Magnetic Resonance in Medicine

HIGHLIGHTS

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Derek Jones

Singapore Meeting

MR in Singapore

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Welcome to 2024 *Magnetic Resonance in Medicine Highlights*

I am very pleased to bring to you this year's edition of MRM Highlights. It is amazing to see, year after year, how many new initiatives and inspiring stories our membership brings to life.

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Most of all, I am delighted to celebrate the forty years of Magnetic Resonance in Medicine, our Society's first scientific journal. There's not only the magazine cover to celebrate it, but also four great articles that will take you on a journey back to the early 1980s to discover how things started! The first one is a historical reconstruction, brilliantly written by none other than our Editor-in-Chief, Peter Jezzard, followed by a chat with the first author of the first published MRM paper (lots of firsts!), living legend Graeme Bydder. And then we celebrate MRM with our membership and industry partners, showcasing their favourite MRM papers of this last forty years!

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But there is more! Through the pages, you will find out more about MR research in Singapore, the breathtaking location of our 2024 Annual Meeting. You will meet our new Executive Director, Anne-Marie Kahrovic, our President Derek Jones and our New Horizons star Ileana Jelescu. Updates are provided on initiatives to democratize MRI by fostering EDI culture and access to MRI education, thanks to the activities of Carinne Piekema and the Gates initiative. And if you are eager to dig deeper into the history of MRI, don't miss the interview with our great Marta Bianciardi, on the Fireside Chats, and the profile from the 1999 YIA W.S. Moore winner, Bruno Madore (but don't forget the current finalists, they're showcased in this issue, too!).

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And if you have learned to know and love Highlights, you'll be happy to see that Highilights picks are still going strong!

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Together with Mathieu Boudreau, Editor of the Highlights Digital Content, and Peter Jezzard, MRM Editor-In-Chief, we want to thank our volunteer collaborators, the ISMRM Central Office, and the team at Wiley who have all helped this magazine to see the light of day. We hope you enjoy reading it as much as we enjoyed making it!

Maria Eugenia Caligiuri
MRM Highlights Magazine Editor

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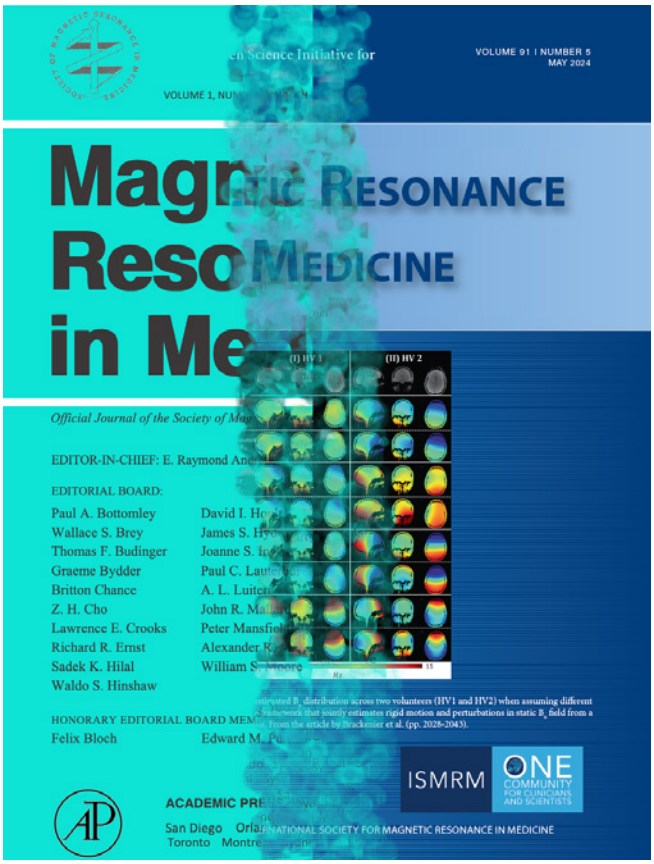


MRI in Singapore

INTERVIEW BY **ADRIAN TANG** AND **WENCHUAN WU**

ISMRM is holding its Annual Meeting for the second time in Singapore (we were last here in 2016). We therefore wanted to find out more about the history and current practice of MR in Singapore. We are grateful to **Tchoyoson Lim** and **Sendhil Velan** (co-Presidents of the ISMRM Singapore Chapter) for telling us about life in Singapore, along with **Ling Ling Chan** of the Singapore General Hospital and Ai Peng Tan from the National University of Singapore.

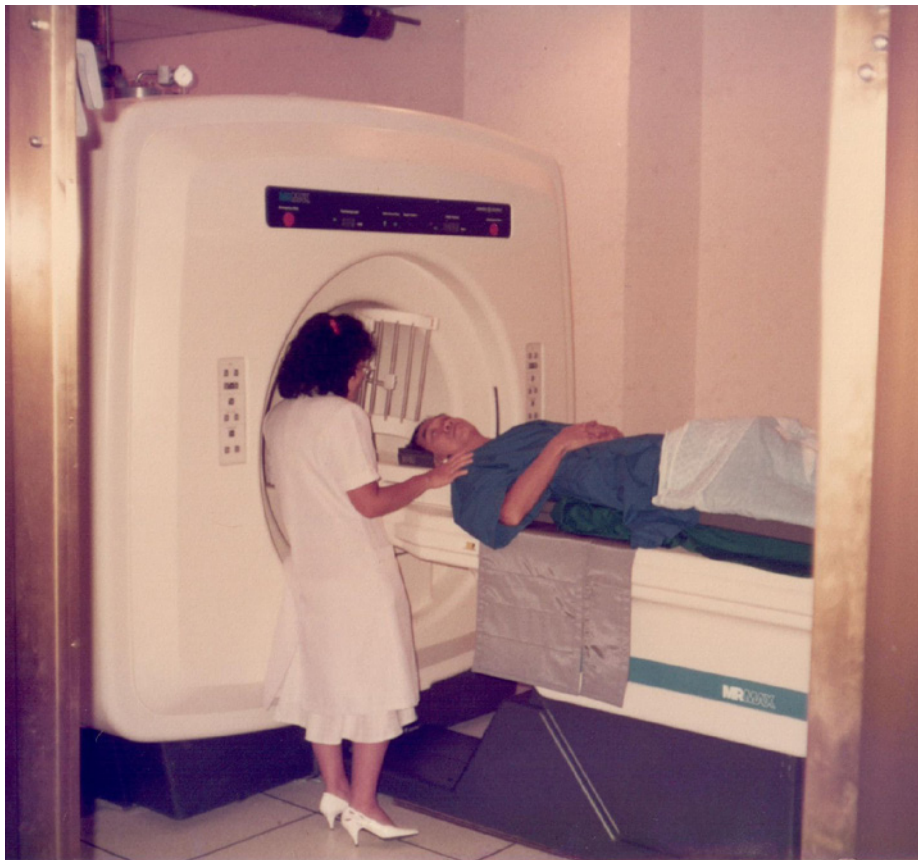
MRMH: Where and how was the first MR scanner installed in Singapore?

Tchoyoson: The first ever clinical MRI scanner was installed in 1987, but ironically instead of a university hospital it was in a private clinic along Orchard Road, which is our premier shopping street! Since then we've had an explosion of MRI scanners – Singapore today is approaching developed-world numbers of scanners, and also radiologists per population. From that humble beginning with one 0.5T scanner, we later introduced the first 3T machine in Southeast Asia. Now we've got a thriving milieu of researchers, clinical practices and radiologists.

MRMH: What is your view regarding access to MR facilities in Singapore today?

Sendhil: The scanners we have include low-field 1.5T and several 3T scanners, not only clinical scanners but also research-dedicated scanners which can be utilized 100% for research programs. We also have a research-dedicated simultaneous MR-PET system. Even though we have research-dedicated scanners the cost of imaging is quite high in Singapore.

Ai Peng: Ling Ling and I are from the two largest hospitals in Singapore. Ling Ling is from the Singapore General Hospital (SGH) site. At the National University of Singapore (NUS) we actually have a research imaging center where only research scans are done. But of course, there are instances when we are unable to scan patients at the research facility, for instance those from cancer clinical trials, and then we scan them on our clinical scanners at SGH. Overall, we have approximately nine scanners on the SGH site, so I think that accessibility is not really a problem. Nevertheless, even though nine scanners sounds good, our waiting time is still pretty long, something like three to four weeks.



The first 0.5T MRI scanner installed in Singapore in 1987.

Ling Ling: The Island of Singapore is divided into three clusters. The SingHealth cluster has quite a few general hospitals and our imaging resources are such that we have a cluster-wide MR service that we call our Radiology Shared Services (RSS), where if any hospital is short then the patients can go to other hospitals for their scan. In the SingHealth SGH site, we have loads of clinical work. Unfortunately, we're not as well resourced, so our research scans, for myself as a clinician scientist, are all done on clinical scanners. They're costed at A-class clinical rates, which is easily on the order of $1000 Singapore dollars without contrast. So when we budget for grants, we need to budget properly!

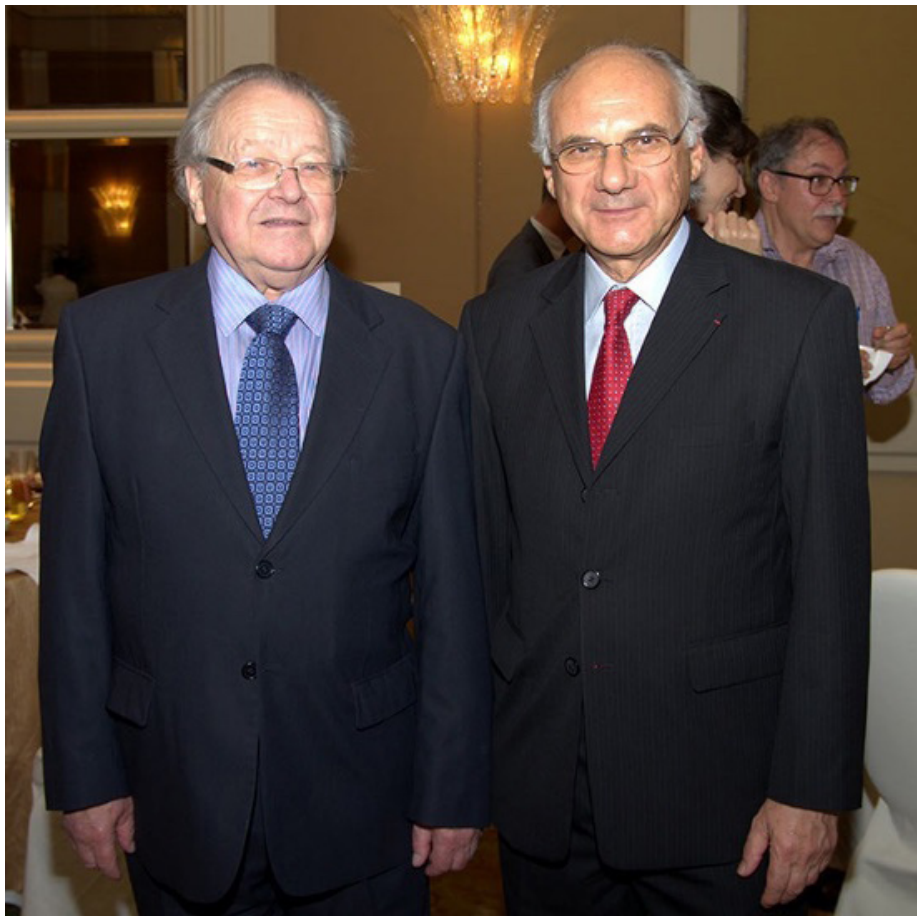
MRMH: What is the relative priority given to research vs clinical MRI in Singapore in terms of national funding?

Ling Ling: The Singapore government has invested quite a bit of money into research, innovation and enterprise (RIE). From the early days of 1991, where only $2 billion Singapore dollars was invested in RIE, the last tranche in 2021 rose to $25 billion. But it takes guts to go into research here because there's a lot of work involved in processes and building platforms. There's a lot of money for 'talent development', e.g., clinician scientists like Ai Peng and myself. There are key areas such as cancer, cardiovascular, neuroscience, infectious diseases and diabetes. But the $25 billion covers research in all areas, not just medical. So, there's also manufacturing, manpower, innovation, enterprise, smart nation, and digital.

Ai Peng: Compared to Ling Ling, I probably get it a little bit easier, because I think now the younger scientists get more support compared with maybe 10 years ago. When I first started research, I was doing it on my own time – my weekends were my research days. And that lasted for about two years, until I had the opportunity to join the Singapore Institute of Clinical Sciences as a PI. They actually bought out one day of my time every week for me to have protected time to do research. I joined a translational neuroscience group under A*STAR, so I get a lot of support in terms of manpower. I was very lucky because last year I got a talent grant from the NMRC, which allows me to spend 70% of my time doing research, so there are a lot of opportunities like that. My plan moving forward is to enter tenure track, and for me that will be at the NUS.

MRMH: Can you tell us about the Singapore Chapter of ISMRM: how has it grown since it started and where do you see it going in the future?

Sendhil: I should start with a little bit of history. Professor Sir George Radda, the former head of the UK MRC, joined as chairman of A*STAR in the early 2000s. Then, in 2005, he created the Singapore Bioimaging Consortium (SBIC), which includes the Laboratory of Molecular Imaging (LMI) with all modalities of in vitro and in vivo cellular imaging (optical imaging, MR spectroscopy and imaging, C-13 hyperpolarization, micro CT, nanoSPECT-CT, microPET-CT, MR-PET, NIRS-MRI, signal and image processing and analysis, all focusing on pre-clinical research). The first high-field 9.4T MRI scanner was a Varian (30 cm bore) installed around 2009-2010. Another high-field Bruker 9.4T magnet was installed around 2013 and an 11.7T system was installed in 2016. These systems support pre-clinical research programs across various labs and institutes and also trials with industrial collaborations. Sir George also set up the National University of Singapore Clinical Imaging Research Center (CIRC) during 2012-2013, where 100% research-dedicated human scanners were installed for the Singapore community.



Sir George Radda and Professor Patrick Cozzone

The 13C hyperpolarized imaging for pre-clinical research was established around 2016. Recently, a human 13C hyperpolarized imaging facility was established at the National Heart Center, integrating the polarizer with a Siemens Skyra system. The Biomedical Research Council supported these resources for the entire Singapore community. After Sir George stepped down, Professor Patrick Cozzone joined as Executive Director of SBIC (2014 to 2021).

MRMH: Do you have dedicated research staff and physicists to try out novel methods and design new sequences?

Sendhil: We do have research agreements with different vendors and research institutes supporting new pulse sequences and reconstruction. Through the Chapter we are trying to improve the educational programs. We are also working with local academic institutes to integrate biomedical imaging courses with proper training to have a continuous supply of researchers. Otherwise, we are dependent on postdoctoral fellows who come from dif-

A 9.4T scanner, installed around 2013.

ferent institutes into Singapore. We also have PhD programs within A*STAR, NUS, NTU and Singapore University of Technology and Design (SUTD) focused on biomedical imaging with clinical problems, which will also support the growing need for MR imaging scientists. So, we will have a pool of scientists coming up continuously into the system.

MRMH: Okay, so potentially, you'd be interested in recruiting physicists who wanted to do PhDs and MRI to Singapore? I'm sure that ISMRM could help with that! Can you tell us a bit about MRI research collaborations between institutions within Singapore, and between Singapore and other countries?

Sendhil: As I mentioned, we do collaborate not only with vendors, but also with scientists from other institutions, like UCLA, where new techniques are being integrated into our research. For example, we have installed free-breathing technology for liver and body imaging applications for pediatric studies where children cannot hold their breath for longer durations. We also have various collaborations for neuro and body imaging from different parts of the world.

Ling Ling: For us, we also collaborate locally with other institutions like A*STAR, mostly for AI imaging topics. We also collaborate with the NUS School of Computing, again on AI topics. But for MR techniques we have mostly collaborated with overseas institutions, such as Mark Haacke with his iron-sensitive sequences for quantitative susceptibility mapping. We also collaborated with Jongho Lee from Seoul National University on high-resolution iron-based midbrain nigrosome-1 imaging and myelin water fraction imaging. A lot of our collaborations also spin off from vendors for our MRI scanners, like Siemens giving us access to WIPs and new methods. We also collaborate with vendors who send us their AI software for us to run analytics e.g., volumetry. We evaluate the utility of the quantitative markers to see how they can be applied to our Parkinson's disease cohorts.

MRMH: Is there already a 7T or higher in Singapore?

Ling Ling: Not yet in this region, although we are actively looking and have interest in UHF (>3T) on this campus.

Sendhil: We have a group in Singapore very actively working on low-field imaging. Dr Shaoying Huang and her team at SUTD are building their own 0.11T scanner. There is a large interest in low field as well as high field, because of the contrast benefits along with other parameters.

MRMH: How do young researchers get involved in MR at PhD level? What careers do they typically go on to?

Sendhil: I can start with that, since as I already mentioned we have PhD students like Chris Ball (see box) who came from the University of Liverpool to do preclinical imaging work in Singapore and continued his PhD at the University of Liverpool through the A*STAR Research Attachment Program (ARAP). The other program called SINGA supports a four-year fellowship for international students to work in any university like NTU, NUS, or SUTD. The students can register anywhere depending on the research specialization. Through the SINGA students we have acquired large volumes of longitudinal imaging data through ongoing cohort studies. AI algorithms are being utilized for automatic quantification and segmentation of imaging data, and also integration with omics data to predict metabolic risks.

Ai Peng: I don't think there's any dedicated MR development lab. But most of the time potential candidates can choose a lab, for example one that deals with neuroimaging, like Ling Ling's lab or my lab. We also have a lab led by Professor Christopher Chen at NUS, who's doing a lot of research in dementia. So, what happens is that when there are potential candidates who are interested in pursuing a PhD, they will usually have a whole list of projects that they can apply to. Subsequently, the typical career path for these people is that they will join a lab as a research fellow. I try to keep my own PhD students in my own lab, if they are a good fit. But because of funding problems they may also need to go to other labs after completion.

Ling Ling: I feel like Singapore could do with more hardcore MR physicists. I don't think that there is enough formal MR physics training available in Singapore. You know, the medical physics course at undergraduate level is a minor program at the National University of Singapore. And mostly the curriculum covers radiation-based medical physics and not MRI. At postgraduate level there are labs, but the projects are mostly on the analysis side of things like diffusion MR, resting-state analysis, etc. But we need more MR physicists around who can tinker with pulse sequence programming on our human MR scanners. We probably need a strategy to hire people to come to Singapore to be able to grow that program.

MRMH: What unique perspectives and expertise does Singapore have to share with international researchers and clinical colleagues at ISMRM?

> *I feel like Singapore could do with more hardcore MR physicists. I don't think that there is enough formal MR physics training available in Singapore.*
>
> –Ling Ling

Sendhil: There's one thing that I would like to highlight about Singapore. Its population includes multi-ethnic Chinese, Malay and Indians, representing a significant proportion of the Asian population. This makes Singapore an attractive location to run a study on an Asian population. Some of our recent research shows that Asians have higher metabolic risks compared to Caucasians. For example, heart failure occurs at a lower BMI and younger age in Asians. We also have observed that there is metabolic dysfunction at lower thresholds of liver fat compared to Caucasians. So Singapore is a great place for Asian-centric research and clinical trials.

Ai Peng: I think one of the unique things that we have, surprisingly, is our small geographic size. This makes it very easy for us to run longitudinal studies, because it takes most participants maybe half an hour to get to the lab. We have an ongoing cohort study that Sendhil is also part of – the GUSTO study of Singapore – which has been ongoing for 13 years now. We have been following up children from birth to adolescence, and we will continue to follow them until they enter adulthood. It is not just about phenotyping using multimodal MRI, we also collect various biological samples from cord and regular blood, and over multiple time points for genotyping and phenotyping. This study has one of the most deeply phenotyped developing cohorts in the world. And that is the most unique thing that I can offer most of the time to my collaborators. I think another real strength that we have is in being

Chris Ball, former ARAP student, says:

I can't say enough how much I enjoyed my time in Singapore, the whole experience was incredible. A*STAR is such an amazing place to start your research career. The lab facilities and equipment are top of the line and you're working with world-class talent, so there is plenty of experience to draw from.

Because Singapore is a relatively small island, all parts of which are amazingly well connected by public transport (as opposed to the UK), collaboration between groups at different sites is really easy. It also means that projects can move forward at a fast pace. I was based at A*STAR but worked with groups on preclinical studies at NUS and NTU and visited a clinical project at the hospital.

I think Sendhil made a good point about English being one of the main languages used in Singapore. Starting a new PhD while overcoming a language barrier would have made the experience a lot harder. But because Singapore is such a melting pot, as Ling Ling put it, there's plenty of opportunity to experience other cultures and learn the language if you wish!

Singapore itself is an amazing place. The culture, the food, the people, it's location in Asia. I feel so lucky to have lived there for a while.

Gardens by the Bay.

very open to hiring research fellows and scientists from all across the world. So we actually have a very condensed community of scientists with all kinds of expertise.

Ling Ling: I think Singapore is a cultural melting pot. I think that's a huge draw for researchers. We are very strong clinically, and there's huge funding for researchers, resulting in a very robust ecosystem. We're also very well connected and serve as a regional hub to the wider Southeast Asia region. The fact that we have English as a first language is helpful. We have funding through the years for many different types of cohorts from GUSTO on the pediatric side through to the elderly, each with very comprehensive, rich and deep clinical and genetic profiling. So I think Singapore is a great place to attract talent and people to, at least I hope.

MRMH: How do you envision yourself and MRI research in Singapore in the next 5-10 years?

Ai Peng: Something that I hope to change in the next 5 to 10 years is to make diffusion and resting-state functional MRI part of the evaluation of children with neurodevelopmental and neuropsychiatric disorders. We know that abnormalities are at the functional level and at the microstructural level. But I think one of the major hurdles is the expertise that you need in the clinical area to do the post-processing and interpretation. For example, we need automated pipelines on the clinical scanner to process these images for tractography and parcellation. It is also extremely difficult to install something new into a hospital system. There are many administrative hurdles that we need to get past, as well as getting the patient's signed consent to allow us to download the images and get our postdocs to pre-process the data.

Ling Ling: I agree with Ai Peng on the pain points on IT security and data access. However, I also think that more recently we have better communicated with the data security people and the IT people to streamline processes for researchers. On a different note, for the area I work on, Parkinson's disease, I hope that we can find better tools for detecting prodrome and translate quantitative imaging biomarkers to track disease progression and differentiate atypical parkinsonism and Parkinson's subtypes for prognosis and novel therapies. There's also ultra-high field, not just 7T but also 5T, that may image the whole body. Those for me are also exciting fields to push the frontiers of human imaging in the clinic.

Sendhil: I would like to add some suggestions. Firstly clinical hyperpolarized imaging, which is being developed in Singapore for heart failure and liver diseases. Secondly, multinuclear imaging for metabolic research applications, including deuterium imaging. And thirdly high field >7T and low field <0.5T imaging.

MRMH: Lastly, what are your top 3 recommendations for delegates to do outside of the conference?

Tchoyoson: I would encourage attendees to try eating chili crab while drinking Tiger beer, both of which are very Singaporean. We've also got chicken rice and a lot of varied cuisine: one I would recommend is Peranakan food, which is unique to Southeast Asia. The diversity of the food options is fabulous.

Ai Peng: I think shopping is still pretty good in Singapore, and Marina Bay Sands and Gardens are really nice places to visit. I personally like the Night Safari, a very interesting option if you have kids.

Ling Ling: The Botanic Gardens is a place to go and luxuriate in the rainforest and Orchid Garden. It's very beautiful, with very nice walks. I also think that Jewel (at Changi Airport) is a great place for shopping. There's a canopy, a mini rainforest and a huge waterfall. It's also very beautiful. Of course, you also need to visit the cultural precincts like Little India, Chinatown and the Malay heritage places. Those are also culturally very interesting.

Sendhil: I would like to add the suggestion of Clarke Quay. Take a boat ride along the river and enjoy the scenic views! ■

ISMRM Executive Director: Anne-Marie Kahrovic

INTERVIEW BY **MARIA EUGENIA CALIGIURI** AND **KATHERINE BLANTER**

With over eight years of experience and mentorship under previous Executive Director Roberta Kravitz, **Anne-Marie** brings a strategic vision and collaborative leadership to ISMRM as our new Executive Director. Anne-Marie's deep understanding of ISMRM's mission and her proven ability to drive strategic initiatives makes her the ideal leader for the Society. In her interim role, she had already demonstrated a commitment to advancing magnetic resonance research and fostering collaboration within the ISMRM community.

MRMH: Dear Anne-Marie, it's a pleasure to present you as our new Executive Director. Now tell us, what should we know about you?

Anne-Marie: My passion for travel and embracing diverse cultures has been a driving force in both my personal and professional life. I've been blessed to have visited over 60 countries, and I've lived abroad in several countries. Being married to someone from another country has further reinforced my connection to the international community. Traveling has not only broadened my global perspective but has also instilled in me a passion for fostering connections and collaboration across borders. "International" is in my blood and it feeds my soul to be part of an international community.

MRMH: Can you tell us about your journey with ISMRM?

Anne-Marie: I joined the ISMRM in October of 2015, and it's been an incredible journey ever since. Joining just before the Singapore meeting was eye-opening for me. Coming from a corporate background in the events industry, adapting to the world of acronyms and the unique approach of a nonprofit association was a whole new experience. In Singapore, witnessing the collaboration and camaraderie among members left a lasting impression on me. There was an undeniable energy and synergy in the air that moved me deeply. It was

Anne-Marie Kahrovic

during those moments, surrounded by the ISMRM community, that I realized this Society had captured my heart. I'm grateful to be a part of this vibrant and welcoming community.

MRMH: How did you make your way to the role of the Executive Director?

Anne-Marie: When I initially joined ISMRM, I assumed the role of Director of Meetings. Over time, I transitioned to the position of Associate Executive Director, where I remained for several years. When Roberta announced that she was looking to retire, she graciously devoted her final year to sharing her extensive knowledge and history in that role with me. Her dedication to transferring this information was truly remarkable, demonstrating her profound commitment to the Society. It was evident that her heart was fully invested in the organization.

MRMH: When you first started as Director of Meetings what was your task?

Anne-Marie: Managing the logistics for the Annual Meeting, workshops, AMPC, and Board meetings requires thorough planning to ensure the success of the event in Singapore. This involves coordinating various aspects and collaborating with numerous vendors to bring everything together seamlessly. Building trust and confidence in these suppliers is essential as you navigate through this process.

MRMH: You joined relatively early in your career. Do you remember any significant changes over time?

Anne-Marie: The pandemic has really emphasized the importance of listening to our membership, who had been advocating for a virtual solution for some time. Now, it's commonplace to simply contact an audiovisual company and request livestream services. This has become the new normal. Along the way, we discovered numerous insights about transitioning to virtual events and striving to replicate the in-person experience online. However, achieving complete parity was not feasible, so we had to refocus our efforts. Our priority became ensuring that those unable to travel still felt connected to their community. ISMRM thrives on community and collaboration, so witnessing COVID-19 disrupt these dynamics was challenging. TheAnnual Meeting

The pandemic has really emphasized the importance of listening to our membership, who had been advocating for a virtual solution for some time. Now, it's commonplace to simply contact an audiovisual company and request livestream services.

in London was a pivotal moment, marked by uncertainty about reacquiring our networking and social skills. However, in Toronto, it was heartening to observe people coming together once more. I distinctly recall looking out over the balcony and seeing groups engaged in deep conversations, signaling the resurgence of interaction. I am so excited to see this community come back together in person in Singapore.

MRMH: Are there any other changes?

Anne-Marie: One significant change implemented last year in Toronto was the adoption of on-demand badge printing, shifting away from pre-printing badges to align with our sustainability initiatives for both meetings and the broader MR community. Previously, we would preprint badges, stuff them, and ship them to the location. Now, however, we've transitioned to shipping the necessary equipment and printing badges on demand. This change has brought about increased efficiency, eliminating the long lines of people waiting to pick up their badges. Leveraging technology in this manner has proven to be a valuable asset in streamlining our processes.

MRMH: Are there any funny stories about Society legends in the Central Office?

Anne-Marie: One evening in Singapore in 2016, a gentleman named Dr. Paul Tofts was standing outside a room, waiting to enter. Two young trainees were utterly captivated by his presence. To them, Dr. Tofts was a true rock star, someone they had admired and learned from. One of the trainees, a young lady, had tears in her eyes as she asked for a photo with him. Initially, I found it a bit surprising, but then it struck me—the field of MR isn't that old; these legends are alive and well in our lifetimes. It's truly amazing for our members to have the chance to meet the very icons they've admired and whose work they continue. It was a moment like meeting a rock star. He *was* their rock star, and they were devoted fans hanging on to his every word.

MRMH: Do you have any particular projects you're aiming to carry on while you're Executive Director?

Anne-Marie: The leadership plays a pivotal role in steering the Society's direction and focus; these will be high on my list of priorities as well as to guide ISMRM in accomplishing its mission of advancing magnetic resonance science, technology, and applications for societal advancement. I am dedicated to spearheading initiatives that will contribute to the organization's continued growth and success. ■

Forty years of *Magn Reson Med*. But how did it all begin?

BY **PETER JEZZARD** (CURRENT EDITOR-IN-CHIEF)

Magnetic Resonance in Medicine is 40 years old this year (the first issue was published in March 1984). But how and why did *Magn Reson Med* come about? This article seeks to tell the intriguing story.

