

MRIS History UK

THE DEVELOPMENT OF MAGNETIC RESONANCE IMAGING AND SPECTROSCOPY

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Riding the wave: a career spent under the development of British MRI.

Part one: developing the Oxford MRI Centre.

Biography

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1 Background.

I feel enormously lucky to have passed my career in what must surely be regarded as one of the golden ages of Radiology. The fact that this career developed more by accident than design does not detract from the enjoyment of looking back over this period. Although the retrospective view so often in life makes past events appear smaller than they appeared at the time, I find myself more impressed rather than less when I look back over the last 50 years of medical imaging.

For this reason I believe that my personal experience of founding a new Magnetic Resonance Imaging (MRI) service when the technique was young is worth recounting. Many of us who practised during this time have stories to tell but each of us tells them from an individual perspective. These views each contribute to the social history of our subject, which is why I am very pleased to be able to offer this personal view to the present collection of individual histories.

In 1975 I found myself becoming dissatisfied with the options of my training in surgery and was considering a move to Radiology. Computed Tomography (CT) scanning of the head had arrived in 1973 and Radiology had become a fast-moving specialty. Accordingly, I decided to make the move without completing FRCS. My surgical mentors were utterly horrified by my decision: I was told that I was wasting my clinical skills and throwing away my career. Such attitudes were commonly expressed in 1975 but few clinicians would say this about Radiology today.

That year by way of preparation I took a course in radiation physics and protection at the UK Atomic Energy Authority in Oxfordshire. On the middle day of the course the Times newspaper published the first images of CT of the body from EMI. Reading the page with interest, it never occurred to me that I would end up directing the new service in the area where I was attending the course but that is how it turned out. By 1979 I had completed my training in Radiology at Guy's Hospital but was too young to find a consultant post. I was fortunate that the department, which had no CT then, had established an attachment to the CT unit at the Royal Marsden Hospital, Surrey, so that its trainees could learn CT under the guidance of Dr Janet Husband (later Prof Dame Janet). On my second week in this attachment Janet asked if I would be interested in the senior research post she had just obtained and so I went to the Royal Marsden to fill in time by spending a couple of years in research before looking

for a consultant post. I completely overlooked the fact that this move would project me onto the growing edge of my specialty and that I would never return to general radiology. After two years, Oxford was looking for a trained specialist to set up their first general-purpose CT service and I was fortunate enough to be appointed to this academic consultant post in 1982.

And what exciting times these were! We were seeing anatomy and pathology in a way we had never done before and every day was a new learning experience. We learned to interpret disease from a new angle, including, we discovered, that some of the diagnostic signs we had depended on in general radiology actually had no scientific basis at all.

2 Local MRI begins.

As if this was not enough, my generation in CT was also fortunate that our position in cross-sectional imaging meant that many of us were entrusted with the development and leadership of MRI services as scanners became available. It is not for me to tell the story of how MRI developed in the UK: there are others among these histories who are far more qualified to do so. However I was of course aware of the developments and early in my time at Oxford I wrote a discussion paper for the Regional Health Authority (RHA), who had entrusted me with providing advice on how to expand cross-sectional imaging (then understood as CT) throughout the Oxford health region.

In Oxford modern imaging had an insuperable geographical challenge. Neuroradiology was based in the Radcliffe Infirmary, the historic hospital site in the town centre, where CT was provided with a second-hand EMI head scanner which had come from Manchester. My general-purpose CT unit was at the Churchill Hospital, the oncology centre, whereas the acute general centre, the John Radcliffe Hospital in Headington, was two miles away and orthopaedic surgery was based at a fourth site, the Nuffield Orthopaedic Centre. Although these three latter units were only a few minutes' travel by road, I therefore had the challenge that my local clinical referrers (I also had to deliver a service to the entire Oxford health region) were divided into four centres. There was, naturally, a wish in all four hospitals to establish their own CT service and the RHA had already agreed that the Radcliffe Infirmary would get the next general-purpose CT scanner it could afford.

In my discussion paper I argued that in view of the rate of development of MRI it was justifiable for a relatively small health district of 500,000 people to have some access to MRI rather than invest totally in CT. Oxford was, after all, a tertiary referral centre and also a university hospital. My paper had been intended to set people thinking about the benefits of ultimately getting MRI but there were significant feelings in the radiology departments across the group who had been patiently waiting for the next CT scanner and my suggestions ruffled feathers in the units. However what I had written caught the imagination of the RHA, who put together a group of us to explore the possibilities of obtaining MRI in the near rather than distant future.

When I arrived in Oxford I had discovered that the group possessed an outstanding imaging and electronics technician, Dermot Dobson. Dermot was so well-regarded throughout the imaging industry that Oxford got significant reductions on its service contracts with the suppliers because they were called out less frequently with him on site. He naturally became a member of the MRI group. We were joined by the Regional

Scientific Officer (RSO), Colin Blake, a quiet and contemplative University chemist who did the Regional job on a part-time basis. While this might have looked unsatisfactory it had the great advantage that Colin had no particular axe to grind between services and I rapidly discovered that he was well regarded amongst RSOs. We were completed by a dynamic supplies officer, Dennis Moles, who with Colin Blake had formed an effective negotiating team when it came to getting the best contracts out of the companies. With this trio and radiology colleagues where possible we began to explore MRI installations across the world to gather ideas on purchasing a system and setting up a service.

Our first visit was to Aberdeen, where the pioneer physicist John Mallard had created an imaging system which was being explored clinically with Frank Smith, the local nuclear medicine specialist. Their equipment, which was based on a resistive magnet, was primitive when compared with what was being developed elsewhere but very clearly demonstrated the potential of the new imaging technique. As we left Colin Blake turned to me and remarked, "it's no longer if, it's when". Whether or not Colin influenced views in the authority, the RHA decided in 1985 to include MRI in its capital programme, to be installed as part of the general acute services at the John Radcliffe Hospital.

This decision was not universally welcomed. The Accident and Emergency team not surprisingly took the view that CT was what they really needed and that their purchase would be compromised by investment in MRI. In fact, the acute centre did get its CT service in a reasonable time as a result of a few high profile problems which occurred due to lack of CT.

To start with we had to explore the market and we knew that we were in the special position. The University's Biochemistry Department had developed nuclear magnetic resonance under the leadership of Sir Rex Richards and out of this had come Sir Martin Wood's company Oxford Magnet Technology, which was producing many of the magnets for scanners. Fundamentally Martin, who had been a technician in Biochemistry, proved to be better than anyone else in winding magnet coils, with the result that the department received so many orders from other centres for his work that eventually he was obliged to set up the company. Further, Oxford was one of the very few centres where NMR spectroscopy of muscle was being explored under the leadership of Prof George Radda. We knew that installing the first imaging system in Oxford would have a high profile, and were fully determined to translate this into financial benefit in the purchase.

MRI had attracted the attention of Margaret Thatcher's administration and was widely held to be a British invention. In fact, the genesis of MRI is complex, far more complex than that of CT with Godfrey Hounsfield (and even with CT there are international contributions to be acknowledged). However EMI, and departments at Aberdeen and Nottingham under the leadership of Sir Peter Mansfield had made major contributions, as had Hammersmith Hospital and the General Electric Company in Wembley, which was regarded as the leading British company of the time. GEC merged together its own Medical Division with Picker Corporation of Ohio and the MRI group from EMI to form Picker International. Naturally, those who worked with the UK systems, such as Ian Young at Hammersmith were determined to maintain the British representation as powerfully as they could.

