EMJ RADIOLOGY

Vol. 2.1 April 2021

emjreviews.com

ECR 2021

EDITOR'S PICK

Giant Cell Arteritis: Navigating Beyond the Headache

INTERVIEWS

The President of the European Society of Radiology (ESR) and four influential members discuss their positions within the society and provide insight into their areas of expertise.

Contents

"Summaries of key abstracts presented at the congress are also included and are written by the presenters themselves, covering topics such as artificial intelligence analysis systems to support prostate cancer diagnostic imaging and a proposal for a new prognostic grading system in achalasia using dynamic barium swallow."

Spencer Gore, CEO

Editorial Board

VIEW IN FULL ←

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This Publication

ISSN 2633-9978

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EMJ Radiology

Welcome

Dear Readers,

Welcome to the second issue of EMJ Radiology following a successful launch last year! This open-access eJournal covers the most important developments in radiology through interviews and articles from experts within the field and a congress review presenting the highlights from the European Congress of Radiology (ECR) 2021.

As the world adapts to virtual means of communication, this year, the ECR took place both virtually and in Vienna, Austria. Hundreds of presentations, studies, and even an unexpected yoga session were delivered. Summaries of key abstracts presented at the congress are also included and written by the presenters themselves, covering topics such as artificial intelligence analysis systems to support prostate cancer diagnostic imaging and a proposal for a new prognostic grading system in achalasia using dynamic barium swallow.

With countries worldwide coping with the coronavirus disease (COVID-19) pandemic, the effects of this novel coronavirus in radiology was a major topic this year. Another topic was the advancement in artificial intelligence and 3D technology in medical imaging, with several ECR sessions presenting and embracing this new era.

We also spoke with the European Society of Radiology (ERS) President, Prof Dr Michael Fuchsjäger, and four ESR Scientific Subcommittee Chairpeople: Dr Elizabeth Loney, Dr Philip Robinson, Prof Apostolos Karantanas, and Prof Olivera Nikolić. The interviewees spoke about their respective areas of expertise and what the future of radiology holds.

Peer-reviewed articles included in this issue present the latest developments in the field. Singh et al. deliver a prospective observational study on breast lesion characterisation with diffusion-weighted imaging versus dynamic contrast-enhanced MRI; Birmingham discusses left hemicolectomy for intussusception of the transverse colon caused by a giant benign lipoma; and, Conway and Harkins discuss medical imaging in giant cell arteritis.

I would like to take this moment to thank all the contributors, Editorial Board, and editorial team for their help in creating this special eJournal.

Spencer

Spencer Gore

Chief Executive Officer, EMG-Health


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Foreword

Dear Readers,

It is with great pleasure that I welcome you to the latest issue of *EMJ Radiology* following the success of the first launch last year, bringing you the latest developments in radiology. They say that 'change is the only constant', and this has been displayed by the scientists and healthcare professionals (medical, nursing, as well as allied health care professionals such as radiographers) who have worked tirelessly to adapt with the changing times. This open-access eJournal will deliver these developments brought about by leading experts following the European Congress of Radiology (ECR) 2021.

The implications of the coronavirus disease (COVID-19) meant that not everyone was able to attend the congress this year, which is why it was delivered virtually and in Vienna, Austria. It showcased the latest innovations in radiology from all over the world, covering interesting topics and challenges in the field by bringing together international authorities. Highlights from the event, including an in-depth review of a session from ECR on deep learning to improve image quality, can be found in the following Congress Review.

Key members of the European Society of Radiology (ESR) were interviewed about the impact of COVID-19 on radiology, facial trauma imaging, genitourinary imaging, and much more. Notable areas of clinical interest provided in this journal include left hemicolectomy for intussusception of the transverse colon caused by a giant benign lipoma and sonohysterography use in the evaluation of the caesarean scar.

The paper that I have selected as the Editor's Pick covers CT and MRI angiography, temporal artery biopsy, ultrasound, and PET scanning for giant cell arteritis and the challenges faced in the diagnosis pathway, a topic that would interest radiographers too.

I hope that you all enjoy reading *EMJ Radiology*, an issue that should be of great interest to a wide range of healthcare professionals, including radiologists and diagnostic and therapeutic radiographers.

Yasmeen Malik

Senior Lecturer, St George's University of London, London, UK

Congress Review

Review of the European Congress of Radiology (ECR) 2021

Location: ECR 2021
Date: 3rd–7th March 2021
Citation: EMJ Radiol. 2021;2[1]:12-21. Congress Review.

VIENNA'S musical culture was a central element throughout the opening ceremony of this year's European Congress of Radiology (ECR), which opened to the music of Johan Strauss's 'Die Fledermaus', performed by the Philharmonic Five. The musical element continued to manifest itself as the musicians performed classical pieces throughout the ceremony ranging from 'Giuditta' to 'Don Giovanni'. Although the coronavirus disease (COVID-19) pandemic forced yet another congress to switch to a virtual setting, Vienna's character and style was diffused throughout the congress.

In what now seems to be an ironic twist of fate due to the COVID-19 pandemic, last year the European Society of Radiology (ESR) President Prof Michael Fuchsjäger chose 'embracing' as the main theme of this year's ECR. Underpinning this theme was Gustav Klimt's painting 'The Kiss', which served as the signature image of the congress. As elegantly put by Prof Fuchsjäger, embracing is an all-encompassing word and radiology is the one thing that attendees collectively embraced.

In addressing the audience during the opening ceremony, Prof Fuchsjäger emphasised that "At the outbreak of a global pandemic, the ESR chose to embrace the innovative and wide-reaching opportunities that only learning can provide."

The ESR online platform offered five parallel streams with a plethora of sessions and themes to choose from, which made navigation an engaging and stimulating experience for attendees. Channel 1 contained live broadcasts from a dedicated studio in Vienna acting as a hub and hosting pop-up events from academic and industry partners in 20 different cities around the world. This channel also broadcast classes of yoga, mindfulness, dance, and Aikido, in line with the special theme of this year's congress: wellbeing.

> *"At the outbreak of a global pandemic, the ESR chose to embrace the innovative and wide-reaching opportunities that only learning can provide."*

Prof Fuchsjäger expressed his belief that "if we can remain resilient and focussed in the face of adversity, we can serve our patients even more effectively."

Ranging from plenary lectures and workshops to new horizons sessions and industry symposia, this congress had something for everyone. With presentations on artificial intelligence, radiomics, thera(g)nostics, and Star Wars-themed image interpretation quizzes, there was a wide range of topics and sessions to choose from. Of course, there was an abundance of sessions on COVID-19, ranging from its radiological manifestations, diagnosis, and the use of artificial intelligence.

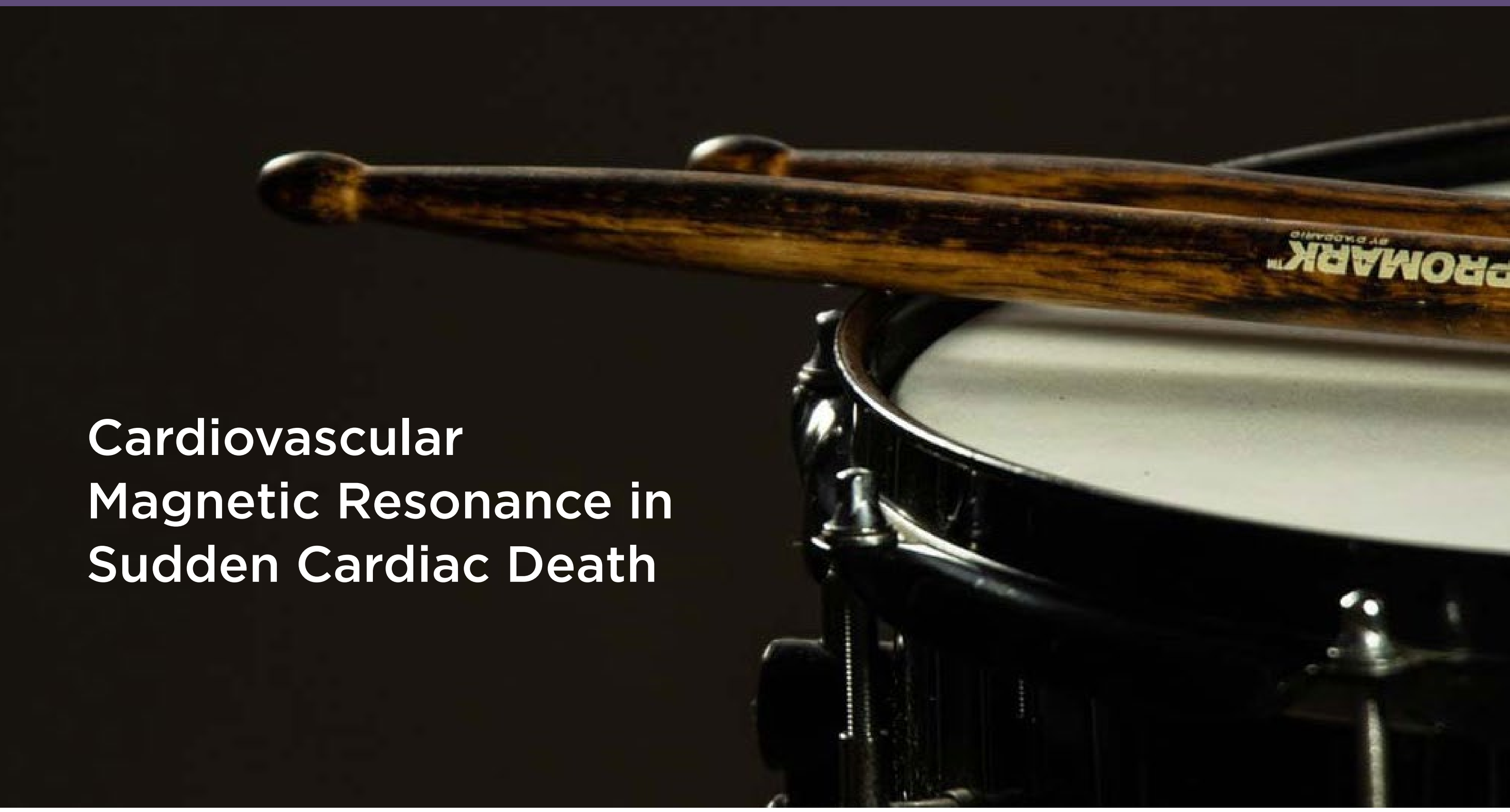
This year's recipients of honorary membership, which is awarded to individuals for their scientific excellence, international reputation, and achievements in national or international radiology, were Prof Sanjiv Sam Gambhir, Stanford, California, USA; Prof James P. Borgstede, Colorado, Denver, USA; and Prof Pek-Lan Khong, Hong Kong, SAR, China. A particularly touching tribute was paid to Prof Gambhir who sadly passed away in July 2020, who Prof Fuchsjäger characterised as "a luminary of exceptional style and wisdom."

The three recipients for this year's Gold Medal of the ESR were Prof Fiona Gilbert, Cambridge, UK; Prof Paul M. Parizel, Perth, Australia; and Prof Francesco Sardanelli, Milan, Italy. The award is presented to outstanding scientists who work in radiology or life sciences and have been active in the organisation and establishment of radiology in national or international organisations. Each of the recipients chose a favourite piece of music to be played at the ceremony, which ranged from cool jazz to Tchaikovsky. Combining an element of surprise with a touch of Viennese culture, the opening ceremony closed with Prof Fuchsjäger joining the soprano Valentina Nafornita to sing a duet from 'Don Giovanni'.

This was a truly memorable congress, hosted on a highly innovative platform paving the way for more virtual events organised by the ESR. In the closing ceremony, Prof Fuchsjäger emphasised that "we adapt, we innovate, and we embrace opportunities, no matter what form our annual meeting might take."

In this issue of *EMJ Radiology* our team has covered a selection of the topics from ECR, aiming to impart some of the knowledge shared at the congress. ■

ECR 2021 REVIEWED →



Cardiovascular Magnetic Resonance in Sudden Cardiac Death

SUDDEN cardiac death is unexpected mortality occurring as a result of cardiac causes and within a short time period. The majority of these events are attributable to ventricular arrhythmias. Underlying structural cardiac abnormalities, including postinfarction scar tissue, are found in most cases of sudden cardiac death. During the ECR 2021 Master Class titled 'Cardiac Imaging in Arrhythmia And Sudden Cardiac Death', Dr Hubert Cochet, University of Bordeaux, Bordeaux, France, discussed the role of late gadolinium enhanced (LGE) cardiac magnetic resonance (CMR) in scar characterisation.