ISMRM predecessor societies SMRI and SMRM are born

The origin of *Magn Reson Med* is tied intimately with the history of the ISMRM and its predecessor societies SMRI and SMRM. In turn, their origins lie in a series of early meetings involving the pioneers of the emerging field of nuclear magnetic resonance imaging (NMRI, as it was then called). These were held variously at the Royal Society of London in 1979 (co-organized by E. Raymond Andrew, of whom more later); then at Vanderbilt University in Nashville, Tennessee, in 1980; then at Wake Forest School of Medicine in Winston-Salem, North Carolina, in October 1981. The chronic problem for the emerging field, and the reason for these meetings, was that developments, presentations and discussions related to NMRI were not given adequate time and prominence at traditional physics, chemistry, biochemistry and radiological society meetings of the time.

While proposals for a formal scientific society in the field of magnetic resonance had been discussed at these meetings, it was not until the meeting in Winston-Salem that a firm proposal emerged. Or rather two firm proposals, since in that early competitive world of MRI there were acute differences of opinion on who should lead the society, and what form it should take. As such, two splinter societies emerged: the Society of Magnetic Resonance Imaging (SMRI), proposed by Sharad Amtey (Texas, Houston), Leon Partain (Vanderbilt), Francis (Frank) W. Smith (Aberdeen, UK) and their colleagues; and the Society of Magnetic Resonance in Medicine (SMRM), proposed by Tom Budinger (Berkeley), Paul Lauterbur (Stony Brook), Alex Margulis (UCSF) and

Attendees of the Winston-Salem meeting in North Carolina in 1981. Some of the founders of SMRI and SMRM are indicated by blue dots and orange dots, respectively. SMRI founders include (left to right): Francis W. Smith; Bill Moore; Leon Partain; Paul Bottomley and John Gore. SMRM founders include (left to right) David Hoult; Ian Young; George Radda; Paul Lauterbur; Tom Budinger and Peter Mansfield. Note the gender (im)balance!

their colleagues. Each society attracted both scientists and clinicians, and many researchers in the field belonged to both societies, although most of the in-vivo spectroscopy community attended SMRM meetings only. Their annual meetings were roughly six months apart, with the SMRI Annual Meeting in the spring, and the SMRM Annual Meeting in late summer.

The need for society journals

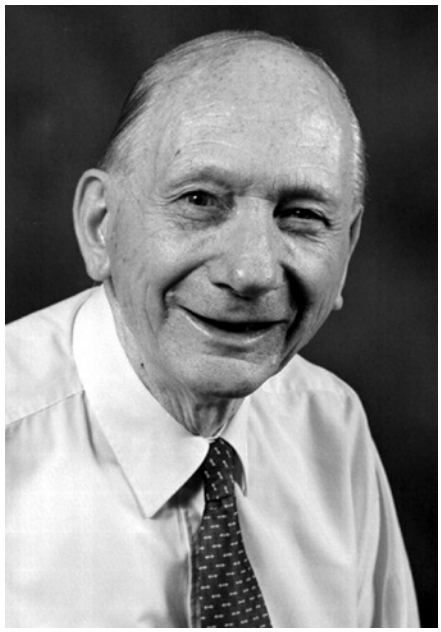
Both new scientific societies felt that they needed a peer-reviewed journal in which to publish the latest developments in the field. SMRI was first to form a specialist journal in 1982, and thus the journal Magnetic Resonance Imaging was established in partnership with Pergamon Press. Its first Editor-in-Chief was Sharad Amtey, who was then at the University of Texas Health Science Center at Houston. Amtey also became the second President of SMRI (1983-1984), following on from Frank Smith of Aberdeen Royal Infirmary, Scotland, who was the inaugural President (1982-1983) of the fledgling SMRI. Over at the SMRM the society office was hosted by Alex Margulis' lab at UCSF, and Paul Lauterbur became its inaugural President. In those early days both the SMRI and SMRM were on tenuous financial footings that were barely sustainable, due to their limited memberships (not helped by a requirement early on for applicant members to have demonstrated activity in a field that was still in its infancy). Both societies relied on their annual meeting revenue to stay afloat.

Four issues of *Magn Reson Imaging* were published in 1982, with no issues published in 1983. After Sharad Amtey resigned as President of SMRI in early 1984 (due to disagreements with the Board), Bill Moore (he of the W.S. Moore YIA prize) was elected in Amtey's place, but sadly died before he could take up office. The decision was also taken to replace Amtey‡ as Editor-in-Chief, and so by March 1984 *Magn Reson Imaging* had a new Editorial Board, and new co-Editors-in-Chief (John C. Gore and Frank Smith). Another four issues were published that same year.

Meanwhile, SMRM's proposed journal, Magnetic Resonance in Medicine, struggled to secure a willing Editor-in-Chief. Paul Lauterbur was intended to be the first Editor, but did not want to take it on. Gerry Pohost (then at MGH) was also asked, but also ultimately declined. Eventually, someone (probably Paul Lauterbur) suggested the name of E. Raymond Andrew, who had recently moved from the University of Nottingham in the UK to the University of Florida in Gainesville, USA.

E. Raymond Andrew becomes founding editor of *Magn Reson Med*

(Edward) Raymond Andrew was widely agreed to be an inspired choice as founding editor of *Magn Reson Med*. He had been involved in NMR for many years (he was a post-doc under Edward Purcell at Harvard) and latterly in MRI, and had avoided taking sides in the early rifts over SMRI versus SMRM. Raymond had been Head of the Department of Physics at the University of Nottingham, and was responsible for recruiting Peter Mansfield amongst other early pioneers of NMR and MRI, which helped make Nottingham the powerhouse that it became. Raymond himself had made numerous early contributions to NMR, in particular proposing 'magic angle spinning' to collapse the dipolar-broadened lineshapes in solid-state NMR spectra into resolvable chemically-shifted peaks. He had been president of the Ampere Group that organized regular NMR meetings in Europe, including an influential 1974 meeting in Nottingham that introduced spatially-selective excitation to MRI. He was an initial co-principal investigator on UK grants that supported very early, if not the first, human MRI systems from 1974 to 1980, with Bill Moore, Waldo Hinshaw, Paul Bottomley, Neil Holland and Rob Hawkes. However, there was intense rivalry within Nottingham between Raymond's group and Peter Mansfield's group, perhaps contributing to his decision to move to the USA in 1983, as he approached mandatory retirement age in the UK.



Founding Editor-in-Chief of *Magn Reson Med*, E. Raymond Andrew (1921-2001).

Under Raymond's stewardship, *Magn Reson Med* quickly established itself as a leading journal in the field of magnetic resonance. Paul Bottomley, who was a member of the initial Editorial Board of the journal, and who still serves as a Deputy Editor of *Magn Reson Med*, puts this down to a rigorous selection of papers and peer review process, overseen by Raymond, perhaps inspired by, and seeking to emulate in quality, the standards set by the highly successful *Journal of Magnetic Resonance,* which was then the main destination for technical developments in our field. This was probably also the reason that Academic Press was chosen as the first publishing partner for *Magn Reson Med*, since it also published *J Magn Reson* at the time.

A personal recollection I have of Raymond, since he spent a brief sabbatical in the lab that I did my PhD in, was his unnerving ability to snooze (loudly) through a talk at our weekly lab meeting, and yet still manage to ask the best and most penetrating question at the end. Quite an impressive skill! He continued as Editor-in-Chief of *Magn Reson Med* until 1991 when Felix W. Wehrli took over. Raymond died in Gainesville in 2001 at the age of 79.

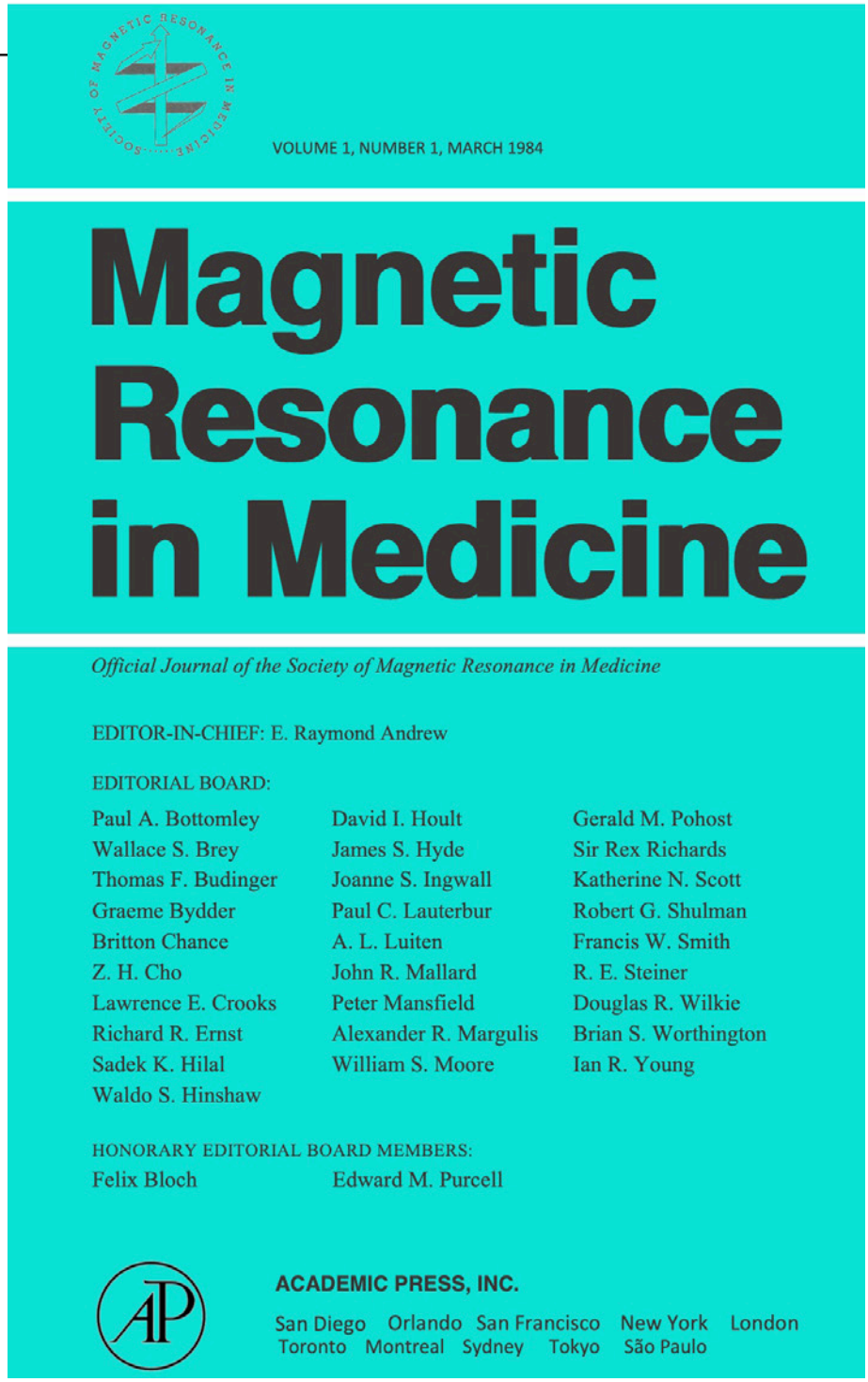
SMRI launches a new journal, and the SMRI and SMRM merge

Around 1990/91 the SMRI leadership, in particular Bill Bradley Jr (California) and David Stark (MGH), wanted the SMRI's journal, *Magn Reson Imaging*, to be more clinical and for the SMRI to have a greater share of its journal's revenue, including subscriptions and advertising income, rather than them going to a for-profit company.

Also, Gary Fullerton (Texas, San Antonio), who was the SMRI President at the time, wanted to be the Editor-in-Chief of the journal. However, *Magn Reson Imaging* had been doing well scientifically and financially under John Gore and Frank Smith, and so Pergamon Press would not relinquish it and wished to keep the arrangements as they were, with John as Editor-in-Chief. As a result, SMRI and Pergamon Press parted company and a new journal, *Journal of Magnetic Resonance Imaging*, was established by SMRI (at considerable financial cost to the society) as its official society journal, and with Gary as its first Editor-in-Chief. In this case the journal was wholly owned and published by the SMRI, albeit produced with the assistance of the Radiological Society of North America, RSNA.

In the early 1990s there was an increasing unwillingness by the vendors to support two similar magnetic resonance conferences each year. Eventually, a merger was agreed between SMRI and SMRM, and by 1994 there was a new combined scientific society, initially called the Society of Magnetic Resonance (SMR), but quickly altered (after complaints of over-reach by the chemistry NMR community) to the International Society for Magnetic Resonance in Medicine (ISMRM). By this point the ISMRM had adopted both *Magn Reson Med* and *J Magn Reson Imaging* as society journals, and so their status remains. Meanwhile, *Magn Reson Imaging* continues as an independent journal (under Elsevier, who bought Pergamon Press), still under the editorship of John Gore, and still with a mission that overlaps our own.

Since the early days, *Magn Reson Med* has changed publishing partners twice. Once with a change from Academic Press to Williams and Wilkins, and then a change from Williams and Wilkins to John Wiley and Sons. It has also seen several Editors-in-Chief. Following Raymond Andrew, Felix Wehrli was Editor-in-Chief from September 1991 – December 2004. He was followed by Michael B. Smith, who served from January 2005 to July 2010. Jeffrey L. Duerk then served briefly as Interim Editor-in-Chief, after which Matthew A. Bernstein was Editor-in-Chief from February 2011 - December 2019. I was honored to take over from Matt in January 2020, after a long period as a Deputy Editor.



Volume 1, Issue 1 of *Magn Reson Med*, showing the first Editorial Board.

Throughout this whole time *Magn Reson Med* has been a top destination for innovations in our field, and has published many of the key developments in magnetic resonance technology and methodology. Which brings us to the present day…

So happy 40th birthday *Magn Reson Med*! May it continue to prosper and serve as a leading journal in innovations in our field.

I would like to acknowledge various individuals who provided sources of information for this article or who have written previously on the history of the ISMRM. These include Paul Bottomley (particularly), John Gore and David Hoult for their recollections, and Ian Young, Leon Partain and John Griffiths for articles that they have written previously. ■

‡ In a strange footnote to ISMRM history Sharad Amtey, who played no further part in SMRI's or our field's history after 1984, died in suspicious circumstances in 2013 following an argument with his wife over their cable TV connection. She was convicted of second-degree murder, but later had this reduced to voluntary manslaughter and was released after serving a year in jail.

A BLAST FROM THE PAST

First of its kind

Graeme Bydder & the very first MRM paper

INTERVIEW BY **MARIA EUGENIA CALIGIURI**

Prof. Graeme Bydder, pioneer and living legend of MRI, was the first author of the first paper published in *Magnetic Resonance in Medicine,* Vol 1: The NMR Diagnosis of Cerebral Tumors. It was an honor and a pleasure to hear the story behind this milestone, his appreciation for Galileo Galilei's supervision of his telescope project, and his thoughts on how to interact with clinicians. Enjoy the journey reading the following interview!

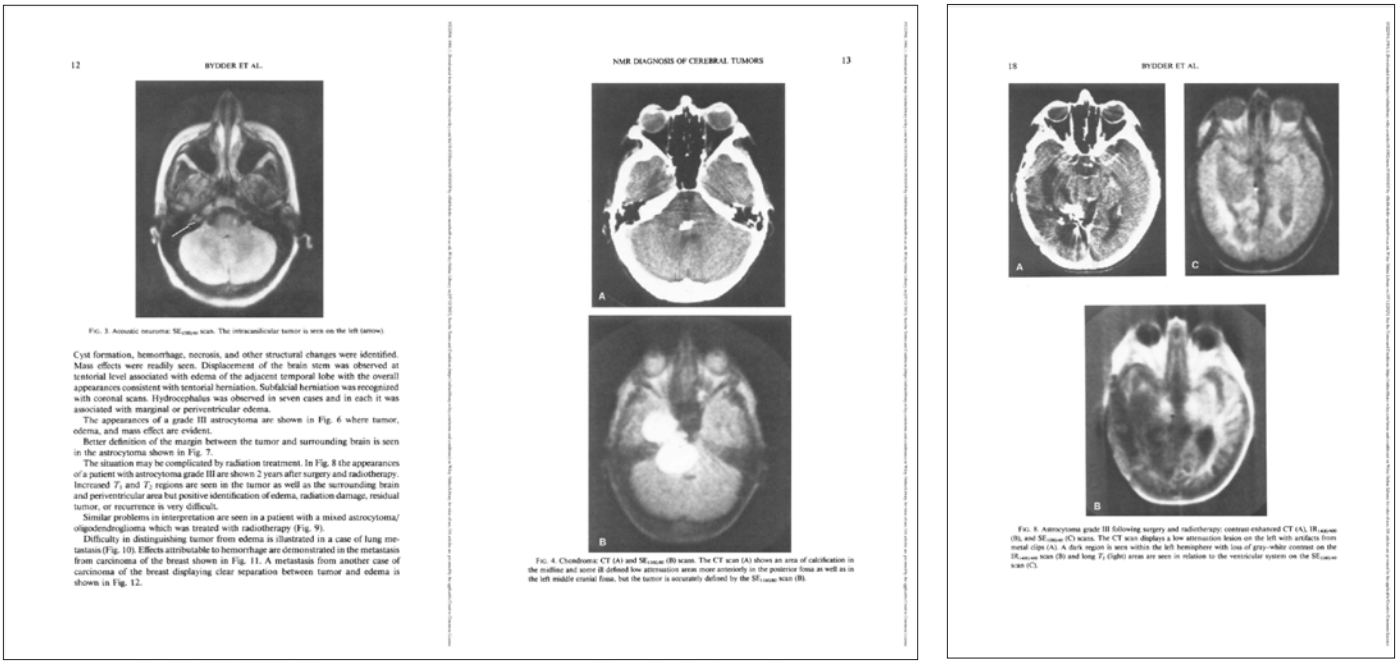
MRMH: What was the rationale of your study?

Graeme: The paper was submitted in 1982 (received Sept 24, 1982, revised November 1982). The approach was multi-sequence NMR using two or more sequences (inversion recovery and spin echo). Previously, only single sequences (e.g., SSFP) had been used, and were not able to show even large tumors. The multisequence approach made MRI, which was a slow technique, even slower and this approach did not find general favor. People were starting to think that MRI was not going to succeed. Furthermore, at the time, there were concerns that NMR/MRI was inferior to CT for imaging tumors, particularly meningiomas. Even though meningiomas are benign, missing them is a serious matter. While CT was used with iodinated contrast agents, no such substance was available for MRI. Thus, key features like the presence of meningiomas (usually strongly contrast-enhancing) and the rims of malignant tumors at the tumor-edema junction were being missed with MRI. Back then, CT was a mature technology which had enjoyed a decade of development, but MRI was new and only research prototypes were available.

MRMH: You were able to collect 52 cases for this study. Sounds like a very large cohort to recruit in the 1980s.

Graeme: It was, indeed. Our hospital only had two neurology beds and no neurosurgery, so most of the patients had to be imported from other hospitals and clinics around London. There was much less organization, as one can imagine, than hospitals and research centres have now. And on top of that, it was not easy to communicate with neurologists from other institutions – they were very sceptical about findings from this new technique. Back then, clinicians trusted genetics and immunology, while medical imaging was not well received.

MRMH: You were looking for a way to prove MRI potential in studying brain tumors which, given the scientific context, must not



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Cyst formation, hemorrhage, necrosis, and other structural changes were identified. Mass effects were readily seen. Displacement of the brain stem was observed at tentorial level associated with edema of the adjacent temporal lobe with the overall appearances consistent with tentorial herniation. Subfalcial herniation was recognized with coronal scans. Hydrocephalus was observed in seven cases and in each it was associated with marginal or periventricular edema.

The appearances of a grade III astrocytoma are shown in Fig. 6 where tumor, edema, and mass effect are evident.

Better definition of the margin between the tumor and surrounding brain is seen in the astrocytoma shown in Fig. 7.

The situation may be complicated by radiation treatment. In Fig. 8 the appearances of a patient with astrocytoma grade III are shown 2 years after surgery and radiotherapy. Increased T_1 and T_2 regions are seen in the tumor as well as the surrounding brain and periventricular area but positive identification of edema, radiation damage, residual tumor, or recurrence is very difficult.

Similar problems in interpretation are seen in a patient with a mixed astrocytoma/oligodendroglioma which was treated with radiotherapy (Fig. 9).

Difficulty in distinguishing tumor from edema is illustrated in a case of lung metastasis (Fig. 10). Effects attributable to hemorrhage are demonstrated in the metastasis from carcinoma of the breast shown in Fig. 11. A metastasis from another case of carcinoma of the breast displaying clear separation between tumor and edema is shown in Fig. 12.

NMR DIAGNOSIS OF CEREBRAL TUMORS 13

A

B

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A

C

B

Excerpts from the original paper: Figures 3, 4 and 8.

have been easy at all. How did you succeed?

Graeme: We dealt with this in part by emphasizing the posterior fossa, where CT had beam-hardening artefacts and was at a disadvantage compared with MRI. In the paper, we showed comparisons with low-grade gliomas which do not generally enhance with CT so the lack of MRI contrast agents was not a disadvantage. One of our successes was a case of chondroma in the posterior and middle fossae, published as Figure 4 in the paper. On CT, it showed calcification in what appeared to be the middle of the pons and was thought to be a pontine glioma within the brain, which was inoperable. However, on MRI, the tumor was outside the brain and operable. Unlike a meningioma, which would have enhanced with CT, chondromas do not enhance and so the tumor was not visible with contrast-enhanced CT, apart from the calcification. This was a major success for MRI. The patient did well after surgery.

MRMH: The paper contains several amazing images. Beyond the one you already mentioned, are there others that you consider of note?

Graeme: In the third figure of the paper we also showed an intracanalicular acoustic neuroma that was not visible with CT, as well as tumors with clips where the CT images were degraded by streak artefacts (e.g., Figure 8).

MRMH: How did you choose MRM as target journal?

Gerald Pohost from MGH, who was supposed to become MRM's first editor, invited our paper in 1982 to launch the journal, but his editorship was not a success and the journal did not get started. Gerald was replaced as editor by Raymond Andrew from Nottingham and Florida State University and MRM was launched in 1984. This was two years after the rival journal *Magnetic Resonance Imaging* supported by SMRI was launched by Sharad Amtey. MRM was the journal of SMRM. Gerald was also secretary of SMRM and had a large workload. He had a later successful career in cardiac MRI at the University of Alabama and the University of Southern California. There was no JMRI at that time and MRM was trying to appeal both to scientists and clinicians (including radiologists) and was seeking clinical papers, which was one of the reasons we were invited to submit our work.

Graeme Bydder, together with Maria Eugenia Caligiuri and Mathieu Boudreau at ISMRM2022 in London.

MRMH: Reading the paper, it becomes clear that yours was a truly ground-breaking study, that pushed MRI along in the race with other imaging modalities.

Graeme: Between 1981 and 1985, MRI went from a total of three clinical scanners to 515 worldwide (as of today, there are about 60,000), so the initial concern that the technique might not get off the ground clinically, as with other new techniques (e.g. thermography, microwave imaging, impedance tomography, near infra-red imaging), was allayed. However, Technicare, the major MR manufacturer during this period, was sold by Johnson and Johnson who moved out of MRI, so the future was not assured. Furthermore, GE's aggressive marketing of 1.5T MRI began in November 1982. It was tough on low field imagers like us who operated at 0.15T, but overall their construction of a new factory to build their 1.5T systems, and assertive position about the future of MRI was a boost, even though it would not be until 1985 that they published clinical results with their 1.5T systems.

MRMH: And in the clinical field, how were your results received by neurologists?

Graeme: In retrospect, the MR findings in tumors as described in 1982 have held up very well. Noise is identifiable on the 0.15T images which were obtained without a closely applied head coil, but the artefact level is low. There was concern about MR provoking fits in patients at the time, but this turned out not to be an issue. The paper served as a holding position until Schering's Gadolinium DTPA (Gd-DTPA) came into clinical practice in March and May 1984. Schering AG [acquired by Bayer in 2006, *editor's note*] was based in West Berlin at that time, which was before the wall came down, and they were keen to demonstrate the advantages of the Western way of life. Hanns-Joachim Weinmann and Ulrich Speck from Schering worked with Roland Felix, who had one of the first 0.35T Siemens MRI systems in West Berlin. Their findings made it possible to see meningiomas and rim enhancement in gliomas with MRI. The pressure was then off in one sense, but in the US Gd-DTPA was not FDA approved for clinical use until 1988, so US-based radiologists had to do their best without it for another four years.

MRMH: Professor Bydder, thank you for sharing your memories with us. It has been a great journey into the good old days of MRI!

Graeme: Thank you for choosing this paper to celebrate MRM's 40th Birthday! ■

All-time favourite MRM papers from ISMRM members

COMPILED BY **CHRISTIAN LANGKAMMER**

To continue celebrating MRM's 40th birthday, we asked our members of the same age (or not!) to share their favourite articles. Read further and see if your favourite is already in the list!

Jack Wells, PhD - UCL, London, UK

A General Kinetic Model for Quantitative Perfusion Imaging with Arterial Spin Labeling

Buxton, R.B., Frank, L.R., Wong, E.C., Siewert, B., Warach, S. and Edelman, R.R. (1998), A general kinetic model for quantitative perfusion imaging with arterial s pin labeling. *Magn. Reson. Med.,* 40: 383-396. https://doi.org/10.1002/mrm.1910400308

If there was one paper that I associate with my Ph.D, I think it has to be this one. I was highly motivated to understand this work because I had been tasked by my supervisor (David Thomas) with taking the ASL images that I had acquired and getting some reliable CBF maps out. In parallel to understanding the biophysics of the paper, a big challenge for me was that I was learning how to use MatLab at the time. Thus, I recall spending many months studying this paper and trying to understand and implement the models described in MatLab (a slow and painful but ultimately rewarding process!).

This pioneering work, published soon after the initial conception of ASL, beautifully describes the interplay between the choice of MRI sequence parameters, the underlying cerebral haemodynamics and the most appropriate biophysical models towards the goal of more accurate CBF quantification with ASL methods. An exciting element of the work is its integration of the relatively new multi-delay time component of ASL acquisitions to capture the dynamic delivery of the labelled bolus of arterial blood water to the brain tissue. This work provides a wonderfully detailed and critical insight into ASL methodologies that has well and truly stood the test of time.

Diffusion-weighted spin-echo fMRI at 9.4T: microvascular/tissue contribution to BOLD signal changes.

Lee, S.-P., Silva, A.C., Ugurbil, K. and Kim, S.-G. (1999), Diffusion-weighted spin-echo fMRI at 9.4 T: Microvascular/tissue contribution to BOLD signal changes. *Magn. Reson. Med.,* 42: 919-928. https://doi.org/10.1002/(SICI)1522-2594(199911)42:5<919::AID-MRM12>3.0.CO;2-8

For my second choice I wanted to choose a paper by Seong-Gi Kim as he has been involved in so many papers that have inspired me throughout the years. This work embodies what I love most about working in MRI research which is trying to gain insight into the physiological processes that underlie the MRI signal. This pre-clinical study combines MRI relaxometry, diffusion imaging and BOLD measurement to better understand the vascular contributions to the BOLD signal. To me, what really comes across in this work is the passion to get to the underlying truth of the haemodynamic changes underlying the measured signals through the refined implementation of several novel and technically challenging methodologies. In particular, the phantom studies presented in Figure 2 were also hugely useful for my some of my earlier studies (e.g https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3564190/) where I was trying to understand why the T2 values of the blood that I had measured were less than that of the brain tissue at 9.4T.

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Jon Tamir - The University of T exas at Austin, USA

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Nikola Stikov - University of Montreal, Canada

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How MRM papers impacted industry

BY **THOMAS LINDNER**

Canon Medical

From the very early days of MRI product development, in the mid 1980s, scan time reduction has always been a major driver. At that time, the typical method of scan time reduction was simply to acquire multiple lines of k-space per TR. The seminal 1986 paper by Hennig, et al.[1] had vital influence for myself and other developers at Canon Medical (then Toshiba) implementing Fast Spin Echo. The FSE/FASE implementations benefited greatly, especially in design of the refocusing (flop) pulses and angles leading to contrast improvement, based on the understanding of stimulated echo behavior from this manuscript.

Continuing in image acceleration, as most vendors will surely agree, a critical evolution in MRI came around the turn of the century with productization of parallel imaging. Early contributors to that in MRM were Carlson & Minemura in 1993[2] who not only described the technique of 2x acceleration using two nested volume coils, but also predicted the corresponding SNR trade-off ($\sqrt{2}$) and the spatial variation that would later be described as the g-factor. Indeed, the thread of publications in the parallel imaging revolution, which led to changes in multi-element coil design, system channel count, and image acquisition and reconstruction techniques, is richly represented in MRM, including among many others, the seminal publications by Sodickson & Manning (1997) and Pruessmann, et al (1999).

Even before the connection between gadolinium and NSF, Canon Medical (then Toshiba) was interested in developing MR Angiography, including run-off peripheral angiograms, without the use of external contrast agents. The 2010 manuscript by Nakamura, et al.[3] is one of the foundational papers in non-contrast 3D MRA, in particular, highlighting the use of ECG-gated acquisition to differentiate arterial and venous signal.

