Open Magnetic Resonance Imaging – Thinking Outside the Tunnel

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Open, upright magnetic resonance imaging (MRI) was first introduced by FONAR (FONAR Corporation, Melville, New York, USA) in the mid 1990s, but has recently received attention in the press and at meetings of the imaging community following the introduction of a new generation of upright systems.

The use of open, upright MRI has expanded slowly in the UK and Southern Europe and it is rarely, if ever, found on National Health Service (NHS) sites. Its intricacies are traditionally of little interest to most radiologists, some of whom seem sceptical of its value. However, these scanners do have their supporters, mainly for the additional findings they can reveal and the special patient circumstances they can accommodate, even though research has so far failed to consolidate any particular diagnostic benefit.

Up to 10% of the population are claustrophobic at some point during their lives[1] and specific research into claustrophobia in MRI has concluded that on average 1.2 to 2.3% of MRI examinations are abandoned due to patient anxiety but may be as high as 15% in some centres[2,3]. Based on NHS figures for MRI activity in 2013-14[4] this would equate to at least 32,892 patients failing to complete or even start their MRI scan. With an increase in MRI referrals of about 12% per year[4] this figure is growing, which suggests there is viability to a service that, as well as being able to provide upright scanning, may also accommodate the majority of these claustrophobic patients.

Here, we discuss an open, upright scanner service which, like most others in the UK, operates in the private sector. Our facility is unusual in that it is operated by a higher education institution that is also a charity and not a for-profit business. We believe that this has helped us to take a fairly impartial view of the role of open, upright MRI in patient care.

Procurement

Setting up a completely new MRI unit in a non-NHS establishment came with a long list of challenges that needed to be overcome, to ensure that a safe and appropriate service was created.

In the first instance, it was necessary to persuade the governors of the Anglo-European College of Chiropractic (AECC) that it would be a good idea to spend a vast amount of money on a project that was far removed from anything they had done before, and in a field in which they had no experience. They approved the project for three main reasons: The first was to enhance the College's undergraduate, postgraduate and research provision, the second to fulfil an unmet health need in the local area and the third to bring to reality an innovation that would both serve the objectives of the charity and be financially sustainable.

The AECC is a higher education college in Bournemouth whose graduates (chiropractors) are publicly regulated. Missing in the facilities available to them as

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practitioners, but gradually becoming more accessible (if not always affordable), were MRI services. Learning to use MRI in a way that would prepare them to meet the required standard of safety and governance was therefore desirable. The College already had plain radiography and diagnostic ultrasound, and had just constructed a new outpatient clinic, in which there was room to extend further. It had also developed an innovative application of fluoroscopy, which allows the mechanics of spinal linkages to be measured. This was a main pillar of its research and collaboration profile and would be enhanced by the addition of MRI.

The business case for installing yet another MRI scanner in the Bournemouth and Poole area was initially unconvincing. There were already eight MRI scanners both private and NHS within a six mile radius of the AECC – and it was difficult to see how the College could attract local referrals with so much choice. Whilst the machine's purchase would be through charitable funds, once installed it would need to become self-sufficient, so it was necessary to have clear objectives about the MRI service we were hoping to offer and how we would differentiate ourselves in an already crowded local market. The solution appeared when the prospect of an open, upright magnet presented itself.

Apart from providing an affordable self-pay service to musculoskeletal (MSK) patients of local practitioners, an open, upright scanner could accommodate patients who would never otherwise receive MRI. These include patients with severe claustrophobia, certain deformities and conditions that would prevent them from lying flat. However, there was an important trade-off. Lower field scanners are limited for some purposes and the college environment is not suitable to support administering intravenous contrast, so careful consideration was needed around whether such a scanner would be economically viable. However, the majority of MRI referrals are for MSK conditions and the added capability of upright scanning ensured that if the correct machine could be found, the benefits of an

open, upright scanner should outweigh the disadvantages in terms of sustainability.

In addition, choosing an open, upright scanner would allow the College to have a unique MRI service, not only in the local area, but in the whole South-West of England. At the time of tendering for the system, there were only two manufacturers who were able to offer MRI that might fulfil the College's clinical and research requirements. A small team was put together, including a radiologist and a senior MRI radiographer, to assess the machines and provide the College with guidance on which system might best suit their needs.