The current approach for the primary prevention of sudden death relies on the measurement of left ventricular ejection fraction (LVEF). Dr Cochet noted that this methodology cannot be considered satisfactory because a large proportion of patients dying suddenly remain undetected, with >80% of them having LVEF >35%. To overcome LVEF limitations, analysis of LGE CMR images has been proposed. Dr Cochet highlighted a recent study that monitored approximately 1,000 patients with coronary artery disease over 6 years and found that quantification of grey zone on LGE images accurately identified a group at high risk of future arrhythmia. Dr Cochet emphasised: "This strategy clearly outperformed the one based on LVEF measurements, which was poorly discriminate."

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On the topic of nonischaemic dilated cardiomyopathy, Dr Cochet stated: "As opposed to ischaemic heart disease, in which LGE may recruit additional participants for implantable cardioverter defibrillator implantation, LGE in dilated cardiomyopathy may be more useful to prevent unnecessary implantations in a subset of patients who are currently considered for implantation but whose risk profile is rather low." A further series of studies have illustrated that LGE qualifications could also be used in hypertrophic cardiomyopathy to improve primary prevention.

Lastly, the importance of CMR in the aetiological diagnosis of patients presenting with ventricular arrhythmia was discussed. Dr Cochet stressed that CMR should be performed even when first-line echocardiography and angiography are negative. ■

Functional MRI for Assessment of Cervical Cancer

THE USE of functional MRI (fMRI) in the evaluation of cervical cancer is increasing. While standard MRI and conventional imaging techniques, such as ultrasound and CT, are effective at detecting tumours that show anatomical distortional and changes in tissue appearance, they often fail to identify the small-volume active tumours, either when they first present or in early disease relapse; the anatomic and functional imaging ability of fMRI makes this possible. Prof Evis Sala, Honorary Consultant Radiologist, Addenbrooke's Hospital, Cambridge, UK, spoke in a session series on the topic of fMRI in cervical cancer, with particular emphasis on treatment selection, planning, and monitoring.

"In helping delineate small tumours, such as adenocarcinoma of the cervix, dynamic contrast-enhanced (DCE) MRI is favourable"

In helping delineate small tumours, such as adenocarcinoma of the cervix, dynamic contrast-enhanced (DCE) MRI is favourable, especially in patients eligible for trachelectomy (fertility-sparing procedure), due to its ability to noninvasively characterise tissue vasculature. DCE-MRI is also a useful tool in treatment planning (radiotherapy versus surgery) and in evaluating treatment response more readily than assessing tumour size.

There is a growing interest in the use of diffusion-weighted MRI (DWI) in combination with T2-weighted images to measure early treatment response. This is due to the imaging ability to observe reduced profusion in the tumour and is more effective than pattern-monitoring early response to treatment. Prof Sala advised not to use positron emission tomography at treatment completion (3–6-month window), because inflammation and nonspecific glucose uptake give the possibility of false positives; here both DCE-MRI and DWI are more suited. In terms of detecting tumour recurrence, DWI also proves effective at identifying small, subtle areas of tumour.

Prof Sala also mentioned her team's success in using a combination of positron emission tomography and fMRI for outcome prediction, with both systems serving as disease-free and overall survival biomarkers. ■

Gadolinium Deposition: An Update

GADOLINIUM-based contrast agents (GBCA) are diagnostic pharmaceutical compounds containing paramagnetic gadolinium ions that affect the magnetic resonance signal properties of surrounding tissue. GBCA are commonly used in clinical practice because of their fundamental ability to selectively decrease the T1 relaxation time within a lesion rather than in normal tissue.

However, during the ECR 2021 Special Focus Session titled 'Can We Limit Gadolinium Use in Neuroimaging?', Prof Dragan Stojanov, Centre for Radiology, Clinical Centre of Niš, Niš, Serbia, pointed to several recent studies that demonstrated gadolinium neurodeposition in patients with normal renal function. Specifically, gadolinium deposition has been recorded in brain structures such as the dentate nucleus and globus pallidus. These findings were confirmed in animal models.

Prof Stojanov explained that GBCA can be divided into two structurally distinct categories: linear (open chain) and macrocyclic chelates. The current prevailing theory is that the degree of deposition depends on the molecular structure of the contrast agent used. In particular, dissociation depends on the kinetic and thermodynamic stability of GBCA. The gadolinium ions of macrocyclic GBCA are caged in the cavity of ligands and this is believed to underlie the heightened stability of macrocyclic chelates relative to linear chelates.

The gradual dissociation of accumulated linear GBCA in the brain allows gadolinium to bind proteins and other macromolecules and this process is ultimately responsible for neurodeposition.

On the basis of these findings, Prof Stojanov revealed that the European Medicines Agency (EMA) recommended the suspension of all commercially available linear GBCA. Consequently, many of the less stable chelates have been removed from routine clinical use in recent years.

Prof Stojanov highlighted that there is currently no clinical evidence of adverse health effects specifically related to gadolinium accumulation in the human brain: "In my opinion, future research is needed to determine the mechanism by which gadolinium deposits within the human tissue and whether this leads to clinically significant sequelae." ■

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How Can Cone-beam CT Change Clinicians' Practice in Interventional Radiology?

THE MAINSTAY of interventional radiology has been 2D angiography, but this has been thwarted by its low contrast resolution. This poses a challenge for small lesions and vessel visibility, resulting in having to take multiple angiograms, which increases radiation dose. Imaging hybrid systems can bridge the gap and give excellent results, but the costs and workflow implications are considered too great a challenge. Cone-beam CT has been around since the early 1990s and earliest applications were for vascular imaging and angiography. At ECR 2021, Dr Raman Uberoi, University of Oxford, Oxford, UK, delivered a presentation entitled 'How cone-beam CT can change your practice in interventional radiology' as part of a Master Class on new diagnostic tools for vascular diseases.

"Innovative equipment and further development of software and hardware for this imaging technique improve speed accuracy and safety procedures, ultimately improving patient outcomes."

As things have progressed over the last 15–20 years, scan times have reduced and multiphasic acquisitions can be obtained. The result is that cone-beam CT provides 3D volume images with great contrast resolution. With cone-beam CT, images can be combined with angiographic images; the correct software allows for treatment planning, catheter and needle navigation, monitoring of treatment, as well as final results assessment.

Excellent training of the patient and staff is vital to the execution of imagery. Cone-beam CT can show the lesion vascular territory at the time of the procedure and offers multimodality fusion, with therapy planning needed for interarterial or percutaneous ablation techniques. These qualities are incredibly valuable as clinicians can automatically identify vessels to be targeted; these vessels can be extracted and lesions targeted.

While the earliest uses of this 3D imaging were for angiography, it can be extremely useful in identifying and targeting branch vessels as well as problems that might compromise stent graft.

Cone-beam CT is now widely available from many manufacturers and its use can be extended to an increasing range of areas including information retrieval. Innovative equipment and further development of software and hardware for this imaging technique improve speed accuracy and safety procedures, ultimately improving patient outcomes. ■

Radiographers and Patient-Centred Care

IN THE PAST decade, there has been a paradigm shift in healthcare systems to suggest that patient satisfaction has become an important factor for healthcare professionals to consider. Patient-centred care means the needs of the patient are addressed, their questions are answered effectively, and the overall patient experience is improved. In medical imaging, image quality, radiation dose, and other technical aspects are essential; however, patient centred-care was a key subject addressed at ECR 2021.

A quality improvement methodology research study from Warrington and Halton Hospitals NHS Trust, Warrington, UK, led by radiographers Drs Louise Harding and Paula Evans, titled 'Always about', was introduced at this year's congress. This methodology uses the Plan-Do-Study-Act (PDSA) cycle by encouraging honest and transparent feedback from patients and reviewing this feedback to make the required changes. The aim was to inspire radiographers: to increase patient engagements in their treatment, listen to patients' needs and concerns, avoid making assumptions, address gaps in the quality care systems, and to improve overall radiographic practice and teamwork.

Dr Andrew England, senior lecturer at Keele University, Keele, UK, outlined the role of the European Federation of Radiography Societies (EFRS) and its initiatives for promoting patient-centred care across Europe. The EFRS is the European voice of radiographers and currently represents over 100,000 radiographers and 8,000 students. It recognises 40 national societies and over 60 radiography educators from Europe and beyond. The core belief of the society is essentially putting patients first by finding ways to enhance quality of care in medical imaging and radiography.

Studies have shown that by bringing the patient to the centre of defining their care needs, the safety and effectiveness of care can improve significantly. Quality improvement methodologies can positively impact patience experience and appreciate how patient-centred care has an impact on radiographic practice. ■

> *"Quality improvement methodologies can positively impact patience experience and appreciate how patient-centred care has an impact on radiographic practice."*

The ALARA Principle: Dose Reduction in CT and Radiography for Children

SPECIAL training is required when utilising medical radiation in paediatric patients. The 'ALARA' principle (which stands for 'as low as reasonably achievable') is a safety concept used to protect patients from excessive exposure to ionising radiation. In radiography, certain exposure techniques are required when treating small children thanks to their weight–mass ratio. A session was presented at ECR 2021 by Dr Erich Sorantin, Medical University of Graz, Graz, Austria, and Dr Jeannette Kraft, Leeds Teaching Hospitals NHS Trust, Leeds, UK, on avoiding or reducing ionising radiation in children.

Prof Sorantin started the session by evaluating how to improve the benefit and risk ratio of children in radiography and CT by adapting exposure and dose settings to paediatric needs. Tips were shared on how patient positioning and using the slice thickness approach in radiography is essential in dose reduction. It was suggested that a child with spinal deformity or scoliosis could have an MRI scan first, perhaps followed by a focussed CT scan of any bony fusion anomaly.

"...medical imaging procedures need to be justified and optimised for radiological protection, especially in children."

CT scans are essential in acute trauma for 3D imaging of deformities and assessment of post-traumatic complications causing plate fusion or bone infection. Dr Kraft, a specialist in musculoskeletal radiology, discussed how medical imaging procedures need to be justified and optimised for radiological protection, especially in children. An example was shared to explain that although CT may be appropriate to assess a triplane fracture of the ankle, it is not needed for all ankle fractures in children.

Ultrasound was suggested as the first-line imaging investigation in "lumps and bumps" and nontraumatic joint pain. Possibilities for low-dose applications in skeletal imaging were presented in this session at ECR 2021. A good example was shown in which a low-dose video graphic system allows for total body imaging in a natural, weight-bearing position, producing viewable 2D images and 3D models. Dr Kraft affirmed its use for imaging of scoliosis or lower limb deformities. ■

Using Artificial Intelligence to Improve Radiomics in Breast Imaging

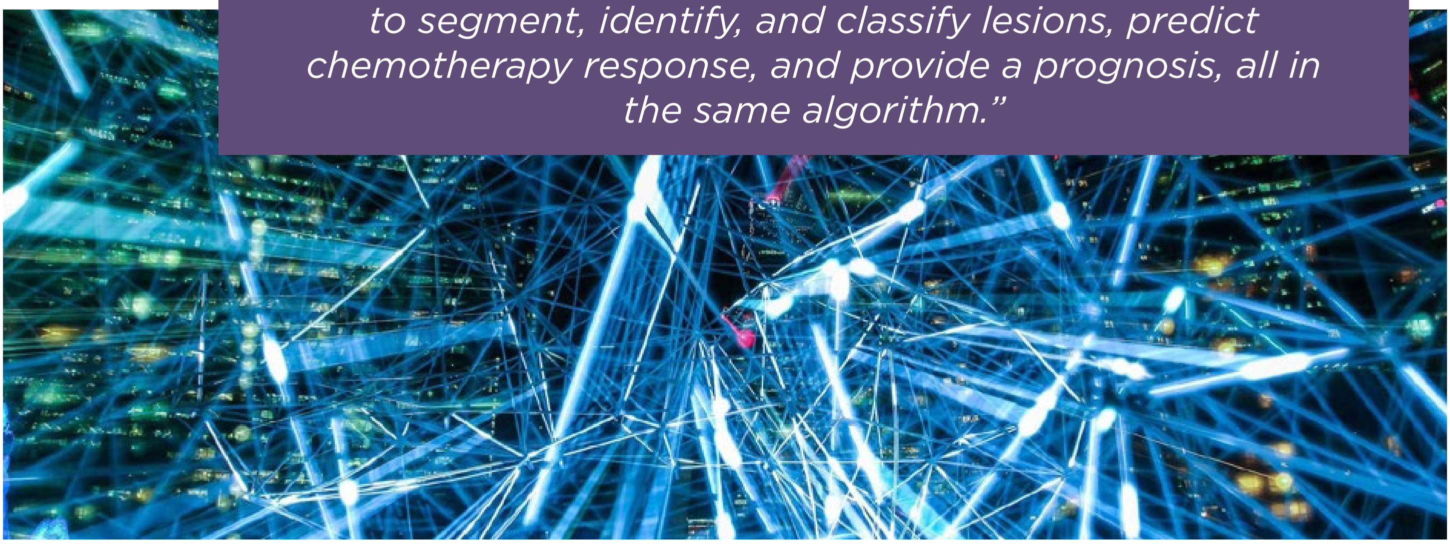
RADIOMICS, a relatively new field in radiology, is the method of extracting large numbers of quantitative features from medical images using data characterisation algorithms and was the topic of discussion at an ECR 2021 Master Class. Dr Riste Mann, Radiologist, Radbound University Medical Center, Nijmegen, the Netherlands, took to the screen in the final lecture of the Master Class to discuss the use of artificial intelligence (AI) in improving breast imaging '-omics'.

