).

Both Siemens (CT) and General Electric (MRI) have collaborated extensively with Dixon with regards to long-term provision of their most modern research hardware and software on a rolling programme in recognition of the pioneering work performed on their equipment in Cambridge and there is on-going collaboration with regard to cardiac and body MRI (Martin Graves, David Lomas, Fiona Gilbert).

3. References to the research (indicative maximum of six references)

1. Mackenzie R, Dixon AK. Measuring the effects of imaging: an evaluative framework. Clin Radiol 1995;50:513-8.
2. Dixon AK. Evidence based diagnostic radiology. Lancet 1997;350:509-512
3. Cross JJ, Kemp PM, Walsh CG, Flower CD, Dixon AK A randomized trial of spiral CT and ventilation perfusion scintigraphy for the diagnosis of pulmonary embolism. Clin Radiol 1998; 53:177-82.
4. Ng CS, Watson CJ, Palmer CR, See TC, Beharry NA, Housden BA, Bradley JA, Dixon AK. Evaluation of early abdominopelvic computed tomography in patients with acute abdominal pain of unknown cause: prospective randomised study. British Medical Journal 2002; 14:325: 1387
5. Hollingworth W, Todd CJ, Bell MI, Arafat Q, Girling IS, Karia KR, Dixon AK. The Diagnostic and Therapeutic Impact of MRI: an Observational Multi-centre Study. Clin Radiol 2000:55:825-831
6. Miles KA, Hayball MP, Dixon AK. Functional images of hepatic perfusion obtained with dynamic computed tomography. Radiology 1993;188:405-11.
7. Somers JM, Lomas DJ, Hacking JC, Coleman N, Broadbent VA, Dixon AK. Radiologically guided cutting needle biopsy for suspected malignancy in childhood. Clin Radiol 1993;48:236-40.
8. Fink M, Freeman AH, Dixon AK, Coni NK. Computed tomography of the colon in the elderly: computed tomography as the first investigation. Br Med J 1994;308:1018

Dixon's intensive charitable fund raising, research grant income and industrial support to the value of over £20M over the last 20 years has allowed patients and research workers throughout the Cambridge University Hospitals Biomedical Campus to benefit from the latest CT and MRI technology. Research gained from industry included funding of the Professorship of Clinical Magnetic Resonance Imaging (Nycomed Amersham) - current holder Professor David J Lomas (£1M) and a programme of research studentships in MRI funded by GE.

4. Details of the impact (indicative maximum 750 words)

Dixon's research has had a direct and major impact on how patients with a variety of different common and life threatening conditions are investigated radiologically throughout the UK and Europe. The evaluative frameworks he developed, together with his clinical research, have informed clinical guidelines. The resulting changes in clinical practice have resulted in benefits regarding both health outcomes and cost-effectiveness.

Impact on Health and Welfare

Outcomes for Patients have Improved & New Diagnostic Technologies have been Adopted

His CT research, in particular his randomised controlled trial (Ref 3 Section 2) is recognised by the Guidelines as having contributed to a major change in the way that patients are now investigated for suspected pulmonary embolus. Pulmonary angiography and then ventilation/scintigraphy, a nuclear medicine technique were abandoned in 2009 in favour of pulmonary CT angiography (1). Similarly his work is still influential in the use of CT imaging in patients with acute abdominal pain (2).

There are now numerous CT-based diagnostic and interventional procedures in widespread use, whose introduction to clinical practice was pioneered by Dixon and reported in medical journals. This includes the biopsy of retroperitoneal lymph nodes, deep seated paediatric tumours and other malignant lesions without the need for formal surgery and often under simple local anaesthesia. Dixon developed CT drainage procedures that were initially experimental but are now standard clinical procedures (4,5). Such help to the surgical community has allowed considerable progress in transplant, pancreatic and other complex surgery because postoperative complications can be treated by interventional radiological procedures (usually CT guided).

Impact on the Economy

The Costs of Treatment or Healthcare has Changed as a Result of Research-Led Changes in Practice

Dixon's work has also made an important contribution to the health economics of radiology. High cost diagnostic tools must be used appropriately, ideally replacing existing less effective technologies, rather than being additional. Dixon's studies, for example those on lumbar spine MRI, the investigation of auditory canal tumours (acoustic neurinomas), MRI knee and shoulder problems have all shown that appropriate and prompt (e.g. immediately upon hospital admission) use of high technology can save the patient numerous less effective and cumulatively expensive investigations and subsequent outpatient appointments. This is corroborated by independent health economic analyses of the strategies pioneered by Dixon.(3,4)

Impact on Practitioners and Services
Professional Standards, guidelines or training have been influenced by research

In 2001 Dixon was asked to develop the pan-European *Referral Criteria* by the European Commission (3). This guidance document remains current and continues to be extensively used by imaging departments around Europe.