The Paramed 0.5T open, upright MRI system (Paramed Medical Systems, Genoa, Italy) was eventually selected, its unique design lending itself well to the positional spinal scanning research the AECC was already conducting, with the potential for further development of these studies. Therefore an extension was built onto the College's dedicated chiropractic clinic and in April 2014, the 26 tonne magnet was lowered into the pit that would house it. The magnet design is superconducting but it is a closed system so there is no loss of helium once the system is set up.

The table design facilitates positional scanning of the patient from completely upright (for weight-bearing lumbar or thoracic spines) to semi-recumbent (for brain and cervical spine imaging in claustrophobic patients) to completely supine (Figure 1). The table can also be lowered to allow weight-bearing imaging of the knee or removed totally from the scanner bore to image the lumbar spine with the patient standing. The spine coil design also facilitates the upright and positional scanning as it is flexible, and can be positioned close to the patient, even if there is a significant curvature.

The College employed a radiographer with extensive experience in MRI and research to set up and run the department. Eighteen months into the project a second senior MRI radiographer joined the team. Four local radiologists came on-board to provide reporting services, and a picture archiving and communications system (PACS) with voice recognition was installed to ensure best quality viewing capabilities, reporting facilities and image storage. The unit also organised connection to the Image Exchange Portal to ensure efficient image transfer to hospitals to provide streamlined and effective continuity of patient care.

The operational remit for this project was exceedingly varied and there was a requirement to ensure that the role of MRI within the College was clearly established, and that all correct procedures were adhered to by the chiropractors when utilising the

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Table 1

To be able to scan patients:

- With claustrophobia (without resorting to sedation).
- With deformities that prevent them from fitting into a tunnel scanner (eg contractures, severe kyphosis).
- Who cannot lie flat for physiological reasons (eg cardiorespiratory/oesophageal reflux/hiatus hernias/dizziness).
- Whose diagnosis needs a scan with loading or non-orthogonal positioning.

service. This required a certain amount of education of the chiropractic referrers who may not have had the opportunity to request MRI examinations previously. This was achieved through written articles[5], in-house presentations, lectures and workshops.

Analysis of service

The College has been providing the service for well over two years now and several aspects are worth specific attention. An open, upright scanner is much less intimidating and with the capability to be flexible in our method of scanning, we have been able to detect significant pathology that might not have been identified otherwise in many of these patients. We have found large disc prolapses, spinal stenosis and even spinal tumours in patients who, due to claustrophobia, were unable to tolerate conventional MRI. An open scanner is a safer option than sedation on a conventional scanner. Also, the ability to scan sitting or in flexion/extension can detect instability not apparent on a supine conventional scan.

Being situated in a chiropractic college, the referral base is very different from an NHS hospital. About 50% of patients are referred by chiropractors from the College and surrounding areas who would not normally have access to MRI. Also, now that the facility is more widely known, an increasing number of patients are being referred by hospital spinal surgeons and rheumatologists. In addition, general practitioners make referrals for a number of reasons; some may not be able to refer to NHS hospitals for scans, some may have difficulty obtaining a timely scan even if they may request MRI directly, and others may struggle to get a timely consultant referral. Necessarily, the scans are private but the cost has been set at an affordable level. Many NHS hospitals are now funding referrals for claustrophobes or patients especially suited to this scanner.

All scans are reported by practising NHS consultant radiologists from local hospitals in their spare time, to ensure reporting quality is equivalent to the standard within the NHS. Image quality is satisfactory and diagnostic although the images do appear a little different from what is seen on a more powerful 1.5T scanner. The image sequences may often be different using the Dixon technique[6,7] but this does have the advantage of providing four sets of images, including a form of fat suppression.