AI can be divided into different subfields depending on the particular goals and tools, such as machine learning and robotics. Deep learning represents a subfield of machine learning that structures algorithms in layers to create a convolutional neural network (CNN); in radiology, a CNN uses image inputs to learn and recognise image features and, as a result, makes intelligent decisions and interprets radiographic images independently. In the case of breast imaging, CNN are en route to classifying breast lesions never seen before by the system, simply by using the information obtained from prior cases. Traditional breast MRI is high-dimensional and multiparametric in nature, making interpretation labour intensive and complex with the potential of interobserver variability. Therefore, Dr Mann, along with a team of researchers, set out to uncover whether automated classification of benign and malignant breast lesions in ultrafast breast MRI using deep learning showed a reduction in the number of false-positive biopsies. The team analysed 576 lesions imaged with MRI and applied deep learning methods. The results reported that 19 fewer false positives were produced with the AI system than the number of biopsied benign lesions in the authors' database, suggesting that AI-based classifications can help radiologists interpret MRI images to improve specificity.

The potential use of AI to predict response to chemotherapy during treatment was also briefly discussed, however this application is not as near in the future as lesion prediction. One day, AI in breast imaging will have the capability to segment, identify, and classify lesions, predict chemotherapy response, and provide a prognosis, all in the same algorithm. "By that time, our jobs will have changed dramatically," concluded Mann. "We might have somehow all become oncologists."

A limitation to CNN is that they require large pools of training images before achieving a clinically useful performance. Future studies should focus on collecting larger datasets to further train AI systems and create deeper CNN structures for improved learning and classification. ■

"One day, AI in breast imaging will have the capability to segment, identify, and classify lesions, predict chemotherapy response, and provide a prognosis, all in the same algorithm."



Pairing CT and Laboratory Data to Predict Prognosis in COVID-19

Katherine Colvin
Editorial Coordinator

Citation: EMJ Radiol. 2021;2[1]:22-23.

PREDICTING outcome for patients can help to direct management decisions, care and surveillance requirements, and align patients and their families with the expected clinical course; however, predicting prognosis for new, unknown conditions like coronavirus disease (COVID-19) presents a challenge. In a shared session with the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) at ECR 2021, Prof Salvatore Cappabianca, Department of Precision Medicine, University of Campania, Naples, Italy, shared study findings evaluating the role for chest CT alongside clinical and laboratory assessments to help predict outcome in patients with COVID-19.

In the early period of the pandemic, Prof Cappabianca explained, studies examined the use of CT imaging for diagnosis of COVID-19; however, evolution of clinical thinking moved to support consideration of COVID-19 as a general viral infection, where the role of CT imaging is in defining extent of disease rather than diagnosis. He discussed his retrospective, univariate, and multivariate analysis, which aimed "to clarify the place of the CT scan in the management of COVID-19 patients, define the possibilities of CT alone in prediction of patients' outcome, and to compare lung CT impairment with clinical data to improve performance in outcome prediction."

The study analysed data from 103 patients presenting to hospital: 41 female and 62 male, aged 29–93 years. Patients had confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection via reverse transcription PCR nasopharyngeal swab, with admission chest CT usually performed after confirmed COVID-19 diagnosis. The chest CT protocol was performed with supine positioning, without intravenous contrast, and imaged lung apices to bases using a standard dose scanning protocol (1.25 mm thickness, 1 mm interval reconstruction). Two experienced radiologists, blinded to clinical and laboratory findings, defined the presence and extension of ground-glass opacities and areas of consolidation using a guideline for structured reporting, to provide a visual score as a severity index. This visual score reporting was supplemented with an artificial intelligence tool, which reported volumes of residual healthy lung parenchyma, ground-glass opacities, consolidation, and emphysema.

Both univariate and multivariate analyses were performed, incorporating data from

The best prediction of prognosis, however, came with combining clinical, laboratory, and CT findings.

clinical and laboratory assessment (including oxygen saturation, procalcitonin, D-dimer, and troponin), clinical picture (such as fever, cough, and presence of respiratory failure), and comorbidities (hypertension, diabetes, cardiac and/or lung pathologies, neurological pathologies, and neoplasm). Outcomes were assessed as discharge home, hospitalisation in stable condition, and hospitalisation in critical condition.

Analysis found that age, oxygen saturations, C-reactive protein, leukocyte and neutrophil count, lactate dehydrogenase, D-dimer, troponin, creatinine and azotemia, alanine aminotransferase, aspartate aminotransferase, and bilirubin were the major clinical and laboratory findings that defined the outcome of the patient; comorbidities and symptomology showed no significant relationship with the evolution of the COVID-19 pathology.

As determined by the artificial intelligence tool, lung volumes of emphysema, residual healthy lung parenchyma, and consolidation were shown to be "highly important predictive tools in the evaluation of the evolution of disease," outlined Prof Cappabianca; volume of ground glass opacities was not a statistically significant predictor. The visual severity score also demonstrated good correlation with patient outcome.

The best prediction of prognosis, however, came with combining clinical, laboratory, and CT findings. The study found that this combined approach yielded a sensitivity, specificity, and accuracy for predicting outcome of 88%, 78%, and 81%, respectively.

Prof Cappabianca summarised the conclusions of his study for the use of chest CT in prognostication for COVID-19: "our experience suggests the usefulness of visual quantification of involved lung as a predictor of the outcome in patients affected by coronavirus disease. Comparison with clinical and laboratory data provides higher correlation with prediction and software-based quantification of consolidation, emphysema, and residual normal lung on chest CT are independent predictors of COVID-19 evolution." ■

Abstract Reviews

Sharing insights and updates from a selection of abstracts presented by leading experts in the field of radiology at the European Congress of Radiology (ECR).

Fully Automated Segmentation of Neuroblastic Tumours on Multisequence MRI Using Convolutional Neural Networks

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Disclosure: The authors have reported payments to their respective institutions.

Acknowledgements: The authors acknowledge the support of PRIMAGE (PRedictive In-silico Multiscale Analytics to support cancer personalised diaGnosis and prognosis, empowered by imaging biomarkers). Horizon 2020 | RIA (Topic SC1-DTH-07-2018) project with grant agreement no: 826494.

Keywords: Artificial intelligence, cancer, MRI, neural networks, oncology.

Citation: EMJ Radiol. 2021;2[1]:24-26. Abstract Review No. AR1.

BACKGROUND

Volumetric segmentation of intrinsically heterogeneous abdominal tumours is essential for the diagnosis, follow-up, and treatment response evaluation of neuroblastomas.[1] Manual segmentation of neuroblastic masses is a tedious and time-consuming task that hinders the radiologists' workflow. Different studies explored semiautomatic segmentation algorithms in CT images, making use of mathematical morphology, fuzzy connectivity, and other image processing tools.[2,3]

As of today, a robust and generalisable solution does not exist for childhood neuroblastoma. In this study, the authors propose an automated segmentation method based on convolutional neural networks applied to children with neuroblastic tumours studied with multiple MRI sequences. The aim is to extract reproducible quantitative imaging biomarkers from these lesions for the prediction of relevant clinical outcomes.

MATERIALS AND METHODS

T1-weighted (T1W), T2-weighted (T2W), and diffusion-weighted (DW) MRI images at diagnosis were collected from 127 patients with neuroblastoma from different European hospitals in the scope of the H2020 PRIMAGE project.[4] Images were subject to high variability in data acquisition due to different scanners, manufacturers, and protocols.

The authors developed a multisequence and multiplanar U-net.[5] In order to justify the use of multisequence MRI, an experiment was performed with different inputs in a subset of randomly selected patients. For the multiplanar approach, the sagittal and coronal planes from the original axial MRI were reconstructed and fed into three separate neural networks. The segmentations from the three two-dimensional networks were fused using majority voting to generate the final 3D neuroblastoma segmentation (Figure 1). The networks were trained using the Adam optimiser with 300 epochs and a batch size of 100. The number of layers, number of convolutional feature maps, and learning rates were chosen based on hyperparameter tuning. In addition, a scheduler was used to set the learning rate in each epoch, starting from an initial value of 0.001 that reduced by a factor of 0.5 if the validation Dice plateaued for 20 epochs. The model was assessed by using a 5-fold cross-validation strategy and comparing the results with other state-of-the-art solutions.

RESULTS

The Dice similarity coefficient values of the method using only T1W, T2W, DW, and a multisequence approach, having the 5-fold cross-validation as different inputs, were 0.732±0.064, 0.745±0.118, 0.786±0.077, and 0.841±0.038, respectively.

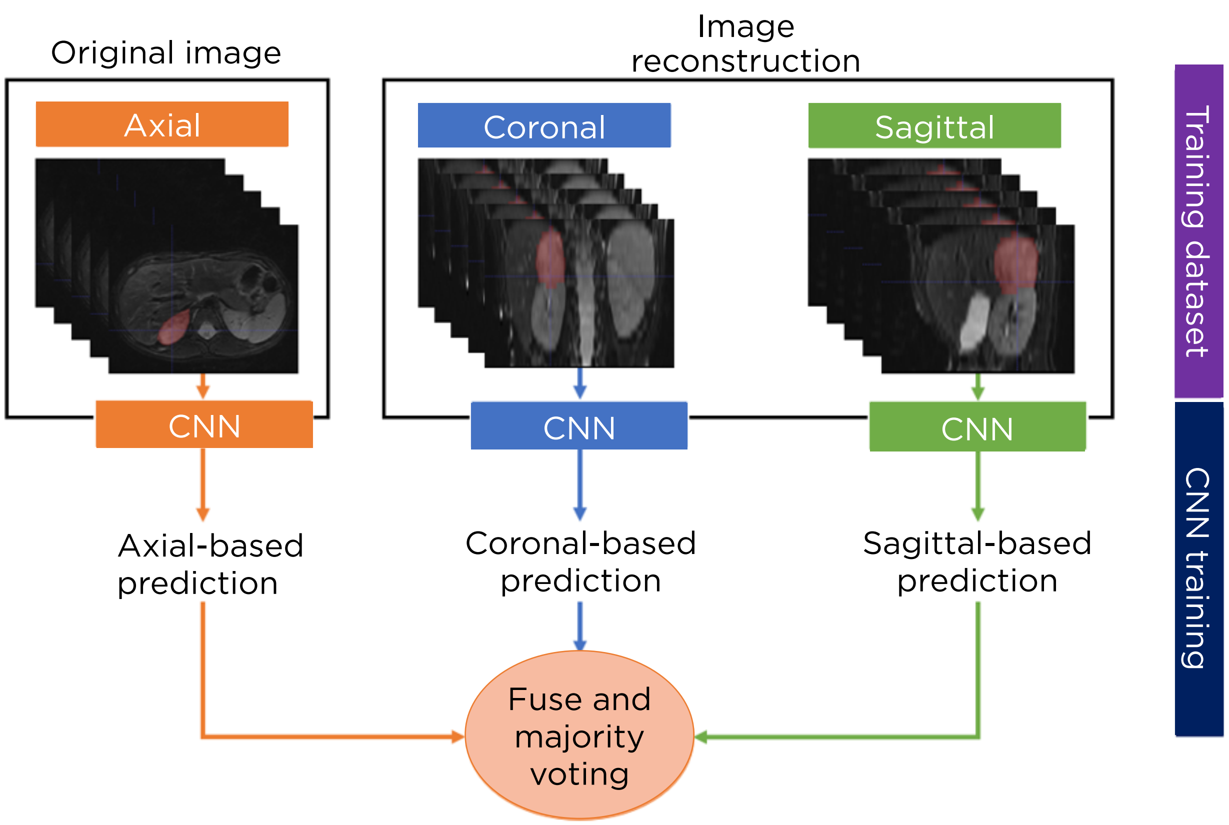

Figure 1: Schematic diagram of the multiplanar scheme used to develop a fully automated segmentation model of neuroblastic tumours.

CNN: convolutional neural network.

The average Dice similarity coefficient of the internal validation using the multisequence strategy was found to be 0.830, showing model robustness and stability across different sites and scanners.