My opinion at the time was that the case of British industry was to be recognised but took second place to a basic principle of clinical practice: when a new service is based on a single piece of equipment the after-sales support provided by the company is a key element of maintaining an effective service. In short, we had clinical responsibility to take a dispassionate and objective view of the market. It was clear that superconductivity was the way forward (John Mallard's company in Aberdeen was not to survive) and while we were determined that the first MRI scanner in Oxford would contain a magnet from Oxford Magnet Technology, we felt an over-riding responsibility to the future. We also had the example of EMI before us: by the early 1980s the company had lost control of the CT market and had been obliged to surrender their interest to the major imaging producers. EMI had arguably taken some wrong turnings in their development and also suffered from the worst possible luck when a dynamic young executive appointed to rejuvenate the company suffered a fatal heart attack on a flight between the USA and the UK.

We were very aware that the history of the imaging industry told us that in what was becoming a crowded market there would ultimately be only a few MRI providers who would be dependable for support in the future. This proved to be the case: of the 10 companies we looked at early in our market survey only three proved to be robust survivors. In the end the decision was effectively taken out of our hands by the confidential tendering process, when the American company International General Electric offered a purchase package for a 1.5 Tesla system which was well in advance of any of the competition. At that time IGE was said to have the largest number of employees in imaging production (of all types) in the UK, so we were at ease with this decision. In fact, Colin Blake and I were called to the Science and Technical branch of the Department of Health to explain our purchase to Gordon Higson, not on the choice of supplier - I doubt that even that particular government could have justified that - but to show how we had been conscientious in our process, which I'm glad to say we were able to do without difficulty.

At this distance it seems difficult to appreciate just how much emotion affected the UK scene in MRI at that time. On one memorable occasion I was called out of the governing body meeting of my Oxford college, despite being governing body secretary (an event generally unthinkable in the ordered routine of an Oxford college) to find myself being given a roasting from a surprisingly high level. It appeared that rumours had been circulating about possible cost advantage to us of buying a system from IGE which was based on an Oxford magnet and might reduce the price offered by IGE. This was commercially sensitive and it became clear that, although innocent, I had become a focus for anger by virtue of being the person leading the Oxford MRI development. The call left me depressed but also feeling that there was far too much emotion doing the rounds. Similarly, during our visits to MRI installations I was attacked by the regional manager, who wanted to know how I could possibly justify taking a scientific officer and supplies officer on these trips. My argument was that site visits were the best opportunity for raising the companies' competitiveness to fever pitch and that our two best players happened to be the two members of her staff. At the time there was a great deal of sensitivity among health authorities about the possibility of "undue influence" on professionals who were engaged in choosing equipment. This was due largely to a couple of high-profile cases which had occurred. I

was inclined to take this with a large pinch of salt on the basis that apart from the few rotten apples who occur in all professions no real radiologist would ever choose a piece of kit with which they would have to work for years on the basis that the suppliers given them a slap-up lunch.

These were turbulent years in the industry and there was a sad follow-up. When IGE had established a reasonable number of sites in the UK they set up an MRI users' group and invited me to become its chairman. The annual meetings were a useful forum for colleagues to compare notes on what they were doing in their departments and also to hear the company's plans for future development: MRI was still young and we were all keen to hear what improvement was coming next. The sad year occurred when GEC decided to move its MRI activities to Picker International Headquarters in the USA, leaving just a small sales and service organization in the UK. IGE eventually picked up the servicing of the Picker scanners. Colleagues from those sites came to the meeting for the first time and it became clear during the company presentation that although IGE intended fully to honour its agreement to service the Picker scanners there was to be no further development of those systems. The look on the faces of colleagues who were doing good work on those scanners was heart-rending as they realised that their services were in effect fossilised. Such situations are hard but occur when clinical idealism meets the realities of commercial survival. I was heartily glad that circumstances a few years before had not put us in a similar position.

3 Building the centre.

With a decision made and the scanner chosen we thought it would all be downhill but our challenges had only begun: we came up against the form of capital planning which existed in the NHS in those days. I had never understood the apparent disconnect between the NHS approach to revenue, in which any expense, no matter how small, had to be justified in advance, and capital planning in which there appeared to be no control over costs until belatedly it was realised that projects were well over budget. Such circumstances often applied to public building work.

The arrangement of buildings on the John Radcliffe site committed us to a stand-alone unit and we had assumed that this would be a small building which might perhaps form a focus for future development of imaging on site. In fact the Regional Health Authority were determined to make Oxford's first MRI centre a prestige development. They retained a single firm of consulting architects on the basis that this maintained uniformity of the site (an argument not exactly supported by the fact that a chocolate-brown MRI centre was installed among the white-tiled buildings of the hospital). Such close relationships can work to the advantage of the service but also contain risks. It became rapidly clear that the word of the consulting architect was virtually law and we had to fight to put across our needs. The fact that the company had never designed an MRI centre before made no difference whatsoever; their view was that it was comparable to an operating theatre.

I had worked with architects before and knew that sometimes they could be rather like hairdressers in that they expect you to have your building the way they want it. I can only rationalise what happened by saying that our architect appeared to have a burning desire that everything that went into the building was his personal expression, because we found ourselves at loggerheads over fundamental issues. The regional planning committee took a dim view of any disagreement and resorted to ordering private

meetings with the architect in which we were to hammer out our differences and produce an agreed plan. I can only be honest and say that the architect appeared perfectly happy to agree with us in private but then came to the next committee meeting with an entirely different plan.

The schedule began to lengthen, costs began to spiral as they so often do in public projects and the opening date of the new service was repeatedly put back into the future. It was difficult for us to accept that the planning committee appeared to have no desire to keep the building simple or costs down. For example, where modern plastic ducting would have been adequate for non-magnetic purposes their decision was to install stainless steel. It became clear that our new centre would be a very substantial building indeed, prompting me in the end to the view that if the RHA appeared determined to spend heavily we might just as well make virtue of necessity and exploit the advantages. However here we hit another rock: I discovered that if I could move rooms efficiently around on the plan to create more facilities this was denied on the basis that planning never took into account future provision. I had to demonstrate a current need for every room, otherwise I couldn't have it, even though this did not change the size of the building. In such circumstances one learns to play the opposition's game and so of course rooms acquired fictitious names on the basis that they would be used for something real when the need arose.

We were extraordinarily lucky to have Dermot Dobson on the team as he really understood not only the technical requirements for MRI (with which at that stage he had never worked) but also the planning implications. One thing the architect never knew was that the building he finally designed would take two MRI scanners if we needed. A large staff room, part of the adjacent corridor and a storeroom were separated from the control room by a single laminated wall that would allow break-through in the future to provide a control area managing two scanners side-by-side. In fact when two scanners were finally installed this did not prove necessary because by then self-shielding systems were available and could be accommodated in a smaller space. However our forward-thinking has been recently endorsed by the decision to install a third magnet.



Figure 1. The Oxford MRI Centre: palace or opportunity depending on the viewpoint.

Our difficulties are illustrated by a conversation I had with the regional architect in Cambridge, where my friend Adrian Dixon had created their MRI centre in around the first six months of what finally proved to be our five-year planning period. At the end of our conversation the architect summed up by saying “we built a bungalow and put the scanner in the lounge”. It was a very different approach to the one we were coping with.