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GE HealthCare

The MRI Systems Laboratory at GE HealthCare Technology & Innovation Center has, as its focus, pushing for higher speed of image acquisition and higher specificity in imaging the brain microstructure. One influential *Magn Reson Med* paper that provided an impetus to gain higher image SNR in the brain was by Murakami, et al.[1] where they showed a method for correcting for coil-related signal intensity variations in a 4-channel volume phased-array coils. This publication was the precursor to the use of 32 to 64 channel phased-array coil for use in brain imaging as the clinical standard-of-care today. Murakami's 1996 paper was based on clinical use of phased-array coils, first introduced in 1991 by Roemer, et al. in *Magn Reson Med* (10.1002/mrm.1910160203), that provided a path for increasing SNR over single-channel or quadrature RF coils, while overcoming the issue of marked signal intensity variations that were the hallmark of phased array coils in the early days of MRI. The multi-channel phased array coil technology later pointed the way to the development of parallel acceleration which provided a means of reducing scan time by Sodickson, et al.[2] and Pruessman, et al.[3] Multi-channel phased array coils today are ubiquitous in clinical imaging and parallel acceleration enabled by phased array coils is an essential clinical tool to speed up examination time.

Our lab built off these earlier 4-channel coil designs and later demonstrated a 128-channel coil by Hardy CJ, et al. in 2008 (10.1002/jmri.21463).

Another influential *Magn Reson Med*

Yoshimori Kassai, Canon Medical Systems, Japan.

Thomas Foo, Chief Scientist at Technology & Innovation Center, GE HealthCare, Niskayuna, NY.

paper was by Assaf, at al.[4] which described a technique for measuring axonal diameter distribution in the brain. The ability to measure axonal diameter has significant implications for brain development and brain processes for a range of clinical indications, such as stroke rehabilitation, brain development, Alzheimer's disease and cognitive impairment, neuroplasticity, and psychiatric disorders. This paper inspired our lab to identify and develop the necessary technologies needed to better measure axonal diameter distribution with a simpler model and in a much shorter, clinically practical time. Our work in developing highly efficient, high-performance head gradient systems with asymmetric transverse gradients, such as MAGNUS (Foo, et al., 2020, 10.1002/mrm.28087), demonstrated that effective axonal diameter distributions can be acquired in as little as 20 min. In addition, this new gradient platform enabled methods that previously could only be used in pre-clinical MRI systems to be used clinically in patients. An example of this is oscillating gradient spin-echo (OGSE) diffusion encoding for assessing cellularity in tumours by Zhu A, et al. in 2023 (10.1002/mrm.29758).

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Philips

Our warmest congratulations on the 40th anniversary of MRM; Happy Birthday! MRM, you are an excellent journal supporting the whole MR community for so many years now as a platform where MR science meets instrumentation and clinical practice.

Most of our Philips researchers, engineers,

Peter Börnert, Philips Innovative Technologies, Hamburg, Germany.

and clinical scientists grew up with MRM, learned from it as readers and contributed to the content as authors and reviewers. Together we shaped MRI as a field, advancing magnetic resonance in a community effort.

Many MRM papers impacted the way in which MRI evolved. Among them, the phased array work from GE research[1] is an outstanding piece of work. This seminal paper that comprised new hardware along with appropriate reconstruction methodology in great detail, triggered many research and development activities within Philips to gain SNR at different field strengths. It paved the way for the next big bang: SENSE.[1] Although, we were all aware that local signal reception has features of an alternative spatial encoding approach, next to Fourier, it took us, as a community, somehow a full decade to realize its potential to accelerate MR scanning, trading SNR into speed. Apart from other seminal parallel imaging concepts (Sodickson and Griswold), Philips focused on the Pruessman, Weiger approach,[2] due to its simplicity, numerical efficiency, SNR-behavior, and beauty (using the same equations as Roemer[1]). With parallel imaging hardware already in its product, SENSE put Philips in the forefront of acceleration technology for many years and triggered the reciprocal idea: Transmit-SENSE. Many different model-based image reconstruction approaches emerged based on parallel signal reception, culminating in Compressed Sensing[3], a sampling concept going beyond Nyquist limitations, allowing for immense acceleration on top, using the power of modern numerical mathematics and appropriate denoising, paving the way for AI-supported technology and solutions, revolutionizing clinical practice today.

Well, this is a rather sampling-centered view, but MRI is nothing without its diagnostic application and the huge variety of image contrasts. Diffusion[4] is a key diagnostic contrast, using the water as a local molecular reporter to probe micro-structure, having applications in stroke detection, tumor assessment, nerve- and muscle-fiber tracking and much more. Lots of work has been and will be spent addressing all the different flavors and anatomies. Robust water/fat separation, based on chemical shift encoding, often dubbed Dixon MRI, was first proposed in the 1980s (in a rival journal) but only achieved its full potential in 2005. Reeder's MRM paper[5] had profound clinical impact, offering unparalleled fat suppression, by exploiting the spectral properties of fat. This triggered many activities within Philips, generating new techniques such as robust flexible echo time implementations for two-point-Dixon (applied in fast body MRI and contrast-media-free peripheral angiography) and six-point-Dixon for un-biased liver-fat quantification, with potential as a biomarker in the future.

Thanks to MRM. Thanks to the present, the past editors, the staff, the numerous reviewers, to all who dedicated time and effort in such a non-profit way, and all the best for the future of MR!

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Siemens Healthineers

While there are numerous technological innovations driven by industry, like high-end gradient coils, phased-array receive coils, and prospective image-based motion correction, to name only a few, a lot of innovative ideas are sparked by the community of MR researchers worldwide. The initial dissemination of those ideas mainly happens by presentations at scientific conferences, like the ISMRM. However, short abstracts and presentations only allow sharing of superficial information. Therefore, it is highly appreciated that technical notes and full papers give a detailed insight into the techniques that have been developed. The prime journal for this is MRM, which is a great source of inspiration also for Siemens Healthineers. Some of the new techniques published there are groundbreaking and have also influenced product development of Siemens Healthineers for many years. One such technique was the introduction of SENSE and GRAPPA,[1,2] which for the first time allowed the acquisition of less data than required by the Nyquist sampling theorem in a robust manner without significant impact on image quality and contrast. This immediately enabled the scan time to be cut down by at least a factor of two without the need for extra hardware and therefore made it quickly into all imaging sequences. For some applications, like EPI, it even improved image quality as the susceptibility-related distortions are significantly reduced. This led the way to applications of EPI not only in the brain, but also prostate and breast.

Even today, parallel imaging is still the standard acceleration technique in research and clinical imaging. Further improvements over the years allowed higher undersampling factors and with the extension to undersampling in the partition direction of 3D sequences. The initial idea of undersampling also brought 3D imaging from research into clinical routine, since now scan times of under three minutes were possible, making it very comparable to scan times of 2D sequences.

With the invention of Multiband and Simultaneous Multi-slice,[3-6] acceleration in the slice direction was also introduced to 2D sequences, allowing for even faster scanning also for 2D imaging. This revolutionized the acquisition of functional and diffusion imaging, where until then scans were time consuming and thus were restricted to research settings only. The papers showed ways to reach new dimensions in temporal resolution and acquisition speed, now allowing multi-directional diffusion encoding acquisitions in clinical routine. Many sites are now acquiring DTI instead of regular diffusion scans to get additional information in the same scan time. Also for routine TSE imaging, the reduction in scan time was significant and the developments came at the right time. The ever-growing demand for scans combined with the reduced reimbursement rates and increasing staff shortage calls for faster scanning and shorter scan slots. Both parallel imaging and slice acceleration play a pivotal role in supporting this, even today.

These innovations, initiated by the above-mentioned papers, became core products of Siemens Healthineers MR applications and are also the foundation of the more recently developed acceleration methods like Compressed Sensing and deep-learning based image reconstruction. Those methods, which recently made it into the MR products, are all based on acquiring less data in k-space and utilizing the additional information from the multi-element coils to reconstruct images in superb image quality, even with high acceleration factors.

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United Imaging

In Spatial Domain Method for the Design of RF Pulses in Multicoil Parallel Excitation[1]

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Grissom et al. introduced a spatial domain approach for designing RF pulses in parallel transmission. The novel design technique is articulated as a minimization problem, where the RF pulses design is formulated as a minimization problem with a quadratic cost function. Compared to earlier methods, Grissom et al. included ROI specification, compensated for B0 inhomogeneity, and allowed the use of arbitrary transmit k-space trajectories. Moreover, the MATLAB code in this paper and future publications by William Grissom were made publically available, thus allowing many RF designers including myself to get started with the theory, simulation, and implementation of parallel transmission RF pulse design.

Despite the development of parallel transmission RF pulse design in recent years, its implementation has always been challenging. This is because additional B1+ and B0 maps need to be separately acquired, moved from the scanner console to a separate PC, and processed before the RF pulse calculation. In addition, the computation time for a sophisticated RF design strategy can be long, especially for designs that involve a large tip angle and a full Bloch simulation. In Universal Pulses: A New Concept for Calibration-Free Parallel Transmission,[2] Gras et al. introduced the concept of Universal Pulses, which are designed based on B1+ and B0 maps acquired on a number of test subjects and are then applied on new subjects without any calibration. Such an innovation drastically reduces the barrier of applying parallel transmission RF pulses to improve B1+ inhomogeneity at 7T.

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PRESIDENTIAL INTERVIEW

ISMRM President Derek Jones

INTERVIEW BY **LAURA BORTOLOTTI** AND **KATHERINE BLANTER**

Prof. Derek Jones, Director of CUBRIC (Cardiff University Brain Research Imaging Centre, in Cardiff, Wales UK) and MRI legend, is currently President of ISMRM. In this interview we talked about his first steps in the field, the path that led him to this point and his priorities as ISMRM President.

MRMH: How did you get started with MRI research in the first place? How was your research initially received? Do you remember your first ISMRM presentation?

Derek: Everything started with me studying Physics at the University of Nottingham, with the intention of becoming a meteorologist! While I was there, with Peter Morris and Richard Bowtell as my tutors (and a final year project in the Sir Peter Mansfield Imaging Centre where I used to see Sir Peter!), I learned about MRI and about Medical Physics more generally. At the end of my undergraduate degree, I enrolled in the national training scheme within the UK's National Health Service to become a medical physicist working in nuclear medicine and radiotherapy. Towards the end of that, I was told by Mark Horsfield (who had done early measurements of diffusion in multiple sclerosis), that this new technique called Diffusion Tensor MRI had just been published, and that if I wanted, I could study for a PhD on this topic with him… and that's when I started in MRI!

My first ISMRM poster presentations were in Vancouver in 1997 on *The nature of chronic ischaemic damage and lacunar infarction demonstrated by diffusion tensor MRI* and on *Full representation of white matter fibre direction on one map via diffusion tensor analysis*. When presenting that second poster, I was presenting alongside Carlo Pierpaoli and Stefan Skare, who ultimately became my colleague and longest-standing ISMRM buddy, respectively, and who I still chat with 28 years later! My first platform presentations were in Sydney in 1998, including *Non-invasive assessment of structural connectivity in white matter by diffusion tensor MRI*. I remember clearly that my nervousness meant that I didn't sleep well for a couple of weeks before that! Back then, when I was a Ph.D. student, people were very kind and supportive, and it felt much less competitive than it does now!

Derek with Stefan Skare, (now at the Karolinska Institute in Stockholm), at the 'Brit Party', ISMRM Honolulu 2002.

MRMH: What were your early days at ISMRM meetings like? Did you recognize many faces? Any advice for people at the start of *their* career?

Derek: The first meetings were much smaller! At my first meeting (New York, 1996) there were just 2,700 attendees! I obviously recognized folks from the British Chapter of the ISMRM. Diffusion MRI was also a small topic at the time, so it was always the same small group of us in the sessions and delivering talks on the podium, so I quickly started to recognize them, and I am still in touch with most of them today.

I think my biggest mistake during those early Annual Meetings was to underestimate how exhausting it could be trying to attend all the sessions and all the social events happening in the week. It is natural to have the feeling of missing out at first, but through the years you learn how to pace yourself and truly enjoy the Annual Meeting. While I enjoy the science, I'm much more selective about the sessions I attend, and prefer to hang out and chat with people.

For those who are new to the field, I encourage you not to hesitate when it comes to approaching prominent figures or big names during meetings. Our ISMRM community is friendly, and experienced researchers will give you the best advice. I also encourage you to speak with people

in charge if you have ideas or if you are willing to get involved as a volunteer. There is always something to do! One of my favourite quotes comes from Elizabeth Andrew: *Volunteers don't necessarily have the time they have the heart* and that reflects exactly the family feeling that our Society has.

A second word of wisdom to those members of our community at the earlier stages of their career is to select one or two research topics, focus on them deeply, and do them well, rather than skimming the surface of a lot of different things. This way, you'll soon become the 'go to' person for those topics, and doors will start to open for you.

Focus on converting your abstracts into papers. Having a couple of good papers, that you're proud of, at the very start of your career will serve you well. Also, you might be disappointed that your abstract has been selected for a poster instead of an oral presentation, but actually posters are the very best way to have an entire hour of full attention on your work. In a conference with eight or more parallel sessions, this is invaluable. Trust me, it's a rare opportunity to get that level of attention and 1-1 interaction. Don't waste it!

MRMH: How has ISMRM evolved over time in your opinion?

Derek: I think the most obvious answer is that the ISMRM community has grown in size. As I said before, at my first Annual Meeting in 1996 (New York), there were 2700 attendees and the whole event was held in 2 big hotels. Imagine trying to do that now!

As our community gets bigger and bigger, there is a growing tendency for individuals to operate in isolated silos, focusing solely on the prevailing topic of interest, and losing sight of the last 'M' (for 'Medicine') in 'ISMRM'. This poses a genuine risk of communities gradually drifting apart. But while the core mission of our community will not change, trends come and go. One thing that I really commend Brian Hargreaves (our 2024 Annual Meeting Programme Chair for Singapore) for is reintroducing the structured synopsis for the abstracts, and the impact statement. It makes you stop and think whether your abstract is addressing the Society's mission, i.e., does it have a direct relevance to medicine? Speaking together with the future Presidents of our Society, we think it is time to re-focus on our core mission of improving health through magnetic resonance. We have introduced a lot of really cool and fun things into the programme at our Annual Meetings, which are interesting, and people find rewarding, but we mustn't lose sight of our key mission. The emphasis on Medicine, that features in our name, needs to grow back now along with robust, reproducible research.

MRMH: How do you see the meeting changing in the future?

Derek: We really need to think about the environmental impact of MR in general, and that includes our Annual Meeting. Being forced to switch the Annual Meeting from in-person to virtual during the pandemic made us all re-evaluate the habit of having all meetings in person. For example, since for as long as I can remember, each November, the Board of Trustees has flown to Chicago for an afternoon's meeting. November last year, I changed this - and meeting materials were shared in advance, so everyone could read them at their own pace, and we then had a two-hour zoom meeting to discuss them. Overall, it was so much more efficient than the in-person counterpart, we saved a huge amount of carbon emission and we saved a lot of people's family time and ISMRM mon-

At the Inaugural Meeting of the African Chapter of the ISMRM in Accra, Ghana, 2023.

Some of the attendees at the ISMRM in Toronto, as part of the Bill and Melinda Gates Foundation/ISMRM Gates of Opportunity initiative.

ey. So, I'd say a re-evaluation of our need to travel will be a big change for the future.

I predict that green initiatives and global accessibility will become key foci of the Annual Meeting moving forward. There are already ongoing activities from the Sustainability Ad Hoc Committee that I set up, and there's a grass-roots low-field movement whose growth is really encouraging. I think we'll see much focus on environmental impact and global accessibility moving forward. The three words that identify the past were faster, stronger, expensive, but the future will be identified as smarter, greener, more accessible and more economical.

MRMH: There has been a high demand from members to guarantee equality, diversity, and inclusion in the Society. What do you think are the results of this effort? Is there anything else that would be worth doing in this regard?

Derek: The results of the Equity, Diversity and Inclusion taskforce, under Krishna Nayak's leadership, are tangible and visible. At the Annual Meeting construction meeting in January this year, I looked around the room and thought: Wow! That's a really diverse group, in every sense! Moreover, the diversity in the leadership of our Society has clearly been increasing. That said, I think the geographical diversity of our ISMRM membership is nowhere near as good as it could be. The ISMRM is still clearly dominated by the northern hemisphere, and it is not the reference organization for magnetic resonance imaging in other parts of the world. We are starting to see more attendance from Africa thanks to The Bill and Melinda Gates Foundation initiative and the formation of the African Chapter of the ISMRM, although we can and should do more to improve attendance from other geographical areas including South America and Southeast Asia. We're in early discussions about how we might be able to improve that, and this is something our future Presidents feel equally passionate about.

One change towards promoting equality in our Society has been to give the same voting right to every full ISMRM member. It sat very uncomfortably with me that if a person was not able to pay the full membership fee, they couldn't vote. To this end, we dropped the title Associate Member, and just offer a reduced full membership fee for people from Low, and Lower Middle Income Countries. As such, everyone now has the same full voting rights.

MRMH: And in terms of emerging technologies, which do you think is worth investing in?

Derek: We've seen increased movement from the vendors to develop non- or low-cryogen systems. Given the critical global shortage of helium, this is clearly an area worth investing in. This feeds into another area that, as President and as an individual, I feel passionate about, i.e., sustainable and accessible MRI. We need to challenge the widely-held perception that low field equals low quality! It is true that the first MR image taken by Sir Peter Mansfield at less than 0.5T was incredibly pixelated, low detailed, and confined to a small field of view, but technology and data analysis have progressed since then, and now it is possible to have high-quality low-field MRI images. I just got back from the 'Accessible MRI' ISMRM workshop in Delhi, and it was super-encouraging to see just what is achievable with low-cost systems. With careful application of our knowledge in MRI and biology, I can see how AI techniques could be used to wisely augment results from these systems.

Also, I think we should start to reimagine how to collaborate more efficiently, making better use of existing resources. For example, I'm keen to explore how we can provide full remote access to MRI scanners, even to researchers on the other side of the globe. In this way the facilities could be used 24h a day, aligning with working hours across different time zones. It would also help in testing the reproducibility and repeatability of results, as different researchers would be able to easily use the same scanner or different scanners to evaluate their techniques.

I am aware that this would require a revolution of well-established habits and would create a whole new set of challenges! One such challenge, of course, is maintaining a robust internet connection. Nobody wants to lose control of their MRI machine in the middle of a scan. But there are also questions about safety, and who would take responsibility for the use of the scanner overnight. In terms of improving reproducibility of results

Attending the 2nd ISMRM Workshop on Accessible MRI in Delhi, India, in February.

obtained by different researchers using different scanners, would the vendors agree to improve accessibility to details of the MR acquisition and reconstruction pipeline? How could we support this kind of level of collaboration financially? It will take time, but I really hope that this will be one of the next revolutions in MRI!

MRMH: What is your opinion on Open Science and research transparency in our field? Are there any initiatives of this kind (e.g., MRHub) that you are interested in?

Derek: It is fair to say that, as a community, we have previously gotten away with murder. Journal publication is the currency of research, and so there is increasing pressure to publish more and more. However, null results and replication studies are much less attractive, and reviewers and editors are less prone to accept these types of studies for publication. The same applies to funding bodies. I wholly support the concept of Open Science and research transparency. In fact, I've submitted 'pre-registered reports' to journals before now, to avoid any sense of Harking, p-hacking and so forth.

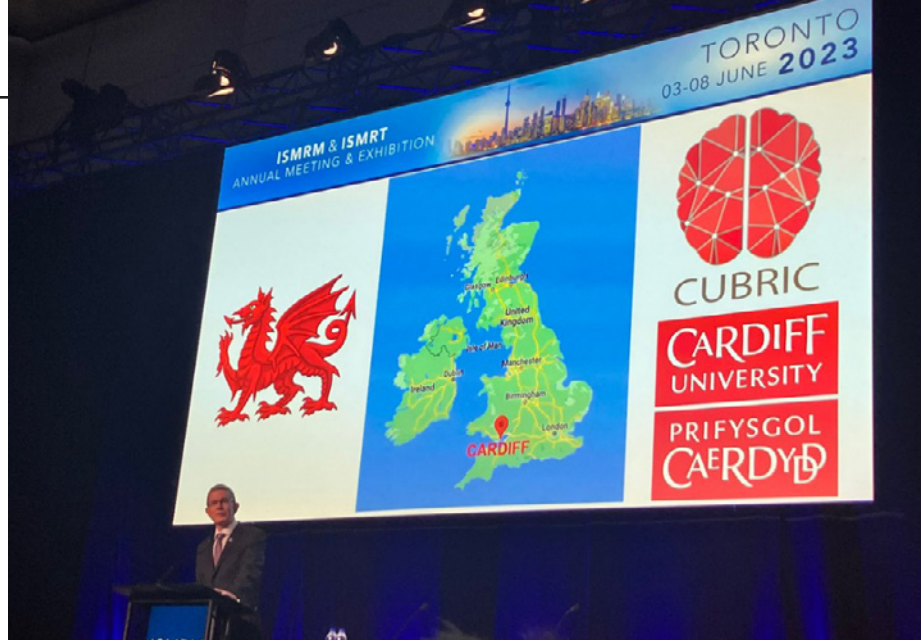
The pressure I mentioned before encourages us to push forward new studies because they bring us research-money. We discourage Open Science practices, because we don't want to be found guilty of fudging results to get a 'cool' result, and we don't invest enough resources and time on reproducibility and repeatability of results. However, our community is starting to pay the price, with the public starting to distrust the reliability of science, and it is time to change if we're going to avoid making this damage irreparable. More education is needed in terms of Open Science. To this end, I am delighted that as a community we have the MRHub and the Reproducibility Challenge initiatives in place, and I hope to see the engagement in these activities grow.

MRMH: How did you get involved with ISMRM in the first place? We'd like to conclude the interview by you telling your tale of how to become the President.

Derek delivering the 2002 Sunrise Educational Course on DTI Acquisition and Gradient schemes in Honolulu, Hawai'i.

Derek: Aha, alright! It started with being invited to give one of the Sunrise Educational talks in the Honolulu, ISMRM 2002 Annual Meeting on *DTI Acquisition and Gradient Schemes*. I remember wearing a Hawaiian shirt, shorts, and flip flops and being worried that everyone would be wearing slightly more formal clothing! In 2005, I joined the Annual Meeting Program Committee (at the time called the Scientific Program Committee), and became Chair of the ISMRM Diffusion and Perfusion Study Group for the first time. I was re-elected to Chair in 2008 when I also joined the ISMRM Board of Trustees. I then became then the Annual Meeting Program Committee (AMPC) Chair for the meeting in Milan in 2014. At the time, the pattern in previous years, (and therefore the natural expectation) was that outgoing AMPC chairs go on the ballot to become the President. However, at the time we were establishing the second phase and substantive expansion of our imaging centre, the Cardiff University Brain Research Imaging Centre (CUBRIC), and I didn't feel I had the time to commit. The same was true when I was approached a few years later. Finally, on the third time of asking, I remembered that phrase again, that *Volunteers don't necessarily have the time they have the heart* and so here we are! So, volunteering for a small contribution to the ISMRM community seeded my path to presidency, and I'm so glad I agreed. (Although I have promised myself that after this year, I will slow down with the commitments, and especially on the traveling!).

To be the President of this community has been a huge privilege and pleasure, but it added substantial workload to my already busy schedule as Director of CUBRIC, as well as supervisor of students and my research group. This experience has made me re-evaluate the need to be always in-person at meetings. While meeting on-line with people in different time zones can be tricky, it saves many things including family time, which is really important to me. It is a fixed-term commitment, but it has been extremely rewarding as I love our Society and the opportunity to 'pay it back' and make a difference in the frame of the ISMRM community has been a major milestone in my life.■



Derek showing everyone where CUBRIC, Cardiff is located (and the Welsh dragon!) – during the ISMRM in Toronto 2023.

During his closing comments in Toronto, Derek delivers on his promise to do 'one last card trick' for magic-fan Roberta Kravitz, before she retired as ISMRM Executive Director.

Silly Presidential grin.

RESEARCHER PROFILE

2024 NIBIB New Horizons Lecturer: Ileana Jelescu

INTERVIEW BY **MARIA CELESTE BONACCI**

Dr Ileana Jelescu is an Assistant Professor in Radiology at the Lausanne University Hospital in Lausanne, Switzerland. For this year's Annual Meeting, she has been invited to present her groundbreaking work in the prestigious National Institute of Biomedical Imaging and Bioengineering (NIBIB) New Horizons Lecture.

Ileana Jelescu, Assistant Professor of Radiology at the Lausanne University Hospital, in Switzerland.

MRMH: Can you tell us about your academic background?

Ileana: I graduated from École Polytechnique in France with a major in Physics and I also obtained a master's degree in Medical Physics from McGill University (Canada). Subsequently, I went on to get a PhD in MRI Physics at Université Paris-Saclay (France), I completed postdoctoral work at New York University and now I'm an Assistant Professor in Radiology at the Lausanne University Hospital in Switzerland.

MRMH: Wow, this is an amazing background! What has been (and still is) your main source of motivation throughout your career?

Ileana: I would say there are multiple sources, it's hard for me to identify just one. It may sound like a cliché, but I've always been fascinated by the versatility of MRI, ever since my undergraduate studies, and somehow this fascination is still very much alive today! Another source of motivation is the opportunity to really go off the beaten path and explore uncharted territory. I think there are only a very few careers that can offer this, and this is why I love research. Finally, there is the most recent source of motivation: being a good mentor for trainees. I really love passing on what I know, and then letting younger generations of scientists take their projects further. And for me as well, this represents a chance to work with immensely energetic and creative people!

MRMH: I loved that answer! It's so important for young researchers to meet a valuable mentor, maybe a role model to look at during one's career. What has been the most important experience of your career?

Ileana: Well, as before, it's quite hard to identify just one. But I would probably say it was learning how to write a good grant application. In the end, I believe it's really one of the most useful skills you can develop in academia. (Laughs).

MRMH: And the most difficult experience? (Sorry, another difficult question!)

Ileana: Yes, it's a tricky question indeed, but it is not hard for me to think of a difficult experience. You have inevitable episodes of failure. In academia, we tend to go all-in with work life, sometimes making very difficult personal sacrifices. To give a concrete example, I remember pushing myself to go through a faculty recruitment process, six weeks after my second child was born, and not getting the position in the end. So I really felt like I lost on both ends, and this was very tough to face. But I think you learn from every experience and especially from the difficult ones, so you have to make the most of it.

MRMH: It's so challenging to find work-life balance, and when parenting comes in it becomes even harder.

Ileana: Yes, because you are constantly torn between two choices, and it takes some juggling to find a good balance.

MRMH: How did you overcome the bad times during your career?

Ileana: On the one hand, I think it's difficult for me to be disheartened in general so, whatever happens, I'm the kind of person who tends to not look back too much at what things could have been, but rather how to move forward from the current situation. I take any failure as some kind of new initial condition, you know - like in physics! I also find it very important to maintain work-life balance, so that if I have a bad time in my career environment, I can tell myself it's just work, and then focus on other aspects of my life, such as family, friends, or hobbies. Being a mom also helps, since all parents share the motto "this too shall pass," whenever they go through rough times with their children! I think that, in a sense, this can be applied to professional rough patches as well. Thinking of it just as some kind of phase, and knowing things will get better in time.

MRMH: Thank you, this is such a good advice for young researchers!

Ileana: Yes, it's definitely part of the game. You always have to look at the bigger picture, and try to be as positive as possible. Thinking "what can I do in this situation now?" And "how do I move forward?" is definitely better than "Oh, why did this happen? I wish it would have been different." Everybody experiences bad times, and one should really think constructively to overcome them.

MRMH: Which people have been most helpful in your career?

Ileana: I have been very lucky with my mentors overall; during my PhD I was supervised by Denis Le Bihan, who is really one of the fathers of our field, and Luisa Ciobanu, a fantastic experimentalist who cares immensely about her students. She really taught me how to run an experiment from A to Z, building coils, programming sequences, troubleshooting issues and handling artifacts. To this day, I still really love designing new experiments and being at the scanner, and I think she's the person who instilled this in me. During the bad times of my PhD, because there were some, they gave me a lot of moral support. In the field that I'm in today, diffusion and MRI microstructure, I also owe immensely to Els Fieremans and Dmitry Novikov, my supervisors during my postdoc at NYU. They really taught me everything that I wanted to know about microstructure, and the work I did there is really the one that established me within the diffusion MRI community and propelled my career. Even after my postdoc, they have continued to provide unwavering support. I left NYU in 2015 and I still talk to them very regularly. By now I guess that I think of them as friends more than supervisors.

The Microstructure Mapping Lab, out hiking in Leysin, Switzerland.

MRMH: What would you suggest to us younger researchers for our careers?

Ileana: You would probably get a different answer to this, depending on who you ask! First, I suggest that you take the necessary time to reflect and figure out if an academic career is really what you want. Because there are several ways of doing research or staying close to research beyond academia that I think are definitely worth considering. Whatever it is you choose, there is no right or wrong answer. It should be a proactive choice on your part, and not a default. So that's why I think this reflection time is actually very important. Also, I think you need supervisors who can actually provide scientific support, mentorship and moral support. If you are at the point where you start thinking about your next steps, you should look for a lab where you can learn a lot. First of all, scientifically, but also in terms of other skills such as efficient management, writing papers and grants, etc. And you should be able to learn not only from your supervisor, but also from other people in the team.

MRMH: It's great that you point out how important a healthy work culture is.

Ileana: Absolutely! You need to find a place where people care about your well-being and also about your future success. Find an advisor who wants to propel you, and who will actively help you become an independent researcher. Finally, I would say that it's very important that you take your career into your own hands, seek advice and feedback beyond your lab, beyond your department, engage in collaborations and network at conferences. Don't be afraid to discuss your research ideas. Apply for your own funding; it is extremely beneficial for your career if you're able to secure your own research money early on. Especially, don't be discouraged if things fail from time to time. Because they indeed fail from time to time for everyone. I think what is really determining is the ability to dust yourself off and grow from that. How you react to any failure is more important than the failure itself. So don't be discouraged!