CONCLUSION

The authors proposed a fully automated segmentation method of neuroblastic tumours based on convolutional neural networks and multisequence MRI with an accurate and stable performance. If further improved and externally validated the proposed method could be of use in clinical trials and oncologic practice for the management of neuroblastoma. Future work with a larger sample will be necessary to evaluate the generalisability of the model. In addition, the co-registration of T1W, T2W, and DW images is still particularly challenging in paediatric cancer. An artificial intelligence-based algorithm to overcome this limitation may benefit the segmentation process. ■

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The Impact of the COVID-19 Pandemic on Adult Diagnostic Neuroradiology in Europe

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Disclosure: The authors have declared no conflicts of interest.

Acknowledgements: The authors would like to thank the European Society of Neuroradiology (ESNR) for its support of the ESNR diagnostic committee and the preparation and distribution of the survey.

Keywords: Coronavirus disease (COVID-19), pandemics, personal protection equipment, surveys, questionnaires.

Citation: EMJ Radiol. 2021;2[1]:26-27. Abstract Review No. AR2.

PURPOSE

The purpose of this survey was to understand the impact the coronavirus disease (COVID-19) pandemic has or has had on the work, training, and wellbeing of professionals in the field of diagnostic neuroradiology. These insights may be used to prepare or improve strategies for similar situations and address potential needs and worries that arose from the crisis.

METHODS

A survey was emailed to all European Society of Neuroradiology (ESNR) members and associates as well as distributed via professional social media channels. The survey was open for 1 month in the Summer of 2020 when the first wave had subsided in most of Europe but the second wave was not yet widespread. The questionnaire featured a total of 46 questions on general demographics, the various phases of the healthcare crisis, and the numbers of patients with COVID-19.

RESULTS

From 48 countries, 167 responses were received (Italy: 12%; Spain: 10%; and the Netherlands: 9%), mostly from neuroradiologists (72%), followed by general radiologists (16%), and residents (9%).

Most commonly taken measures during the crisis phase were reduction of outpatient exams (87%), reduction of number of staff present in the department (83%), reporting from home (62%), and shift work (54%). In the exit phase, these measures were less frequently applied, but reporting from home was still frequent (33%). However, only 22% had access to a fully equipped work station at home. Most frequently applied safety measures (>80%) were regular cleaning, distancing measures, and screening patients for infection. While 81% felt safe at work, fewer than 50% had sufficient personal protection equipment during the entire crisis.

Mental wellbeing is an area of concern, with 61% feeling (much) worse than usual during the acute crisis phase and 44% still feeling (much) worse at the time of filling out the survey. Main worries concerned personal health and safety (72%), adapting to COVID-19 operational changes, nonwork obligations (35%), personal finances (27%), job security (20%), and impact on research obligations (15%) and academic career advancement (11%). The impact on training and education of residents and fellows couldn't be assessed with certainty, as only 15% of respondents fell in this category. Seventy-eight percent followed online courses or congresses and 73% considered these a viable alternative for the future.

CONCLUSION

The COVID-19 pandemic substantially affected the professional life as well as personal wellbeing of neuroradiologists, with changes in workload, type of work, and the workplace. Many respondents felt a negative effect on their wellbeing and that safety and personal protection were insufficient, especially in the early stages of the crisis. Another concerning finding was the widespread reduction of imaging examinations, especially during the acute phase. However, the findings also indicate that the neuroradiological community has responded with great flexibility and resilience and seems to take valuable tools such as remote working and online education on board for the future. ■

Multistage Artifical Intelligence Analysis System to Support Prostate Cancer Diagnostic Imaging

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Disclosure: Mr Suchánek had a paid internship with Granta Innovation. Dr Rundo had received consulting fees from Lucida Medical. Dr Mehan had an unpaid internship with Lucida Medical. Prof Padhani holds shares from Lucida Medical. Prof Sala has received consulting fees from Amazon; is employed by, holds shares in, and received consulting fees from Lucida Medical; and has received payment or honoraria for lectures from Siemens and GlaxoSmithKline. Dr Rix is employed by, has patent applications, receives supporting fees, and holds shares for both Lucida Medical and Granta Innovation. Outside this research, Dr Barrett has received research support from Cancer Research UK and Alliance for Cancer Early Detection (ACED); and has unpaid roles with NICE, RCR, NCCP Ireland. The other authors have declared no conflicts of interest.

Keywords: Artificial intelligence (AI), machine learning (ML), MRI, prostate cancer, radiomics, risk calculation, segmentation.

Citation: EMJ Radiol 2021;2[1]:28-30. Abstract Review No: AR3.

BACKGROUND AND AIMS

While prebiopsy multiparametric MRI (mpMRI) substantially improves detection of clinically significant prostate cancer (csPCa) and reduces unnecessary biopsies and diagnoses of insignificant cancer, there remain ongoing challenges with underdiagnosis, biopsy rates, and overdiagnosis. Major studies indicate that 21–49% of patients may still undergo a potentially avoidable biopsy,[1-4] and up to 12% of csPCa may be missed.[5]

Artificial intelligence (AI) has the potential to support, and improve accuracy and consistency of, clinical interpretation of prostate MRI. This study compares a new AI-based system for detecting Gleason ≥3+4 csPCa using MRI, with human readers and existing computer-aided diagnosis (CAD) literature.

MATERIALS AND METHODS

An AI-based system was developed using a proprietary, multistage architecture designed to produce prostate segmentation for prostate-specific antigen density estimation and fusion biopsy, cancer risk calculation to help reduce unnecessary biopsies, and lesion identification to support biopsy targeting.

Data was obtained from open source, anonymised prostate MRI datasets and divided into training, development validation, and held-out test sets. Segmentation models were trained on axial T2-weighted imaging MRI data and accompanying prostate annotations, from the PROMISE12 and NCI-ISBI 2013 Challenge datasets,[6,7] acquired using a variety of 1.5T and 3T scanners. Models for cancer assessment (risk calculation and lesion identification) were trained on PROSTATEx,[8] an mpMRI dataset acquired at one centre on two 3T scanners (MAGNETOM Trio and MAGNETOM Skyra, Siemens, Munich, Germany), with histopathology findings from MR-guided biopsy as ground truth.

Accuracy was evaluated on development validation and held-out test sets and compared with literature on radiologist interpretations and similar AI/CAD approaches.

RESULTS

As a prebiopsy rule-out test, the system identified patients with Gleason ≥3+4 csPCa with sensitivity 93% (95% confidence interval: 82–100%), specificity 76% (64–87%), negative predictive value (NPV) 95% (88–100%), and receiver operating characteristic area under the curve (AUC) 0.92 (0.84–0.98), using axial biparametric MRI (bpMRI) data from the PROSTATEx combined development validation and held-out test sets (80 patients; 35% csPCa prevalence). Performance was higher on the 40 patient held-out test set. Performance results for the model using axial mpMRI data were similar. Radiologists at Likert/Prostate Imaging Reporting and Data System 3 (PI-RADS 3) thresholds achieved per-patient sensitivity of 88–93%, specificity of 18–68%, and NPV of 76-97%.[1,3,4] Comparable AI/CAD publications report 93% sensitivity using held-out or blinded test data at specificity ranging from 6% to 42%.[9,10] The achieved results, including mpMRI data, are summarised in Table 1.

Table 1: Performance of the proposed AI system for identifying patients with Gleason ≥3+4 cancer, compared with major radiology studies.

Study or model/dataset	Sensitivity	Specificity	NPV	AUC
AI system/bpMRI data, combined DV/held-out test dataset from PROSTATEx (128 lesions, 80 patients; present study)	93% (82-100%)	76% (64–87%)	95% (88-100%)	0.92 (0.84–0.98)
AI system/mpMRI data, combined DV/held-out test dataset from PROSTATEx (128 lesions, 80 patients; present study)	93% (83-100%)	78% (65–88%)	95% (89-100%)	0.91 (0.84–0.97)
Radiologists, 4M[4]	94%	73%	N/A	N/A
Radiologists, PROMIS[1]	88% (84–91%)	45% (39–51%)	76% (69–82%)	N/A
Radiologists, MRI-FIRST[3]	93%	18%	N/A	N/A

AI: artificial intelligence; AUC: area under the curve; bpMRI: biparametric MRI; DV: development validation; mpMRI: multiparametric MRI; N/A: not available; NPV: negative predictive value.

Target identification was evaluated through submission to the PROSTATEx Grand Challenge, a blinded test with 208 radiologist-identified lesions from 140 patients. The system identified lesions containing csPCa with area under the curve 0.84, using bpMRI data. For prostate gland segmentation, the system achieved 92% average Dice score on held-out test cases from the PROMISE12 dataset (10 patients), in line with the state-of-the-art.

CONCLUSION

The AI system showed promising performance and specificity, suggesting it could help support exclusion of csPCa with high sensitivity and NPV, while assisting the identification of lesions to target for biopsy. Its accuracy appears to exceed published results for similar prostate CAD/AI systems. Limitations of this research include methodological and dataset differences between the reported studies, and small test set sizes. Workflow integration, training, and evaluation with larger, more diverse datasets and prospective studies are recommended, and regulatory approvals are planned. ■

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Quantitative and Visual Analyses of the Effect of Dose Reduction on Image Metrics and Quality in ^{18}F-FDG PET/MRI in Paediatric Oncology

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Disclosure: The authors have declared no conflicts of interest.

Keywords: ^{18}F-FDG, low dose, paediatric, PET/MRI, tracer dose.

Citation: EMJ Radiol 2021;2[1]:30-32. No: AR4.

BACKGROUND AND AIMS

PET/MRI scans can provide a significant advantage in the paediatric age group, because they are more radiosensitive than adults and more prone to radiation induced long-term adverse effects.[1] Radiation exposure can be significantly reduced by up to 70% by replacing CT scans with MRI using hybrid PET/MRI scanners.[2] Additionally, the higher sensitivity of solid state PET detectors in current PET/MRI scanners, and the possibility to extend PET acquisition times due to the simultaneous acquisition of PET and MRI, make it possible to further reduce the radiation exposure by decreasing the injected radiotracer activities.[3,4] The aim of this study was to evaluate the effect of reduced injected tracer activities on the quantitative image metrics and the visual image quality in whole body ^{18}F-FDG PET/MRI with time-of-flight capability in paediatric oncology.

MATERIALS AND METHODS

Seventy-seven oncological whole body PET/MRI examinations of 54 paediatric patients were analysed (standard injected activity: one-half dose [1.9 MBq/kg] and standard PET scan duration: 5 min per bed position). Lower activity PET images (one-third dose [1.2 MBq/kg] and one-quarter dose [0.9 MBq/kg]) were retrospectively simulated by truncating the originally acquired list mode data sets. In order to examine the influence of dose reduction on quantification, volumes of interest (VOI) were placed within normal organs: liver, mediastinal blood pool, bone marrow, psoas muscle, and bladder, and around FDG avid lesions. VOI positions and size were selected on the original data sets and copied to other simulated data sets for obtaining the same VOI size and localisation. Objective quantitative parameters were assessed by measuring the standardised uptake value (SUV) metrics: SUV_{max}, SUV_{mean}, SUV_{var}, and SUV_{peak}, signal-to-noise ratio (SNR), and contrast to noise ratios (CNR) in each PET data set. Differences in quantitative parameters of simulated data were recorded as relative percentage changes compared to the original data. PET images were also evaluated visually for general image quality by using a 4-point scoring system (1: excellent, 2: good, 3: average, 4: inadequate/poor).[5]

RESULTS

SNR were significantly different among PET data sets ($p<0.001$) and showed gradually increasing image noise with decreasing doses. CNR_{max} and CNR_{min} did not show any significant differences among PET data sets ($p=0.152$ and $p=0.259$ respectively). The mean relative percentage changes in SUV metrics in physiological organs and in FDG avid lesions were found to be lower at one-third dose data set, compared to one-quarter dose data set. Lesion SUV_{max} and SUV_{mean} values were significantly higher in one-quater dose data set, compared to the original and one-third dose data sets ($p<0.05$ for all). However, these SUV metrics did not show statistically significant difference between the original and one-third dose data sets.

While the mean visual score at one-quater dose data set was significantly higher compared to the original and one-third dose data sets ($p<0.001$ and $p=0.001$ respectively), there was no significant difference between the original and one-third dose data sets (Figure 1).