One of my lasting regrets is that, seeing how large the building was to be, I got an agreement from the planning committee that the air handling plant, which was to occupy a huge loft which could have accommodated two floors, would be concentrated in one corner and leave the rest available for future development (one vision was that we might use this space to move the small University Department of Radiology onto site from the Radcliffe Infirmary where it had few remaining functions). Sadly this decision was countermanded some time during the commissioning phase and when we moved in we discovered piping ran across so much of the loft floor that the space was useful only for small areas of storage.

The decision to have MRI had been taken in 1985 and several years later we were still mired in planning. In the end I wrote a critique of the process and sent it to a clinical colleague who was a member of the RHA, asking him to raise it at the public meeting of the authority. Wisely, and as I expected, he did nothing of the sort but sent it to the chairman with a covering note saying that this was uncharacteristic of me and that there must be reason for concern. The outcome was dramatic: a senior member of the consulting architects came to the next planning meeting to outline a streamlined plan for completion and our consulting architect was relieved for health reasons (this was not a political euphemism: he did indeed have medical issues).

Even so, the building and commissioning phases needed our constant attention. One day late in the construction Dermot Dobson turned up to discover that the scanner power supply ports were being moved along the wall of the examination room. It had

been decided that there would be a re-design of the rear wall and that the scanner would have to move. In those days of unshielded magnets rooms were designed around the safe levels of exposure and distance provided the primary protection for patients and staff. The decision to move the magnet compromised all our plans for safety and would have put the operating staff into a high exposure. The fact that such a fundamental error could be made after five years' planning was woefully symptomatic of the problems we had faced.

The design of the Oxford MRI Centre did at least give me an opportunity to apply principles of decor and layout which I believed to be important to clinical care. Many hospitals are designed as healthcare factories, with very little of the home atmosphere which can be conducive to health and recovery. Being aware of the work that had been done on the correlation between colour, design and basal cerebral activity, I wanted our decor to be in natural greens and browns, and to be carpeted throughout, to provide a welcoming and relaxed atmosphere. First we had to detach our architect from his determination to have the internal walls white-tiled but that was one of the minor fights. To emphasise that the operating area was different and subject to entrance control we designed this in subdued blues and purples. With the aid of the regional supplies department we were able to choose furniture to match the colour scheme. Overall we had in mind the atmosphere of a small private hotel: "good morning, madam, we have your reservation here". These ideas might be thought over-indulgent in a health service that is always short of funds but in fact the extra cost is an insignificant proportion of the outlay involved in any new facility.



Figure 2. Design principles: creating relaxation.

One of the more pleasing episodes came during this period when, because I was a University Lecturer, I came up for election to a fellowship at one of the Oxford colleges. After a brief period of Trial by Dinner at several colleges I was elected to

University College and was delighted to discover when I took up the post that the College had obtained support from Oxford Instruments, the parent company of Oxford Magnet Technology, and that I was to be the College's first Oxford Instruments Fellow in Radiology. There are several very good reasons for becoming an Oxford don; in my case it was to lead to some enjoyable teaching and, most especially, a leadership role in the College's summer study parties on Mont Blanc, but at the outset my appreciation was very much enhanced by association with the company and Sir Martin Wood, after whom we were to name the hospital's new MRI centre.

4 Establishing the service.

When the centre opened I found myself running CT and MRI in parallel, as I continued to do for several years. We always intended our service to be provided from subspeciality expertise across the three main areas of application, neuroradiology, musculoskeletal and general body work. In the latter area we were consciously ahead of our time, as most MRI units in the UK were concentrating on neurological applications with some orthopaedics. To expand the clinical team we recruited Dr Niall Moore from Cambridge to provide expertise in body MRI, and Dr James Byrne to support the neuroradiological service. Our two first radiographers, Liz Warren and Cathy Westbrook, came to us from neuroradiology at the Radcliffe Infirmary and around them we built a team of radiographers, clerks and nurse.

While we expected our service to cover a large region, its primary function was to support the local medical facilities. As the major applications of MRI were still concentrated into different Oxford hospitals I set up a rather large management team which incorporated clinical and administrative colleagues from each of the centres. When we were up and running it was no great surprise to discover that each of the three divisions ideally wanted 100% of the service. The "creative tension" which resulted was not always welcome but a little professional competitiveness fuelled clinical improvements and certainly kept the service on its toes.

To supplement our design philosophy we decided to have MRI-specific uniforms and alighted on a design which was somewhat more stylish than the standard radiographic uniform of the time. We strengthened the impression of what I suppose would be called branding by allocating the same uniform to the clerical staff, but in a different colour. Predictably, I fear, we were accused of elitism, although it was notable that within a year two other imaging units had followed suit, so to speak.

It transpired that the hospital laundry could not guarantee to return our uniforms without them disappearing into the general pool, nor could they guarantee the return of our MRI-specific patient gowns, which had no pockets in order to avoid patients entering the scanner carrying anything metallic. The hospital quoted for private laundering at a cost so high that it was clear that the first two months' expenditure would fund instead a washing machine and tumble dryer, which we duly installed in the larger of our two store rooms. What might have been thought to be an imposition on the work and goodwill of the team proved instead to be something of an advantage, not least because they were able to bring in their laundry to do while at work and frequently did so.

Margaret Thatcher's government had put through an NHS reform in which districts were allowed to cross-charge for supplying services and the district manager took the

view that the MRI centre could be a local pilot scheme. We were planning a regional and supra-regional service and it was clear that, properly managed, the centre could bring in a significant income. The hospital agreed that if this were the case we would be allowed to retain our income in order to fund future development. This proved to be too modern an idea for the NHS of its time: each year the hospital was obliged to windfall-tax our surplus in order to reduce its deficit. Not surprisingly, those colleagues from the other hospitals, who thought they had been contributing to expanding the service, were disenchanted and moved to pressing their hospitals for their own scanners and within a few years there were three scanners in the town.

In the meantime the business of the MRI centre flourished. We had been lucky in recruiting as centre manager a distinguished and well-known colleague from IGE itself, Lesley Irvine. She brought into our team commercial expertise that served the unit extremely well in its development, although it is fair to say that, having been used to organisations in which decisions, once made, were honoured, she found it difficult to adjust to the NHS approach in which any decision could be countermanded by someone in a distant office who had no relation whatsoever with the service. Ultimately she left us to market the Nuffield Orthopaedic Centre, for whom she provided the same effective service.

Another innovation we embraced was that of the extended working day. Hospitals own a great deal of expensive plant and in many this is fully utilised for only a fraction of the day. This relative lack of use means in turn that institutions have to invest in more facilities than they would need if operated for longer. In 1989 I had taken sabbatical at Johns Hopkins Hospital, Baltimore, in order to get some experience in the leading MRI centre established by Dr Elias Zerhouni under the enlightened and benign chairmanship of Dr Martin Donner. They ran their centre for all the hours of every day and at the time that I left them were considering seeing in-patients during the night so that more out-patients could be examined during the day. I could see a certain logic in this, at least in the sense that when in hospital patients rarely get a good night's sleep, though I could not envisage the night-time support services of a British hospital being up to the challenge. Back in the UK, my proposals for an extended working week came up against the NHS concept of global costs. My ideas meant doubling the staffing complement and the management could see only justification for a single complement. To mitigate the effects of this we set up a shift system during the week which allowed us to operate from early morning until late evening five days a week. The radiologists were compensated for evening work with an afternoon off but we rapidly found that this did not work because when the rest of the hospital was working we all had to be available for consultation. How we eventually surmounted this particular problem is described in Part 2 of this article.