MRMH: Totally agree, particularly when the tension is high within a lab, character and temperament really do make the difference. Sometimes workplaces become 'haunted' by bad feelings and toxic competitiveness.

Ileana: Right. I think what you mentioned here is extremely important. Rather than feeling this competition, I think you can learn from other people's success, and maybe they can also pull you up. As long as you find trustworthy people to work with and learn from, of course. Research is really about collaboration and teamwork. So you have to find the right team members, to help each other and stay away from negative feelings or attitudes.

MRMH: We have talked about learning useful academic skills to become a satisfied researcher. Which do you think are the most important personal skills to nourish for a scientist?

Ileana: I would say, first of all, curiosity, and intellectual honesty. But then, because it's also a challenging environment, I think you really need to have a lot of energy to do your work, and resilience to face the inevitable difficult moments. Finally, as I said earlier, I think team spirit is very important and this is something that you should not lose sight of.

MRMH: Yes, this is a tough journey, but the achievements can be satisfying. And looking at the future, what do you wish for yourself?

Ileana: I just hope I'm never bored with my work, and if I'm ever bored I will probably do something else!

MRMH: Wow, that's the right attitude I guess! Is there anything else you would like to add?

Ileana: I sincerely wish that all young researchers remain passionate about expanding knowledge and improving healthcare, because this is really our main mission. And I have to say, I'm very optimistic about the new generation of researchers. I really believe in them, and I also wish they can find the strength to resist wrong incentives. There are a few wrong incentives in academia which you must avoid – make the academic culture constructive and prioritize quality over quantity.

MRMH: 'Quantity vs quality' is truly an important topic!

Ileana: I think it's a crucial one. There's the real risk of diluting the content and the value of what we do. It's definitely not the young generation's fault, it's just how things have developed. I feel people today are given the wrong incentives, such as number of papers, or h-index. Instead of doing something really solid, of good quality, you will chop it up into 10 small things, and I think down the line this is detrimental to the quality of research, as well as to the money invested in it.

MRMH: I totally agree. This culture makes it even harder, for example, to accept paper rejections. I had a bad experience with my first PhD paper, I couldn't understand why the article wasn't published. But after going through bad rejections and major revisions I understood the importance of this event for my personal and professional career.

Ileana: Well, this is what I meant! You may go through these rough times, but eventually things work out, improve. I do not know a single person who hasn't had a paper rejected! I also see it in my students. Sometimes they're discouraged and I try to bring the morale back up. But it's also a journey you have to make by yourself. You can hear other people's stories, and have your supervisor tell you that everything will be fine, but to convince yourself you have to go through it somehow!

MRMH: Thank you for this inspiring chat, Ileana!

Ileana: Thank you so much for the time and the opportunity. I really appreciate it. ■

Towards global access to MRI education

INTERVIEW BY **LAURA BORTOLOTTI**

Maureen Nayebare, an Electrical Engineering student at Mbarara University of Science and Technology, Uganda, talked with us about her recent participation in the ISMRM mentoring program: "I was privileged to have been among the African delegates to be sponsored by the Bill and Melinda Gates Foundation, to attend the ISMRM 2023 conference in Toronto."

MRMH: How did you feel attending in person for the first time the ISMRM Annual Meeting?

Maureen: As an undergraduate student at Mbarara University of Science and Technology in Uganda, it was a chance for me to meet great MR scientists from around the world. It was a great opportunity I got through Dr Johnes Obungoloch, my supervisor at his Low Field MRI lab in Uganda.

Nayebare Maureen

MRMH: What did you like the most?

Maureen: The educational seminars I attended while in Toronto were extremely informative and I was also able to see exciting exhibitions that were engineered by different companies and as an Electrical Engineering student, there were a lot of discoveries I made!

MRMH: Who was your mentor?

Maureen: My assigned mentor was Prof. Udunna Anazodo. What I love most about her is that she welcomed me, showed me the right path to take and started off by teaching me how to thrive as a researcher in MRI. My mentor has become my role model, teacher and friend. I am grateful for her splendid help, lessons and encouragement.

MRMH: What is the most important thing you learned by participating in the mentoring program?

Maureen: The most important thing I have learnt from my mentor is how to be consistent and patient while carrying out research. An encouraging trait of hers is her consistency in monitoring my progress and her readiness to listen to me speak about what I am learning and some challenges I face. The fact that she has always been interested in my work over here in Uganda, even when she is miles away, keeps me reminded of how supportive she is. I am excited to take on the MRI journey because of the great people I look up to like Dr Johnes Obungoloch and Prof. Udunna Anazodo.

Nayebare at work in her lab.

MRMH: Did you attend the first ISMRM African Chapter meeting?

Maureen: Unfortunately, I wasn't able to attend the ISMRM African Chapter meeting in person. However, I presented my first abstract online and through this I gained confidence and courage.

MRMH: Is there anything else you want to share with the ISMRM community?

Maureen: I am so grateful for the ISMRM African Chapter because, through this, I have had the chance to meet African scientists who are passionate about MRI. As a young woman, with the zeal to positively impact Uganda and Africa at large, ISMRM has given me a platform to achieve my dreams. I look forward to more collaborations! ■

YIA 1999

Looking Back: ISMRM's 1999 W.S. Moore Young Investigator

INTERVIEW BY **CRISTIANA TISCA**

Bruno Madore, PhD, won the 1999 W.S. Moore Award for his paper titled *Unaliasing by Fourier-encoding the overlaps using the temporal dimension (UNFOLD), applied to cardiac imaging and fMRI,* published during his post-doctoral appointment at Stanford University. He completed his PhD at the University of Toronto, Canada, and then went on to do post-doctoral research with Norbert Pelc and Gary Glover at Stanford University. He is currently an Associate Professor of Radiology at Brigham and Women's Hospital, Harvard Medical School. His research focuses on improving motion correction in MRI and PET using ultrasound sensors, and on the development of novel acquisition and reconstruction strategies for MRI.

MRMH: Thank you very much for agreeing to this interview. To kick things off, what got you into the field of MRI?

Bruno: I did my undergraduate studies in Physics and, nearing the end of my studies, I was not sure about what to do next. I first decided to go into nuclear fusion, the energy of the future and secured a scholarship for a summer job at the Tokamak in Montreal, where I worked on plasma simulations. Nearing the end of my job there, though, I realised that there would be few job opportunities in this area and that the next breakthrough would be quite far away. After some thinking, I reoriented myself towards the Medical Physics programme at the University of Toronto. I hesitated between a project in ultrasound imaging and one in MRI, but in the end I decided to pursue my PhD with Mark Henkelman, in MRI.

MRMH: And how did you get into the topic of your W.S. Moore Award winning paper?

Bruno: The work presented in that paper was conducted during my post-doc at Stanford University. How I came up with the idea is a bit of a story. I arrived in Stanford not having any permanent accommodation, and my supervisor, Norbert Pelc, was leaving to go on a six-month sabbatical four days later. The work that my advisor suggested just before he left was to develop a method that would reduce acquisition time in situations where a part of the imaged object changes less rapidly in time than other parts.. These were intense days for me, for example I needed to find someone to loan me a bicycle, so that I could use the bicycle to shop for a car, because I needed the car to look for an apartment, so that my father would have an address where to ship everything I owned. But within a couple of days of thinking about the problem, before my advisor left for his sabbatical, I put together the theoretical part of the paper. It involved a way to transfer information between spatial and temporal axes, allowing a smaller k-t space to be acquired. These were some of the most intense and productive days of my life. After that, we designed the experiments that would validate the theory, and Gary Glover nicely got involved, enabling the 'and fMRI' part of the work and the title. The conceptual framework that we proposed in this paper proved very successful: over the years, it became embedded in how many research groups designed their dynamic MRI acquisitions.

Bruno Madore

MRMH: That's very cool! How have your research interests evolved since then?

Bruno: After that paper, I looked into applying this framework to different scenarios, such as combining it with parallel imaging or applying the idea to fat-water separation, to diffusion imaging or to ultrasound imaging, which I've been keen on since the early days of my PhD. Along the way I also got interested in thermometry, and the way it is used in image-guided therapy. I also got interested in multi-pathway, multi-echo MRI acquisitions and how they encode temperature differently, which led to the development of quantitative imaging approaches. More recently, I got interested in sensors for motion correction in MRI and PET, particularly for abdominal and cardiac imaging.

MRMH: Could you tell us a bit about your current position?

Bruno: My current university appointment is part of Harvard Medical School. About a third of my work is clinical, where I may debug artifacts on clinical scans, perform QAs, or solve problems that researchers have

in clinical MRI settings, for example. The remaining two thirds I dedicate to research and grant-writing. I do occasional teaching as well.

MRMH: On a different note: What do you think is a yet unmet need in MRI research?

Bruno: I believe that motion correction continues to be a problem. A lot of effort has been done to abbreviate exams by removing redundancies, but in a way this makes the motion problem even more acute. Removing redundancies is a bit like putting many eggs in the same basket, and it can make abbreviated exams even more vulnerable to motion. I believe that external sensors and other complementary measurements acquired during the scan can be very important in aiding motion correction and can be incorporated into the MRI reconstruction framework using ML, for example.

MRMH: What is the achievement that you're most proud of?

Bruno: I think it's really hard to achieve a good balance between work and personal life. I have three children aged between 16 and 20. When I look back, I am happy that I was there for them as they were growing up, taking them to school, coaching their hockey

Bruno and his family in 2007.

practices, playing with them and cooking for them. Meanwhile, I also managed to make progress in my career, getting grants and establishing collaborations. I am really proud of having done both. If I spent less time with my family, could I have written a few more grants and gotten a few more papers? Of course, I'm sure I could have, but it would not have made me a happier person.

MRMH: And finally, what advice do you have for ISMRM trainees and early career researchers?

Bruno: I strongly believe in the creativity that ISMRM trainees and career researchers have and encourage them to look for big ideas that can change the world for the better. At early career stages, it's a great time to bet on high impact projects. But the world is hard to change, so they should be kind to themselves if it does not pan out. Failing on a big bet does not make you less smart, or less good, and it does not even mean it was a bad bet. It just means you need to decide where to go next, a process that you'll be going through your entire career. If you keep betting your time and effort in reasonable ways, sometimes it will work out just fine. Great poker players manage to uncouple playing well and winning. I think this is a good strategy to follow. ■

The Radiological Sciences Laboratory (RSL) at the Lucas Centre, Stanford University, around 1999.

2024 ISMRM Young Investigator Award Finalists

EDITED BY **JIANPAN HUANG**

This year, the Society nominated eight finalists for its two Young Investigator Awards (YIA), and the winners will be announced at the Annual Meeting. The W.S. Moore Award, for authors of papers published in JMRI, is given for original clinical research, whereas the I.I. Rabi Award, for authors of papers published in MRM, is given for original basic science research. As usual, we have an outstanding group of finalists, and we have the pleasure of showcasing them here, in the Highlights magazine.

Nikou Damestani

W. S. Moore YIA Finalist

My passion for medical physics began during a summer internship as part of my undergraduate physics degree at King's College London. I shadowed the ultrasound phantom and imaging development team and gained exposure to a variety of clinical research. I became fascinated with novel imaging techniques and how they can be applied across multiple cohorts, motivating my decision to pursue an MSc in Neuroimaging. I was then awarded the NIHR Maudsley Biomedical Research Center PhD studentship to work on a project that focused on the accessibility of MR research. Under the supervision of Dr. Fernando Zelaya and Dr. David Lythgoe at King's College London, I developed and optimised an acoustically silent fMRI technique, in collaboration with GE Healthcare, known as 'Looping Star'. This project introduced me to hemodynamic imaging as an approach for improving our understanding of the fundamental mechanisms behind many diseases. For my postdoctoral research, I combined this passion for accessible research and interest in cerebral physiology by joining the lab of Dr. Meher Juttukonda at the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital. Our work was focused on the effect of aging and age-related neurodegeneration on large cohort data using advanced hemodynamic imaging techniques. While at the Martinos Center, I received a postdoctoral fellowship from the American Heart Association to characterise the effects of menopause on cerebral hemodynamics.

NOMINATED PAPER

MRI Assessment of Cerebral White Matter Microvascular Hemodynamics Across the Adult Lifespan

The overall goal of this study was to characterise the typical aging process from a physiological perspective. It is well established that white matter structural integrity decreases with advancing age, but less is known about the mechanisms that underlie this process. Prior evidence suggests that vascular impairment may be a driving factor of this neurodegeneration. However, this physiology remains largely under-investigated, and few studies thus far have been able to probe white matter hemodynamics. This is due in part to the longer arterial arrival times in white matter, compared to grey matter, which reduces signal-to-noise-ratios when using arterial spin labeling (ASL) MRI. In this study, we used advanced ASL approaches with high spatial resolution and multiple post-labeling delays to help overcome these limitations. We combined this perfusion imaging data with diffusion imaging as part of the Human Connectome Project in Aging to explore relationships between white matter physiology and structure, as well as how these associations differ by age and sex. This work sought to establish normative patterns of white matter physiology that improve our understanding of typical aging and serve as a reference against which atypical aging processes can be identified and compared.

Retta El Sayed

W. S. Moore YIA Finalist

Born and raised in Damascus, Syria, the oldest capital city, I come from a family deeply committed to education, which instilled in me a strong passion for learning from a young age. Currently, I am a PhD candidate in the joint Biomedical Engineering program at Georgia Institute of Technology and Emory University. Since childhood, I have been drawn to math and science, and over time, my passion has only deepened. The concept of applying engineering principles to medicine is

particularly intriguing to me, and within the field of biomedical engineering, I found my niche due to its direct impact on improving human life.

My research interests are directly related to cardiovascular disease, the world's leading cause of mortality. Central to my research is the power of magnetic resonance imaging (MRI) as a tool offering precise patient-specific diagnoses, predicting surgical procedure outcomes, and application to a wide variety of biomedical challenges.

Specifically, I'm investigating the complex flow patterns in patients with carotid webs, a poorly understood catalyst for cryptogenic and recurrent ischemic strokes in young individuals. By leveraging 4D flow MRI, I aim to shed light on hemodynamics metrics related to an increased stroke risk in subjects with carotid webs and ultimately improve diagnosis and treatment strategies to enhance patient well-being.

I am fortunate to work on this multidisciplinary project under the supervision of Dr. John Oshinski, whose research expertise lies in developing MR imaging techniques for vascular hemodynamics evaluation, and Dr. Jason Allen, who focuses on advanced MR imaging for traumatic brain injury assessment. As I progress in my career, I am committed to advancing cardiovascular imaging and its clinical applications. I relish finding solutions to problems that face the scientific and medical community and am increasingly motivated to work on research related to medical imaging.

Finally, being chosen as a finalist for the Young Investigator Award is a tremendous privilege, and I am grateful to the YIA committee and the ISMRM community for this incredible opportunity.

NOMINATED PAPER

Assessment of Complex Flow Patterns in Patients with Carotid Webs, Patients with Carotid Atherosclerosis & Healthy Subjects Using 4D Flow MRI

Occlusion of any carotid artery branch can lead to a transient ischemic attack (TIA) or stroke. While vessel stenosis is commonly linked to atherosclerosis, other factors like fibromuscular dysplasia (FMD) can also alter arterial vasculature. In the carotid arteries, a variant of FMD presents as carotid artery webs (CaW) and is associated with recurrent ischemic stroke. CaW may account for one-third of cryptogenic strokes in patients aged 30-48 without traditional vascular risk factors. Unlike atherosclerosis, CaW is not characterized by inflammation, or plaque deposition but instead composed of intimal hyperplasia.

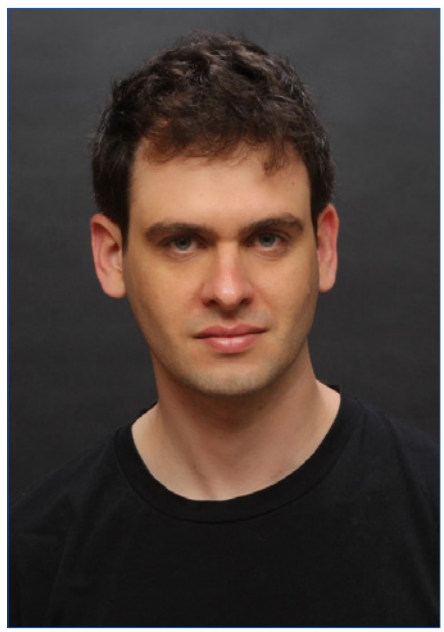
CaW typically causes <50% stenosis, which is often asymptomatic and managed medically without surgery in the case of atherosclerotic lesions. However, conventional medical therapies like anticoagulation and mono or dual antiplatelet agents, that are effective for atherosclerotic plaques, show limited efficacy for CaW. Moreover, these therapies increase bleeding risk, necessitating carotid revascularization through endarterectomy or stenting in these younger patients.

One theory is that the web geometry is expected to cause more complex flow patterns when compared to atherosclerosis and healthy subjects, therefore, the manuscript utilized 4D flow MRI to compute hemodynamics parameters such as wall shear stress and oscillatory shear index as parameters related to vascular dysfunction. These hemodynamics metrics were compared between patients with CaW, mild atherosclerosis, and healthy controls. The results of the hemodynamic parameters were indeed significantly different in patients with CaW compared to atherosclerosis, suggesting their potential as an additional evaluation tool. This research significance stems as it pioneers the evaluation of disturbed blood flow in CaW using 4D flow MRI, offering insights into stroke risk assessment. The ultimate aim of this work is to develop a stroke risk assessment tool to guide clinical decision-making for patients with incidental findings of carotid webs.

Aviad Rabinowich

W. S. Moore YIA Finalist

Advancing patient care through innovative imaging techniques to address clinically relevant and life changing questions intrigues me the most. It is also why I chose to pursue a medical and research career as a radiologist. This holds a special significance for me when addressing the pediatric population, a group for whom precision in diagnosis



and treatment are pivotal.

As I began my residency in radiology at the Tel Aviv Sourasky Medical Center and the Tel Aviv University, I chose to focus my interest on the field of MRI; realizing the vast potential of this technology with its profound capabilities in diagnostics and critical role in healthcare. I was very fortunate to have the opportunity to join Prof. Dafna Ben Bashat's laboratory for my PhD research.

My doctoral research focuses on utilizing MRI to enhance the prognostication of pregnancies affected by fetal smallness for gestational age (SGA), a common complication with limited predictive tools for perinatal outcomes. My approach involves assessing the intrauterine body composition of fetuses to understand their nutritional status based on the premise that malnourished fetuses may exhibit atypical development. Our future goals include refining FGR risk stratification models by integrating multiparametric data from MRI and ultrasound.

Upon completing my residency and Ph.D. studies, I intend to gain further training in pediatric diagnostic and interventional radiology and continue integrating MRI research with my clinical career.

Being named a finalist for the Young Investigator Award is a profound honor, symbolizing the collective effort of a multidisciplinary team comprising radiologists, obstetricians, pediatricians, and researchers, to whom I extend my heartfelt gratitude. I also wish to express my appreciation to the ISMRM committee for this esteemed recognition.

NOMINATED PAPER

Fetal MRI-Based Body and Adiposity Quantification for Small for Gestational Age Perinatal Risk Stratification

SGA often results from placental insufficiency, where the placenta nutrient supplies are inadequate for the rapidly growing fetus, potentially causing perinatal complications. The current practice includes calculating fetal size as a proxy for fetal nutrition. However, fetal size by itself is probably an oversimplified indicator of fetal nutrition and not entirely indicative of disease severity. Since fetuses rapidly accumulate fat in late gestation, a lack of nutrients results in less fat accumulation, suggesting that a direct assessment of fetal nutrition might be more informative.

In our research, we evaluated the impact of fat accumulation and MRI-based measurements of fetal size on the perinatal outcomes of SGA-affected pregnancies. Our focus was on the effect of fetal size, fat-to-body mass ratio, and fat signal fraction on fetal distress and newborn outcomes. We utilized common MRI sequences, T2-weighted balanced steady-state gradient echo (TruFISP), and T1-weighted Dixon and applied two specially designed neural networks for segmenting the entire fetal body and the subcutaneous fat.

Overall, we showed the utility of MRI-measured body composition parameters, mainly fat-to-body ratio and fetal size, for obstetric interventions due to non-reassuring status and adverse neonatal outcomes, respectively. We also demonstrated that our MRI-based metrics offer greater specificity than traditional sonographic measurements.

In conclusion, MRI-derived body composition metrics provide insights into fetal health and could improve the prognostication of SGA conditions. Although MRI is not routinely used for SGA per se, its capabilities and versatile information provide additional information that should encourage its consideration in clinical practice.

Rui Tian

I.I. Rabi YIA Finalist

At the Max Planck Institute for Biological Cybernetics, my current Ph.D. research, supervised by Prof. Klaus Scheffler, focuses on advancing MRI spatial encoding leveraging nonlinear B_0 fields. My primary project involves developing fast MRI methods utilizing a local B_0 coil array, addressing challenges inherent in this non-conventional setup spanning various subfields in MRI. Recently, I also utilized mathematics developed for nonlinear gradients to enhance conventional imaging methods, eliminating the adverse effects of undesirably occurring nonlinear B_0 fields.

My academic journey began at Purdue University in the USA, where I pursued a biological engineering and pharmaceutical science dual degree, driven by my fascination with human physiology, possibly stemming from my high school competitive swimming experience in China. However, realizing my strength in physics over chemistry/biology, in the third year,

I shifted to a major in Electrical Engineering from its minor. After undergraduate research in wireless communication (under Prof. James Krogmeier), MRI RF coil (under Prof. Joseph Rispoli) as well as assistance in MRI scanning (under Prof. Thomas Talavage) and a visit to Dr. Hanbing Lu's lab, I moved to ETH Zurich for systematic training in MR as a master student, following Joseph's suggestions and a recommendation letter from Prof. Mark Lundstrom.

Arriving in Switzerland, I was fortunate to work on a technique called phaseless encoding, importing elements of super-resolution microscopy to MRI, supervised by Dr. Franciszek Hennel in Prof. Klaas P. Pruessmann's group. This experience not only yielded original contributions to MRI methodology, but

also deepened my appreciation for the beauty of science beyond engineering, immersing myself in the traditional scientific culture of continental Europe. However, after two exciting internships – one supervised by Caixia Fu at Siemens, and the other one focusing on 5 nm nitrogen vacancy centers supervised by Dr. Takuya Segawa in Prof. Christian Degen's group - I once again struggled with the decision to continue in academia given the seemingly well-established physics of MRI.

Eventually, while on a graduation tourism trip in Italy, I accidentally encountered a paper called spread spectrum MRI and its recent ERC Advanced grant, which reignited my passion for academic research. After a lab visit and numerous discussions, I was fortunate to obtain the opportunity to work on this local B_0 coil project within Prof. Klaus Scheffler's department in Germany.

NOMINATED PAPER

Accelerated 2D Cartesian MRI with an 8-channel local B_0 coil array combined with parallel imaging

Four years ago, in the earliest stages of our ERC project, I aimed to establish a local B0 coil system in our 9.4T Siemens human scanner for accelerated in-vivo scans. Alongside the significant efforts invested in system design and integration, a fundamental question poses a long-standing challenge: How can nonlinear gradients, despite disrupting the basic k-space formalism for MRI, establish its essential role given the well-established Fourier imaging using linear gradients?

My quest led me to explore diverse strategies for localized spin phase modulation unique to our setup during MRI signal readout, that hopefully can outperform conventional acceleration like wave-CAIPI. Despite numerous failed attempts, finally, I observed the sampling efficiency increases as the local coils' modulation currents became optimized with PyTorch, surpassing a preliminary paper on local B0 modulations!

However, upon examining the optimized waveforms, I suddenly realized they formed a linear gradient field along the phase encoding dimension! While this outcome was disappointing for nonlinear gradient encoding, I remained very unsatisfied with the understanding of its origins.

Recalling a moment during my first Ph.D. supervisors meeting with Prof. Klaus Scheffler and Prof. Martin Uecker, an obscure mathematical paper about k-space sampling for parallel imaging was referenced. Now it seems relevant to my puzzle, as the static RF receivers' modulation and the dynamic local B0 modulations should share a similar mathematical foundation.

After a long time scrutinizing that paper, its relevance gradually became apparent! I extended this framework to incorporate nonlinear gradient encoding, and a clear picture of k-space sampling efficiency by various nonlinear fields appeared, with optional combinations with conventional acceleration techniques, enabling rigorous comparisons and explanations of optimal B0 modulations.

Additionally, with the optimized field calibration inspired by subspace methods and collaboration on safety evaluations with Dr. Mathias Davids and Prof. Axel Thielscher, our local B0 setup produced high-quality in-vivo images with significant acceleration. This substantially pushes fast MRI with nonlinear gradient modulations, setting a potential example for other nonconventional spatial encoding techniques, and I am deeply honored to have my first Ph.D. paper nominated for the young investigator award.

Shohei Fujita

I.I. Rabi YIA Finalist

I am a post-doctoral fellow at the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital and Harvard Medical School in Boston. I am interested in technology development, validation, and clinical translation of multi-parametric/contrast MRI that can improve patient outcomes.

Before coming to the United States, I studied at the University of Tokyo, Japan. There, I learned the fundamentals of programming, signal processing, and software development at the School of Engineering. As I freely pursued my interest in robotics, I began to develop a passion for medical applications and decided to transfer to the medical school at the same university. In medical school, alongside the medical curriculum, I initiated my research career in the field of image processing for electron and optical microscopes, including

FFT-based image processing. Eventually, I developed a foundation in both medical and engineering skills and chose MRI as a research field where I could utilize them as a physician-scientist.

It is remarkable how much I have learned through the ISMRM community by attending talks, poster sessions, and exchanging ideas with peers and leading experts all over the world. ISMRM is a great place not only for learning through personal interaction, but also to build collaborative relationships. In 2019 at the annual meeting in Montreal, I met Dr. Ken-Pin Hwang from MD Anderson Cancer Research Center and started our collaboration. I also met Dr. Borjan Gagoski from Boston Children's Hospital and my mentor, Dr. Berkin Bilgic, from the Martinos Center and Harvard/MIT, through

the ISMRM community. We have been working closely ever since. In addition, I am fortunate to collaborate with multi-disciplinary experts including members from the industrial field. These relationships have become invaluable assets to me. The collaborative research resulting from these connections led to the publication of the nominated paper. As a junior researcher, I am grateful for all the support I have received from the society.

NOMINATED PAPER

Cross-Vendor Multiparametric Mapping of the Human Brain Using 3D-QALAS: A Multicenter and Multivendor Study

A significant challenge in utilizing MRI data more effectively is the variety of scanners used across different medical facilities. Patients often receive scans from different scanners over time, making it difficult to compare these images quantitatively. This discrepancy prevents the effective pooling of MRI data for research or clinical purposes, as measurements are typically confined to the context of the vendor's equipment. There has been little exploration into the consistency of multiparametric mapping measurements across scanners from different vendors, restricting the potential for wider application in studies.

Our study bridges this gap by presenting multiparametric MRI research that standardizes and evaluates quantitative values derived from scanners of multiple vendors. Utilizing four major MRI vendors which represents a large segment of the global market, our research introduces a practical approach for multicenter studies.

We employed the 3D-QALAS method (3D-quantification using an interleaved Look-Locker acquisition sequence with a T2 preparation pulse), which we standardized across different vendors to achieve reproducible mapping of brain T1 and T2 relaxation times and proton density. Initially validated using a NIST/ISMRM phantom, our multivendor evaluation on healthy volunteers demonstrated an inter-vendor coefficient of variation of 4%, comparable to conventional quantitative mapping techniques within the same vendor.

Furthermore, we applied our technique to patients with multiple sclerosis, demonstrating its feasibility and potential in real-world settings. Our observations in patients suggest that 3D-QALAS could distinguish between the white matter of healthy individuals and the normal-appearing white matter of those with multiple sclerosis, even when using scanners from different vendors.

We hope this study points towards a promising future for quantitative MRI, emphasizing the importance of standardized techniques that can be widely adopted, enhancing clinical and research capabilities.

Felicia Seemann

I.I. Rabi YIA Finalist

My journey in MRI started at Lund University, Sweden. I was fortunate to do both my MSc and PhD in the Lund Cardiac MR Group, where I received multi-disciplinary training spanning from technical development focused on MRI image post-processing, to cardiovascular physiology and experimental validation in animals and humans with mentorship from Dr Einar Heiberg and Dr Marcus Carlsson. During my doctoral studies, I developed and validated novel imaging tools to noninvasively assess subject-specific cardiovascular physiology using MRI. I focused specifically on the physiology of longitudinal ventricular pumping through valvular motion, and a method to derive ventricular pressure-volume loops using MRI and brachial cuff pressures. Supported by the ISMRM Research Exchange Program, I also did an incredibly rewarding six-month research exchange at Yale University, where I worked with Dr Dana Peters on MRI assessments of diastolic function and transmitral flow. This experience was critical in my decision to pursue a career in MRI.

I am currently a postdoctoral fellow in the Laboratory of Imaging Technology at the National Heart, Lung, and Blood Institute in Bethesda, mentored by Dr Adrienne Campbell-Washburn. Here, I transitioned from working with conventional magnetic field strengths to focusing on high-performance 0.55T MRI. The unique lung imaging capabilities of this field strength expanded my cardiac-centered interests to the entire thorax, where I have been combining cardiac and lung imaging in the same exam. These two organs are highly coupled both anatomically and physiologically. It is incredibly exciting

to be working on pushing the boundaries of what cardiopulmonary information can be obtained using MRI. My Young Investigator Award Finalist paper is at the core of my research interests, where we use 0.55T lung imaging to give insight into cardiovascular disease. I am thriving in this intersection of imaging technology and experimental physiology, and am eager to continue my MRI journey!