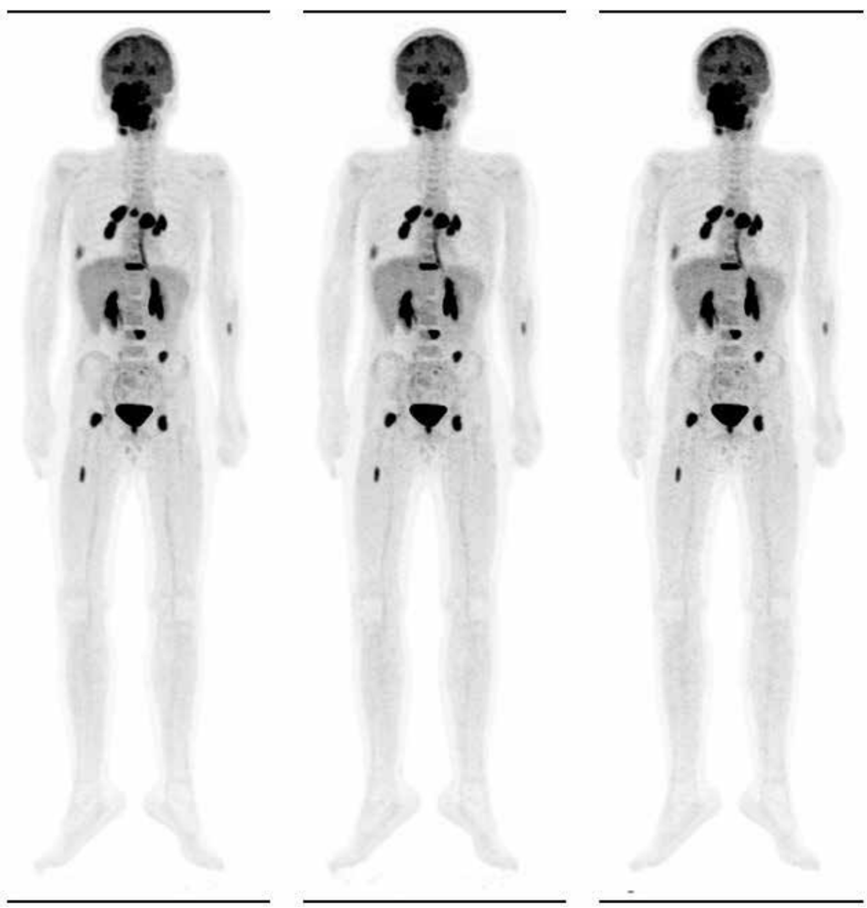

Figure 1: 11 year-old male with newly diagnosed embryonal rhabdomyosarcoma. Maximum intensity projection images of the patient for the original data set (1.9 MBq/kg), and simulated activities of 1.2 and 0.9 MBq/kg (from left to right). SNR were 10.2, 9.5, and 8.1, respectively. CNR_{max} values were 16.3, 15.3, and 15.2, and CNR_{min} values were 11.3, 10.3, and 9.8 respectively. In accordance with quantitative results, while there was no significant difference in the detectability of ^{18}F-FDG avid lesions, image noise, and granularity increased with decreasing tracer activities.

CNR_{max}: Maximum contrast-to-noise; CNR_{min}: minimum contrast-to-noise; SNR: signal-to-noise.

CONCLUSION

The study's quantitative and visual analyses showed that the reduction of injected activity to 1.2 MBq/kg can be feasible in paediatric oncological PET/MRI, with a smaller relative percentage change in quantitative parameters and with similar image quality to the original data set. The level of the lowest tracer dosing that is proposed in our study is lower compared to the lowest tracer dose limits recommended in the previous studies.[6-8] ■

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Outpatient CT Centre for Emergency Triage of Patients with COVID-19: Local Experience from Saint Petersburg

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Disclosure: The authors have declared no conflicts of interest.

Acknowledgements: The authors would like to thank radiologists, radiographers, and emergency medical services staff for their daily hard work during the coronavirus disease (COVID-19) pandemic.

Keywords: Coronavirus disease (COVID-19), CT, emergency medical service, outpatient triage.

Citation: EMJ Radiol. 2021;2[1]:32-34. Abstract Review No. AR5.

BACKGROUND AND AIM

Novel coronavirus disease (COVID-19) was characterised by a great influence on healthcare systems all over the world. During the first peak in the spring of 2020, the number of patients was devastating and clinical decisions were restricted by system capacity. Hospitals' emergency departments were overloaded with patients with COVID-19, and ambulances spent many hours in line for patients' hospitalisation. To improve healthcare system performance, some elements of triage should be implemented, as in mass casualty or disaster response. Chest CT is a highly sensitive imaging modality to diagnose COVID-19 pneumonia.[1-3] At the start of the pandemic, with a lack of fast PCR results, some countries implemented CT-based triage at the hospital emergency department level.[4,5]

The aim of this work was to discuss the organisational principles of outpatient CT-based triage emergency centres.

MATERIALS AND METHODS

In April 2020, outpatient triage was started at the city level. Centres were equipped with CT, crash carts, vital monitors, defibrillators, and oxygen. There were consultant physicians, radiographers, and medical receptionists inside. Radiologists assessed images remotely using radiology information systems. Patients were admitted by ambulance to outpatient CT centres and assessed by consultant physicians (for symptoms, dyspnoea, and oxygen saturation levels). Based on chest CT results (severity of lung involvement) and clinical performance, decisions for hospitalisation were made. The triage algorithm is presented in Figure 1. Because of the hazardous environment, all staff were equipped with Level 2 personal protective equipment and strong infection control procedures were implemented.

RESULTS

Between April–November 2020, 37,537 suspected and laboratory-tested patients with COVID-19 were triaged. Local radiology pneumonia severity classification (CT 1–4) was used for assessment: CT 1 with <25% of lungs involved; CT 2 with 25–50%; CT 3 with 50–75%; and CT 4 with ≥75% and more. Patients with CT 1–2 and good clinical performance were sent home for observation by ambulatory physicians. Patients with CT 3–4 and dyspnoea, oxygen saturation <94%, and comorbidities were admitted to hospital. During the 7 months, 21,986 patients with COVID-19 pneumonia were diagnosed. Overall, 5,532 moderate-to-severe and critical patients were hospitalised and 32,005 patients were referred for home treatment.

CONCLUSION

Based on the study results, the authors make several proposals.

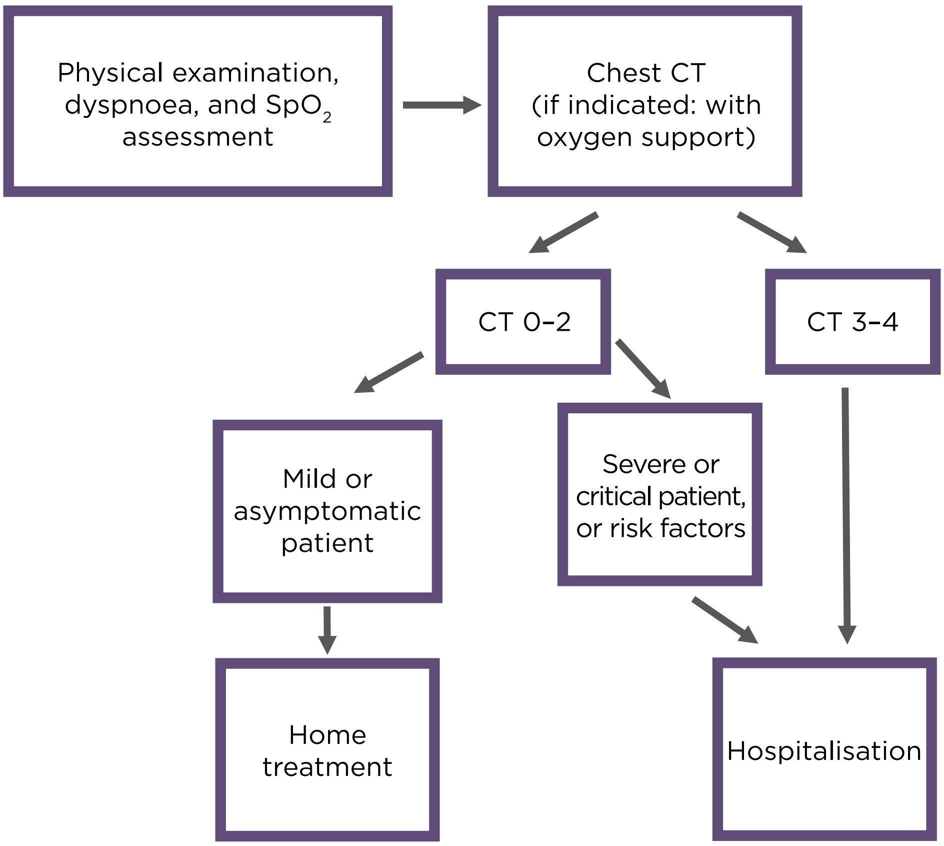

Figure 1: Triage algorithm.

SpO_2: oxygen saturation.

Firstly, outpatient triage of patients with COVID-19 using CT is an acceptable strategy in a respiratory pandemic environment. Secondly, CT triage is a fast tool for clinical decision-making. Thirdly, infection control is a key point for medical staff safety. ■

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A Proposal For a New Prognostic Grading System in Achalasia Using Dynamic Barium Swallow: The FBF Score

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Disclosure: The authors have declared no conflicts of interest.

Acknowledgements: The authors would like to thank Miss Simona Borrelli, RTR BSc, for her great support throughout the process.

Keywords: Achalasia, barium, barium swallow, fluoroscopy, gastrointestinal tract.

Citation: EMJ Radiol. 2021;2[1]:34-36. Abstract Review No. AR6.

BACKGROUND AND AIMS

The role of barium swallow in the diagnosis of upper gastrointestinal tract diseases has been overshadowed in the last few years, and for many reasons. Important improvements in diagnostic technology have gradually led classic barium radiography to hold a lesser role.[1] In fact, the internationally recognised diagnostic gold standard for achalasia,[2,3] the topic of this study, is the high-resolution manometry evaluation, which allows the diagnosis and staging of achalasia according to the Chicago classification. Considering the aim of radiologists, which should be to innovate on a daily basis without forgetting about techniques that are effective, available, and easy to perform, such as barium swallow,[4] the authors designed a study to establish a new radiographic grading system for achalasia; this was named the FBF score (from the name of the corresponding institution: FateBeneFratelli, Benevento, Italy). The score is totally congruent with the Chicago classification assumptions and allows for more accurate and clinically oriented prognostic grading, especially precise subtype diagnoses, completely comparable to manometric ones, using the authors' in-house barium swallow protocol.[5,6]

MATERIALS AND METHODS

The authors started to develop their FBF scoring system by profiling the three achalasia subtypes described in the clinical/manometric Chicago classification (I: hypotonic; II: panpressurising; and III: spastic) into three equivalent radiographic grades; this was done using five morphodynamical findings as scoring criteria: bird-beak sign (2 points), lumen dilation (2, 4, or 6 points, respectively, for a lumen calibre of <4 cm, 4–6 cm, >6 cm), hypotonia (2 points), stasis (2 points), and spasm (-2 points). The score, ranging 0–12, is calculated by adding up the points from each finding (if found). Scores 0–6 are considered FBF/Chicago Subtype III, while scores 6–8 are considered Subtype II (except score 6, with spasm, which is considered Subtype I) and scores of >8 are consistent with Subtype I.

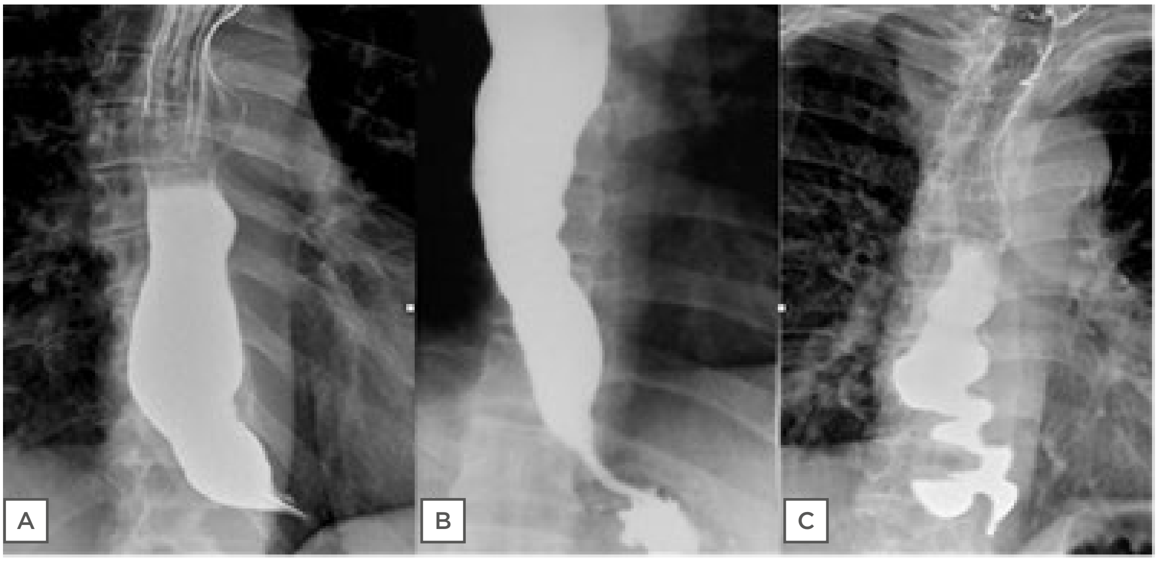

Figure 1: Radiologic profiles of achalasia subtypes: A) hypotonic, Subtype I; B) panpressurising, Subtype II; and C) spastic, Subtype III.