During this phase we suddenly found ourselves the focus of national attention in an unwelcome manner. The Labour opposition to Mrs Thatcher's government was very much opposed to market principles being introduced into the Health Service and in a House of Commons debate the claim was made that the MRI Centre in Oxford was selling itself preferentially to an adjacent district and that patients in Oxford were losing out. The local MP was interviewed on the lawn outside the Houses of Parliament, explaining that this was the sort of problem that he had expected and how terrible it all was for his constituents. The claim caught the attention of the media and

the next morning I arrived at work to find the local representatives camped outside the Centre, determined to interview me.

One principle which all of us in the MRI centre shared was that referrals were pooled and appointments allocated on the basis of clinical need. This applied whichever district the referral had come from. I was able to explain this in my interviews but had difficulty when asked to deny the claim, for the simple reason that I knew no one had done the analysis and so could not possibly be in a position to provide the evidence. In fact when we did the analysis later there was absolutely no truth in the accusation but by that time it had served its political purpose.

There were two interesting follow-ups to this incident. Firstly, the regional chairman invited the local MP to visit and at the end of hearing how we were running the service he was prepared to admit that he had been misinformed. Of course, by this time it made no difference what he said. Secondly, a member of my management team resigned their NHS position before the next election in order to stand as the opposition candidate in the very district to which we have been accused of selling our services. It seemed clear that we had merely been a pawn in someone else's game.

5 Academic objectives.

When I had been appointed to set up Oxford's first general CT service my post was a university one. At the time it was widely felt that new imaging techniques had an academic implication that could be well met by being led by an academic radiologist. In my approach to the MRI centre I took exactly the same view: Niall Moore's appointment was through the University in the same way that mine had been.

It was always our intention that what we did to contribute to new practice would be largely in clinical applications rather than technological development, for which the UK was already well served. In any case this played to the strengths of the team. The clinical research which came out of the unit is now a matter of published record and beyond the scope of this text, and as time has now passed has naturally been largely superseded. However what we did not anticipate was a significant contribution to service management, as described in Part 2. Additionally, Dermot Dobson, through his contacts with the industry, was able to make his own contribution, most notably in early methods of image transmission which would ultimately lead to him setting up his own company. The device he developed, Imlink, was used by Philip Anslow, a neuroradiology colleague, to start a national consultation and distance learning facility in CT and MRI of the brain, probably the earliest such programme in those days before internet image transfer.¹

It was also my hope that the centre could form a new focus for the University Department of Radiology. This small department, which had had a distinguished past history, had been rather stranded at the Radcliffe Infirmary with Neuroradiology when the rest of the hospital had moved to Headington. Accordingly it had lost its ability to integrate with most of the departments of the medical school and clinical hospital. For this reason we had taken pains to include in the MRI Centre a good teaching room (for which there was in any case a need in Radiology), a library, office provision for research staff and a well-equipped electronics laboratory for Dermot Dobson.

Central to our marketing plan was the concept of providing teaching to introduce MRI to the districts who would be using our service and also as a knowledge basis for development of their own services. We had the advantage of being able to support this

from our multidisciplinary team. Rather cheekily, perhaps, we decided to run our first course when we had taken possession of the building but did not yet have a working scanner. This did not appear to detract from the appreciation of our audience to any appreciable degree. We discovered that our generous building was almost ideally designed for running such courses and our educational efforts were only enhanced by June Forman, one of the radiographers from the Radcliffe Infirmary, who with a Danish friend provided catering of an extraordinary standard. On course days our own staff would descend like a flock of gannets on the left-overs as soon as the paying delegates had gone into their afternoon sessions.

Our radiological course was a basic clinical one and ran for several years. Two years after we started Liz Warren and Cathy Westbrook decided that there should be a corresponding radiographic course, which ran for nearly ten years and ultimately eclipsed the medical course. Not only that, but producing the lecture notes stimulated Cathy to fill a gap in the market for radiographic textbooks. *MRI in Practice*, which appeared in 1993, was a run-away success, reaching its fifth edition in 2018, and eventually acquired two companion books.

In sabbatical time in the USA Cathy had come to know Prof Felix Wehrli, a leading MRI scientist. He and I also worked together: we were both engaged in an intensive course which IGE offered to its users in Europe. Basically this was a complete survey of MR technology by Felix while we clinical lecturers were brought in to accompany the science with the relevant applications. It was a format which worked particularly well and in which I acquired friends in MRI from around the world. When *MRI in Practice* was in production Cathy asked Felix and I to write the Foreword. We tackled this in a break from our teaching at a course in Paris, bouncing ideas off each other while I sketched out a text in pencil. We changed our ideas so often that my notes became a scrawl and I have never forgotten the look of complete incredulity that went across his face when I asked him if he had a rubber I could use. There are some expressions which do not travel well internationally.

After handing on the leadership of the MRI Centre I returned to academic projects. Cathy Westbrook's experience in the USA had markedly strengthened her commitment to academic radiography and when she returned to the UK I was in the lucky position that a university radiographer at the Radcliffe infirmary had retired and I could use the post to set up a new research and education post in the MRI centre. Cathy was with us for four years before leaving to develop teaching courses in the private sector, in which she has been very successful. Her successor, John Talbot, was with us a regrettably short time before he was seduced away to join Cathy in her enterprises (their courses now extend across the world, with the exceptions of Russia, China and South America). It is a source of tremendous personal satisfaction that these two radiographers moved on to significant achievement, as indeed did their successors, Nick Nicklin, Christopher Alvey and Steve Turnbull.

It was during this period that I had one of the more bizarre scanning mornings of my career. The BBC were putting on an educational series about the human body, for which we had supplied some images, when they told us they needed an example of someone with an erection. The challenges were obvious and although some members of the team might have been inclined to pick up the gauntlet, enthusiasm died when it was realised that no matter how much confidentiality was applied the images would

probably turn up on the department noticeboard. Accordingly, we prevailed on the medical students to put out the word among their peers at College and the BBC offered a healthy fee on the basis that many students would do anything for money. When a candidate came forward we could not have been more careful about his feelings and informed consent. We sealed off the Department and sent most of the staff away for a long coffee break. I had only Cathy and John Talbot to carry out the examination, the scanner being obscured by curtaining the observation window. I interviewed the young man in my office beforehand and carefully explained that the exercise was sworn to secrecy and that if our attempts failed no-one would ever know. I still cringe that my own nervousness prompted me to use the words “suck it and see”. In fact our candidate proved to be a trooper and although the circumstances did indeed prove somewhat constraining and the results may not have been the greatest achievement in the history of priapism, the BBC got their images. I later heard that our efforts at confidentiality had been pointless because he asked for a copy of his images and was apparently happy to show them to his friends.

In our purchase agreement IGE had provided some funding for research support and we came to use this to provide bursaries for doctoral students, ultimately seeing 8 of these go through the centre and develop their careers. In the same timescale I was engaged in running the medical school’s taught Master’s course in Radiology, supported by the research radiographers and Dermot Dobson, and many of the students undertook MRI projects for their dissertation. Finally, for a time we had a series of medical students who were undertaking third-year research projects as part of their Final Honours School. There were times when it was difficult to find room for all those working in the centre despite its size! By the time I came to retire over 80 graduate students had been through our hands.