NOMINATED PAPER

Dynamic Lung Water Magnetic Resonance Imaging During Exercise Stress

Shortness of breath during physical activity is an early symptom of heart failure which is caused by pulmonary

edema, also known as lung water. This lung water accumulation is the result of fluid leaking from the blood vessels into the pulmonary interstitium, and is driven by an exercise-induced abnormal increase in pulmonary blood pressure. A clinical tool to measure lung water during exercise is therefore of interest to unmask heart failure at early disease stages. Therefore, we developed a method to derive quantitative and time-resolved dynamic lung water density maps from a continuous MRI acquisition during exercise stress.

We acquired proton density weighted 3D lung volumes over 10 minutes, and paired this with a motion compensated sliding window reconstruction to generate a time course with 20s temporal resolution. We validated that the method is capable of detecting transient lung water dynamics in controlled porcine experiments while simultaneously performing MRI-guided catheterizations to record pulmonary blood pressure. We then applied the method to healthy subjects and patients with heart failure, imaged in transitions between rest and supine exercise using an MRI-compatible pedal ergometer, and detected exercise-induced increases in lung water in all subjects. We also observed patient vs control differences in lung water accumulation and clearance rates, computed from the lung water density time-derivative. No other imaging technique can make these measurements. To provide broad access, we have implemented this method at 1.5T and 0.55T, and have made the reconstruction pipeline available open source. We currently continue studying the capabilities of exercise lung water MRI in larger patient cohorts, and believe this methodology could become a clinical diagnostic test to determine whether the non-specific symptom shortness of breath has cardiac or pulmonary origins. The method may potentially also be used in research to better understand the mechanisms of exercise-induced lung water in patients with heart failure, and could be extended to imaging other dynamic processes during exercise.

Victor Han

I.I. Rabi YIA Finalist

Growing up in San Diego, California, a biotech hub, I was exposed to biology research early on in high school. In my undergraduate years at Caltech, I was lured by the prospect of designing tools to solve problems and studied electrical engineering and computer science. In 2017, I enrolled in the PhD program at the University of California, Berkeley, and during

my first semester I took Professor Chunlei Liu's course, Advanced Brain Imaging Methods. After being amazed by how MRI can noninvasively image at depth with so many possible contrast mechanisms and no ionizing radiation, I started working under Chunlei's supervision. Instead of specializing in integrated circuits as I had previously thought when I applied to graduate school, I started thinking about how I can improve MRI hardware fundamentally.

In 2020, I had the honor of being an I.I. Rabi YIA finalist for my work on multiphoton MRI, where I showed that excitation with multiple RF frequencies all not at the Larmor frequency can be practical and useful in human MRI. After completing my PhD in 2022, I continued working in Chunlei's lab. In addition to extending and refining my multiphoton MRI work, I pivoted to work on multinuclear MRI coils. This year, I am very excited to have the honor of once again being an I.I. Rabi YIA finalist for my new work: the ADAPT Coil. The versatility of the magnetic resonance phenomenon has always fascinated me, with its ability to measure temperature, magnetic susceptibility, diffusion, etc. Both multiphoton MRI and the ADAPT Coil are outcomes from my pursuits towards unleashing the full potential of MRI's versatility. In the future, I hope to develop new imaging techniques that can push the boundaries of what is possible in dramatic ways and ultimately bring benefits to human health.

NOMINATED PAPER

Any-nucleus distributed active programmable transmit coil

There are 118 known elements. Nearly all of them have NMR active isotopes and at least 39 different nuclei (^{23}Na, ^{31}P, ^{13}C, and many, many more) have been shown to have biological relevance. Despite the unique information available from these nuclei, most of today's MRI is based on only one nucleus – ^{1}H. Although various technological advances have made the imaging of nuclei other than ^{1}H, or X-nuclei, more clinically feasible, the proliferation of these studies is still held back by the low availability of the tools able to perform them. Whenever an X-nucleus is to be studied, a heavy investment is needed to obtain additional expensive MRI hardware (e.g. RF amplifier, coils, and receiver chains) to enable imaging of the specific nucleus of interest. As a major step towards solving this issue and utilizing all potential nuclei, we have developed a single MRI coil capable of scalable and efficient excitation of arbitrary nuclei in up to 3T human-scale MRI. We call this coil the Any-nucleus Distributed Active Programmable Transmit (ADAPT) Coil.

In the ADAPT Coil, we depart from traditional tuned coils and integrate many high-frequency semiconductor power switches directly into a coil structure. By doing so, the coil and

RF amplifier are merged into a single programmable device that directly converts DC electric power into RF fields at any relevant frequency. By using only low-cost commercial parts and commercial fabrication methods, it can be widely disseminated. Due to its programmability, the ADAPT Coil has many potential uses such as exciting arbitrary nuclei, being reused between scanners of different field strengths, including emerging low-field portable scanners, being programmed to produce DC shimming fields, and performing heteronuclear polarization transfer. The ADAPT Coil combined with recent progress in other directions such as machine learning and hyperpolarization may bring about exciting advances.

Jessie Mosso

I.I. Rabi YIA Finalist

After growing up in Marseille in the South of France, I graduated from an engineering school and obtained a master's degree in Physics (ESPCI Paris) and in Neuroscience (Sorbonne Université, Paris) in 2019. During my graduate studies, I conducted research internships on the topic of in-cell dissolution dynamic nuclear polarization at the University of California, San Francisco, and at the Ecole Normale Supérieure, Paris, which constituted my first introduction to MR. I joined EPFL, Switzerland, in September 2019 to start a PhD at CIBM and LIFMET under the supervision of Dr. Cristina Cudalbu and Prof. Rolf Gruetter. My PhD research primarily focused on method development for the study of metabolism (using ^{1}H MRS and FDG PET) and microstructure (using diffusion-weighted MRS and MRI) in a rat model of hepatic encephalopathy. Employed on a European Union Horizon 2020 innovative training network during my PhD, I was fortunate to learn and benefit from a vast network of connections and expertise also outside the scope of my initial training, including in human brain and non-brain MRS and quantitative MRI. In September 2024, I will be joining the group of Prof. Els Fieremans and Prof. Dmitry Novikov at the Department of Radiology, New York University Langone Health to extend my knowledge of diffusion-weighted MRI and explore its combination with MRS. Building upon these acquired methodological MR skills, I aim to orient my future research line towards the study of sex differences in health and disease, for which I have a long-lasting interest. During my PhD, I initiated the first MR study comparing male and female rats with hepatic encephalopathy,

hopefully paving the way to understanding the poorer clinical outcome for women with hepatic encephalopathy compared to men. The impact of such studies towards individualized treatments and precision medicine will be undoubtedly immense given the current knowledge gap in our understanding of metabolic differences between men and women, and I am intimately convinced that MR will be instrumental in closing this gap.

NOMINATED PAPER

Diffusion-weighted SPECIAL improves the detection of J-coupled metabolites at ultrahigh magnetic field

Diffusion-weighted MRI (dMRI) has provided a fundamental tool both for clinical diagnosis and understanding of brain microstructure. Its MRS counterpart, diffusion-weighted MRS (dMRS), has emerged as complementary in informing on microstructure in a cell-specific manner: contrary to water, which is located in all cellular compartments, metabolites traditionally measured with ^{1}H MRS have preferential location in specific brain cells. However, these metabolites are approximately 10 000 times less concentrated than water in the brain and suffer from J-evolution, rendering dMRS less sensitive than dMRI and fostering the need for advanced dMRS acquisition schemes. In this work, we propose a new dMRS sequence, dubbed DW-SPECIAL, that is designed to shorten the minimum echo time and reduce the specific absorption rate (SAR) compared to the current gold-standard sequence for rodent dMRS studies. This was achieved by converting the SAR- and echo time-demanding LASER localization into a SPECIAL localization module, where the adiabatic inversion is placed in the mixing time of the diffusion module. In doing so, we preserve most of the advantages of the current gold-standard but halved the minimum achievable echo time. The shorter TE reduces metabolite signal loss by T_2 relaxation and J-evolution and enabled the estimation of diffusion properties of low-concentrated and J-coupled metabolites for the first time with such precision. Benefiting in addition from an ultra-high magnetic field (14.1T), DW-SPECIAL successfully probed the diffusion properties of glutamine, produced in the astrocytes and well-separated from glutamate at high field, and of low-concentrated metabolites including ascorbate, lactate or glutathione in the rat brain. We envision this work to provide better fundamental understanding of cell-specific brain microstructure in vivo by accessing the diffusion properties of low-concentrated and J-coupled metabolites. The extended range of probed metabolites may provide new clinical biomarkers of brain cell alterations in disease, both in rodent and human dMRS studies at high field, for which the less SAR-demanding DW-SPECIAL is a new candidate sequence. ■

Cultivating Diversity in MR Studies

INTERVIEW BY **BENJAMIN KEEDWELL**

Carinne Piekema, PhD is Engagement Manager for the Wellcome Centre for Integrative Neuroimaging (WIN) at the University of Oxford, UK. With a background in neuroscience and science communication, Carinne provides support for a host of public-, patient-, and policy- related activities as well as leading her own initiatives. Recently, Carinne spearheaded a project to improve inclusivity measures for research volunteers at WIN – read on to find out more.

MRMH: What motivated you to undertake this project?

Carinne: What we know is that in neuroscience, a lot of research is still based on white people, and what we also know is that many diseases like Alzheimer's disease and stroke affect people from different ethnic backgrounds in very different ways, and so the treatment should reflect this, yet we haven't got enough information and data to investigate this properly. We were wondering why it is that we don't have a representative sample; why don't we have much diversity in our research participants?

MRMH: How did you decide which issues to target?

Carinne: We had five contributors from different underrepresented backgrounds help inform us on these specific questions. We set up three workshops with them. The first was focused on taking them through our procedures, adverts, participant information sheets, and safety screening forms, as well as a scanner demonstration. And then based on that, we asked them lots of questions about how they thought those things looked and where there were issues. We ended up with this huge list of things the contributors felt we were missing. A lot of it was based in linguistics, so how we talk about and explain things.

MRMH: What changes have you already overseen?

Carinne: For volunteers who don't want

Carinne Piekema and Stuart Clare (Director of Operations, WIN) at Discover Bucks Museum, Aylesbury for the 'Your Amazing Brain' exhibition, an engagement project developed by WIN and Banbury Museum & Gallery.

Carinne Piekema

to have uncovered arms, we now have long-sleeved scrubs as well as MR-safe headscarves and the option to request an all-female or all-male scanning team.

The other thing that we had a long discussion about was the safety screening forms which ask quite intrusive questions. It's fine to ask those questions because they are there for the safety of the participant. But what makes it much safer and more likely that people answer your questions truthfully is that you actually have an explanation for why you are asking them. And now the screening forms have got these explanations. I'm particularly pleased about that one because it's empowering for participants to understand why we ask those questions.

Another thing we've implemented is if you go in the scanner, there's one form, and if you just go in the control room, there's a different form. It used to be the same form, and it would have the same intrusive questions, but that's not the case anymore. There's also more information on our website about what to expect with videos signposting how to find us.

MRMH: Was it challenging to implement these changes?

Carinne: The really nice thing was that the team we assembled included researchers, it included us as engagement professionals, and then it also included radiographers. That meant that everybody was on board with the project, and everyone at different levels was involved with all of these ideas, so everybody was very willing to put them into place.

MRMH: How can advertising for volunteers be more inclusive?

Carinne: It was very interesting; we learned quite a lot in this process about advertising. Working in engagement, we're always saying you need to not use jargon. But actually, it's not just jargon, it's words like 'research' and things like the Oxford University logo which seem so normal to us but can come across as very daunting and off-putting for particular communities. We're currently working on some guidance for writing research summaries with advice on what terminology to use.

MRMH: How are you planning to build on the project's success?

Carinne: Another thing that was interesting to learn about, and that we still feel we need to address more, is building trust with the communities that we want to take part in our studies. We're in the process of getting funding for a 'community connector programme' that would involve actively seeking out relationships between our Centre and a few different communities in Oxford to really try and build some of those relationships. The programme will initially focus on just a few communities in Oxfordshire, but once we have a proof of concept, that hopefully means we can scale up.

MRMH: Is there anything else you would like to add?

Carinne: It's been one of those projects where I've been so pleased by how much we can get done with such a small amount of money and time in terms of making practices much better. It will be really good to open up the opportunity for researchers to ask questions that we have until now not really been able to answer, because if we have a large number of participants from different backgrounds we can start to ask more nuanced questions about rehabilitation and treatment. ■

Marta Bianciardi: Fireside Chats

INTERVIEW BY **MELISSA LOWE**

Marta Bianciardi, Associate Professor in Radiology at Harvard Medical School and Massachusetts General Hospital, is a member of the ISMRM Ad Hoc Moments in MR History Committee, formally known as the ISMRM Ad Hoc Historical Archives Committee. She currently leads the organisation of the ISMRM Historical Fireside Chats, together with Gregory Hurst (Greg, past Committee Chair) and John Port (current Committee Chair). In her spare time, Marta enjoys sailing, playing hockey and being inspired by her three kids, and in this interview she tells us about the 'Fireside Chats' initiative, founded in 2019, discussing some of her favourite memories from ISMRM and future plans for the Committee.

Marta Bianciardi moderating a Fireside Chat.

MRMH: What is the ISMRM Ad Hoc Moments in MR History Committee?

Marta: The aim of the Ad Hoc Moments in MR History Committee is to document MR history and disseminate it to ISMRM members and publicly. Since 2001, when the Committee was established by John Griffiths (also the first Committee Chair), the Committee has run formal one-on-one closed-door interviews at the ISMRM Annual Meeting with MR Pioneers, ISMRM AMPC chairs, ISMRM Presidents, Young Investigator Award Nominees and Gold Medal Winners. The Fireside Chats are informal chats about moments in MR history in the presence of attendees. They were introduced at the 2019 ISMRM Annual Meeting, where we ran eight campfire style historical talks, covering topics such as 'First Clinical MRI in China', 'Early Years in Nottingham, Mansfield group' and 'Pioneers of fMRI'. The Committee has also brought these Fireside Chats to other events, such as the ISMRM workshop in Italy on 'Current Issues in Brain Function' where I interviewed Professor Bruno Maraviglia; this was an incredible experience, as Bruno built the first MRI scanner in Italy, and I had previously worked in his lab for my PhD.

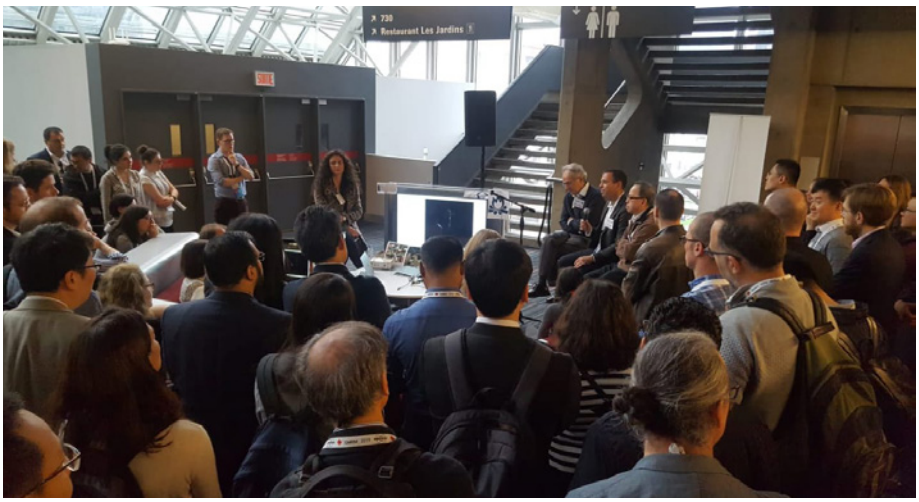
MRMH: Why did you join the ISMRM Ad Hoc Moments in MR History Committee?

Marta: I joined in 2018, after receiving an email from ISMRM asking for new members in several committees. I did not know I was just one click away from diving into MR history. I had experience in giving formal educational and scientific talks, but I had never acted as a moderator for informal, interactive discussions, like the 'Fireside Chats'. I was shy growing up, so this was out of my comfort zone; but I have found it incredibly enjoyable and fulfilling!

MRMH: How was the 'Fireside Chats' initiative founded?

Marta: I consider myself a founder of this initiative, along with the 2019 Ad Hoc Historical Archives Committee members; in particular, Greg Hurst, who was the Committee Vice-Chair at that time, and John Port, who was the Chair of the Annual Meeting Program Committee at that time.

2023 Fireside Chat at the ISMRM workshop on Current Issues on Brain Function (Padova, Italy) on Italian Pioneer Bruno Maraviglia who build the first MRI scanner in Italy in the early 1980s.



Left, Example campfire format at ISMRM during the 2019 Pioneers of fMRI Fireside Chat; Right, fMRI Pioneers: Kamil Ugurbil (left), Peter Bandettini (middle), Kenneth (Ken) Kwong (right).

After two member-initiated symposia on MR history proposed by Greg Hurst were not accepted by the AMPC board, the Committee organised a brainstorming session to discuss how to bring more history alive at ISMRM. I proposed to have a booth and a storyteller about pioneering studies, and the final campfire format was suggested by John Port.

MRMH: What is the campfire format of a Fireside Chat?

Marta: The Fireside Chats have an informal, interactive style; we arrange couches and chairs surrounding the Speakers, creating a campfire like atmosphere where the audience can easily participate and ask questions. The Pioneers bring memorabilia with them, such as pieces of hardware (for example small coils/parts of gradients, the original computer and goggles used in the first fMRI experiments), original lab notebooks, manuscripts, old pictures, while these can be passed around the audience. Some talks are completely improvised, and some are thoroughly rehearsed and prepared; it can depend on the style of the moderator and the 'pioneers'. We aim to have several pioneers per topic, to give a variety of perspectives.

MRMH: What speakers/topics have been included at past Fireside Chats?

Marta: We have had industry speakers, such as GE, Siemens and Philips scientists, sharing the early years of research and development. Speakers from universities, such as UCSF, Aberdeen and Nottingham, have discussed their historical contributions to MR development. We have paid tribute to late pioneers in the field, such as Professor Paul Lauterbur (who invented MRI) and Professor Jim Hutchison (who built the first full-body MRI scanner in 1980), with their former trainees sharing stories and memories. Pioneers have discussed developments in MRI techniques, such as non-contrast MRA, Diffusion and Spin-Warp Methods.

MRMH: What has the audience response been to Fireside Chats at ISMRM?

Marta: The sessions have been well attended, with some attracting up to 70-80 people. The broader MRI topics attract larger audiences, such as 'Pioneers of Diffusion MRI' and 'Pioneers of fMRI. Topical discussions are popular; at ISMRM 2023 we hosted a session on the New Zealand Pioneer Professor Paul Callaghan, covering his expedition to Antarctica investigating sea-ice structures using the Earth's magnetic field MR. The sessions are usually hosted within a hallway at the conference, with the aim of catching the interest of those walking by.

MRMH: What are your favourite memories

2019 Fireside Chat on Early Years at Aberdeen, with tribute to Jim Hutchison. Moderator: Greg Hurst (left), and Speakers: David Lurie (middle) and Fraser Robb (right).

2023 Fireside Chat on Paul Callaghan's Legacy. Above, from right to left, speakers: Petrik Galvosas, Yang Xia (with remote presentation from Robin Dykstra) and Moderators: Sergei Obruchkov and Marta Bianciardi. Right, the first MR experiment in Antarctica using the Earth's magnetic field.

from the Fireside Chats?

Marta: There have been many funny moments throughout the history of the Fireside Chats. During the 'Pioneers of Diffusion MRI' talk in 2022, the moderator, Derek Jones, started the session by asking the crowd 'What do you do around a campfire? You toast your marshmallows, and you sing Kumbaya'. He then began singing Kumbaya and encouraging the crowd to join in; the slight time delay from those joining remotely through Zoom made for an interesting rendition! At the same Fireside Chat, it was also amusing to listen to Professor Robert (Bob) Turner mimicking the sound of the NIH scanners before ('boop-boop-boop-booop-bbbbbbb, i.e. spin warp technique) and after he arrived at the NIH and built a new gradient coil for echo-planar-imaging ('pi-pi-pi-pi-pi-pi-pi'). During the 'Pioneers of Gradient Systems' talk during the same year, the moderator, Brian Rutt, dressed up with a cowboy shirt and boots to fit with the campfire theme.

I moderated the 'Pioneers of fMRI' talk in 2019, with speakers Professors Ken Kwong, Peter Bandettini and Kamil Ugurbil. These fMRI Pioneers have been competing against each other throughout their careers; there was a lot of collegial teasing between them, leading to humorous but insightful anecdotes about stories behind the scenes (such as rumours heard at the airport about the other teams' work or key abstracts not delivered in the mail).

MRMH: What does the future hold for the ISMRM Ad Hoc Moments in MR History Committee?

Marta: Thanks to the unconditional support of Sally Moran (Director of IT and Web at ISMRM), we have an archive of recorded historical interviews and Fireside Chats, and we wish to make these available to the wider ISMRM community, and possibly the public, through platforms such as YouTube. Note that more than half of the about 170 interviews have been performed by James (Jim) Prichard, during his remarkable 20+ years of service on the Committee. To reach a wider audience, we plan to create short-form videos presenting the highlights of Interviews and Fireside Chats and display them on monitors throughout the conference or on YouTube. This initiative is led by the current Committee Vice-Chair Jeff Dunn. To ensure the Committee is capturing diverse ways of thinking, we would like to encourage people from a variety of backgrounds and ages (especially women and younger investigators) to join our Committee and share their ideas. You might also be just one click away from a very rewarding experience!

MRMH: What should we expect from ISMRM 2024?

Marta: The final topics have not been confirmed, but we expect about four talks, one per day of the conference. We are still not able to toast marshmallows during these sessions, but interactive and entertaining educational talks on MR history are guaranteed. We look forward to seeing all of you there! ■

2022 Fireside Chat on Pioneers of Diffusion MRI, the first campfire in hybrid format, with (from left to right) online speakers Denis Le Bihan and Mike Moseley, as well as in-person moderator Derek Jones and speakers Robert (Bob) Turner and Peter Basser.

MR Technologist-Led Research: Optimizing Impact and Clinical Translation

INTERVIEWS BY **GLENN CAHOON**

At the 2024 Annual Meeting of the ISMRM and ISMRT in Singapore, the spotlight will be on showcasing cutting-edge developments, addressing barriers to translating research discoveries into tangible clinical outcomes and improving access to these technologies across the globe.

In the dynamic field of magnetic resonance imaging, radiographers and technologists provide a vital link between patients and clinicians and possess an intimate knowledge of the equipment and its limitations. They play an important function in translating and implementing technological advances into clinical practice as well as identifying needs and opportunities. As the field of MRI matures, we are seeing more MR technologists and radiographers undertaking research degrees, and leading ground-breaking research to enhance patient care.

To shed light on the pivotal role of the MR operator in MRI research, and the collaborative synergy of the ISMRM and ISMRT in the wider MRI community, we sat down with several distinguished PhD-qualified MR technologists to talk about the significance of MR technologist-led research.

> YOU CAN FIND THE EXTENDED INTERVIEW AND A SELECTED REFERENCE LIST ONLINE

Anne-Dorte Blankholm, PhD, Research Radiographer, University Hospital Aarhus, Denmark.

Moreno Zanardo, PhD, Post-Doctoral Researcher, IRCCS Policlinico San Donato, Milan, Italy.

Greg Brown, PhD, Adjunct Lecturer, University of South Australia.

Interviewees

Anne-Dorte Blankholme's work exemplifies the practical applications of MRI in assessing patient outcomes and optimizing clinical interventions, highlighting the potential for radiographers to drive research initiatives that directly impact patient care. Anne-Dorte's efforts in MRI research spanning over three decades, reflect the evolution of MRI education and research opportunities for radiographers in Denmark. From establishing MRI safety procedures in Europe to pursuing advanced degrees in MRI, Anne-Dorte's career trajectory exemplifies the transformative impact of radiographer-led research on clinical practice and patient care.

Greg Brown's research has focused on the sources of variation in quantification, creating a specific magnetic susceptibility / R2*phantom with novel materials and construction, and developing a new calibration between

liver Iron concentration and R2*. His projects advance the utility of MR methods for tissue iron measurement in patients with iron overload, particularly transfusion induced iron overload in thalassaemia, myelodysplastic syndrome, dysplastic anaemia, sickle cell disease. Greg has worked for over a decade on gradient echo relaxometry, using phantoms to develop a stable analysis for MR acquisitions in a clinical population.

Karyn Chappell's groundbreaking research focuses on harnessing the magic angle effect in musculoskeletal imaging. Through the development of the Magic Angle Directional Imaging (MADI) technique, Karyn aims to provide new insights into orientated collagen fibers within musculoskeletal tissues. Her innovative approach not only challenges conventional MRI practices but also holds promise for revolutionizing outcome measures and treatment options for musculoskeletal injuries and diseases. Karyn's story, rooted in her early experiences, and now at Imperial College London, epitomizes the radiographer's role as a catalyst for MRI innovation and the transformative power of radiographer-led research in advancing the field. Karyn's involvement in professional associations like BAMRR, ISMRM, and ISMRT underscores the importance of mentorship and leadership in nurturing the next generation of MRI researchers.

Karyn Chappell, PhD, Post-Doctoral Research Radiographer, Imperial College London, UK.

Maureen Hood is a seasoned researcher specializing in advanced biomedical imaging techniques, particularly focusing on magnetic resonance imaging (MRI) in cardiovascular disease (CVD) and brain-heart interactions. With a career spanning clinical and pre-clinical research, she adeptly integrates imaging physics with molecular biology to gain a deeper understanding of disease mechanisms. As Director of a pre-clinical imaging core, she facilitates the incorporation of imaging biomarkers to enhance data quality and minimize animal usage in longitudinal studies. Maureen's background in radiography uniquely positions her to contribute significantly to research advancements and innovation in medical imaging.

Shawna Farquharson has spent her scientific career focusing on the application of 'cutting edge' imaging techniques to clinical populations to help understand the structure and function of the brain, and the translation of scientific advances to improve patient care. She is responsible for providing national-scale project management to ensure coordination and harmonization across Australia's advanced imaging network, to improve accessibility for researchers, health professionals and industry.

Maureen Hood, PhD, Associate Professor of Radiology and Radiological Sciences, USA.

Christian Montalba's research endeavours focus on identifying biomarkers for neurological diseases using MRI and machine learning techniques. Through his work, Cristian not only contributes to the understanding of conditions like multiple sclerosis and schizophrenia but also expands his skill set to embrace emerging technologies like artificial intelligence. As a research assistant, Cristian highlights the crucial role of radiographers in acquiring and processing MRI images, facilitating interdisciplinary research collaborations. His experiences underscore the pivotal contribution of radiographer expertise to the broader scientific community.

At the Cerebral Imaging Center of the Douglas Hospital, Liana Sanches utilizes her expertise as an MRI operator to advance neuroscientific research. Through structural and functional MRI analyses, she contributes to understanding, preventing, and diagnosing psychiatric and neurodegenerative diseases. Liana's focus on quantitative MRI underscores the versatility of MRI in addressing complex neurological questions and fostering collaboration across research domains. Her multidisciplinary approach, merging MRI expertise with neuroscience, highlights the potential for translating research findings into clinical applications, bridging the gap between theory and practice.

Shawna Farquharson, PhD, Senior Scientist, Australian National Imaging Facility, Australia.

For Hiroyuki Takashima, the focus of his research journey has been on improving the quality of MRI images and their impact on patient care. From Otaru, Hokkaido, Japan,

Cristian Montalba, PhD, Research Assistant at the Biomedical Imaging Center, Pontifica, Universidad de Chile, Chile.

Liana Guerra Sanches, PhD, MRI Specialist, Douglas Research Centre, Montreal, Canada.

Hiroyuki Takashima, PhD, Chief in Musculoskeletal MRI, Sapporo Medical University Hospital Sapporo, Japan.

Hiro emphasizes the cohesive nature of the MRI community in his country. Despite regional differences, Japanese professionals maintain strong connections and collaborative spirit, exemplifying the power of teamwork in advancing MRI research. Hiro's commitment to academic engagement and continued learning through organizations like ISMRM and ISMRT, and dedication to teaching the next generation underscores the importance of knowledge dissemination and skill development within the field.

John Totman's career has been marked by a dedication to bridging the gap between clinical practice and MRI research. John emphasizes the importance of practical applications and collaboration, and the need for a stronger research environment amidst a well-established clinical landscape. John's journey underscores the significance of international collaboration and knowledge exchange, which fuelled his career progression from the UK, to Singapore, and eventually to Abu Dhabi. His efforts in setting up research centres and facilitating educational initiatives highlight the critical role of radiographers in facilitating interdisciplinary research and driving innovation.

Moreno Zanardo's research revolves around optimizing MRI acquisition protocols to enhance diagnostic accuracy and predictive capabilities. By coordinating studies investigating pre-cardiovascular surgery brain MRI and Alzheimer's disease risk prediction, Moreno demonstrates the transformative potential of MRI in clinical practice. Moreno's journey from a PhD fellow to a Researcher Radiographer exemplifies the thriving MRI community in Italy and the pivotal role international networks like ISMRM and ISMRT play in fostering continuous learning, connections, and access to cutting-edge advancements in MRI research.

MRMH: How has ISMRM and ISMRT influenced or supported your research, and what role do professional societies play in advancing radiographer-led research?

John: I was first introduced into the community by two MRI physicists I worked with in London and attended my first annual conference in Denver in 2000 and presented my first poster at the 2001 annual conference in Glasgow. Since then, I have gone on to be an author on 70 papers. Everything I have done over the last 25 years is as a result of connections I made through the ISMRM and ISMRT.