Between June 2017 and June 2020, 141 patients (mean age: 59.2 years; male: 60.2%; female: 38.8%), already diagnosed with achalasia using high-resolution manometry, were evaluated with dynamic barium swallow. They then received blinded review by two radiologists who had gastrointestinal experience, and were subsequently graded using the FBF score. Radiographic grading accuracy and sensitivity were evaluated using manometry data as gold standard. The five scoring criteria were each evaluated for sensitivity and specificity with regard to each radiological grade.

RESULTS

The FBF score allowed the authors to predict the clinical/manometric subtype with high accuracy, with sensitivity values reaching 91.30% for Subtype III, 95.40% for Subtype II, and 98.03% for Subtype I, the latter being correctly diagnosed in 50/51 patients with FBF ≥8 (presence of ≥4 combined radiographic findings). Spasm showed high specificity in Subtype III (95.65%), while stasis resulted in high sensitivity for Subtype II (93.18%).

CONCLUSION

Radiographic grading of achalasia using the FBF score was shown to be highly sensible and accurate when compared to the manometry results, especially in Subtypes II and III. FBF score implementation might allow more precise morphodynamical analysis, structured reporting, and better overall diagnostic support for manometry, patient stratification, and therapeutic choices. It should be noted, however, that this study is monocentric and the patient number is limited (141); even though preliminary data suggest a substantial comparability between barium swallow plus FBF score and high-resolution manometry, further studies are needed for a complete validation. ■

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Does Shear Wave Elastography Definitively Characterise TIRADS 3 and 4 Lesions? An Efficient Resolution to the Pandora's Box of Numbers!

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Disclosure: The authors have declared no conflicts of interest.

Support: Shear wave elastography (SWE), thyroid biopsy, thyroid cancer, thyroid disease, thyroid imaging reporting and data system (TIRADS), thyroid nodule, thyroid ultrasound.

Citation: EMJ Radiol. 2021;2[1]:36-38. Abstract Review No. AR7.

BACKGROUND AND PURPOSE

Thyroid disease affects 42 million people in India and among these 12% have a thyroid nodule. Furthermore, India and the USA have both recorded a steep rise in thyroid cancer incidence during the last decade.[1] Though the sensitivity of ultrasound for detection of a thyroid nodule is high, it shows a dismal performance for differentiation between benign and malignant nodules.[2] Moreover, the not so satisfactory performance of thyroid imaging reporting and data system (TIRADS) in characterisation of thyroid nodules has been substantiated in a meta-analysis by Wei et al.; the accuracy of TIRADS stratification showed a pooled sensitivity and specificity of only 75% and 69%, respectively.[3] The American College of Radiology (ACR) TIRADS was developed in 2017 for better characterisation of thyroid nodules.[4] While ACR TIRADS 1 and 2 are certainly benign nodules and TIRADS 5 are definitely malignant, TIRADS 3 and 4 nodules are unfortunately in a rather grey zone. In this context, various investigators have explored the application of shear wave elastography (SWE) for better characterisation of thyroid nodules.[5-8]

Therefore, the aim of the present study was to assess the diagnostic performance of established SWE values in evaluating and predicting malignancy in ACR TIRADS 3 and 4 suspicious thyroid nodules, using cytology and histopathology as the gold standard. The secondary purpose was for the authors to determine their own SWE value cut-offs in definitively characterising thyroid nodules as benign or malignant.

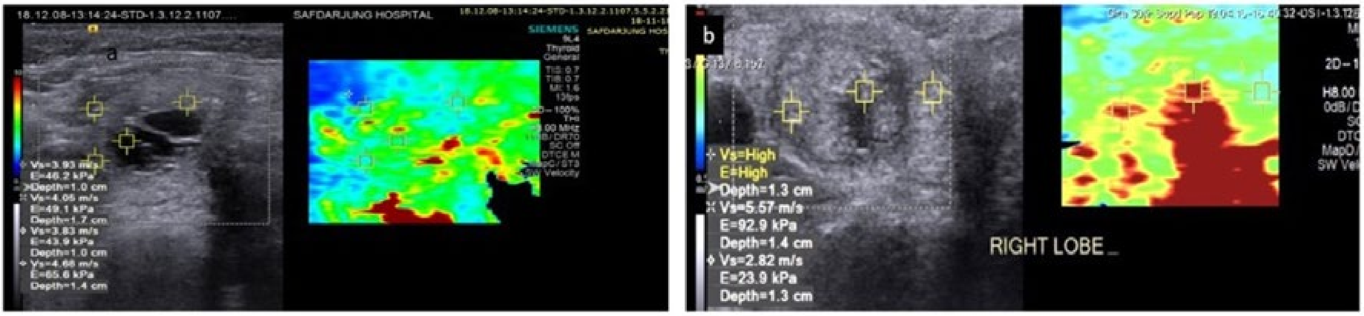

FIG 1 A

COMPOSITION	SOLID AND CYSTIC	1 POINT
ECHOGENICITY	HYPOECHOEIC	2 POINT
SHAPE	WIDER THAN TALL	0 POINT
MARGINS	SMOOTH	0 POINTS
ECHOGENIC FOCI	NIL	0 POINTS
TOTAL		3 POINTS = TIRADS 3

FIG 1B

COMPOSITION	SOLID AND CYSTIC	2 POINTS
ECHOGENICITY	HYPOECHOEIC	1 POINT
SHAPE	TALLER THAN WIDE	3 POINTS
MARGINS	SMOOTH	0 POINTS
ECHOGENIC FOCI	NIL	0 POINTS
TOTAL		6 POINTS = TIRADS 4

Figure 1: SWE in TIRADS 3 and 4 nodules. A) The SWE study in a 25-year-old female patient with a TIRADS 3 thyroid nodule. The SWE value was 65.6 Kpa, the biopsy and histopathology revealed a colloid nodule. **B)** The SWE study in a 27-year-old female patient with a TIRADS 4 thyroid nodule. The SWE value was 92.9 Kpa, the biopsy and histopathology revealed a papillary carcinoma.

SWE: shear wave elastography; TIRADS: thyroid imaging reporting and data system.

MATERIAL AND METHODS

This was an institutional review board-approved prospective study, standardised by using the same ultrasound equipment (Siemens Acuson S3000™; Siemens Healthineers, Erlangen, Germany) and the same two radiologists performing the ultrasound each time (first and second authors). The patients first underwent conventional ultrasound and the nodules were classified according to ACR TIRADS system. Sixty consecutive patients with TIRADS 3 or 4 lesions were recruited for the SWE study. In patients with multiple nodules, the single most suspicious nodule was interrogated. Lesions were classified into benign or malignant using the previously established SWE cut-off value of 85.2 kPa, with higher values being considered as malignant.[5] Pathology diagnosis obtained either by fine-needle aspiration cytology or biopsy was considered as the gold standard. Statistical analysis was performed for determining sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and diagnostic accuracy of SWE, based on established cut-off values. SWE values obtained from the current cohort were correlated with final pathology diagnosis and retrospectively evaluated for construction of a receiver operating characteristic curve. A new cut-off value for SWE was then computed and proposed.

RESULTS

In evaluated nodules, ACR TIRADS classified 29 nodules as TIRADS 3 and 31 as TIRADS 4. Using established SWE cut-offs, 27 nodules were classified as benign and 33 as malignant (Figure 1). Fine-needle aspiration cytology and histopathology revealed 28 nodules as benign and 32 as malignant. Using established SWE cut-offs, sensitivity, specificity, PPV, NPV, and diagnostic accuracy were 81.3%, 96.4%, 96.3%, 81.8%, and 88.3%, respectively. The retrospectively determined cut-off value for SWE was 74 kPa, with sensitivity, specificity, PPV, NPV, and diagnostic accuracy of 96.9%, 85.7%, 88.6%, 96.0%, and 91.7%, respectively.

CONCLUSIONS

SWE using established cut-off values shows good diagnostic performance for a more definitive characterisation of TIRADS 3 and 4 nodules. The lower SWE cut-off obtained in our study differs significantly from that obtained in other studies ($p<0.05$) and shows a superior sensitivity, NPV, and diagnostic accuracy to the previous values. The authors propose that a SWE cut-off value of 74 kPa should be used in future studies, in view of patients' safety towards avoiding repetitive biopsies. ■

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Occupational and Psychological Impact of the COVID-19 Pandemic on Radiographers in Ireland in 2020

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Disclosure: Ms Creedon received waived registration to ECR 2021. The other authors have declared no conflicts of interest.

Keywords: Burnout, coronavirus disease (COVID-19), infection control, personal protective equipment, radiographers.

Citation: EMJ Radiol. 2021;2[1]:38-39. Abstract Review No. AR8.

BACKGROUND AND AIM

Coronavirus disease (COVID-19) has spread rapidly worldwide, with health services adapting to limit the potential spread and to manage the potential consequences of the novel virus on populations. Healthcare workers have had to increase infection control procedures and alter work practices to safeguard both patients and staff, while radiographers are among the first-line health professionals to come into contact with suspected positive and confirmed positive patients.[1] Each imaging examination requires direct patient contact and increases the radiographer's potential exposure to the virus.

This research established the early response of radiographers in Ireland to the COVID-19 pandemic. This examined personal protective equipment availabilities, inadvertent exposures to COVID-19, changes to workloads and infection control practices, and radiographers' mental health concerns, among other areas of interest.

METHODS

The occupational and psychological consequences on radiographers were established through means of a two-stage questionnaire distributed 6 weeks apart. The questionnaires collated radiographers' experiences during the initial COVID-19 response in Ireland (March 2020) with those during the ending of initial emergency measures in Ireland (May 2020). Results were analysed using descriptive statistics and thematic analysis.

RESULTS

From the questionnaires, 646 responses were received, corresponding to 16% of radiographers in Ireland,[2] with all six Irish health regions represented. The majority of radiographers (77%) reported having adequate personal protective equipment when needed; however, by May 2020 almost one-half (45%) were inadvertently exposed to patients positive for COVID-19. COVID-19 exposure was largely attributed to poor communication and testing and only 8% of those who had been inadvertently exposed were subsequently tested for COVID-19. A vast majority (93%) of radiographers expressed confidence in their infection control practices, though 56% reported difficulty in keeping informed on changing protocols. Anxiety levels related to the COVID-19 crisis showed a substantial decline throughout the 6-week period, though extreme anxiety and distress were noted in responses from both surveys. Reports of extreme anxiety reduced from 22% in March 2020 to 5% in May 2020. Several radiographers (40%) self-reported burnout, with 30% considering changing career or taking early retirement since the onset of the pandemic. Listed causes of anxiety included poor communication, social discomfort experienced by partners, childcare concerns, and the infection risk from colleagues. Many radiographers praised the 'pod system' (team-working based on shift patterns). Up to 30% of radiographers felt more valued as a team member since the onset of the pandemic, though many radiographers felt under-valued and under-appreciated in the workplace.

CONCLUSION

Clear communication regarding changing protocols and patients' infectious status is essential to safeguard healthcare workers and to avoid inducing unnecessary anxiety and distress. Attention must be paid to burnout and to radiographer mental health to avoid long-term negative consequences of the COVID-19 pandemic on radiographers and radiography services. ■

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Interviews

We spoke with the European Society of Radiology (ESR) President and four ESR Scientific Subcommittee Chairpeople about their respective areas of expertise and what the future of radiology holds.

Featuring: Prof Dr Michael Fuchsjäger, Dr Elizabeth Loney, Dr Philip Robinson, Prof Apostolos Karantanas and Prof Olivera Nikolic.

Prof Dr Michael Fuchsjäger

President - European Society of Radiology (ESR)
Medical University Graz, Graz, Austria

Q1

What were your proudest achievements during your term as ESR President?

My main focus in the past year was to establish the European Congress of Radiology (ECR) as an online event that lived up to the quality and charm of its onsite equivalent, which posed quite a challenge but also offered the possibility of creating new ideas in terms of novel interactive concepts for online education and scientific exchange.