An academic radiologist finds that their work is often dependent upon interested clinicians, who stimulate ideas and support new projects. I was lucky to work in a university hospital where the great majority of colleagues, University or NHS, had an interest in the academic implications of their specialty and over the years had been involved in a series of satisfying projects. Throughout this period I remained a general body radiologist but in the later part of my career returned to an early interest in the face and neck. This was very largely the result of the arrival in Oxford of a dynamic colleague in maxillofacial surgery, Stephen Watt-Smith, who brought with him an acute perception of the value of imaging and its potential for development, and of 3D imaging and modelling in surgery. Such colleagues are among those who stimulate the radiologist to be a better practitioner and together we were able to explore the facial applications of MRI to a degree that I had not expected.



Figure 3. A research group meeting in MRI paying careful attention to Dermot Dobson's advice (From second on left: Stephen Watt-Smith, Stephen Golding, Cathy Westbrook, Dermot Dobson).

It is the nature of new techniques that they begin as a highly specialised subject and then as knowledge grows and more colleagues are brought in the service diversifies. In 22 years I watched the Oxford MRI Centre develop from a tightly focused exploration of a new technique into simply part of the general armamentarium of modern imaging. MRI was the product of collaboration between science, industry and medicine, as all new developments are. Today this collaboration has produced combined imaging, dynamic imaging and molecular imaging that could not have been contemplated when I began Radiology in 1975. Today we have an ability to influence patient care to a degree that was not imaginable then. This process continues and will ensure that medical imaging extends in the future into areas that we cannot yet visualise. For all that, I retain the view that the watershed created by the development of CT and MRI was a time of which we are unlikely to see anything similar. The developments we lived through took us into unexpected places and unforeseen interests.

I have written little of the technical advances which took place in our service. We did indeed install our second scanner in response to the enormously expanding applications of MRI. We moved into self-shielding systems when available and then into high field imaging. These developments were not specific to us but were shared by the other units working in our time and many colleagues can speak eloquently of the benefits which were brought to the practice of medicine. Some examples of what came specifically out of the Oxford MRI Centre and the sometimes surprising places where they led are described in Part 2 of this article.

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Part 2: exploring high throughput MRI and where it took us.***1 The Idea.***

In the mid-1980s, while we were exploring MRI centres across the world in order to gather ideas for our own service, my colleague Andy Molyneux from the Radcliffe Infirmary and I visited an American centre where we watched a radiographer scan the patient, print and develop the images, check them, telephone the radiologist to come and decide whether anything further was needed, and make a cup of coffee while waiting for the radiologist to arrive. Both trained in the British NHS where every second of examination time counted, we found it difficult to accept what we were seeing.

In the taxi cab afterwards we discussed this and found that we shared a vision of how examination times could be shortened and the productivity of the scanner increased. Within a few minutes we had sketched out the principles of the Oxford project in high throughput MRI, which we intended to put to the test as soon as possible after our own service began.

The high throughput project was based on the simple concept that there would be some examinations which could be conducted to a standard protocol, in which the radiologist's inspection would be an unnecessary delay. Though this is conventional now, at the time it was standard thinking in high-technology imaging that examinations should be closely supervised by radiologists to ensure that they were complete so that a repeat examination would be avoided.

Once the Oxford service was in operation we defined basic protocols for common applications in MRI of the brain, cervical spine, lumbar spine and knee. These were based on our estimates of the minimum time needed to prepare the patient, conduct the sequences and remove the patient from the couch. Separate project days were dedicated to each type of examination and we tested our target times by measuring the duration of each element of the examination on every patient. One aspect of these days which we did not anticipate was the competitive spirit it stimulated in the staff, who did their best to beat the previous record and by the end of the day were running at impressive speed: for example they were able to reduce the time taken to remove the patient from the scanner and the examination room to a mere 30 seconds, which on reflection we decided had a feeling of indecent haste about it.

Naturally, the patients who took part in these days were fully informed that our objective was to increase the availability of MRI and many of them rose to the challenge just as enthusiastically as did the MRI centre team. Patients were told that because we did not know how smoothly the exercise would run we could not confidently guarantee their appointment time and on one of the first project days one patient came so early that they were examined and, we estimated, back home in Northampton before the time we had originally scheduled their examination.

To ensure that the radiologists reporting the studies were happy that the examination was complete we asked them to give a confidence level as well as stating whether the patient needed to be recalled. Our hope was that the increased number of patients who could be seen would justify a small number of recalls. In fact, our first few days showed a recall rate of only a few percent and we were able to reduce this to zero by careful patient selection in the rest of the project.

This first phase demonstrated that “routine” examinations of the brain, the knee and the lumbar spine for suspected disk degeneration could be carried out with high levels of reporter confidence within 20 minutes. We successfully applied a slightly longer protocol of 30 minutes to the investigation of lumbar root symptoms. Cervical spine examinations, however, proved less suitable for the approach and we dropped these from the investigation. Later my neuroradiology colleague Philip Anslow proposed a short, single-sequence examination for screening patients for unilateral hearing loss and this was successfully added to our approach.

Taking into account the appointment times which were conventional in MRI at the time, our results indicated that the productivity of British MRI scanners could be increased between two and three times, depending on the spectrum of practice of the individual centre. Our initial results were presented by Niall Moore in 1991 at that year’s annual congress of the British Institute of Radiology in Brighton and I sat in the audience to enjoy the ripple which went around as Niall shared our projections of what this could mean for British MRI. Our first paper was submitted to the British Journal of Radiology that September, within a year of our opening the MRI centre.¹

Our high throughput days required the team to pull together in the spirit of a single objective and somehow acquired the title “Blitz” from the war-time spirit that had characterised London. Shortly afterwards, when Prof Ian Isherwood - a good friend and mentor - became president of the European Association of Radiology he rang me up and told me very firmly that this was not an acceptable title to be using in a European context.

There were immediate spin-offs from this research. We began to schedule unsupervised sessions in which we could get through large numbers of routine examinations: this meant that the radiologists could be released from the pressure of the extended working days we had embraced when the centre opened. My colleagues at the Nuffield Orthopaedic Centre realised that our simple protocol of two sequences of the lumbar spine offered a method of screening for lumbar disease which was far more sensitive than the radiographs then still in common use and better radiation protection than the CT which was being increasingly used. Able to show a case for cost-effectiveness to the hospital management, they successfully established this as the standard practice throughout the entire hospital group.²

The Oxford high throughput project caught the popular imagination and I found myself invited to give presentations of what I took to calling a “Radical Approach to MRI” throughout the UK and beyond. As I did so I tried to put across the vision that the Radiology department of the future would contain MRI scanners which were working solidly to unsupervised standard protocols alongside scanners where radiologists were supervising more complex examinations, a situation directly analogous to how most other imaging techniques operated. I remain of the view that there are some examinations where the patient’s interest is best served by supervising

the examination: unfortunately increasing demand in Radiology has forced this approach into the background today.

At the time the concept was not always well received because some colleagues wished to retain the principle of direct supervision of examinations and I had to withstand some criticism. At one international meeting Donald Longmore, a leading cardiac surgeon who had turned to investigating cardiac MRI, stood up after my presentation and told the audience that radiologists would not need to go faster if they did not spend so much time on the golf course. I could only reply that I had never once played golf in my life and, mercifully, the chairman of the session also came to my aid.