Liana: Education is the key and opportunity is the way. ISMRM and ISMRT can help in both ways. I was introduced to ISMRT in 2012 and encouraged by a colleague to submit a poster. Suddenly I had arrived in a new Universe. All those people were talking just about MRI! More than ever, I was sure I wanted to stay in MRI. I moved my career to research, as a specialist in MRI research protocols, and then as a research assistant, then completed my PhD and had the opportunity to move to Montreal, Canada.

Hiro: Since becoming a member of ISMRT, I've had the opportunity to stay informed about global trends in MRI. Naturally, the environment for MR technologists varies in each country and region. In these diverse circumstances, interactions with various members of ISMRM/ISMRT, including MR technologists, significantly contribute to advancing my own research. Our common language revolves around MRI, and I believe that language barriers will diminish over time with advancements in AI.

Maureen: Professional societies, including ISMRT, play a crucial role in fostering collaboration, sharing knowledge, and providing a platform for continuous learning. They serve as catalysts for advancing radiographer-led research by creating environments where professionals can connect, exchange ideas, and contribute to the collective growth of the field.

Anne-Dorte: The ISMRT has contributed to my learning curve, gave me confidence in the possibility to move forward with further education and towards enhancing the quality of MR examinations for better patient- exam-

John Totman, PhD, Head of Department, Radiography and Medical Imaging, Fatima College of Health Sciences, Abu Dhabi.

inations and treatment and making an impact on ensuring better patient safety as well. The ISMRM/ISMRT has taught me that it is possible to be respected and recognized globally as a radiographer no matter if you are an MR-Technologist, radiographer, MSc or PhD.

Greg: The ISMRM and ISMRT provided me with a community and intellectual space to develop, share and expand as a practitioner, a scientist and as a person. I cannot imagine what life or MRI would have been like without this community. I have met people willing to listen to research ideas, who are keen to see your latest results or are there to share perspectives and connections. Knowing radiographers from overseas has kept my perspectives more global… but their perspectives kept my work grounded in a clinical utility that is perhaps central to radiographer-led research.

Karyn: I joined ISMRT to meet other radiographers who were doing or had completed PhDs in MRI. There is an amazing group of ISMRT PhD radiographers who offer a constant source of inspiration, support, and advice. That visibility is so important in a career where it isn't the norm to do research and not many radiographers choose it as a career path.

MRMH: In the course of your research, what challenges have you encountered and how have you addressed them?

Maureen: Becoming a scientist as a second career phase has made the effort to establish myself as a scientist challenging. I learned to make success by changing directions and taking advantage of the unexpected opportunities that pop up, such as taking on radiation countermeasure research.

Anne-Dorte: It can be challenging to acquire funding as a radiographer [even] to attend meetings it's often not a priority for institutions. From a career point of view, it has been challenging getting recognized and getting equal opportunities relative to PhDs from other professions. Recently, things are maturing, possibilities are beginning to open, so, I anticipate radiographers with a PhD will have a brighter future entering a career pathway as a researcher.

Shawna: One of the biggest challenges for Radiographer-Scientists that I see globally is that very few countries have a professional career framework to support PhD Radiographers. Radiographer-Scientists typically do not receive the same support for their research activities as Clinician-Scientists.

MRMH: What is the role of radiographers in the translation of new technologies and research findings into clinical practice, and how can ISMRM and ISMRT help?

Moreno: I believe that environmental sustainability is becoming increasingly important, and radiographers will play a crucial role in this context. I recently conducted the 'GREENWATER trial on the potential recovery of Gadolinium before its dispersion into the environment. A recent review I published highlights how MRI scanners and workstations contribute to the environmental impact of healthcare facilities. Sustainable actions include favouring the most energy-efficient imaging technologies and educating radiological staff on energy-saving practices without compromising service quality.

Christian: Radiographers are not only a key part of image acquisition. In research, we act as a bridge between clinical and engineering applications. Being involved in both worlds can give you an amazing perspective and help you take the best from each area.

Hiro: If a technical innovation improves scanning time or quality, radiographers will incorporate it into their clinical routines.

Karyn: Radiographers are great at facilitating the translation of novel research. I have presented at many different conferences to get my research out to the wider community. I lecture at several universities informing the next generation of radiographers, which is important as much of my research will hopefully come into practice in their working lifetime, in the hope of improving the speed of translation.

Greg: Radiographers attending ISMRM or ISMRT meetings are often the ones to bring novel techniques to the attention of their local practices. Radiographers focus on local translation, be it a new pulse sequence or acquisition method, or a new MR technology offering from a manufacturer. Radiographers want tools, and the best of them look for tools that are relevant to their patients and institutions.

Shawna: Radiographers often must choose between being a Radiographer or a PhD. This remains an important challenge that as a community we should help to address because PhD Radiographers are uniquely positioned to help bridge the translation gap.

Conclusion

The voices of these MR radiographers and technologists from around the world paint a vivid picture of the current and future role they play in driving MRI research forward and translating new scientific discoveries into everyday practice. Through collaboration, innovation, and dedication, MR radiographers and technologists are not only shaping the future of MRI but also advancing healthcare delivery on a global scale. ■

If their stories have sparked an interest in pursuing a research career, be sure to check out our Masterclass series in this year's ISMRT program in Singapore. These sessions will address professional development pathways, including How to do a Ph.D.. For those already on their research journey, you can now save 25% on your membership fees with our new ISMRM and ISMRT Dual Membership.

Code Reviewing for Magnetic Resonance in Medicine

INTERVIEW BY **SHAIHAN MALIK** AND **MARIA EUGENIA CALIGIURI**

Last year, MRM started offering authors the option of a Code Review of any code they provide in a Data Availability Statement, in partnership with the Reproducible Research Study Group (RRSG). If authors request it, RRSG volunteers will download the code and check that it installs and can be run. Here we collected feedback on this pilot initiative from both sides: reviewers and reviewed authors. Enjoy!

Calder Sheagren, University of Toronto, Canada.

Reviewers' feedback

Calder Sheagren

I decided to volunteer because I found the code reviews as a good way to get involved more with MRM and evaluate papers from a usability perspective.

I found the process of reviewing very easy. The paper I was reviewing had a clear README going through the instructions for environment setup and code use, so the main objective of the review was to make sure that these instructions worked for me as well. Writing the review was more like play-by-play commentary where I noted the commands I ran and whether they worked or not.

In terms of the impact of Code Reviews, having a verification that researchers' code is available and has been demonstrated to work will help in my paper-reading process, as many repositories provided with papers may not be available, may not have code, or may not have data to test their code.

Finally, this process made me aware of the effort required by authors to ensure that their code can be run from a fresh environment outside of their lab. A major component of the code review process is the preparation and troubleshooting for outside use, which helps many readers in the future!

Xingwang Yong

As a trainee, I learnt MRI from various GitHub repositories. In my first year as a PhD student, I came across the 'mriphysics' GitHub website. As a newbie, the fascinating animations immediately drew my attention. I wondered if I could make some beautiful figures and starting to write simulation code. In the end, I managed to reproduce some animations from the website. Through this process, I gained a deeper understanding of basic MRI concepts.

I also tried to reproduce figures from MRM papers related to my project to make sure I truly understood the idea in the papers. This is not trivial because some papers did not provide detailed parameters and I had to guess. Besides, this might be time-consuming because one has to start from zero, which makes me wonder if it is worthwhile to invest so much time to just reproduce existing work.

Benefitting from so much from the community, I think it is the time for me to do something for the community. So I decided to do the code review. I intentionally chose to review code from the fields that I am relatively unfamiliar with, because the code reviewer's responsibility is to assess the accessibility of the code instead of its scientific aspects. By avoiding commenting on scientific aspects, I can concentrate more on the ease of installation, external dependencies, etc.

Xingwang Yong, Zhejiang University, Hangzhou, Zhejiang, China.

I believe by open-sourcing the code used in papers, we can greatly reduce the barriers and flatten the learning curve, which is beneficial for everyone in the community.

Anais Artiges

I joined the way most of us did: by being asked to in the ISMRM Reproducible Research Study Group. I want to support reproducible research and I know from experience how hard it can be to produce sharable software when it is not your area of expertise. I think having feedback from external people on the installation and running process is precious to the release of any scientific code. I enjoy helping authors identify what is good in their implementation and what they can make better. The process is quite smooth, with clear evaluation points that allow us to provide efficient

feedback. I designed a spreadsheet to format all my reviews the same way and be certain to assess each important point. However, I think the guidelines for the authors are still very light. It would be easier for us if the review was targeted with a clearly defined application and tangible results to obtain and compare without having to decipher which result in the paper is obtained with which code. I hope these reviews will become the norm, ensuring that any released code can be run smoothly and is giving the expected results.

I will be delighted to help with more reviews in the future.

Anais Artiges, NYU Grossman School of Medicine, New York, USA.

Felix Horger

Code review encourages researchers to make their code available, as well as more readable and understandable, to members of the scientific community, who can then better observe the fine details and practical problems of a published technique. Have you ever tried implementing an algorithm from a paper, suddenly wondering how they solved a seemingly tiny yet crucial problem that makes the algorithm fail if not treated appropriately?

Code review also has potential to make people aware that writing good code is an underappreciated art. If code reviews become part of the path to publication, researchers will be incentivised to write good code, and this will consequently honour the value good code has for science.

From a code reviewer point of view, on the other hand, this process raises awareness on the fact that collaboration accelerates progress: there's no need to reinvent the wheel, and also code with good architecture can be used for equivalent subproblems that can occur in different contexts.

Other positive aspects of code review are: increasing reproducibility, reducing the risk of the classic "works on my computer" case, and getting to know better coding languages. And if you made a mistake in your code and you can't find it (or don't know it is there), there is a chance someone else will. Consider, for example, the success of open source projects like Linux. Also, since the MRM

Felix Horger, King's College London, United Kingdom.

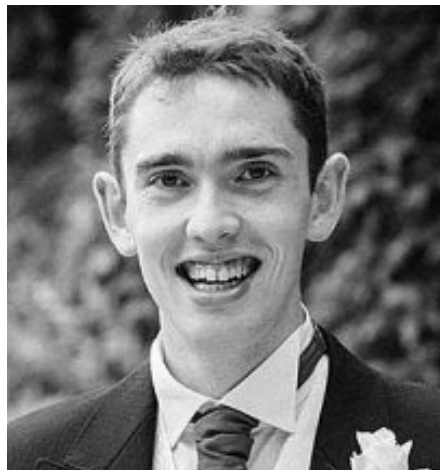
code review asks you to use version control, everyone can do an elegant `git pull` and the code is updated. Finally, making useful code public means more citations for you! Famous examples are BART or MIRT.

Feedback from an author

William Clarke

I was very happy to see the option for code review when submitting my MRS fitting paper. This work is software-heavy, with lots of individual parts, example scripts, associated datasets, and linked code repositories. The paper would have been near unreadable (*maybe it still is*) if I'd described all of these parts in excruciating detail. I was, therefore, leaning heavily on the packaged examples for those who want to use the proposed tool. It was therefore incredibly reassuring to have an independent reviewer, on a completely different computing setup, try and install all the dependencies and run all of the components.

The actual process was very easy. I selected 'yes' to 'code review' on the MRM submission site, and then a few days after receiving the scientific reviews I received the code review. This comprised an understandable, 1-page document, setting out if my submission met the open and objective review criteria. I'm lucky to work in a centre with dedicated and very helpful software engineers, and I've now accumulated some experience of publishing my own software, so the review criteria were all met. However, I think the review criteria are very attainable by all those



William Clarke, Wellcome Centre for Integrative Neuroimaging, University of Oxford, UK.

who publish in MRM.

Clearly having code, data, and documentation out there, alongside the formal publication, is of really significant benefit to the community. It makes understanding the method *and* building upon the work much easier. I think especially so for relatively junior researchers, who are probably having to do actual implementation. However, so often (well-intentioned) code deposits don't work, or are undocumented, or are near impossible to use without the author's own setup. This fantastic effort by the RRSG seems to be a very encouraging and gentle way to bring this modern part of publication up to a consistently useful standard.

Overall, I'd really encourage authors to tick that box and request code review. Afterwards, you can be confident that all the extra effort you've gone to by including your code can be fully appreciated. ■

In vivo magnetic resonance 31 P-Spectral Analysis With Neural Networks: 31P-SPAWNN

INTERVIEW BY **MATHIEU BOUDREAU**

EDITOR'S PICK FOR JANUARY

This MRM Highlights Pick interview is with **Julien Songeon** and **Antoine Klauser**, researchers at the University of Geneva in Switzerland. Their paper entitled In vivo magnetic resonance 31 P-Spectral Analysis With Neural Networks: 31P-SPAWNN was chosen as this month's Highlights pick because they shared the source code for their proposed method (simulations, their deep learning network, and sample datasets).

MRMH: Tell us a little bit about yourselves.

Julien: I grew up in France, but did my undergraduate degree in physics at the University of Geneva. I then specialized in high energy physics for my master's degree, and am currently focusing on applied physics for my PhD, which I'm defending soon. My thesis focuses on phosphorus magnetic resonance spectroscopy.

Antoine: I followed a similar trajectory to Julien, actually. We're both products of the same physics department at the University of Geneva, but I did my master's in condensed matter physics. I then went to the Netherlands, where I did my PhD thesis in very fundamental theoretical physics. After that, I wanted to focus on something more applied, and I was really attracted to neuroscience in general, which led me to develop an interest in MRI. So, after my PhD, I started working in the development of MRI methods and spectroscopy.

MRMH: Your article focuses on phosphorus spectroscopy. Why is this technique important?

Julien: In my thesis we use phosphorus spectroscopy in the context of organ transplantation, to evaluate the metabolism and viability of the organ prior to transportation in the hope that this might lead to transplants from more marginal donors. Because organ transplantation is a very time-sensitive procedure, the phosphorus spectroscopy data need to be both acquired and processed very quickly to assess any potential injuries to the organ. Generally, Phosphorus spectroscopy allows to measure and analyze the metabolic activity of phosphorus-containing compounds in living tissues, providing insights into cellular energy metabolism and various disease processes.

Julien Songeon

Antoine Klauser

MRMH: Could you give us a brief overview of your paper?

Julien: The idea in this paper is to use an artificial intelligence (AI) approach with convolutional neural networks for the analysis of phosphorus spectroscopy data. We present a method for generating a simulated dataset to train the network, and also present different network architectures for metabolic quantification, baseline, and parameter values. A pipeline for the spectral reconstruction was developed and compared against the LCModel method, which is the gold standard for 1H spectroscopy. We found that the data processed with our method compared well with LCModel, with the advantage of having a substantially faster computation time – computation would take a few hours with the LCModel and our method reduced this processing to a few minutes. In addition, we found that our model performed well even at

Link: https://onlinelibrary.wiley.com/doi/full/10.1002/mrm.2944

low SNR, which is an inherent challenge in phosphorus spectroscopy.

Antoine: What's really nice about this work is that it's an out-of-the-book demonstration of this approach. We have a very theoretical model based on a fundamental description of the signal, that is to say, in the form of an operator describing the energy level transitions for each metabolite. And from that theory, we simulate the metabolite magnetization, and then follow up using AI to extract the best concentration estimates. So, we really do move from theory to practice, and it seems to work very well in this case.

Julien: The nice thing about this AI approach is that data can be simulated with a model that mimics the real data faithfully, because the mathematical descriptions of the metabolites signal resonances are well known. We are then able to train an AI model using data containing millions of simulated spectra.

MRMH: Reading your paper, I was surprised to learn that you used three different deep learning models for this project. Could you explain why?

Julien: We wanted the AI model to produce three sets of outputs: the baseline spectra, metabolite concentrations, and spectral parameters. For the first case, the baseline spectra, the output baseline has the same dimensions as the input, and the U-net (although mostly used for image processing) is one type of AI architecture that's specialized for this task. The other two outputs have much lower parameter dimensions than the input spectra, and so another type of architecture (LeNet-5 model), specialized for this task, was used. We could have had just two models, by using a single model for both metabolites concentration and spectral parameters. Separating the two is advantageous only when you only want to do quantification of the concentrations and don't want to reconstruct the spectra. In that case, you can just use the quantification network.

MRMH: Can you clarify what you mean by baseline spectra, for those of us whose spectroscopy knowledge may be a bit rusty?

REPRODUCIBLE RESEARCH INSIGHTS WITH

Julien Songeon

Why did you choose to share your code/data?

This approach naturally facilitates the demonstration presented in the manuscript, allowing interested readers to test the method themselves. Also, we enable others to validate and reproduce our results effectively.

Also, rather than adopting a competitive approach, we prefer, in this way, to promote collaboration in MR research, because a collaborative mindset can foster advancements and progress in the field. Ultimately, code sharing can assist other researchers who wish to pursue similar research directions. They can utilize our work as a foundation, potentially saving significant implementation and coding efforts. This accelerates the pace of research and encourages researchers to build upon existing knowledge rather than wasting resources on replication efforts.

What is your lab or institutional policy on sharing research code and data?

Our institution has a highly flexible policy regarding the sharing of code and data. While open science practices are strongly encouraged, there are no clear advantages for us nor mandatory constraints in place that require us to share.

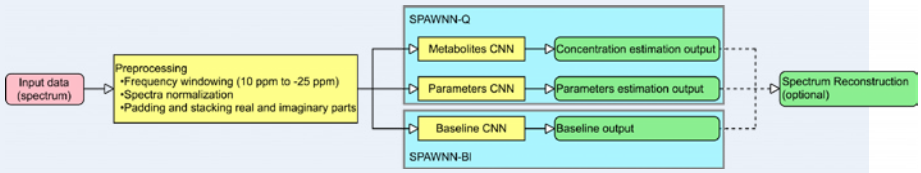
How do you think we might encourage researchers in the MRI community to contribute more open-source content along with their research papers?

I believe that if code and data sharing were recognized to add clear value to a submitted manuscript, then authors would have a positive incentive to provide open-source content. In addition to evaluating factors such as innovation, soundness of methodology, quality of results, and clarity of demonstration, editors should acknowledge the inclusion of code and data as a valuable contribution to the scientific community.

Questions about the specific reproducible research habit

Your code repository is really well documented. What advice would you give to people preparing to share their first repository?

When preparing to share a code repository, you need to think about the future users of your code and what information they will need to understand and use it effectively. The README file should explain the purpose of the code, and provide installation instructions, dependencies, and examples. The files could have comments within the code to clarify specific sections or functions. To help users navigate the repository and locate relevant files easily, I suggest organizing your code and files in a logical manner, using explicit naming. Finally, I would recommend including examples and/or tutorials, providing sample input data and scripts that demonstrate how to use your code. This can really help users to understand the expected workflow and apply the code to their own research.



Flowchart of the 31P-SPAWNN analytics pipeline

continued

What questions did you ask yourselves while you were developing the code that would eventually be shared?

In the development phase, we aimed to create code that could be easily adapted and reused for different experiments or in different research scenarios.

We also considered the computational complexity and performance of our code to ensure that it could handle large training datasets or complex computations effectively.

Finally, we paid attention to the clarity and comprehensibility of our code. We aimed to write code that would be accessible to other researchers.

How do you recommend that people use the project repository you shared?

Start with the README file. Read the README file and try to rerun the command shown. It will provide an overview of the capability and usage of the code and model.

Once you have a good understanding of the code, try to run it on your own data, adapting the number of points and the bandwidth and retraining a new model.

Then, further adaptation could be implemented: you could add other metabolites, apply the method to other nuclei, explore other model architectures.

Are there any other reproducible research habits that you didn't use for this paper but might be interested in trying in the future?

Using tools like Docker or Singularity to create reproducible and portable computing environments. This ensures that the code can be executed consistently across different systems and configurations without cumbersome installation or setup. In addition, keeping track of and archiving the successive versions of the code in a systematic manner allows researchers to easily track and manage changes to the code over time. This can be particularly useful when code is linked to a publication and extra data are required during the peer-review process. Also, we could try making automated pipelines that capture the entire workflow, from data acquisition to final results. Doing this simplifies the reproducibility process and reduces the potential for human error. ■

Lab photo while snowshoeing.

Julien: Sure! Following an excitation of the magnetization, the metabolites' specific frequencies of resonance will result in the presence of peaks in the measured spectrum, with the integral of a peak being proportional to the metabolite concentration. The baseline is a distortion of the entire spectrum consecutive to the excitation and the measurement.

Antoine: It's kind of a spurious signal that's spread over the entire spectrum. And it's unwanted; if you just do simple model quantification, that baseline will bias your results because you've got this low frequency wave standing on your spectrum.

MRMH: Great – thanks for clarifying that! You shared some open source tools, quite a lot actually. What motivated you to share all this material, and how do you hope people will use it?

Julien: Since it's a new model for analyzing spectra, we wanted to share the tools so that phosphorus spectroscopy might become more accessible. We shared our code that we developed for SPAWNN with the use of FID sequences. This code can be modified by other groups who plan to use, e.g. different sequences; they would simulate data that mimic their specific measurements, adapting the model to fit their needs.

MRMH: To finish off, what do you enjoy doing when you're not working in the lab?

Julien: I quite enjoy teaching – I find it's a lot of fun to create new original exercises for the students. I'm also involved in a lot of student association activities, leading conferences, and so on. One memorable activity was something called My Science Career Day, where we invited alumni to show how they transitioned outside of academia, which is not a perspective that we're exposed to a lot during graduate school.

Antoine: As for me, I have kids, so that takes up a bit of my free time [laughs]. I live between Lake Geneva and the mountains, so depending on the weather and the season, I enjoy going swimming in the lake or hiking in the mountains. ■

Deep, deep learning with BART

INTERVIEW BY **MATHIEU BOUDREAU**

EDITOR'S PICK FOR FEBRUARY

Our latest MRM Highlights Pick interview is with **Moritz Blumenthal** and **Martin Uecker**, researchers at University Medical Center Göttingen in Göttingen, Germany and Graz University of Technology. Their paper entitled Deep, deep learning with BART was chosen as this month's Highlights pick because they shared code capable of reproducing the figures from the publication, and also integrated it in another open-source tool (BART).

MRMH: Please tell us about yourselves and your backgrounds.

Moritz: My background is in physics. I have an undergraduate degree in this field and then did a Master's degree as well, researching a topic that lies at the border between cosmology and particle physics. Afterwards I felt that if I were to do a PhD, I wanted to work on a more applied topic. Having a good background in maths, I looked into some deep learning projects, and just by coincidence one of my friends visited Martin's lab and found that he was about to start a big data project. One thing led to another and I decided to do my PhD with Martin, working with deep learning and MRI.

Martin: My story is very similar. I also studied physics and mathematics at the University of Göttingen, and my diploma thesis focused on theoretical physics. I, too, was first introduced to MRI by a friend, who in my case happened to be Tobias Block. He told me something about MRI, which I thought sounded very interesting. I applied to do a PhD in the lab of Jens Frahm and there worked on parallel imaging and image reconstruction mostly, and that's how I first got into the field.

MRMH: Before jumping into the paper, could you explain what BART is and tell us a little bit of the history behind it?

Moritz: BART stands for Berkeley Advanced Reconstruction Toolbox, and it was a project I started in Miki Lustig's lab where I did a postdoc. When I moved to Miki's lab, I said I'll come, but I want to make all my source code public because I wasn't allowed to do that with my previous work. Miki agreed, and that's how open BART was started. It took a while to get to the first release, which was at the Sedona meeting in 2013, and at that time it was just a zip file or tarball. Back then, sharing code was still a new thing for the community. We presented in a software demo session there, and then people started to actually use it. This was important as it motivated us to develop faster and better reconstruction techniques for compressed sensing. And then the rest is history. It got ever more famous as more people used it, and we extended it repeatedly, every time we published new things.

Joint research group photo of the labs in Graz and Göttingen at this year's ISMRM annual meeting in Toronto. Moritz is 4th from the right in the back row, and Martin is third from the left in the front row.

MRMH: So, congrats on BART's 10th birthday! Could you now give us an overview of your article?

Moritz: Basically, the article stemmed

Link: https://onlinelibrary.wiley.com/doi/10.1002/mrm.29485

REPRODUCIBLE RESEARCH INSIGHTS WITH

Moritz Blumenthal

Why did you choose to share your code/data?
The main purpose of this particular publication is to describe the deep learning implementation in BART, which is our open-source toolbox for image reconstruction. Sharing the code was therefore a natural choice. In general, we think that sharing code together with a publication is a way to generate more impact, as the hurdles to using and building upon your technique are significantly reduced.

What is your lab or institutional policy on sharing research code and data?
In our lab, we share almost all of our code and the data for each publication if possible. In fact, most of our code is integrated into BART. Together with our publications, we then share scripts, for preprocessing and post-processing the data, and the data itself, as long as it does not contain any confidential information about patients.

Are there any other reproducible research habits that you didn't use for this paper but might be interested in trying in the future?
In an ideal world, the manuscript itself would be part of the reproducible pipeline. If we could simply start one script knowing that the result will be the ready-to-submit PDF, then we would be sure that everything relevant to the publication is contained in this reproducible pipeline.

How do you think we might encourage researchers in the MRI community to contribute more open-source content along with their research papers?
Sharing of code requires a substantial amount of additional effort and opens up your work to criticism. The incentives are therefore against sharing code, and this needs to change: this is a task for the community, which needs to value these research papers more.

Questions about BART and its Deep Learning Framework

What advice do you have for people who would like to get started with deep learning in BART?
We have a lot of tutorials on using BART, available at https://github.com/mri-recon/bart-webinars. These resources consist of Jupyter Notebooks and recordings of the webinars where they were presented. For those interested in the deep learning features we recommend taking a look at Webinar 6. For other questions, we have a mailing list where you usually get a response in a day or two.

BART has recently celebrated its 10th anniversary – could you share some of the lessons you've learned managing an open-source tool that's widely used in the MRI community?
One lesson is that it takes a lot of time and effort to maintain an open-source project, and it can be a long time before this time and effort pays off. But in the end, it was worth it! Partly because integrating new methods into BART is a really useful way to preserve them. We can build directly on top of previously developed methods, and we found that this works much better with methods that were integrated directly into BART than with ones where the code was published as a separate project.

from the idea behind my PhD project. Nearly everybody does deep learning nowadays, and although BART offered some initial support for this (e.g., automatic differentiation), many users depend on other deep-learning packages not specialized for MRI. Our motivation here was to introduce everything we needed to do deep learning in BART ourselves, partly to ensure reproducibility of the image reconstruction pipelines designed with deep learning. We knew from our own experiences that reproducing other people's open-source deep learning reconstruction pipelines is challenging when using tools such as TensorFlow that get updated often, and certain versions may only be compatible with other software dependencies. All this means you have to recompile software and it can get fairly messy. We wanted to have this under our control. The paper describes how we optimized the necessary numerical methods added to BART to do deep learning. In particular, we describe how we implemented automatic differentiation for complex numbers. The rest of the paper shows some example implementations and reproductions of other published work.

Martin: I think Moritz explained our rationale very well. Personally, I found that, ultimately, if you maintain software, every dependency you have can become a problem. So having everything under control ensures that the tools needed will be compatible in the long run.

MRMH: Did you encounter any unexpected challenges during the development of this framework?

Moritz: Not unexpected so much, but quite a lot of work was needed to make it fast. It was one of the major problems we had to solve, and it was a challenge.

MRMH: Martin, were you surprised by any of the results of Moritz's work?

Martin: Yes – I was very impressed in

the end, because I'd only expected him to implement a little bit of deep learning, but he actually went far beyond that, implementing a complete framework. It was so much more than I'd expected originally, so I was surprised and very pleased.

MRMH: Do you have any practical advice for people who might want to start using this framework?

Moritz: We made a webinar for one of the recent ISMRM conferences, and made both the recording and an interactive notebook for Google Colab available to everyone (here). I think this would be a great place to start, because it's a complete end-to-end example of deep learning in BART, and includes the necessary data in the MRD format. If I had a new student fresh from a Bachelor or Master's degree, I would start by giving them this notebook. We also shared scripts with our paper on GitHub, but in a less beginner-friendly format, so the webinar repository is definitely the best place to start for beginners.

MRMH: Could you share your thoughts on how to make research more reproducible, in particular on the computational side with software like BART?

Martin: In general, I think there are easy ways to make things reproducible, and also harder ways. Somehow, we always pick the harder ways I think [laughs]. One way people do it is by basically freezing the software environment at the time of publication, and often that allows others to reproduce your results. And that's a good strategy for some people, but it's not what we aim for with BART, which is being fully backward compatible. The goal is that anybody can directly start to continue working on a topic with the most recent BART version when starting from one of our papers. So, we need to integrate the innovations for new papers into the BART framework itself, and then keep it reproducible so that we can actually reproduce the results of all our previous papers as well, which can be very challenging even with tools like unit testing.

Moritz: Another problem with research in anything dealing with computation, in particular deep learning, is that it involves a very long chain of float point operations. And because of this, it can be sensitive to small things, even which numbers we sum together first. Although this may cause an only tiny numerical difference initially, that can propagate through the remaining operations and get larger. Therefore, although your end results should be good quality, you won't have *exactly* the same number as before. Switching computers and running the same code can also result in this type of small but non-zero numerical difference. It can be hard to be 100% reproducible when dealing with computations.

Martin: I think that in the end, providing you did everything right, you should get similar results even when switching computers. If not, your method was likely not very stable to begin with.

MRMH: And to end off, could you tell us what you enjoy doing when you're not in the lab?

Moritz: One of my hobbies is badminton, which I play in my spare time. I was a badminton trainer for four years, and have organized tournaments and other events. I'm new to Graz, and recently found a club here. It's a great sport to play if you want to meet people after moving to a new city.