The centrepiece of every congress is its scientific programme and together with the ESR team we managed to offer a largely extended programme, including early morning and late-night sessions to make the live parts of the programme attractive to participants from all time zones.

It was also my wish to give back to the numerous abstract submitters who have always been the cornerstone of every ECR, and therefore we introduced a new format where submitters present the best rated abstracts during the main programme.

I was particularly excited to see the 'In Focus' programme being held at the congress this year. With a focus on the wellbeing of healthcare professionals, this programme was extremely timely and very important in light of the pandemic.

The ESR as a whole has adapted swiftly and ably to the new conditions and continues to serve its members and imaging professionals at large during these trying times. It was very important to me to see our support programmes 'Invest in the Youth' and 'Shape your Skills' continue, which enabled young professionals to participate in ECR for free.

Together with our colleagues from the European Board of Radiology (EBR) we were also able to establish an online version of the European Diploma in Radiology exam, which was very well received by candidates as it offered candidates from all around the world the opportunity to sit the examination even during the pandemic.

Q2 This year's ECR featured the Pop-Up World Tour for the first time. What inspired this addition to the programme, and how did it impact international collaboration in the field?

What we have missed most about our onsite meeting is the chance to meet our colleagues and partners from all around to world and the exchanges that spring from that. So, we wanted to offer the possibility for our closest institutional and industry partners to join us for ECR 2021 and to present themselves from all around the world. The Pop-Up World Tour included broadcasts from 20 cities and was a part of Channel N° 1, which acted as a central fixed point, around which all other congress events ultimately revolved.

I think this concept also demonstrated one of the greatest benefits of online meetings: there are no limits to international co-operation as everyone is just a click away.

Q3 One focus of this year's congress was physical and mental wellbeing. What impact has the coronavirus disease (COVID-19) pandemic had on the wellbeing of healthcare professionals in radiology?

For many, the pandemic has had a negative impact on their mental health, and this is particularly true of those working in healthcare. Healthcare professionals at large throughout the world have been subjected to enormous stress and extreme workloads, as well as making sacrifices and putting their own safety at risk to help those who have been afflicted by COVID-19. I felt that it was only right to make the wellbeing of us all a primary theme of this year's congress. Events such as ECR help unite us and remind us that we are not alone in our struggles, but are in fact working together to support each other. I believe that our In Focus programme in particular provided useful and practical advice for those who have been negatively affected by the pandemic in their professional duties.

"With a focus on the wellbeing of healthcare professional, this programme is timely and important in light of the pandemic."

Q4

The ESR recently published an article detailing the results of a patient survey of value in relation to radiology. What is value-based radiology, and what were the key takeaways from the survey?

Value-based healthcare (VBHC) is a concept seeking to place quality, rather than quantity, at the centre of healthcare decision-making to simultaneously reduce costs and improve health outcomes. It is an attempt to provide a different perspective and relocate patients at the centre of healthcare. The notion of including patients' perspectives has long been integral to the ESR's Value-Based Radiology Subcommittee: the ESR was a pioneer amongst medical scientific societies in creating a Patient Advisory Group (ESR-PAG) within the society structure.

To date, radiology's place in the value chain has remained, to a large extent, overlooked: radiology is either omitted from the value chain, or included only as a cost. But swift and accurate diagnosis is crucial in determining the ability to meet patients' needs successfully. In the future, planning and resource allocation will almost inevitably depend on value-based metrics, so it is of the upmost importance to make sure that radiology's contribution to achieving optimum value is recognised. For this reason, the recent patient survey is vital to our understanding of how patients perceive the value of radiology and how that value to patients may be maximised.

I will just very briefly summarise the key take away points and strongly recommend reading the full article.[1] It was shown clearly that patients are currently unfamiliar with VBHC and value-based radiology concepts, while being generally satisfied with radiology services. The patients' conception of value is foremost based on appropriately performed examinations and correct diagnoses. The survey shows significantly that insufficient communication is a main cause for patients' dissatisfaction, while simple measures could have a significant impact in improving communication and patient satisfaction.

> *"It cannot be denied that AI will have and already is having a major impact on the field of radiology and will significantly change work flows and the future roles of radiologists."*

Q5

Artificial intelligence (AI) is an increasingly prevalent technology in medicine, especially in the field of radiology. How do you see AI being integrated into the field?

It cannot be denied that AI will have and already is having a major impact on the field of radiology and will significantly change work flows and the future roles of radiologists. There are tasks that in the future will be more quickly and more effectively handled by software. But this only makes the role of the radiologist more complex, allowing us to focus on different aspects whilst also creating new responsibilities.

In my opinion, it all comes down to the education and training of future radiologists as those are the ones who will use those tools and will work in an even more technically driven environment.

As stated in the ESR white paper on AI, the implementation of AI in radiology requires that trainees learn how to best integrate AI in radiological practice, and therefore a specific AI and informatics module should be included in the future radiology training curricula. Furthermore, leadership should be taken in educating policymakers and payers about radiology, AI, their integration and the associated pitfalls.

Q6

Are there any current challenges in radiology, and how they can be potentially overcome?

Radiology is a field that is rapidly developing, and this comes with challenges and opportunities in various areas of the field.

AI is boosting innovations and poses a great potential to radiology, which we have to fully leverage while at the same time trying our best to ensure the highest standards for clinical validation for AI applications. Radiology is at the forefront of AI integration and I would like to see the discipline remain in the driving seat of innovation in healthcare.

An ongoing challenge, not exclusive to radiology, is finding ways to attract young professionals to our discipline and ensuring that future radiologists have the right skill set to work in an environment that is more and more digital and driven by technological developments. Also, in the aspect of education, AI is offering great potential.

The diagnostic pathway can be jointly improved by driving forward the field of integrated diagnostics, with radiology, pathology, and laboratory medicine having a substantial overlap in their mission and therefore a great potential.

We have to sharpen the public conception of the value of radiology and continue to demonstrate that in the frame of wider public health discourse. Studies to quantify the value of radiology in this context should be our focus.

It is among the ESR's top priorities to encourage research activities and to promote better integration of imaging studies in clinical trials alongside advocating for European research funds for our field.

Turf battles are neither a new thing nor do they only affect radiology, they are common to other medical disciplines as well, but still, they pose the biggest challenge. Outside specialties help themselves to procedures reserved for radiologists and this is weakening radiology as a discipline. This makes it even more important that radiologists stand together and focus on their strengths but also analyse the weaknesses of the discipline. Turf battles, coming from within or without, can only weaken us as a discipline. ■

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Dr Elizabeth Loney

ECR 2021 Scientific Subcommittee Chairperson for Head and Neck
Associate Medical Director and Consultant Radiologist, Calderdale and Huddersfield NHS Foundation Trust, Huddersfield, UK

Q1 With 16 years of experience as a consultant head and neck radiologist in the UK, what initially sparked your interest to pursue a career in this field?

When I qualified from medical school, I wanted to be an ear, nose, and throat (ENT) surgeon. There was no dedicated radiology training on my course as an undergraduate and the subject wasn't on my radar. After 5 years as a surgical trainee and lots of exams, I was frustrated with the extremely long hours, and I rarely saw my young son. My friend from medical school, Dr Elizabeth Dick (who ironically is now the President of European Society of Emergency Radiology [ESER] and the ECR subcommittee chair!) said over coffee one day: "What about radiology?" She was entering a registrar training programme and said how great a subject it was, with a far better work–life balance. I looked into it and thought, "This is fantastic; I can still work in the area I love (head and neck), the specialty is rapidly developing, and I get to see my family." I've never regretted my decision to change and believe that my experience in ENT surgery has made me a better radiologist as I understand what the surgeon wants to know from a radiology report.

Q2 What was the most important lesson you learnt from your previous role as the President of the British Society of Head and Neck Imaging (BSHNI)?

Being President of the BSHNI was a great honour and privilege. Society members entrusted me to lead and develop a really special organisation with a family feel. My mantra has always been 'inclusive, not exclusive', and I believe I brought that to the role. If we want to raise reporting standards and encourage people into the speciality we have to teach and support the many, not the few. Being President is not about pushing your own agenda, but listening to others, collaborating, and doing the right thing for the society. I learnt to trust and delegate to a greater extent than before. It is not possible to do everything yourself, which is why you have a committee, and I was fortunate to work with some amazing people. Together, and with the wonderful European Society of Head and Neck Radiology (ESHNR) team, we delivered some excellent, well-received events.

Q3 Leadership skills are an essential part of strategically shaping scientific advancement. How do you inspire the novice radiologists who look up to you for guidance?

Everyone is a leader, although most don't think of themselves in that way. You might be training students, managing a small team, or in charge of a large organisation, the skills are the same. The biggest difference is, the higher up the ladder you get, the less you know about the areas you cover. It's not possible to be an expert in everything. As radiologists we are used to knowing a lot about what we do. As a leader we must trust others to be the expert, and look at the bigger picture.

Lead by example, don't ask others to do what you would not do yourself. Get involved and don't stand on the side-lines, shouting. Too many people complain about things, but when asked to help make changes, they step back. Don't be that person.

Take people with you; encourage discussion and collaboration. Explain what you are doing and why. Share the credit when things go well and take the blame when they don't. Learn from your mistakes and don't be afraid to admit to them.

Always be kind. To your colleagues, other healthcare professionals, and yourself. On numerous occasions something good has happened to me as a result of a small kindness I may have forgotten, sometimes years before. If you are reliable, hardworking, and honest, good things will come to you. I think someone once said: "People will forget what you do and say, but not how you made them feel." Wise words indeed.

Q4 You delivered a presentation on facial trauma imaging at the 2021 ECR. What was the main take away message from this?

I think my main message is, "Always have a system." I present my personal approach to reporting facial trauma scans, the 'Loney 3-step System', I suppose! It's pretty simple, but deliberately so. Complex facial trauma can seem like a tricky subject but if you consider the mechanism and force of injury, other injuries the patient may have sustained and avoid 'satisfaction of search' by being systematic, it makes it easier.

Q5 You have recently been appointed as the Scientific Subcommittee Chairperson of Head and Neck. Could you please explain what this position entails and how it contributes to the success of the ECR?

I felt very honoured to be offered this position, and a great deal of responsibility to come up with an engaging, educational scientific programme for ECR 2021. About 18 months ago, I worked with my excellent subcommittee members to put forward ideas for sessions and suggested speakers, some of which were accepted by the Programme Planning Committee. Speakers were then invited, some to present live and others to be prerecorded. In addition, the subcommittee vetted and scored all abstracts submitted in the head and neck category in November 2020, personally, I read over 200! I am always inspired by the work and effort authors put into their submissions. During ECR itself, there are sessions to chair and moderate; the culmination of 18 months' work to maintain the high educational standards ECR is known for.

Q6 The radiology world has changed radically in the past decade, especially with technological advances such as AI imaging, what role do you think AI will play in the day-to-day of head and neck imaging?

There is no doubt that AI will play an ever-increasing role in radiology, but perhaps not so much in head and neck imaging in the short to medium term. Algorithms for reading chest radiographs and lung CT are already here but the head and neck is a complex anatomical area and plain films play a much smaller role. Trauma imaging in this region may be the first area to receive AI input as part of a major trauma body scan, and other areas such as temporal bone and sinus CT might lend themselves to computer algorithms, but complex oncological imaging seems likely to remain in the 'human reporter' domain for some time to come. Initially, double reporting might be useful as a quality assurance tool, however. Radiology has a history of embracing innovation and making it work for us. Long may that continue! ■

Dr Philip Robinson

ESR Scientific Subcommittee Chairperson, Musculoskeletal
Chapel Allerton Hospital, Leeds, UK

Q1 What led you to pursue a career in musculoskeletal (MSK) radiology?

The variety of MSK diseases and their differing imaging needs are some of the factors that initially got me interested in MSK radiology as a trainee. Unlike many other radiology subspecialities, MSK radiology potentially allows important diagnostic decisions to be made on all the modalities, requiring an understanding and expertise in assessing plain films, ultrasound, CT, and MRI. Intervention is also an important role for the MSK radiologist including biopsy, diagnostic, and many potential therapeutic interventions. This variety along with the many potential research and teaching interests has helped to maintain my day-to-day enthusiasm!

Q2 What do you hope to achieve in your role as ESR Scientific Subcommittee Chairperson for Musculoskeletal?

I hope as a committee we have developed a MSK programme that has a broad appeal to radiologists from across all of Europe and also for differing levels of experience. Sessions include state of the art applications and innovative techniques, as well as more basic comprehensive educational coverage. Despite the current pandemic we have tried to optimise our usual programme virtually, but also adapt to new technology and delivery opportunities, which will be highlighted by the ECR.

Q3 What are the current challenges in radiology, and how they can be potentially overcome?