2 The International Society of Strategic Studies in Radiology.

It was one of these high throughput presentations that led to an entirely unexpected new development in my career. Dr Peter Rinck, who was at that time based in Belgium, had engaged in running a series of meetings which resulted in review books on different aspects of Radiology. For September 1993 he had organised a multinational review under the aegis of the European Magnetic Resonance Forum with the title “The Rational Use of Magnetic Resonance Imaging”. Although I had more than enough invitations to speak, I wrote to him to suggest that our work might fit well into his programme, one of the very few occasions when I ever did this to a meeting organiser.³

The meeting was in Lugano, which I knew well because it was one of our venues for the IGE users’ courses. It covered medical recommendations, new developments and the socio-economic aspects of MRI with a lot of valuable content and was a great success, both generally and for me personally. At the end of my presentation Alex Margulis, chairman of Radiology at the University of California, San Francisco, stood up and told the audience that in his opinion I had just delivered the most important talk being given at the meeting. Such career moments are rare - at least they have been in mine - but utterly memorable.

At that time Alex was known to me only by reputation and by virtue of being joint editor of the standard textbook in gastrointestinal imaging used when I was in training. A native of Belgrade, he had emigrated to the USA during the Second World War and worked his way up to become chairman in San Francisco, where he had created one of the world’s leading centres for Radiology practice, education and research. He had been one of the first people in the USA to appreciate the significance of MRI and had built up a famous programme.

After the session ended Alex came up to me and said he was very interested in what I was doing. He suggested that “his people” and “my people” could work together on a more extensive project which might attract the support of the NIH in the USA. I didn’t like to tell him that “my people” amounted at that stage to myself, my secretary and whatever support my colleagues had the time to offer.

A few weeks later I was at the RSNA meeting in Chicago and, seeing him in the crowd, went up to explore the idea further. His opening words, indeed almost his only words, were “Ah. We’ve been talking. There has to be a new society on costs and benefits of Radiology. We’re going to meet in Oxford. You’re going to organise it. Go and talk to Albert Baert and Hans Ringertz”. I think I slightly rocked back on my heels and remarked that I had run meetings before and would be happy to do so. I knew Prof

Albert Baert from Leuven well, having taught with him on Janet Husband's London International CT course but Prof Hans Ringertz of the Karolinska Institute in Stockholm was known to me only by reputation. Both of them were leading members in the European Congress of Radiology.

The only time that we had available for a meeting was in the trade exhibition at the time when it closed on the final day of the meeting, when the lights were dimmed, a cheer went up from all the stands, and the industrial members began to strike camp with impressive speed. In the event, among the noise and chaos we agreed that there needed to be an exploratory day meeting, which we would hold in Oxford in the summer of 1994. I duly reported this back to Alex, who was to be responsible for the invitations.

When the list of delegates reached me I discovered I would be hosting around 20 of the leading figures from Radiology around the world. The meeting facilities in the Oxford MRI Centre would be sufficient for us, I knew, but I realised I had to make a bit of a splash: this would be the worst audience in which to have egg on my face. Alex was providing generous funding, so I booked out one of the Oxford hotels which was based on a 15th century hospice to offer them historical character and also booked one of our best local restaurants for after the meeting. In a final mood of largesse I had flagpoles put up across the front of the MRI centre and flew the national flags of all the delegates; this called down real criticism from some of my hospital colleagues but was very much appreciated by the delegates when their coach from the centre of town came up the hill towards the centre and they saw all their national colours.



Figure 1. (From left) Alex Margulis, Albert Baert and Hans Ringertz at the 1994 exploratory meeting.

The upshot of this exploratory group was that the first meeting of what would initially be the Oxford International Symposium on Costs and Benefits in Radiology was set for the summer of 1995. I knew St John's College had established an attractive modern conference centre which was supported by a new residential block comprising en-suite facilities in the Scandinavian style and I thought this would do us very well.

At this point I discovered just what makes an Alex Margulis achieve the position they have. I began to receive frequent and clear instructions on what was required and he expected to check every detail of what I was doing. On one occasion he announced that he was flying through the UK for a connecting flight at Heathrow and would like a dawn meeting at the airport to review progress. Unfortunately I had to be out of the country that weekend so he opted instead for my secretary Beryl Walters to attend the meeting in my place. He made a considerable fuss of her and afterwards never ceased to enquire after her. He was one of those rare people who have a gift for making others feel like personal friends; in all our years of communication after this he never treated me as anything other than an equal, despite the considerable difference in our standing.

In these days of instant communication it seems almost impossible to think that the first Oxford Symposium was planned entirely by fax. In San Francisco Alex was responsible for sponsorship and the invitations, while the programme was drawn up and printed in Munich by Prof Joseph Lissner, one of the founding fathers of the European Congress of Radiology and of the journal *European Radiology*. I was responsible for local arrangements in Oxford and they were frequently on a knife edge; two weeks before the meeting I was still getting faxes referring to people whose names were new to me. It was also, unusually, a blisteringly hot summer and my secretary Beryl and I took to reviewing the arrangements in the evenings, when the temperature had fallen slightly, checking and re-checking every detail. There was also to be a spouses' programme and I was able to call on my brother-in-law Barry, who ran coach tours, to put on visits to the Cotswold villages and similar places. For everyone's enjoyment we arranged an evening visit to the Royal Shakespeare Theatre at Stratford-upon-Avon for a production of *Romeo and Juliet*.

Shortly before the meeting Alex panicked over my arrangements for accommodation and called me to say that the delegates were so distinguished I could not expect them to sleep in a college. I failed to persuade him that St John's would do very well and had to go around Oxford gathering together what luxury rooms were still available. In the event, in view of the summer heat, some of the delegates (mostly Americans) complained about the lack of air-conditioning in their hotels and moved into rooms in St John's. Alex also told me that he was putting his educational assistant Tym Peters on a plane to help us with the last arrangements, even though I thought that Beryl and I by this time had everything more or less under control. In fact Tym proved to be a delightful and useful assistant and we kept in touch for years until he moved away from UCSF.

The meeting was a leading-edge review of management and technical issues in Radiology, the results being published as guidance for bodies engaged in health policy, such as WHO. Representatives of these bodies were frequently invited to later meetings. The first Oxford Symposium was a great success and closed with the

resolution that it would meet every two years, the second meeting to be held in San Francisco in 1997. The meeting incorporated in 1999 as the International Society of Strategic Studies in Radiology (IS3R) and has continued meeting every two years since.⁴ I continued to take part in the meetings until I retired and as I look back it still seems remarkable that a simple talk on a relatively simple concept in a small Swiss town could have projected me into a forum with the leading radiologists from across the world, many of whom became good friends.



Figure 2. The first Oxford Symposium, St John's College 1995.

3 Clinical Guardian for MRI, Department of Health.

By 2004 waiting times for MRI across the UK had become unacceptable in many regions. Tony Blair's government decided to address the problem by outsourcing the purchase of half a million routine MRI studies from the independent sector. This move caused considerable controversy among UK hospitals. Many colleagues asked why, if funding was available, it could not have been provided to the NHS to expand the service. Others were philosophically opposed to public money being used to support the independent sector.

In response to this, and especially to address the question of standards in the new service, the Department of Health set up an extensive programme of clinical audit, the like of which had not been applied to British imaging outside the national breast screening programme. Examinations were double reported and all discrepancies investigated. The providers carried out regular clinical audit with feedback to their reporters, and every year an audit of randomly selected cases was to be carried out for the Department of Health. My friend from Cambridge, Prof Adrian Dixon, who was currently Warden of the Royal College of Radiologists, was appointed as Clinical Guardian with oversight of the entire programme.