Martin: As for me, unfortunately I don't have much spare time since becoming a professor. What little free time I do have I like to spend with my family. ■

BART (Berkeley Advanced Reconstruction Toolbox) logo.

Could you share some resources/tutorials on how to use BART?
As mentioned in our reply to Question 1, there are our BART webinar tutorials and the mailing list. Additional resources are linked from the BART webpage: https://mrirecon.github.io/bart/.

What advice do you have for people who would like to contribute to BART?
Talk to us! We can give advice about what contribution makes sense, and what requirements need to be fulfilled so that we can later accept it into BART. It is also more fun to develop things as part of a community. ■

Simultaneous Optimization of MP2RAGE T1-weighted (UNI) and FLuid And White matter Suppression (FLAWS) brain images at 7T using Extended Phase Graph (EPG) Simulation

INTERVIEW BY **MATHIEU BOUDREAU**

EDITOR'S PICK FOR MARCH

This latest MRM Highlights Pick interview is with **Sila Dokumaci** and **David Carmichael**, researchers at King's College London. Their paper entitled Simultaneous Optimization of MP2RAGE T1-weighted (UNI) and FLuid And White matter Suppression (FLAWS) brain images at 7T using Extended Phase Graph (EPG) Simulations was chosen as this month's Highlights pick because they shared code that reproduces their simulations, and did so by building upon another open-source software package (EPG-X).

Ayse Sila Dokumaci

David Carmichael with his children.

MRMH: Tell us a little bit about yourselves.

Sila: I completed my undergraduate studies in electrical and electronics engineering at Bilkent University in Ankara (Turkey). I then moved to Switzerland for my graduate studies focusing on MRI. I did a Master's at ETH Zurich and a PhD at the University of Bern. And after that, I came to King's College London for a postdoc position and decided to stay. I've worked on many different research topics, including MR spectroscopy and MR elastography. I've been working with David on our 7T system since January 2020.

David: I did my PhD with Roger Ordidge and Bob Turner at UCL in London, and basically stayed at UCL for a long time after that. I then came across to King's College in 2018 as a reader which, in our different, slightly odd, and archaic terminology, is kind of not quite a professor. I came here for one reason, namely the nice new 7T Terra they had just installed. I was kind of excited to try it and get my hands on that machine! In particular, I'm interested in the methodological side and also in clinical neuroscience, particularly pediatric epilepsy, and the 7T felt like a good system to use to explore this realm. And that's what led us to this paper.

MRMH: Before we dive into the paper, could you give us an explanation of FLAWS and extended phase graph simulations, which are

Link: https://onlinelibrary.wiley.com/doi/full/10.1002/mrm.29479

both mentioned in the title of your paper?

Sila: FLAWS stands for FLuid And White matter Suppression. It is a variant of the MP2RAGE protocol and provides different contrast to the conventional UNI image (which, instead, is optimized to provide good contrast between white matter and gray matter, and gray matter and CSF). Extended phase graph simulations are a specialized type of MRI signal simulation that keeps track of echoes formed throughout the repetitions of the sequence, from start to finish.

David: The way I think about EPG simulations is to consider what happens to magnetization when it's dephased, and you then apply another RF pulse. This situation is quite easy to imagine, for a couple of RF pulses at least. The set of spins is often visualized as a disc of magnetization that rotates then gets flipped, and continues to undergo other manipulations like pinching of the center to form a nice kind of pasta shape or something like that (for those of you with a culinary bent! [laughs]). But try tracking that over 50 pulses; you just can't. So that's the basis of the phase graph algorithm – it allows you to track these different bits of the magnetization and how they get rotated/refocused/flipped over a large number of pulses. That's the beauty of it, and using this methodology you can work out what your magnetization is doing throughout a very complex process.

Sila: Added to that, EPG calculations are conceptually doing the same thing as isochromat simulations. But one method is working in the spatial domain (isochromat simulations), and the other in the Fourier domain (EPG). In EPG, magnetization evolves as a Fourier series that gets more complex after each RF pulse and gradient, and these Fourier components are computed, directly, much more efficiently than the other way.

MRMH: That was very enlightening. Thank you! Having described these fundamental concepts, could you give us a brief overview of the paper?

Sila: As David mentioned, our end goal is to get good images in children with epilepsy at

REPRODUCIBLE RESEARCH INSIGHTS WITH

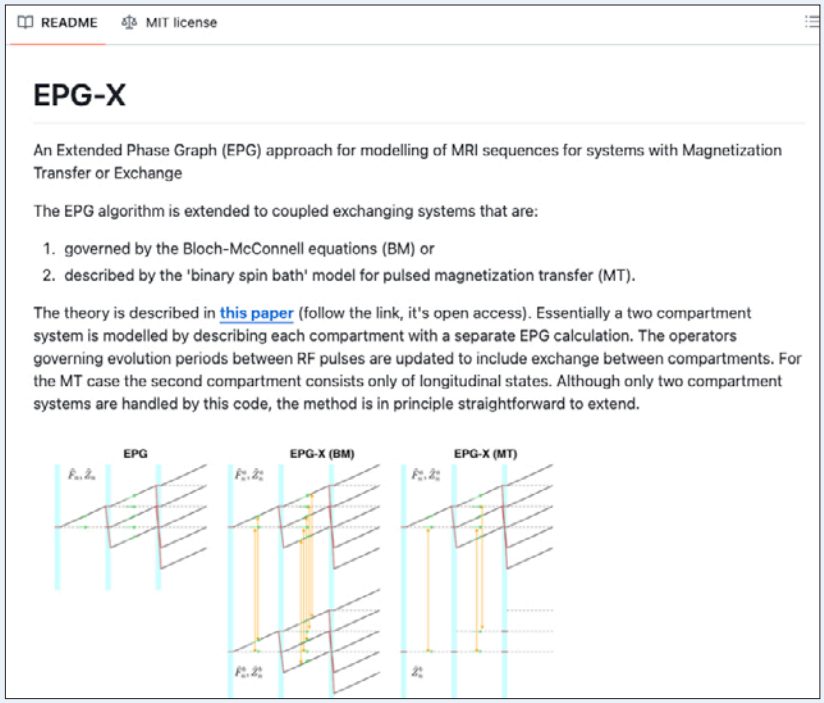
Sila Dokumaci

Why did you choose to share your code/data?
We were encouraged by MRM's open research policy. I was hesitant at the beginning because the code is far from perfect, but it was good enough to lead to the data presented in the paper so hopefully it will be useful for other researchers too.

What is your lab or institutional policy on sharing research code and data?
The institutional policy is to share code used in research by default. Sharing data is generally preferred and encouraged although with patient data there are sometimes restrictions.

At what stage did you decide to share your code/data? Is there anything you wish you had known or done sooner?
This was decided during the writing of the manuscript. I commented my code from the beginning of the development stage, and this proved to be a great help when preparing it for publication.

How do you think we might encourage researchers in the MRI community to contribute more open-source content along with their research papers?
We see the value of open-source content because there is a huge investment of time for software development – the more it is used, the better and the more quickly we can get to the important questions rather than coding from scratch. It is also critical for reproducibility. However, it is not valued the same way as papers and grants, and you do not get more credit for it. In addition, it is an investment of time and energy to answer potential questions and maintain the content.



The GitHub repository that hosts the EPG-X software.

continued

Questions about the specific reproducible research habit

What advice do you have for people who would like to get started with extended phase graph simulations?

The base code for EPG-X simulations is available from Dr Shaihan Malik's GitHub: https://github.com/mriphysics/EPG-X. A lot of information is available there, including examples and detailed descriptions of his implementations. I found Dr Matthias Weigel's review article Extended phase graphs: Dephasing, RF pulses, and echoes - pure and simple useful for learning more about EPG simulations in general. That paper provides some examples for MRI sequences, and a good way to start would be to replicate the examples shown in Dr Weigel's paper using Dr Malik's EPG codes. After doing that myself, I felt confident enough to check the details of Dr Malik's code and build on it.

Can you share tips or additional resources on how to use EPG-X?

I am sure there are many other resources, but three additional papers worth consulting would be the original EPG theory from 1991 by Professor Juergen Hennig, published in two parts (Hennig, Concepts Magn Reson 1991), and Dr Malik's EPG-X work (Malik et al., MRM 2017).

How do you recommend that people use the project repository you shared?

I put some effort into providing a ReadMe guide in the repository, so I hope that it will be helpful to get people started. Otherwise, they can contact me with any questions.

Are there any other reproducible research habits that you didn't use for this paper but might be interested in trying in the future?

I am paying more attention to what others are doing in terms of reproducible research. ■

7 Tesla to help with surgery. MP2RAGE is widely used at 7T for structural imaging because it is insensitive to receive field inhomogeneities, proton density effects, and T2* effects. MP2RAGE typically outputs a uniform image (UNI) that is the result of combining the two images acquired in the sequence, and UNI is optimized to get the best WM-GM and GM-CSF contrast. But other groups have explored different protocol parameters optimized for GM-dominant images, such as FLAWS. In this paper, our goal was to optimize the MP2RAGE protocol so as to get both FLAWS and UNI contrast images simultaneously and efficiently, and we did so by using EPG. We found that the end result only marginally compromises UNI contrast, and we tested it both in children and in adults, obtaining 0.65-millimeter isotropic resolution images that cover the whole brain in under seven and a half minutes.

David: The MP2RAGE UNI images have been around for a while, and at 7T they're the starting point for most imaging protocols. But it still takes a significant amount of time to acquire these images, and we want to obtain them at higher resolution. Also, for clinical applications, having the range of contrasts you get from the FLAWS image is quite advantageous. Obtaining both UNI and FLAWS images at high resolution is not very feasible in the pediatric population, in which you need to keep the scan time low. What we found, and showed in this paper, is that nice UNI and FLAWS images can be obtained simultaneously in 7-8 minutes without there being too much of a disadvantage, in terms of contrast, compared with what we would have had if we had just optimized the individual images on their own.

MRMH: Your study appears to be particularly driven by the needs of the pediatric epilepsy population. Could you describe some of the challenges when imaging this population?

David: Epilepsy is the most common neurological disorder in children, and unfortunately, in a considerable proportion of cases many of the drug treatment options are quite ineffective. If you have focal epilepsy, your only effective treatment option is surgery, but first the focal abnormality that is starting your seizures needs to be identified. In pediatric epilepsy, the most common type of abnormality is focal cortical dysplasia (caused by cortical layer malformations that occurred during the development of the brain in the womb), which has a propensity to generate seizure activity. Focal abnormalities are quite subtle, and challenging to detect on conventional radiological images as the GM-WM border is not quite defined enough. FLAWS, however, helps us get better contrast here. The expected markers include a slightly unusual gyration and some hyperintensities. And to image these features in children, in whom the cortex is only about two millimeters thick, you need to have submillimeter resolution.

MRMH: To finish off, what do you enjoy doing when you're not in the lab?

Sila: When I have free time, I love doing sports – I can get very competitive. I also enjoy bird watching. There's a very beautiful park next to where we live where you can spot many different birds, like kingfishers.

David: I've got quite an interest in football, and today I'm in a pretty good mood because the England women's team have made it to the World Cup final, which is pretty exciting for us. I have three children, and have managed to get roped into doing some coaching for kids, including my eldest. There are actually a lot of parallels between getting a bunch of 11-year-olds to do what they're asked on a football pitch and managing team meetings [laughs].■

Fast measurement of the gradient system transfer function at 7 T

INTERVIEW BY **MATHIEU BOUDREAU** AND **TERESA LEMAINQUE**

EDITOR'S PICK FOR APRIL

This MRM Highlights Pick interview is with **Hannah Scholten** and **Herbert Köstler**, researchers at the University Hospital of Würzburg in Germany. Their paper entitled Fast measurement of the gradient system transfer function at 7 T was chosen as this month's Highlights pick because it demonstrated exemplary reproducible research practices by sharing code in a well-formatted GitHub repository, shared scripts that reproduced figures, and also shared data.

Hannah Scholten in front of the Würzburg Residence (a Baroque style palace).

Herbert Köstler's lab group on the terrace of the university hospital. (Herbert is far left, Hannah is far right).

MRMH: Can you tell us about yourselves and how you got into MRI?

Hannah: Sure. I actually decided that I wanted to get into medical imaging before I even started university. I attended a mathematics seminar for high school students in Berlin, and one of the lecturers there was a professor who designed some algorithms for computed tomography. I chose to study physics for my undergraduate degree at RWTH Aachen University, and did my bachelor thesis on the topic of magnetic particle imaging under Volkmar Schulz. I then did my master's degree thesis on MRI fingerprinting (coincidentally, with Teresa who's joining this call today). I moved to Würzburg for my PhD, and I'm now in the fourth year of my PhD and part of Professor Köstler's group.

Herbert: I studied physics and mathematics at the Technical University of Munich and the University of Fribourg in Switzerland, and did my diploma thesis on solid state physics. But when I was looking for a PhD position, I came in contact with some MR groups, and I was happy to get a position in Ulm in the group led by Rainer Kimmich, who did a lot of work on magnetic resonance methods. Now I hold a professorship in experimental radiology here at the University of Würzburg.

MRMH: Before jumping into the work reported in your paper, could you explain what the transfer function is and what it is for?

Hannah: Maybe it's easier to explain the concept of the impulse response function, which is just the system transfer function but in the time domain (instead of the frequency domain). The impulse response function of any linear and time invariant system describes how that system reacts to an input in the form of a short external impulse that disturbs it. You

Link: https://onlinelibrary.wiley.com/doi/10.1002/mrm.29523?af=R

REPRODUCIBLE RESEARCH INSIGHTS WITH
Hannah Scholten and Herbert Köstler

Why did you choose to share your code/data?
When I started my PhD, I myself had to implement a method that was described in a paper, where the authors did not share any code or data. I think it would have saved me a lot of time had they done so. I therefore decided I wanted to share my code and data to make it easier for other researchers to try out my method.

What is your lab or institutional policy on sharing research code and data?
There is no general policy, but we are increasingly tending to share code and data if possible.

How do you think we might encourage researchers in the MRI community to contribute more open-source content along with their research papers?
I think we need to make people see the benefits of opening up their research. I often wish I had the code someone used in their paper, so I could try out my own ideas on it, or check something that I didn't understand from just reading the paper. That said, I believe that I can only expect others to share their code if I also do so myself. Highlighting reproducible research practices, as you are doing by conducting these interviews, is certainly a step in the right direction.

Are there any other reproducible research habits that you didn't use for this paper, but might be interested in trying in the future?
I was not able to share my sequence code for this paper, as it is written in the proprietary sequence coding framework from Siemens. In the future, I would also like to try using open sequence programming frameworks, such as Pulseq or gammaSTAR, which would allow me to also share the sequences I use.

Questions about the specific reproducible research habit

Your code repository is really well documented. What advice would you give to people preparing to share their first repository?
Thank you. I would recommend keeping the code as clean as possible from the start (a piece of advice I did not follow myself, by the way). I had to spend quite a bit of time cleaning up the code, i.e., removing useless pieces I had only commented out before, renaming variables meaningfully, or adding explanatory comments. The last two points, in particular, are not too hard to do right from the start, I think, and they can be helpful to you, too, even if you don't choose to share your code. Also, if you plan to share data along with your code, choose your platform accordingly. I realized too late that the amount of data I wanted to share was too much for GitHub, so I had to upload the data separately.

What questions did you ask yourselves while you were developing the code that would eventually be shared?
When I named my variables and wrote my explanatory comments, I always tried to put myself in the position of someone who did not write this code, but nevertheless has some understanding of the subject. I also asked myself how to make the code executable on a different computer without having to change too much, for example the data paths. I thereby discovered some MATLAB commands that can use this impulse response function to then calculate the system response for any arbitrary input shapes.

MRMH: When would a system be considered linear and time invariant?

Hannah: A linear system means that for any given output resulting from input, if the input is doubled then the resulting output would also double. And time invariance just means that if I apply the same input tomorrow, the output produced by the system will be the same as today.

MRMH: Thanks! Tell us about the work you did for this paper.

Hannah: With this project, we wanted to improve the measurement of the system transfer function of MRI scanner gradients, called the gradient system transfer function (GSTF). We developed a measurement method that requires only a spherical phantom and can measure the transfer function with a very high frequency resolution and with lower noise. The high frequency resolution of the GSTF is especially interesting when you want to look at mechanical resonances that last a long time.

Herbert: Importantly, the measurements for this new method are extremely fast.

Hannah: Yes, with this method we can measure the GSTF in 14 seconds for each gradient axis, whereas previous methods took at least several minutes.

MRMH: Are any specific pieces of equipment required for your method, besides a water phantom?

Hannah: No, the advantage of our method is that you only need a commonly available phantom. Some alternative methods use field cameras, which perform very well, but are not as easily implemented due to the extra hardware.

Herbert: Specialized equipment isn't required, but you do need the special se-

quences or access to pulse programming; I don't think that the vendors currently offer sequences that play out and measure triangular gradients in the way we do for determining the GSTF.

MRMH: What could happen if someone failed to take into account these deviations from nominal to actual gradient waveforms?

Hannah: The impact depends on your use of gradients. For example, accurate knowledge of the gradient waveforms is very important in non-Cartesian imaging (e.g., radial, spiral) in order to know the actual k-space trajectory and avoid image artifacts. This application is what we had in mind when we started this work.

MRMH: Why is it that the actual gradient waveform can deviate from the nominal waveform in an MRI experiment?

Hannah: Because of the dynamic switching of the gradient fields, there are time-varying magnetic fields that will induce currents in other conducting structures in the MRI scanner (known as eddy currents), and these currents also create magnetic fields that will distort the actual gradient fields in the scanner. And on top of that, the coils in the scanner housing vibrate due to Lorentz forces. Clearly, if the coil wiggles, the field will wiggle as well, causing other disturbances in the gradient waveforms. These mechanical resonances are more impactful at ultra-high fields (e.g., 7T), and appear narrower in the GSTF than at lower field strengths. That is why the high frequency resolution of our new method is advantageous for characterizing and correcting those resonances.

MRMH: In your paper you describe two scenarios of what you can do with your GSTF once you've measured it: 1) it can be used to correct the influence of the nominal-actual gradient difference after the measurement has been done, or 2) it can be used to prepare a good gradient pre-emphasis so that the actual gradient shape generated by the scanner approaches the nominal gradient shape you desire. Is one method better than the other?

I hadn't known before, for example how to change the working directory to the one where the currently open script is located.

How do you recommend that people use the project repository you shared?
I think the most interesting use case is for other people to try and run my code for calculating the GSTF (gradient system transfer function) with their own data. I have included a demo script and explained how the data have to be structured for that purpose. I was very happy when someone emailed me a few months ago with a question about the GSTF, and said my code had helped them to validate their own implementation. So, I also see code sharing as a small networking opportunity. ■

Hannah: It really depends on the sequence. For example, if you're using a bSSFP sequence, where it's important that the gradients are balanced to physically get the desired effect during your measurement, then using a pre-emphasis calculated from your GSTF is really the best option because the effect on the magnetization during the measurement cannot be corrected post-hoc after your image has been acquired. But if the effects of the gradients only really concern the k-space trajectory, like when using a spiral spoiled gradient echo sequence, I don't think it matters that much which gradient correction method you choose.

Herbert: That's right – if the gradient is just guiding the imaging data, you can correct almost everything in the reconstruction. But if the magnetization itself is controlled by the gradient, like in bSSFP, or if you're using them with special pulses, you will have to apply a gradient pre-emphasis because in these situations, the impact of the gradient distortions cannot be corrected later during image reconstruction. The other thing is, if the MRI vendors could be convinced to build in a gradient impulse response function-based pre-emphasis, many problems we encounter might be solved in a single step.

MRMH: Could AI play a role in further improving GSTF calculations?

Hannah: Yes, and it could do even more. I recall seeing an abstract of someone doing AI-based gradient waveform predictions at ISMRM in London (Title: Gradient Waveform Prediction Using Deep Neural Network). The GSTF is somewhat limited by assuming a linear and time invariant gradient system, but we actually know that those assumptions are not completely true. A neural network could maybe model nonlinearities better, which would be interesting to explore.

Herbert: If we used AI, could we calculate the GSTF very rapidly? Yes, and we are deeply convinced that the calculation could be done much, much faster. But as Hannah mentioned, we could maybe also describe the system even better, which could be important for animal imaging scanners, which use huge gradients. There, the GIRF (gradient impulse response function) model does not sufficiently describe the system, and a learned correction could maybe improve imaging, but that's something to be explored in the future.

MRMH: Finally, do you mind telling us a little bit about your city, since some of our readers may not yet have been lucky enough to visit Würzburg?

Herbert: There are a lot of vineyards in the area, and even vineyards in the city close to the Main River. There's also a beautiful castle on a hill.

Hannah: I definitely recommend coming to Würzburg, it's a really beautiful city. ■

Wirelessly interfacing sensor-equipped implants and MR scanners for improved safety and imaging

INTERVIEW BY **TERESA LEMAINQUE**

EDITOR'S PICK FOR MAY

This MRM Highlights Pick interview is with **Berk Silemek** and **Lukas Winter**, researchers at Physikalisch-Technische Bundesanstalt (PTB) in Berlin, Germany. We chose to feature their paper entitled Wirelessly interfacing sensor-equipped implants and MR scanners for improved safety and imaging because they openly shared design files and software for the MRI implant sensor they developed.

Berk (right) and Lukas (left) demonstrating some open-source hardware used in their research.

OSI² ONE open-source low-field MRI build workshop in September 2023 at the PTB in Berlin.

MRMH: What's your background and how did you get into MRI?

Berk: My background is in EEE (electrical and electronics engineering). Eight years ago, I started working as a research engineer at the National Magnetic Resonance Research Center (UMRAM) in Ankara, Türkiye, with Ergin Atalar, who introduced me to emerging MR hardware, parallel transmission (pTx) and implant safety concepts. I came to PTB to pursue my PhD, where Lukas served as my supervisor. My PhD project was part of a bigger EU project called MIMAS. Currently, I am involved in a continuation project called STASIS.

Lukas: I studied Electrical Engineering and Information Technology at the RWTH-Aachen in Germany, with a specialization in medical technology. My diploma thesis was on real-time neurosurgical robots and I worked at Siemens on Computed Tomography algorithms, so I had some imaging but practically no MRI experience during my studies. Nevertheless, I considered MRI such a cool technology, which wouldn't bore me after 6 months, so I picked a PhD in ultra-high field MRI in Berlin, and I've never regretted it.

Link: https://onlinelibrary.wiley.com/doi/10.1002/mrm.29818

MRMH: Let's turn to your paper. What was your goal behind this project?

Lukas: Our main motivation was, of course, to do some impactful research! In this particular case, we worked on an MR safety issue that has existed for many years, namely the fact that implants can heat up in an MRI system. Currently the responsibility for patient safety lies with the clinical personnel. The workflow to guarantee safety is, however, very challenging, and accidents can still occur even for MR conditional implants. Our vision is that implants like deep brain stimulators communicate with the MR scanner via an embedded sensor. The really cool thing about it is that the measured sensor data can be used to enhance both safety and imaging performance. Simultaneously! In the end, the MR manufacturer and implant manufacturer would each have the responsibility for their device, taking the MR operator out of the equation. For the past few years, it was our research focus to demonstrate - step by step - how this can be done.

MRMH: What did you investigate in your research?

Berk: We established wireless communication between a custom-built reference implant and an MR scanner with the aim of getting relevant safety information from the implant tip during MRI. The reference implant mimics a deep brain stimulator. There are small, low-cost sensors embedded in the implant's electronics, which measure voltages from the electrode tip, where the maximum RF-induced heating occurs. In a calibration step with external probes, we determine how sensor voltages are related to E-fields and temperature changes. This allows us to know, within milliseconds, what is happening in the tissue during a scan. Furthermore, if we have two or more RF channels available, this information allows us to cancel RF-induced heating while maintaining image quality. This approach gives us the best of both worlds, imaging and safety!

Lukas: In a nutshell, we know from simulations of very complex, but realistic, geometries of implants that parallel transmission can substantially suppress RF-induced heating while maintaining image quality. However, if there is a slight modification in the setup, e.g., if we move the guidewire by only 1 cm, we may suddenly see heating rates double. This makes it really problematic to rely on simulations alone for RF pulse optimizations. Real-time information from the patient would be a big step forward and one way to get it is to use sensors. In the paper, we show that it is possible to use very cheap sensors to apply our methodology and that communication between implant and MRI system is feasible. Many implants that are available as medical products already have sensors embedded that could be utilized. Both implant and MR manufacturers use Bluetooth protocols to communicate with external devices, so let the magic happen.

MRMH: That sounds great! How is your reference implant build up, and what quantities does it measure?

Berk: Deep brain stimulators come with a lead that has an uninsulated tip, which can heat up in an MRI scanner. These implants and implant leads are extremely expensive, and you cannot just buy them off the shelf! We've built a reference implant including

REPRODUCIBLE RESEARCH INSIGHTS WITH

Berk Silemek

Why did you choose to share your code/data?

There aren't many reasons not to share code/designs, apart from the extra work needed on the documentation side. Sharing means: more impact, better reproducibility of scientific results, saving of resources (both time and money) for others, easier transfer of results to products, faster innovation cycles, educational access to the findings, etc. Sharing should be the gold standard and the question should rather be: Why did you choose not to share your code/data?

What is your lab or institutional policy on sharing research code and data?

In our MR department, we strongly pursue open-science practices of all types: data, code, hardware. At the same time, we are bound to institutional policies, of course. So, in the end, it has to be decided case by case what can and will be shared. We must say, however, that our whole organization, Physikalisch-Technische Bundesanstalt (PTB), is increasingly acknowledging and embracing the open-science idea. In general, we get a lot of support and face very few restrictions in this respect.

Have you observed any tangible benefits or impact on your research or career as a result of adopting reproducible research practices?

Yes, sharing is caring, and we feel that the impact of our work increases substantially as a result of sharing our designs. For example, we received a lot of feedback to our earlier open-source hardware projects (e.g., the measurement robot COSI Measure (https://github.com/opensourceimaging/cosi-measure)) that were reproduced and helped others in their research. This feedback helped us to improve our existing workflow and our own design (i.e., releasing COSI Measure version 2.0). The best aspect was meeting a lot of incredible people and labs, and starting to work collaboratively on further improving designs useful to everyone's research, even if it is in completely different domains.

How do you think we might encourage researchers in the MRI hardware community to contribute more open-source content along with their research papers?

Hmm, that's a good question. Prizes, reproducibility challenges, hackathons, better infrastructure/blueprints for sharing, but also reviewers asking for more sharing of designs might help to motivate this. But the thing that could prove crucial would be for the projects' PIs to state, in their grant applications, that the resulting designs will be shared under an open-source license. If I make that promise at the beginning, which by the way may help to secure the funding as well, it's easier in the end to implement. This would also be an important signal to the funding bodies that open-source science practices are also needed in the hardware domain, helping to shape guidelines and policies, and maybe even obtain dedicated resources to fund open-source hardware projects and infrastructure. We have observed this evolution in open-access policies and now also in open-source software, so hardware would be a logical and great next step.

It would also be helpful to really reflect on the implications of sharing. The goal is not to make a new device and produce a paper to go with it; the goal should instead be to address the bigger picture: how can I advance science the most? The answer includes making my resources available to others through open-source designs, and enabling them to build upon previous work openly, similar to citing a

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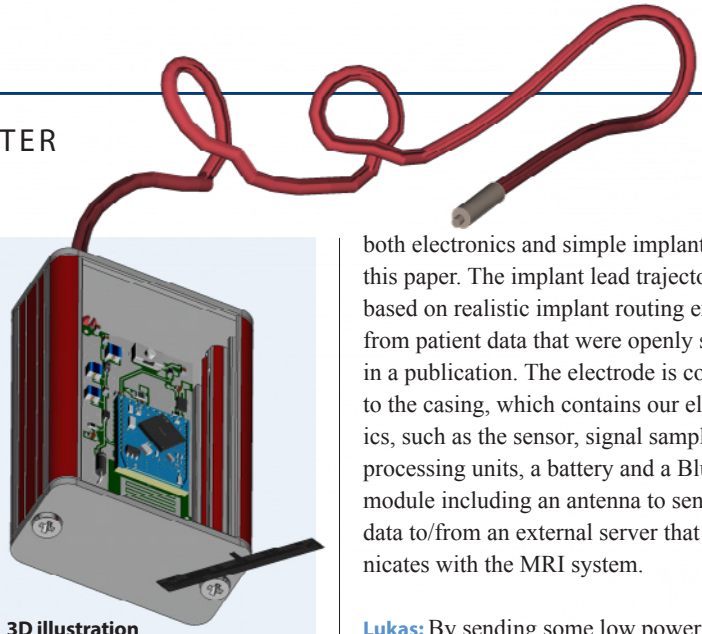

paper. Also, if I can cite/reuse other designs and improve them, this will promote easier reproducibility/transition of my own results to allow a wider benchmarking and quicker advancement in the field.

Questions about the specific reproducible research habit

What advice do you have for people who would like to share details and open-source content about their MR hardware, so as to make their research reproducible?

Maybe our first piece of advice would be: have a look at other similar and successful open-source hardware projects and learn from their documentation/communication strategies. Some more practical tips: provide all files, the production pipeline, and the machines that are necessary to reproduce but also distribute your design, which includes source files (e.g., a CAD model in FreeCAD) and not only production files (e.g., 3D models in STL). Try to use open-source software tools that everyone can easily access (e.g., Python). Publish those files with an open-source hardware license (e.g., CERN OHL v2). Use repositories that are easily accessible, have version tracking and other useful tools for collaboration (e.g., GitLab or GitHub). If you have further questions, reach out to the community, e.g. the Open Source Imaging Initiative (www.opensourceimaging.org) – they are happy to help.