Dixon chaired the highly successful Royal College of Radiologists "*Making the best use of the Department of Clinical Radiology: Clinical Guidelines"* (4) originally issued free-of-charge to all general practitioners and now available online as iRefer (5). This gives information on which imaging pathway to follow for different clinical problems. The process that was used to create the guidance was accredited by NHS Evidence-National Institute for Health and Clinical Excellence (NICE) in June 2010 (6).

The UK and European guidelines are greatly influenced by Dixons research (Ref 1-8, Section 3) in two areas 1) The early evaluation of CT and/or MRI compared to established imaging strategies in a wide variety of common and life threatening conditions led to increased appropriate use of these sophisticated techniques in secondary care. 2) The increased use of CT or MRI to extend the remit of imaging to assist with diagnosis and treatment of patients with clinical problems where previous imaging techniques were unable to make significant contributions. As evidenced by numerous citations in the Guidelines, the studies undertaken by Dixon made major contributions to CT becoming the preferred investigative tool in the evaluation of: an abdominal mass, the acute abdomen, the adrenal gland, aortic aneurysms and dissection, appendicitis and large bowel problems, particularly in the elderly (3,4,5).

Dixon also realised the potential applications of CT technology to radiotherapy planning and to quantify functional aspects of tissues. For example his pioneering work with Professor Ken Miles on perfusion CT was the proof of concept demonstrating that in vivo clinical imaging could measure changes dynamically, resulting in this technique being tested as a potential biomarker in clinical trials in 2010 (7). Intriguingly the industrial partners did not originally see the need for such detailed analysis and thus the software for this technique, pioneered in Cambridge, was made freely available to the research community and healthcare systems; it can now be incorporated on most clinical CT and MR systems.

The research collaboration in Cambridge with industry provided extremely valuable feedback on their prototypes which was essential for both Siemens and GE leading to significant improvements in their MR and CT machines.

The Government became extremely concerned about cancer waiting times in 2000. Dixon worked with the Department of Health (DH) to advise on CT specifications in a national scheme which oversaw the installation of £1.5 billion of CT equipment (personal work with the National Cancer Tsar, Sir Michael Richards and others in the DH). When the Government's scheme for outsourcing MRI services ran into early problems in 2003, the DH again turned to Dixon to provide leadership and quality control. The technical lead for Imaging in the Department of Health states that Dixon was responsible for implementing increased CT availability and MR for NHS England (8). On part-time secondment to the DH (2004-2007) as MR Clinical Guardian, he helped introduce audit and dual reporting for remote teleradiological sites to raise standards and ensure a high quality service from external providers (9). Dixon showed that the standard of routine NHS reporting was high but

the turnaround time was slow; this led to increased government funding to allow NHS machines to be used for an extended working day– the forerunner of the now imminent 7 day working for Radiology Departments (see letter from the Minister of State for Health), (10).

High cost diagnostic tools must be used appropriately, ideally replacing existing less effective technologies, rather than being additional. Dixon's studies on Lumbar spine MRI, the investigation of auditory canal tumours (acoustic neurinomas), MRI knee and shoulder problems have all shown that appropriate and prompt (e.g. immediately upon hospital admission) use of high technology can save the patient numerous less effective investigations and subsequent outpatient appointments. Dixon's work has also shown that these novel uses of CT and MRI can save costs for society.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Henzler T, Schoenberg SO, Schoepf UJ, Fink C. Diagnosing acute pulmonary embolism: systematic review of evidence base and cost-effectiveness of imaging tests. J Thorac Imaging. 2012 Sep;27(5):304-14. doi: 10.1097/RTI.0b013e31825da2bc.

2. Stoker J, van Randen A, Laméris W, Boermeester MA. Imaging patients with acute abdominal pain. Radiology. 2009 Oct;253(1):31-46. doi: 10.1148/radiol.2531090302.

3. European Commission. Referral guidelines for imaging. Radiation Protection 118. Luxembourg: Office for Official Publications of the European Communities. 2001-125pp. ISBN 92-828-9454-1. These guidelines remain current to date.

4. Remedios D, Barter S, Dixon AK et al. Making the best use of clinical radiology services (Referral Guidelines). *The Royal College of Radiologists 2007; Sixth Edition.* http://www.rcr.ac.uk/content.aspx?PageID=995-

5. iRefer, 2012 see http://portal.e-lfh.org.uk/

6. https://www.evidence.nhs.uk/documents/accreditation/reports/nice-data-users-profilefolders-mderry-desktop-maggie-rcr-final-accreditation-report-1.3.pdf

7. Padhani AR & Miles KA. Multiparametric imaging of tumour response to therapy. Radiology 2010 256:348-364

8. Letter from Imaging technical lead, NHS contracting, Department of Health

9. Dixon AK, FitzGerald R. Outsourcing and teleradiology: potential benefits, risks and solutions from a UK/European perspective J Am Coll Radiol. 2008; 5(1):12-8.

10. Letter from, Minister of State for Health, Department of Health