Adrian Dixon decided to move on from this position after two years in the programme as he was becoming Editor of *Clinical Radiology*. After the turn-around time for the report and language problems caused by overseas radiologists had been addressed, it

had become clear that waiting times had fallen substantially and that most of the initial concerns had been addressed. The Department of Health decided to add further Clinical Guardians with responsibility for other types of imaging and I decided to apply for the one in CT, a technique with which I felt I still had an instinctive relationship. Throughout my career my moves have largely been things into which I have fallen and there was very little reason to go looking for additional work but at that stage of my career I felt I was ready for a new challenge and I decided to go for it as strongly as I could.

There were several surprises in the selection process. The first was that I had long since lost the competitive instinct needed by an interview candidate. The second, and much more welcome, was that the manager of the programme was Philip Webster, a radiographer I had worked with years before when running a trial of a mobile CT system at his then base in Northampton and with whom I predicted accurately that I would enjoy working. The final one was that the panel invited me to take up instead of the CT position the MRI one in succession to Adrian.

In the intervening years the approach to high throughput that we had explored in Oxford had been gradually absorbed into UK practice. There was nothing surprising about this; it was a simple concept which would have evolved naturally, although we had chosen to make it an early quantitative research project. When I became Clinical Guardian it did not escape my notice that the independent sector universally used what we would previously have regarded as an Oxford approach, productivity being an essential component of the commercial world.

The Clinical Guardian had oversight of the guidelines and pathways used in the programme and was also responsible for ensuring that the qualifications of the radiologists employed by the reporting houses were comparable to those in UK hospitals.⁵ Most important of all was oversight of the audit results coming from the providers and the annual sample audit. Examinations were scored on five points of defined criteria, for the technical quality of the scan, the clarity of the report, and the competence of the clinical opinion which resulted. Adrian had already demonstrated that the results were completely acceptable but the striking feature was that successive years showed steadily increasing accuracy of reports towards perfection throughout the five years of the programme. By now I was clinical director of Radiology in Oxford and I remember feeling, as I reviewed results which reflected a very high level of competence, that I had no evidence to tell me whether my own department was performing to the same level. Here was proof positive that clinical audit and feedback improved clinical performance and the experience convinced me of the need to establish such programmes throughout all the service.

4 “Black Bone” MRI.

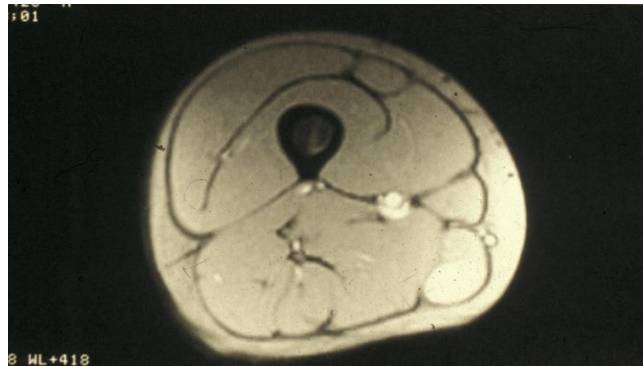
Never having regarded myself as particularly accomplished at original thought, I have tended to assume that much successful research comes from accident or error. My Alexander Fleming moment came in 1989 when, before the opening of the MRI centre, we had hired a mobile MRI service for two days a week to give us some initial service.

In those days before the development of Fast Spin Echo a SE T2 -weighted sequence was the longest one we had and to keep the length of examinations at an acceptable

level we were often prepared to accept the rather different T2*-weighting of a Gradient Echo sequence. This could be obtained in the same time as an SE T1-weighted sequence. I was examining the soft tissues of a thigh one evening on the van when the radiographer set the flip angle incorrectly and presented me with a black femur on soft tissues which had been almost completely greyed out. I remember realising that here was something which exploited the susceptibility of bone and suppressed the usual signal from other tissues and could be used to replace other forms of imaging of cortical bone.

This, which I suspect may have been the best research idea I ever had, was a long time in the gestation, 14 years to be precise. As time passed I kept thinking about doing something about it but the years were full enough until one of our doctoral students was having difficulty getting sufficient material into a thesis on a related subject. I suggested that he should add an exploration of the parameters for optimal display of cortical bone and suppression of soft tissues. When this proved successful it demonstrated that a cross-sectional image of cortical bone could be added to any other MRI scan with minimal time penalty and I began to think of all the patients in my practice in maxillofacial imaging who in addition to MRI underwent repeated examination by CT in the course of monitoring their surgical treatment. The ability to replace CT, if it proved reliable, would be a major step forward both in protecting the patient and in reducing demand on the resources of the department.

(a)



(b)



(c)



(c)

Figure 3. “Black Bone”MRI: (a) an 1989 idea from a mistake: an “Alexander Fleming moment”, (b) used later to monitor a giant cell tumour of the right mandible, (c) used to provide 3D reconstruction of the skull (kindly provided by Dr Karen Eley).

The subject was picked up in detail by Karen Eley, a junior surgeon working with my colleague Stephen Watt-Smith, who carried out a project on craniosynostosis in work for a Master’s degree.^{6,7} Subsequently in her doctoral degree she explored “Black Bone” in considerable detail, demonstrating amongst other things its geometric accuracy and the fact that it could be used, like CT, as a basis for 3-D image formatting.⁸ As a result of this experience Karen decided to turn to Radiology. It is very satisfying to be able to report that Karen has gone on working successfully on this aspect of MRI throughout her later posts and though collaborations has succeeded in developing fully automated techniques to produce 3D reconstructions of the skull.



Figure 4. Lucky in my collaborations: with Stephen Watt-Smith (right) and Karen Eley at a meeting in Bruges.

5 MRI in radiation protection.

Shakespeare wrote “some are born great, some achieve greatness, some have greatness thrust upon them”. I do not know whether he would have shared my view that the same expression could be applied to research opportunities. In 1994 I had thrust upon me an interest in radiation protection, something which I had never previously imagined. I was telephoned by an administrator in Brussels to say that the European Commission (EC) was setting up a new group on quality criteria and radiation dose in CT and I had been recommended as the British radiologist in what were planned as

pairings of national radiologists and physicists. I had not the slightest idea why my name had been recommended; if I had expressed any views on this subject at any time I could not remember doing so. Nor could I claim any expertise; the subject was not something in which I felt either skilled or more than generally interested at the time but, as I discovered of her later, Hannelore was a woman of profound determination who was not to be deflected from an agreed plan. To the laughter of my secretary Beryl Walters, who was listening in to the call, and after an interminable argument in which it was clear I was always on the losing side I eventually agreed to go to the first meeting in Brussels without an obligation. It was to be the beginning of a new research interest, although I had no idea of that at the time.

I went to this meeting with considerable trepidation because although I knew the basics of dose and image quality, I had never explored the physics in detail. I had the advantage of knowing the British physicist, Paul Shrimpton of the National Radiological Protection Board (NRPB) just down the road from us in Oxford and I also knew the German radiologist, Georg Bongartz from Munster. My insecurity in what proved at first to be a daunting line-up of distinguished Europeans was not helped by the fact that I arrived late at the meeting and almost immediately fell asleep after a dawn flight from Heathrow. Having got through the first day our organisers took us to our accommodation before going on to a working dinner. We found we were being put up in a faded and rather seedy University club, the rooms of which were just about at the level of those one had occupied as a junior house officer in Victorian hospitals. Over dinner we admitted to each other that we thought our careers had gone too far to be offered accommodation like that.