An NHS hospital is unlikely to buy an open low field MR scanner as it cannot perform all the more technical scans including cardiac, abdominal, vascular and diffusion weighted studies. However, there is clearly a need for an open scanner in every geographical region for claustrophobic patients and to detect MSK-related instability. The types of patients seen and the longer scan times required by the 0.5T magnet, means that we are in the enviable position of being able to allow much longer time slots for each individual compared to those allocated commonly within the NHS. Many of our patients have failed to complete MRI in conventional scanners or have refused to even attempt a scan. Accordingly, we give patients long appointments (our shortest appointment slot is 60 minutes) so we can spend time putting them at ease, fully explaining the examination and discussing the best and most comfortable way to scan them. Good communication is vital and by conveying a sense of calm and relaxation, we aim to allay their anxiety from the outset[8].

Previous studies assessing the advantages of using open configuration MRI have documented the improved tolerance of patients for this type of MRI[9] and in our own experience so far, we have not failed to perform an MRI scan on any of our patients. In order to get the best quality images, we prefer to achieve our anatomical imaging in the supine position, but within reason we can be flexible depending on an individual's needs.

How often is upright scanning useful?

Aside from the obvious benefits of having an open scanning facility, the College was also very interested in assessing whether there were significant imaging differences between supine and weight-bearing lumbar spine studies. Many patients present with pain experienced only when sitting or standing, or indeed when in flexion or extension, so did scanning them in the position of pain demonstrate pathology differently? By retrospectively assessing our positional scanning over a seven month period initially we were able to make some interesting comparisons.

Discussion of the merits of open, upright scanners centre around the premise that weight-bearing scanning is frequently decisive for diagnosis. However, the principles of good clinical governance suggest that selection and justification are more likely to be deciding factors. The same is true for open and/or upright scanning, which tends to be requested for patients with special requirements and not as a replacement for general MRI. A sample of these requirements is listed in Table 1. Between 40-45 % of our referrals for open, upright scans have been because of claustrophobia. While sedation is an option for some patients and encouragement and reassurance works for others, when MRI is necessary, it is necessary and should not be delayed if an open, upright scanner is the

only way available to achieve it. In addition, many spinal patients who are referred for open, upright scanning are elderly and reclined sitting is a common scanning posture. Age sometimes results in severe kyphosis, where the spine cannot be imaged in a conventional scanner to investigate the cause (Figure 2).

Nerve root pain

Most patients referred for weight-bearing lumbar or cervical spine scans have suspected neural compression, either due to segmental alignment or stenotic lesions. In a small case series we conducted in 2015 and 2016 (N=45) about 60% of these patients showed nothing different in terms of stenosis between lying and weight-bearing scans. In the rest, compression was more common in the weight-bearing position and less frequent lying down (Figure 3).

Neural disruption was more common than malalignment, but sometimes both were present. Figure 4 shows an example of this as L3 nerve root compression that is apparent only on weight-bearing lumbar extension, partially due to the bulging disc and partially to the retro-position of the vertebra.

Such cases might benefit from the investigation through enhanced conservative management in the light of the findings, making upright scanning a potentially useful tool for chiropractors, osteopaths and physiotherapists working in the community, while referral by surgeons and rheumatologists for upright scanning for suspected nerve compression is perhaps more often made due to claustrophobia or deformity.

Conclusion

Open, upright scanning is an invaluable and innovative imaging modality for key groups of patients who may otherwise not benefit from MRI diagnosis. Ours is a truly patient focused service whilst at the same time being cost effective and accessible. The current hardware, software and physical limitations of this kind of system mean that it is unlikely to expand into the more complex fields of MRI. However, it is clear that open, upright scanning has a useful place in the MRI community and, as research continues into the benefits of postural scanning, there will undoubtedly be new applications identified for which this scanner is uniquely suited.

Figure 1: Bournemouth open, upright MRI scanner with table in the upright position and flexible spine coil in situ.

Figure 2: Example of a weight-bearing sagittal T2 sequence on a patient with severe kyphosis.