3D illustration of the wireless device

What are your hopes with regard to how the MRI hardware community might use the code and design files you shared?

We hope that by sharing the design files for our sensor-equipped implant, we can offer the community low-level access to and rapid prototyping of the methodology that we are proposing. We would like sensor-equipped implants to communicate with an MR scanner because we envision that this has strong potential to improve patient safety, reduce the burden and responsibilities shouldered by clinical personnel, and boost imaging performance and clinical efficiency. If more scientists and developers from academia and industry investigate this new approach, it is more likely that this methodology will be implemented in the clinic. We hope that sharing all the resources that we developed (hardware, firmware, software and their documentation) will increase our chances of reaching this goal in the shortest time possible.

Your Open Source Imaging Initiative (OSI2) has existed since 2016 and has been a major part of the movement for open science in the area of MRI developments. Can you tell us about its origins, its current state, and where you see it going?

Driven by the lack of accessible MRI resources, OSI^2 was founded to stimulate the development of open-source software and hardware around MRI research. Because too few designs were (and still are) available evaluating/comparing performances of scientific breakthroughs, resources were (and are) being wasted on replicating existing work or reverse engineering closed-source commercial solutions. This problem of inaccessibility extends to the technology itself: MRI machines, powerful tools for diagnosis and treatment, remain prohibitively expensive, which limits many patients' access to them. OSI^2 believes that sharing both electronics and simple implant leads for this paper. The implant lead trajectories are based on realistic implant routing extracted from patient data that were openly shared in a publication. The electrode is connected to the casing, which contains our electronics, such as the sensor, signal sampling and processing units, a battery and a Bluetooth module including an antenna to send/receive data to/from an external server that communicates with the MRI system.

Lukas: By sending some low power RF pulses, you basically measure the impulse response at the implant. And from the aforementioned calibration step, you know how the signal you measure corresponds to a safety relevant quantity, like temperature or SAR.

MRMH: What components would I need if I were to start working on the same topic? A pTx system? Are these systems readily available?

Lukas: The reference implant is relatively easy to rebuild. All electronic parts are available online in the bill of materials that we provided. With the code that is shared, you can start setting up some first experiments using wireless transmission. If you want to use pTx, you may be surprised to learn that pTx systems – I mean the simplest ones – are fairly widely available, because the body coils of most modern 3T scanners can be driven by two channels. More channels would be better, of course, but such systems are still rare, unfortunately.

The research pTx system we used currently has sixteen transmission and four receive channels and has been published in 2020 in MRM (https://doi.org/10.1002/mrm.28379) alongside open-source design files and code for a rebuild. It's a bit more expensive because of the component costs, but very flexible since it allows you to perform experiments over a wide frequency range (0.5T-7T). It works stand-alone but can also be hooked-up to an MRI system to perform imaging. Lastly, you'll need some RF coils. For easy reproducibility, we have published (https://gitlab1.ptb.de/) the design files for our 8-channel pTx RF coils for 3T and 7T.

MRMH: How far is the concept from real life? What steps are you taking to bring sensor-equipped active implanted medical devices closer to clinical practice?

Lukas: Let's be realistic, right now, there seem to be few incentives for MR vendors to change the status quo, because the liability does not lie with them. Implant manufacturers have to perform heavy testing for implant safety to label their devices as MR conditional, but that is it. They specify the conditions but the clinical personnel needs to set these conditions at the scanner and is ultimately responsible.

However, what we are asking from the vendors is to sit down together and agree upon a practical implementation protocol. We are absolutely aware that it might be a huge and costly step, especially if products need to be partly redesigned. On the other hand, in the current approach, you need large safety factors and have to reduce power levels substantially, thus sacrificing image quality. Much better and safer imaging could be obtained when using a sensor-equipped implant. This will be an incentive for companies at some point. We are gathering more data to demonstrate that the proposed concept is feasible and also works with commercially available implants. Papers like this one will eventually be recognized by standardization working groups and regulatory bodies. This could motivate vendors to implement the concept and talk to each other. Besides providing such data and sharing our designs, we are working on uncertainties, communication workflow and risk-analysis, and on test standards to calibrate the sensors. This is all happening within the EU project STASIS (https://www.ptb.de/stasis/) and will help to frame our concept. We are sharing our designs so that manufacturers or anyone else who's interested could investigate these aspects alongside the methodology and help to translate it into clinical practice.

MRMH: What do you enjoy when you are not doing lab work on implants?

Berk: I try to play basketball twice a week, Lukas sometimes joins me, and I play a bit of chess.

ing resources globally is a much more efficient way to tackle these challenges. Initially, we just wanted to encourage the community to share and support more software and hardware projects by providing a platform where their work can be highlighted. We wanted to form a community that believes in the idea of open-source science. But the ultimate goal was always to join up these dots at some point and build a complete open-source MRI research system that can be the basis for developing a medical device for use in clinics. There has been tremendous progress since then, and at the ISMRM meeting in London in 2022, the first open-source low-field MRI prototype, the OSI^2 ONE v1, was presented. There is a large international group working on an upgrade of this first prototype into a robust, safe and well-documented reference scanner. This includes a lot of work around the process of regulatory approval, which will be shared as well, to create important blueprints that are currently lacking (https://www.a4im.ptb.de/home). At the same time, we are in the process to found the NGO Open Source Imaging Initiative. In this official body, we have a better tool to support the community and implement many more ideas for our open-source medical technology vision. So, the future is looking very bright and the current and growing experiences, blueprints, and infrastructure in the making can be translated to many other complex projects in the domain of open-source medical device development.

Are there any other reproducible research habits that you didn't use for this paper but might be interested in trying in the future?

In the software domain, many tools, standards, and libraries exist to make life easier for an open-source project. As regards hardware, there is still some room for improvement and exploration. While we tried to share all the design files and significant checkpoints to ensure reproducibility for our paper, we acknowledge the need for further improvement in the documentation. Currently, we are actively working on a revised version of the hardware that will feature enhancements specifically tailored for manufacturing purposes. There are many other features that we consider useful and will try in the future such as: markdown-based documentation and automated scripting to help with versioning, but also other things like the generation and update of manuals, risk analysis etc., a map to track the location of reproduced designs, and test methods/scripts or videos of assembly and operation. Reflecting on past open-source projects, we have encountered challenges with obsolete parts. To mitigate this issue, we are trying to suggest alternative parts and encouraging feedback from the community. ■

Lukas: Spending time with my kids, yoga and meditation, cooking, dance... Many, many interests and little time for them all.

MRMH: How do you like your city, Berlin? Would you recommend it to international researchers?

Lukas: Definitely! Berlin probably has everything you might want, apart from mountains and the sea. There's a nice vibe in the city, which I personally like very much. And so, I recommend coming to Berlin. By the way, we will be having a safety workshop in Berlin next year, so that might be a good opportunity.

MRMH: Berk, what does the immediate future look like for you?

Berk: I just defended my PhD thesis. At the moment, I'm continuing to work on the STASIS project.

MRMH: Congrats, and all the best! Thank you for the interview. ■

The road to the ISMRM OSIPI: A community-led initiative for reproducible perfusion MRI

INTERVIEW BY **MATHIEU BOUDREAU**

EDITOR'S PICK FOR JUNE

This MRM Highlights Pick interview is with current and past members of the ISMRM Open Science Initiative for Perfusion Imaging (OSIPI) leadership, **Laura Bell** (Genentech), **Ben Dickie** (University of Manchester), **Petra van Houdt** (the Netherlands Cancer Institute), **Henk Mutsaerts** (Amsterdam University Medical Center), and **Yuriko Suzuki** (University of Oxford). Their first two-year roadmap has resulted in a collection of MRM publications which were coordinated by different task forces:

- The road to the ISMRM OSIPI: A community-led initiative for reproducible perfusion MRI
- ISMRM Open Science Initiative for Perfusion Imaging (OSIPI): ASL pipeline inventory
- Contrast-agent-based perfusion MRI code repository and testing framework: ISMRM Open Science Initiative for Perfusion Imaging (OSIPI)
- ASL lexicon and reporting recommendations: A consensus report from the ISMRM Open Science Initiative for Perfusion Imaging (OSIPI)
- A community-endorsed open-source lexicon for contrast agent–based perfusion MRI: A consensus guidelines report from the ISMRM Open Science Initiative for Perfusion Imaging (OSIPI)
- The ISMRM Open Science Initiative for Perfusion Imaging (OSIPI): Results from the OSIPI–Dynamic Contrast-Enhanced challenge

The aim of OSIPI is to develop reproducible research practices in the field of perfusion imaging (DCE, DSC, ASL) through resources such as software inventory, an open source, benchmarked code library, a lexicon of technical terminology, shared data resources, and supported by the use of reproducibility challenges.

MRMH: Could you each tell us about yourselves and what your involvement with OSIPI has been?

Laura: I first got involved with OSIPI back in 2018 while I was doing a postdoc in brain cancer imaging at the Barrow Neurological Institute, specifically using DSC perfusion techniques. During this time, I was involved with initiatives like QIN and QIBA, and started to really understand the reproducibility concerns when it came to image analysis. I was elected as the trainee representative of the ISMRM Perfusion Study Group at the same time as Steven Sourbron was the incoming Secretary. Steven wanted to continue building the interest in perfusion freeware; and, together, we decided to send out a call to action to the study group to understand what the community needed. From this, OSIPI was born. I was on the founding board, and then Co-Chair of the first roadmap once OSIPI's plans were finalized and saw through our first publications in MRM.

Henk: My research started with the issue of ASL reproducibility between different MRI vendors and scanners, and I was shocked by the lack of standardization. When developing our standardized ASL pipeline within the European Cooperation in Science and Technology (COST) Action ASL in Dementia, together with Jan Petr, I saw how important image processing harmonization was for comparing studies. I joined the BIDS community to develop the ASL extension to BIDS, and when Steven and Laura were setting up OSIPI, I found myself getting enthusiastic about this important effort. I gave them some feedback and ideas which they liked, apparently enough to want me to join the OSIPI leadership when I was the trainee representative of the ISMRM Perfusion Study Group.

Yuriko: I first started working in MRI as a clinical scientist for Philips, and then did my PhD with Thijs van Osch in Leiden. All my experience was in the acquisition side until I moved to Oxford for my postdoc with Michael Chappell, where I did image processing work for the first time. It was then that I heard of OSIPI. I'm still in Oxford now, as a Royal Academy of Engineering research fellow, but I think I am still an acquisition-person. So it's natural that I first joined OSIPI as a co-lead of the task force for the ASL lexicon to standardize the acquisition parameters. I became secretary while Laura was Chair and Henk Co-Chair, and the current Chair of OSIPI now.

Petra: I'm currently working as a research associate at the Department of Radiation Oncology in the Netherlands Cancer Institute. When I first came here, I got involved in a study of DCE for head and neck cancer, and I was quite shocked that the results were so different when using the different software packages. I first learned about OSIPI at the OSIPI Member-Initiated Symposium at ISMRM 2019. I was really enthusiastic about the plans to make perfusion imaging more reproducible, and after talking to Steven, I later became a co-lead of the task force for the DCE and DSC code library. I'm also part of the leadership now.

Ben: I did my PhD in human DCE MRI in cancer, and I am currently a junior PI developing MRI approaches to measure vascular leakage in the brain. As regards to OSIPI, I came to the party quite late — it had already been set up and was already one year into the roadmap. I came across the OSIPI website and noticed the initiative was set up by Steven Sourbon, who I had done my mas-

Link: https://pubmed.ncbi.nlm.nih.gov/37279059/

Clockwise from above: OSIPI logo, Laura Bell, Petra van Houdt, Yuriko Suzuki, Ben Dickie, Henk Mutsaerts.

ters with. I found the DCE and DSC lexicon task force quite appealing, so that's where I focused most of my involvement until I recently became involved in the leadership of OSIPI as the new secretary.

MRMH: What is the background story of OSIPI?

Laura: As I mentioned earlier, Steven and I met through the Perfusion Study Group in 2018. We had similar interests, past frustrations working with open-source tools, and enthusiasm about reproducibility with regard to the data analysis pipeline. We initially wanted to build a new software platform, so we sent out a call to action to the Perfusion Study Group, and got over 100 responses! The feedback was great, but what really stood out to us was that the community loudly and clearly said: we don't need another data analysis pipeline, we need better ways to validate the ones we have! From the responses, an initial founding board was formed of 7 people (Laura Bell, Patricia Clement, Charlotte Debus, Andrey Fedorov, Simon Levy, Steven Sourbron, and Frank Zoellner). The seven of us met bi-weekly to digest all the feedback, form a governance structure, and identify OSIPI's mission and its aims. We put together an ISMRM Member Initiated Symposium (MIS) in 2019 as a way to initially advertise OSIPI and get larger buy-in from the community. We really wanted to build a sustainable initiative that would continue on and allow it to evolve with time. After this, the founding board dissolved and OSIPI became the structure we know today. Operationally, OSIPI officially started early on in 2020 with its first 2 year road map.

Reflecting back on this, I'd also like to mention that my involvement with OSIPI may have been different had it not been for the support of my PI, Chad Quarles, at the time. In 2018, I had a seven-month-old daughter, and at the time, ISMRM didn't have caregiver funds and I was overwhelmed with a newborn. My PI was really supportive and encouraged me to go by helping to find ways my mother-in-law could travel with me and my daughter.

MRMH: Let's focus on the lexicons for a bit. How do you envision perfusion software adopting these terminologies?

Ben: Well, to begin with, our DCE\DSC software task force (TF 2.3) is now basing the structure and terminologies of its Python based perfusion analysis software around the DCE/DSC lexicon. Through this effort, we aim for parameter map outputs from software (such as Ktrans maps), and the processes used to generate them, to be effortlessly encoded into DICOM parametric maps using the lexicon terminology. We also plan to build tools for this software library that can generate automated outputs for methods text to be included in publications. More generally, we would encourage developers of other perfusion analysis softwares to start incorporating the lexicon terminology and structures into the design of their software so that the lexicons are embedded in all analysis softwares.

Henk: The difference between the work of the contrast- and ASL-based task forces is that for ASL, the image processing needs more standardization than the quantification model, as the latter has already been simplified and standardized for clinical ASL, specifically in the seminal 2015 MRM white paper by Alsop et al. Another difference is that ASL has much greater variety in acquisitions, whereas for DCE/DSC the variety lies in the modeling part, and the arterial input function. Hence, the ASL Lexicon Task Force mainly defined acquisition parameters, whereas the DCE/DSC Task Force defined processing/modeling parameters. The ASL lexicon is thus more important for the acquisition methods section of a manuscript, and less so for the processing choices compared with DCE/DSC. Furthermore, for ASL we also created BIDS.

MRMH: How are your lexicons different from (or similar to) what has been developed in ASL-BIDS?

Yuriko: We share the same aim: improving the reproducibility in ASL research. So, there's definitely some overlap, and it's not just in content but also in contributors; three of the core members of the ASL-BIDS (Henk, Patricia Clement and Jan Petr) were also the members of our ASL lexicon task force. We believe harmonizing ASL Lexicon and ASL-BIDS is crucial. While BIDS aims to organize the data structure for standardized data storage, our lexicon defines terminologies for all the parts of ASL, from pulse sequence parameters, ASL-derived parameters, and model parameters. Our target audience is researchers who develop pulse sequences and analysis tools to avoid misunderstandings in how these components are reported because the development of ASL is widely expanding, and also those who use these ASL techniques and tools to find how their ASL studies should be reported for better reproducibility.

Henk: This is also reflected in the content; ASL-BIDS thus far contains only the standard clinical ASL sequences defined in the white paper, whereas the lexicon has more exotic sequences and options. ASL-BIDS needs an extension for the nomenclature of ASL derivatives, and this is where OSIPI could help a lot from its DSC/DCE experience.

Ben: As far as the DCE/DSC community is concerned, DICOM is still the main data format used. We're now primed to speak with DICOM and other stakeholders regarding standardizing how data is recorded within DICOM fields, which will hopefully take us a step closer to a standardized clinical implementation of these methods.

MRMH: With regard to the OSIPI code toolbox, how does this task force compare with the software inventory task force?

Petra: The software inventory aim was to investigate and compare packages that already exist, and that are typically full end-to-end pipelines. We also didn't restrict this task force only to open source software; widely used but proprietary perfusion software analysis tools were also included in this inventory. In contrast, the code library is a collection of code snippets that may concern only one part of a typical analysis pipeline. And for this repository, we added a testing framework to compare all the different code snippets to see if they give similar or different outputs. In this way, researchers or developers that are looking for new code can make an informed decision on which implementation to choose for their own analysis. The code repository will hopefully reduce duplicate development and improve reproducibility.

Henk: The users would differ too. The software inventory is useful for the clinical and/or first-time user, to see what suits them. The availability of manuals and demos, and so on, is important. The code snippets, on the other hand, target technically-savvy developers who want to create their own custom pipeline without having to reinvent the wheel. There is also a difference between DSC/DCE and ASL. In contrast with ASL, not many publicly available, let alone standardized, DSC/DCE pipelines exist. This would be a strong reason for DSC/DCE developers to create a DSC/DCE pipeline within OSIPI, whereas for ASL several pipelines exist and they are relatively standardized.

MRMH: Has your data inventory task force used BIDS and/or the lexicons in the process of organizing the data?

Laura: Actually, it has been a challenge to get momentum for our data inventory task force (TF3). Generally, we've found that there is a lot of interest from people wanting to share data, and this interest is still growing. But many of us lack experience in sharing data or lack the resources to understand how to share perfusion data. So as a shameless plug, if you're reading this interview and are interested, please reach out!

MRMH: Pulse sequences are a major reproducibility challenge in MRI. Have you considered exploring vendor neutral sequences (like PulseSeq) for a future OSIPI task force?

Yuriko: That's not currently in our roadmap, but speaking for myself, it is something I'm very interested in. In particular, reproducibility on the ASL side is quite dependent on the sequence design, as the post processing is fairly simple. In the future, it would be very interesting to see involvement or collaborations between OSIPI and the vendor-neutral pulse sequence community.

Petra: To date, OSIPI has focused more on the analysis part of perfusion imaging. We hope to collaborate more closely with QIBA (the Quantitative Imaging Biomarker Alliance) regarding harmonizing acquisitions.

MRMH: Do you feel that any of the progress made by OSIPI has brought these tools closer to clinical use, or brought additional benefits for patients being imaged with these techniques?

Laura: I think we are still in the early days to understand the impact OSIPI's tools may have clinically. We've had a few interactions that I'm quite proud of, including hearing from new academic clinicians who have stumbled upon some of the OSIPI resources, and used them to implement standardized imaging protocols and analysis into their workstreams. The efficiency of having a centralized location of resources and knowledgeable contacts will only further support the clinical translation and eventually benefit patients.

Yuriko: In the first roadmap (2020-2022), we focused on developing the resources. But when we started our second roadmap (last year), many task forces decided to make the developed resources more user-friendly and accessible, targeting not only core researchers, but also, for example, radiographers and clinicians who work more closely to patients. To support this idea, we opened Aim 5 Exchange and Education platform in the second roadmap. So, I hope we will see more benefits in the near future.

Petra: We're really excited to announce that OSIPI has been accepted as a mentor organization for the Google Summer of Code program in 2024. While we have the support from our community, the access to software developers to ensure our resources will be user-friendly and sustainable will only keep setting us up for success. ■

CONTRIBUTORS

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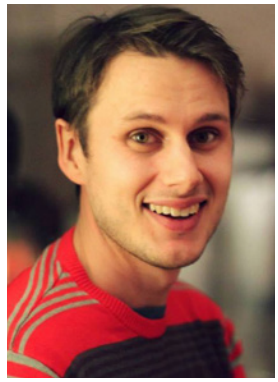
Mathieu Boudreau



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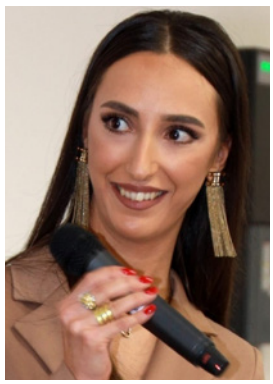


Maria Celeste Bonacci is a PhD student in Biomarkers of chronic and complex diseases at the Magna Grecia University of Catanzaro. Her research is focused on the discovery of new Biomarkers in neurological diseases, with particular attention to epileptic syndromes, through the analysis of multimodal MRI images and electrophysiological data (EEG and qEEG). In her spare time, she likes sports, watching TV series and loves to travel and have new experiences.

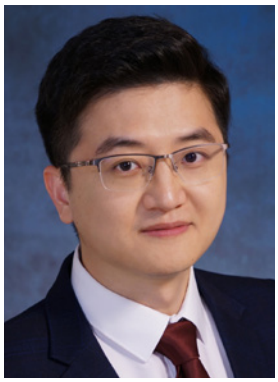
Laura Bortolotti

Laura (she/her) is a post-doc at the Sir Peter Mansfield Imaging Centre (SPMIC) at the University of Nottingham, England. Her work focuses on developing Motion Correction (MoCo) techniques for MRI. She developed a contactless head motion tracking system at 7 T using NMR field probes during her PhD and now she is transitioning to implementing a MoCo device to 0.5 T upright scanner. Laura loves being involved in public engagement, and she finds difficulties in balancing her enthusiasm for volunteering opportunities and her need to observe working hours. She is an advocate for improving Equality Diversity Inclusivity (EDI) and sustainability in the workplace.

Glenn Cahoon

Glenn Cahoon is Lead MRI Radiographer at the Olivia Newton-John Cancer Center at Austin Health in Melbourne, Australia. His role is to support the introduction of an integrated MRI service within the Radiation Oncology department. Glenn has been an active member of the MRI community for over 25 years supporting the development and education of MR Radiographers and Technologists both locally and internationally. Glenn has served on the Governing Board of the International Society of MR Radiographers and Technologists (ISMRT) and is currently President of the Society. Glenn is a passionate supporter for extending the scope of practice for radiographers and has recently published on the current and future role of the MR Radiographer in Radiation Therapy. In his spare time he enjoys riding his Ducati on one of the many winding roads outside of town.

Jianpan Huang



Jianpan Huang is an Assistant Professor in the Department of Diagnostic Radiology at the University of Hong Kong. He was selected as an ISMRM Junior Fellow in 2022. His research focuses on developing advanced methods for Chemical Exchange Saturation Transfer (CEST) MRI and exploring the applications of these methods in the fields of neurological diseases and cancer. Outside of work, he enjoys reading, playing basketball, playing guitar, and traveling with his family.

Benjamin Keedwell

Ben is a first-year PhD student in Clinical Neurosciences at the University of Oxford, having previously studied Physics at the University of Warwick. His research is focused on developing MRI methodologies for the assessment of intracranial vessel stiffness, and so aims to address difficulties in the early diagnosis of vascular disease. In his spare time, Ben enjoys running and drawing, and is a fan of all things fantasy-related.

Christian Langkammer

Christian works at the Medical University of Graz, Austria, and his research focuses on iron and myelin in the brain, with a particular interest in post-mortem MRI and quantitative susceptibility mapping. Also, in his free time, those wonderful 1H protons are his favorite things in the world, in all their glorious states of matter: snow, ice, and water hold a special place in his heart.

Teresa Lemainque

Teresa is a researcher in the department for Diagnostic and Interventional Radiology of the University Hospital in Aachen, Germany. She started to work there as an MRI physicist after obtaining her PhD from RWTH Aachen University in 2021. Her current research interests are novel (quantitative) imaging methods and their application in body MRI. She loves interdisciplinary work and fostering exchange between natural and medical scientists. In her free time, Teresa enjoys playing the bass in a local metal band, which usually no one believes when talking to her.

Thomas Lindner

Thomas is Assistant Professor at the Department of Neuroradiology at the University Hospital Hamburg-Eppendorf in Germany. He obtained his PhD at the Radboud University Nijmegen and is currently the team lead of the MRI research group, supervising researchers from various backgrounds performing MRI experiments and also 2 PhD students. His main research focus is Arterial Spin Labeling sequence development and postprocessing. When not at work, Thomas enjoys time with his wife and daughter, his dog Kona, gardening, cooking and participating in long-distance triathlon events.

Melissa Lowe

Melissa is a Medical Physics Trainee at King's College Hospital in London, specialising in Imaging with Non-Ionising Radiation. She earned a Master's degree in Physics from the University of Oxford before joining the NHS Scientist Training Programme. She is currently working on a project to optimise motion robust T1-weighted imaging in fetal MRI. Outside of work, she loves metal music and spends her free time going to gigs and festivals.

Shaihan Malik

Shaihan is a 'Reader' (Associate Prof) at King's College London where he heads the Imaging Physics and Engineering research department. His recent work has focused on ultrahigh field MRI, particularly on applying this technology to children and infants, though he is involved in quantitative imaging and low-field MR projects as well. Outside of MRI Shaihan spends most of his time being a dad, which happily aligns with his passion for cooking; he spends rare moments of spare time cycling, watching football, and trying to play the guitar and piano with variable success.

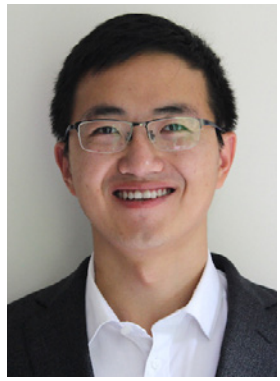
Adrian Tang

Adrian is a clinical Radiologist with GI/HPB and Head Neck systems interest. Radiology training started in Leeds and ended on a 3-year Translational Fellowship at Royal Marsden (Sutton). He has an interest in how errors are made and avoided in clinical radiology and how AI is going to help with this. Three years ago, he left an NHS job to work freelance which allows him to do fun stuff alongside the above, such as support BIC-ISMRM as Clinical Liaison, ride bikes, grow trees and travel.

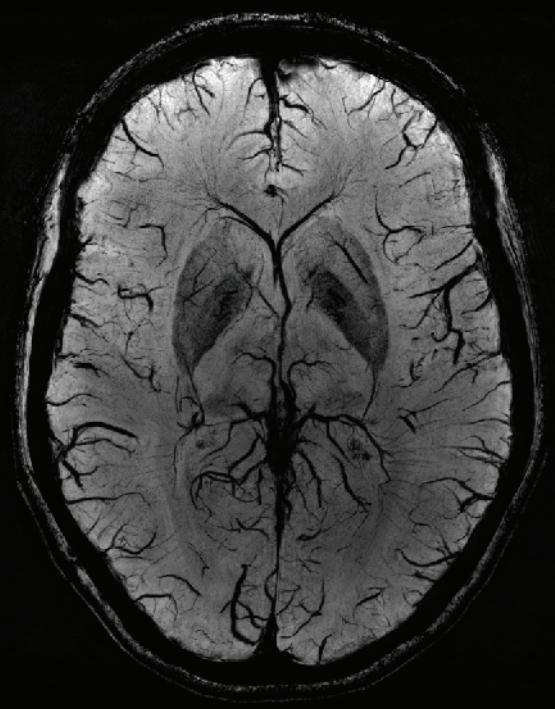
Cristiana Tisca

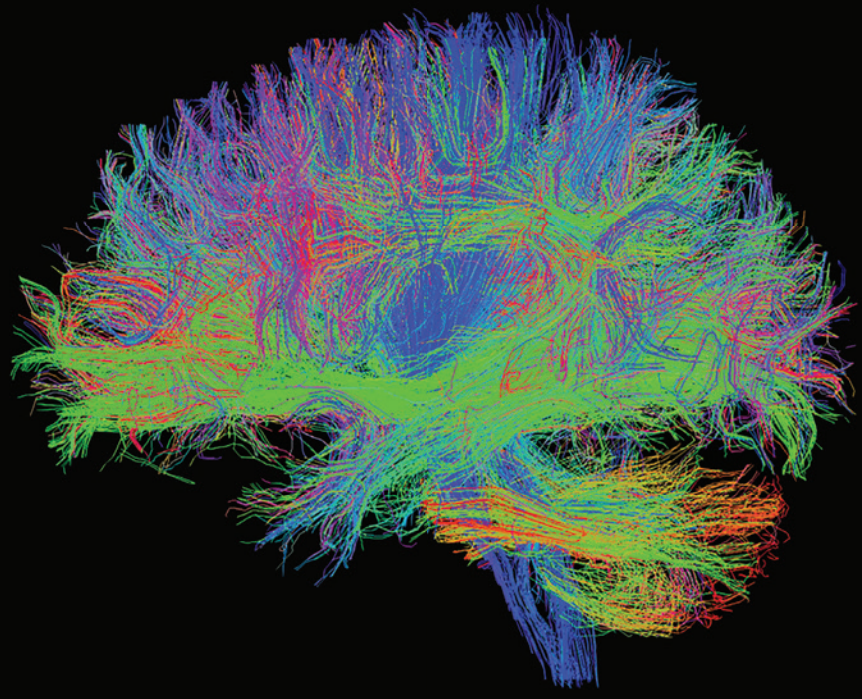
Cristiana is a post-doctoral researcher at the Wellcome Centre for Integrative Neuroimaging, University of Oxford, where she also obtained her DPhil. She specialises in multi-modal pre-clinical MRI and MRI-histology data fusion, characterising new rodent models with genetic modifications relevant to the UK Biobank neuroimaging studies. Cristiana loves board games, reading and long walks in nature.

Wenchuan Wu



Wenchuan Wu is a Royal Academy of Engineering Research Fellow at the Wellcome Centre for Integrative Neuroimaging, University of Oxford. He is a member of the MRI Physics Group, and his current research interest is developing new MRI acquisition and reconstruction methods for studying brain structure and function. In his free time, he loves reading, music and exploring the world with his kids.





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