We also discovered that we were required to pay individually for our dinners and I loaned Georg the money for his as he was carrying no Belgian francs. Others were similarly affected so afterwards we all had to go and find an ATM to reimburse each other. Having done so, Georg turned to the rest of us and announced, "I cannot sleep in this room without a beer". So we headed for the centre of the city and explored the local beers, which in Brussels at that time you could do for a long time because there were plenty to choose from and bars which did not acknowledge conventional closing times. By the early hours of the morning, when we were staggering across the city and trying to find our dismal hotel, everyone had reached the matey stage and decided that we were all long-lost friends. The next day my distinguished colleagues did not appear anywhere near so daunting. The core of this group stayed together through successive different arrangements for 14 years.⁹ I wonder if we would have done that if we had not all gone out and got drunk together in Brussels on the first night? The role of alcohol in team-building: discuss.

At that time there was growing concern over the contribution that CT was making to the collective radiation dose received by the population.¹⁰ Successive surveys by the NRPB had shown that CT made a contribution out of proportion to its frequency and also that there were worrying variations between departments in the doses administered for identical examinations, sometimes of an order of magnitude difference. Further, these surveys provided average values but exposures were concentrated on patients, and were therefore individually higher than the surveys suggested. In the early days CT had been largely limited to examination of the brain, for which there was no alternative, and to oncological applications in which radiation

protection was of secondary importance. However CT had become more common and was being applied increasingly to benign conditions and in children, in whom the delayed effects of radiation had more opportunity to emerge. This trend was enhanced by the successive development of spiral CT and then multi-spiral examination.

One of the challenges we faced in CT was that the image reconstruction technology could compensate for a wide range of incident doses. In the days of conventional radiography we knew that overexposure meant a blackened film but CT scanners simply hid the effects of high exposure. At low exposure levels there were, of course, justifiable concerns that image quality would be degraded by quantum mottle and diagnostic accuracy would fall. One of the important questions to be answered, which would deal with the unfortunate variation between departments, was what was the minimum exposure that would generate a reliable examination?

Unfortunately CT has suffered from a very weak evidence base in this area and it was clear that more research was needed. By this time I had gathered a small research group in the MRI centre and we turned our attention to very simple but rewarding explorations of how far we could reduce exposure.

Another major area for research, in my view, was the extent to which CT could be replaced by techniques which did not employ ionising radiation. This had been a regular recommendation from the NRPB but had not had a noticeable response in British hospitals. For example, while it was clear that most investigation of the brain could be safely undertaken by MRI, departments were still carrying out CT for common applications. Similarly, MRI of the lumbar spine was more reliable and safer (and to my mind easier to interpret) than CT but many departments still regarded CT as the routine investigation.

There were, of course, areas where safety considerations were over-riding, such as the investigation of the orbit, the thyroid gland or benign gynaecological disease.

Ultrasound had taken over the primary investigation of these areas but CT still remained a secondary investigation. I was very keen that MRI should become the secondary investigation wherever possible, certainly where it offered comparable or superior information to CT, but possibly also where interposing MRI, even where it was not so accurate, would result in fewer patients proceeding to CT.

One of the limiting factors was that CT was very much regarded as a rapid technique and MRI as a slow one. In fact, much of the work we had done on high productivity had shown that MRI could be as fast or sometimes faster than the equivalent CT examination, at least until multi-slice spiral CT was developed. The work which my colleagues at the Nuffield Orthopaedic Centre had done on replacing radiographs and CT with MRI as primary investigation of the lumbar spine was a case in point.

The success of such approaches very much depends on people being prepared to think “outside the box”. Radiological practice, with its pressures of demand and time, often mitigates against changes in established approaches. However with the “Black Bone” technique we had shown how some CT studies which were needed to supplement MRI could be replaced, provided that clinical referrers were prepared to accept the results: this is also an area where change in practice may be slower than one might hope. By way of a small example, I changed the local investigation of patients with suspected blow-out fractures of the orbital floor. In this condition the common clinical perception was that fractures through the cortical bone of the orbital floor had to be

demonstrated so that the surgeon could decide whether the patient required a prosthesis. No MRI technique would reliably demonstrate the cortical bone separate from the orbital fat and air in the adjacent sinus but in fact demonstration of the cortical bone was not necessary to the requirement of the surgeon. What the surgeon needed to know was whether the orbital floor was in the right position or not: if it was not displaced it would heal normally and demonstration of the cortical fracture was irrelevant. We therefore replaced the CT studies which had been carried out for this purpose with a single coronal SE T1-weighted sequence through the orbits, which took only a few minutes and answered the clinical need. It became standard practice in our CT unit, when patients arrived with this referral, for the radiographers to send them on to the MRI centre, where their short examinations were fitted in between other patients.

In the same way we began to work on replacing all facial investigation with MRI. In two rewarding studies conducted with my surgical colleague Stephen Watt-Smith we showed that when MRI was used for investigating salivary disease it did so in a single investigation which could replace multiple techniques. We went on to extend this to show that referrals from primary care could be effectively triaged for surgical or medical referral on the basis of a short MRI examination.¹¹

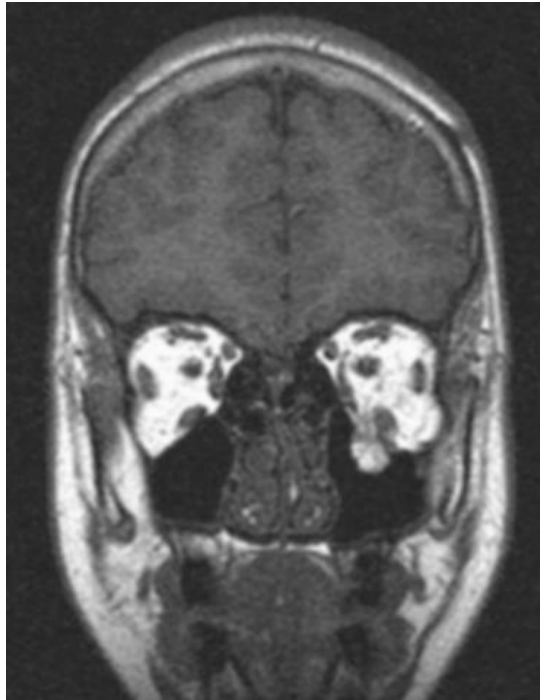


Figure 5. Single sequence MRI of an orbital floor fracture with blow-out of the orbital fat into the maxillary sinus on the left: fast, radiation-free and all the surgeon needs to know.

During my time in MRI I have seen many new applications developed and MRI put to much greater use in clinical practice but in my view there is still a case for more work on how the technique can be used to reduce the use of ionising radiation. Claims that MRI is slow and expensive do not really stand up to intense scrutiny: as some of the Oxford work showed, these factors are merely susceptible to different approaches to

service management. I regret, though, that rising demand on British radiologists mitigates against both the thinking required to develop these approaches and also willingness to change established practice. I feel I can look back on four decades of Radiology with a great sense of satisfaction with what has been achieved across the subject but for all that there remains plenty of innovative, valuable and inspiring work for future generations to do.

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