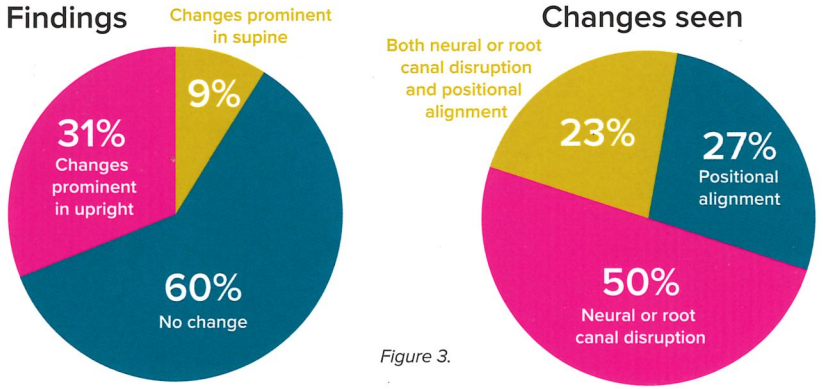
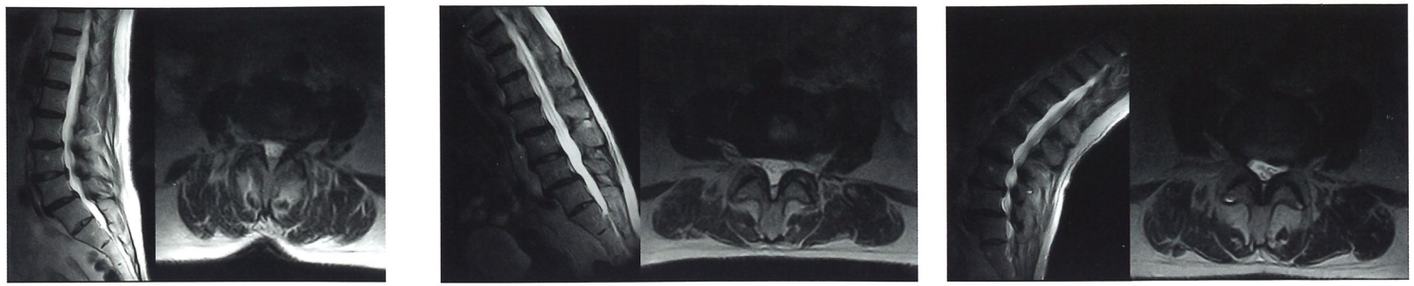


Figure 3.



Supine Sagittal T2 | Supine Axial T2 L3/4 | Flexion Sagittal T2 | Flexion Axial T2 L3/4 | Extension Sagittal T2 | Extension Axial T2 L3/4

Figure 4: Example of nerve root compression that becomes more severe in weight-bearing extension and lessens in weight-bearing flexion.

Debbie Horne is a Senior MRI Radiographer who qualified in Ipswich in 1988. She has over 20 years' experience of MRI in Swindon and Salisbury (NHS) and was a volunteer providing MRI services to athletes at the London 2012 Olympics. Debbie assisted with the initial procurement choice of the Paramed MRI and eventually joined the team at the Bournemouth Open Upright MRI in 2015.

Mel Jones qualified as a Radiographer in 1996, commenced MRI training in 2002 and went on to gain an MSc in Magnetic Resonance Imaging. Since then Mel has managed NHS and private MRI departments, as well as a research MRI unit for Oxford University (Acute Vascular Imaging Centre). She came to the AECC in 2014 as Superintendent MRI Radiographer to set up the Bournemouth Open Upright MRI.

Andy Morris trained in Medicine and Radiology at Liverpool Medical School and has been a Consultant Radiologist at Salisbury District Hospital since 1984. He has had a special interest in musculoskeletal imaging and MRI for over 20 years and was a key investigator in the research and development of the AECC's quantitative fluoroscopy systems.

Alan Breen is Professor of Musculoskeletal Research at the AECC as well as in the Faculty of Science and Technology at Bournemouth University. His specialty is the intrinsic biomechanics of the spine, which has been the focus of many research projects and a substantial proportion of his 112 journal publications and over 240 conference papers. Alan is also Clinical Director for Special Imaging at the AECC, with responsibility for quantitative fluoroscopy and MRI services, having led the procurement of the first upright MRI scanner at a chiropractic college.

Compression was more common in the weight-bearing position

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