Obviously normal practice for most radiologists has been interrupted by the pandemic but prior to this there were many challenges in terms of available resources, equality, and defining the role of imaging in patient pathways to be most effective. The pandemic has actually changed some of our practice for the better and going forward we should adopt this as normal practice, for example, virtual meetings, virtual clinics, and other areas that have reduced waste. In future we should embrace the advantages of AI and also devote research resources to define where MSK imaging sits best in a patient's clinical pathway.

Q4 What areas of MSK imaging do you believe merit wider attention?

AI and radiomics may develop to have a large role in clinical imaging, but we should equally look at using AI to enhance radiology and

clinician training and governance. I believe that we should increasingly not just look at the diagnostic accuracy for an imaging technique, but also its relevance or ability to significantly alter a patient's management. This year's ECR 2021 refresher course sessions include state of the art sessions on MSK CT (including dual energy and 4D applications) and MSK ultrasound (including tumours and elastography). The MSK scientific sessions also include many interesting presentations involving MSK radiomics.

Q5 What are some emerging developments that you believe could be practice changing in musculoskeletal radiology?

Quantitative MRI and radiomics should play a major role in MSK radiology going forward, contributing to routine and complex MSK disease management and prognosis, for example, rheumatological diseases or improved tumour characterisation. MSK ultrasound and newer applications such as elastography may allow improved dynamic assessment of tumours, muscles, and tendons.

Q6 Sports overuse injuries is one of your research interests. What is it about this area that interests you most?

This branch of MSK radiology again provides a variety of problems that need radiology expertise to help solve. The main modalities used for diagnosis are ultrasound and MRI helping to diagnose and offer prognostic information for muscle, tendon, joint, and bone injuries. Assessing elite athletes and using imaging to help determine the next steps in their treatment or rehabilitation is very rewarding as is working with the clinical team involved. ■

"The pandemic has actually changed some of our practice for the better and going forward we should adopt this as normal practice, for example, virtual meetings, virtual clinics, and other areas that have reduced waste. "

Prof Apostolos Karantanas

ESR Subspecialties and Allied Sciences Committee Chairperson
Department of Medical Imaging, University Hospital, Heraklion, Greece
Medical School-University of Crete, Heraklion, Greece
Biomedical Laboratory, Institute of Computer Science, FORTH, Heraklion, Greece

Q1 Upon completing medical school in Greece, you went straight into radiology training; had you always known radiology would be your specialty of choice?

No, actually not. At the end of my undergraduate studies, in the early 80s, there was a robust social and political movement in favour of the rights of the patients with psychiatric disorders. Young people, and this is the right thing to do, are sensitive to human rights and of course to patients' rights. This happened to me as well. Emotion took over realism and lifelong planning. However, when I was actively involved in psychiatry during the last year of my medical studies, I was disappointed in the results. Then, I had a short trip through focussing on ophthalmology, but soon I thought its scope was very narrow. I like the big picture. At this point, a good friend of mine, a young consultant in radiology, told me that radiology is the right path for those who like physics and experiments, and for those who are able to adapt to changes. There was neither PC nor internet at the time, of course. Soon, a cascade of events, including ultrasound, CT, interventional radiology, and informatics, starting within the first months of my training, showed me that I made the correct decision.

Q2 Having worked internationally in both the USA and the UK, could you tell us how radiology practice differs across the world and what you have learnt from your international experience?

In the USA, there is clearly as much infrastructure as required to practice updated radiology. There is also an orientation towards quality, safety, and excellence, which has been established over the decades among various scientific bodies. The USA is one of the countries most committed to setting high standards in clinical radiology globally, and to practice for the benefit of the patients. In the UK I really enjoyed, and learned a lot from, the clinical approach to patient problems. Funding is limited compared to the USA, but the existing technology is better used.

In my practice, as a musculoskeletal radiologist, I encourage my residents to meet and talk to the patients and I train them to get a complete history and make a basic clinical examination. Patients are capable of providing us with half the diagnosis.

Q3 You recently authored the paper 'Diabetes: a silent player in musculoskeletal interventional radiology response'. What should radiologists and those in allied sciences be vigilant for regarding this topic?

The paper was primarily authored by a young Portuguese radiologist, Sofia Dimitri-Pinheiro, who is conducting PhD under my supervision. We are doing a joined project, in two countries, Portugal and Greece, on the results of minimal invasive, ultrasound-guided treatment of adhesive capsulitis. Diabetes affects practically all organs and systems, with the musculoskeletal one being relatively spared up to now as regards literature reports. Recent research has shed light into the fact that diabetes has an important role in the development of several disorders, such as adhesive capsulitis of the glenohumeral joint, stenosing flexor tenosynovitis of the finger, and the very common calcific tendinopathy.

Q4 What do you hope to achieve in your role as ESR Subspecialties and Allied Sciences Committee (SASC) Chairperson?

I do not only hope but also plan to achieve several goals. The SASC has an important role, clearly defined by the ESR statuses. I have to act as a link between the ESR leadership and the presidents

> *“Technological innovations are so quick that the only skill we, and particularly the younger radiologists, should have at the highest possible level is ‘open eyes’”*

of all 15 ESR Subspecialty and Allied Sciences Societies as well as between the SASC and other relevant ESR bodies in order to facilitate co-operation and co-ordinate efforts. In addition, I advise the Executive Council on matters relevant to the subspecialties of radiology and allied disciplines and I assist the ECR Programme Planning Committee in the preparation of the educational and scientific programme.

Apart from the conventional duties, I have started an update of the hot topics of all subspecialty societies and I have invited them to nominate representative to the European Society of Medical Imaging Informatics (EuSOMII) because of the rapid development of AI in research, education, and clinical practice.

Last but not least, my main tasks will be: 1) the establishment of increased exposure of radiologists among clinicians and patients because of the invisibility that teleradiology has induced and 2) the establishment of curriculum and accreditation for forensic radiology, which is a rapidly expanding field that radiologists cannot ignore.

Q5 The ‘In Focus’ programme for ECR 2021 will focus on physical and mental wellbeing. Is this becoming a larger conversation in the medical profession?

Yes, indeed. If you visit the website of the National Health Service (NHS), UK, one of the main topics on the first page is ‘healthy living’, with tips and tools on the best choices about health and wellbeing. I totally agree with this perspective and a constant conversation on this issue goes on, among various medical professionals. This is also the case the other way around. Wellbeing, or good health status, is directly related to the public demand that physicians be fully aware of need for lifelong learning. Thus, one of the most important issues in this conversation is maintenance of certification and this is a matter of extensive discussion throughout the world.

Once a week, I offer a second opinion service for patients with musculoskeletal problems; these patients carry with them numerous imaging studies! In the vast majority of the visits, particularly during the pandemic which induces extra stress, the imaging findings do not match the subjective descriptions from the patients regarding their symptoms. In other words, the body looks healthy, but the subject feels and acts like a patient. Thus, healthy living is a wide umbrella which includes mental activity, body training, and psychological stability.

Q6 What are the key challenges that are faced by radiologists and those in allied sciences? And what approach would you recommend combatting such challenges?

Sherlock Holmes used to say on the obvious, yet for others obscure, events: “Elementary, my dear Watson.” Technological innovations are so quick that the only skill we, and particularly the younger radiologists, should have at the highest possible level is ‘open eyes’. In other words, ‘open mind’. Radiology now is part of an extended family. In our practice, we work very closely with medical physicists, mathematicians, informatics, advanced image analysis specialists, statisticians and more. Clinical radiologists provide the data and the ideas on specific clinical questions which have not yet been answered, and allied scientists provide the best possible analysis with excavation of the data and extraction of invisible, yet clinically useful information. We approach quickly the destination bearing the name ‘precision medicine’. ■

Prof Olivera Nikolic

ESR Scientific Subcommittee Chairperson for Genitourinary Imaging
University of Novi Sad, Faculty of Medicine, Novi Sad, Serbia
Centre of Radiology, Clinical Centre of Vojvodina, Novi Sad, Serbia

Q1 What initially sparked your interest in radiology, and why did you choose to specialise in genitourinary imaging?

During my medical studies I had just one semester of radiology and that was not enough to realise what radiology actually covers and how important it really is, having in mind that it is not only diagnostic, but a therapeutic discipline as well. Despite this, my internship gave me the opportunity to realise that radiology will be the most dynamic and significant medical discipline in the future, considering the fact that it is tightly connected to technological advances that I have always been impressed with. Having in mind all previously written, my ambition and curiosity made radiology straightforward choice for me and I have never regretted, neither would I change a thing if I had a chance for another try. During the course of my residency, I got a grant from Prof Gabriel Krestin to participate at European Society of Urogenital Radiology (ESUR) symposium in Rotterdam, the Netherlands, in 2001, which greatly influenced my further orientation towards genitourinary radiology. At that time, I became an ESUR member and for many years later I have been the only member from Serbia.

My mentor Prof Ilona Lukac, the pioneer of ultrasound imaging in the territory of ex-Yugoslavia and one of the few radiologists involved in scrotal imaging, also influenced my decision to choose genitourinary imaging, offering me a master's thesis in colour Doppler ultrasound of acute scrotum. The rest that happened was logical follow-up. I obtained a postgraduate scholarship in KU Leuven, Leuven, Belgium, and worked with Prof R. Oyen, finished my PhD thesis in the genitourinary field (dual-mentorship Prof R. Oyen and Prof S. Stojanovic from Novi Sad). In 2015, during ESUR symposium in Copenhagen, Denmark, I was among first three candidates who passed European Diploma in genitourinary radiology and in January 2021 became an ESUR fellow. Finally, after many years of enthusiastic work the dream came true.

Q2 Radiology has seen major developments in recent years as a result of technological development. What has been the biggest change in your day-to-day practice since you started in the field?

In the period when I started residency in diagnostic radiology, the equipment that we were working with and conditions at my radiology department were fairly modest. We were reporting looking at the films while typing on mechanical typing machines. There were no digital imaging archiving data bases like picture archiving and communication system (PACS) and hospital information system (HIS) as well as no workstations, all available nowadays making the diagnosis faster, more accurate and precise, and providing more comfortable environment for radiologist. On my road, I passed all the steps from mechanical typing machine to complete digital automatisation; however, that helped me to appreciate what we have now and it was very exciting to go through all these phases.

Q3 What are your goals as ESR Scientific Subcommittee Chairperson for Genitourinary Imaging?

First of all, my goal is to involve more young doctors to become members of ESUR, to bring ESUR their youthful perspective, enthusiasm, and fresh ideas. Secondly, I will work on the popularisation of the field of genitourinary radiology, since it plays a significant role in the reproductive function of every individual, and lately has been put aside compared with more

> *"PSMA PET/CT is an adequate replacement for conventional imaging, providing superior accuracy, to the combined findings of CT and bone scanning."*

popular disciplines such as neuroradiology and interventional radiology, which are more attractive to residents for their adrenaline nature. Furthermore, with all active ESUR members I will give my best to keep the scientific impact of ESUR, since the groups and members of our society have been very successful in publishing guidelines, reviews, and original articles in the previous years.

Q4

There is currently a lot of excitement around the use of PSMA-PET in prostate cancer staging. What are your thoughts on this imaging technique?

Conventional imaging is deficient at picking up early biochemical recurrence in males with low prostate specific antigen levels, such as those between 0.2 and 2.0 ng/mL. With PSMA PET/CT, it is possible to depict prostate bed abnormalities and locoregional lymph nodes, as well as those that have spread distantly, particularly bone metastases, even when prostate specific antigen levels are very low. PSMA PET/CT is an adequate replacement for conventional imaging, providing superior accuracy, to the combined findings of CT and bone scanning. This could lead to high impact of PSMA-PET in prostate cancer staging, but further studies will confirm its role in patient management and outcomes.

Q5

What are some innovations on the horizon in the field of radiology, specifically genitourinary imaging, that you believe to be particularly noteworthy?

Radiomics and radiogenomics for prostate and ovarian cancer, genitourinary molecular imaging, and functional renal MRI are the future perspectives in the field of genitourinary radiology.

Q6

What advice would you give to aspiring young radiology professionals at this time?

Young radiology professionals should always trust themselves, work hard, stay consistent, be patient, and believe in their dreams, and then results will come. ■

THE HISTORY OF CT

CELEBRATING **50 YEARS** SINCE THE FIRST CT SCAN

1967 Godfrey Hounsfield conceives idea of CT scanner

Hounsfield co-invents CT scanner alongside Allan Cormack at EMI (Electric and Music Industries) Labs

1970 CT scanner clinical trials commence

1971 **Hounsfield and James Ambrose perform first CT scan on brain of patient at the Atkinson Morley Hospital, Wimbledon, UK**

1972 Hounsfield and Ambrose publish the first CT test results, with great reaction from the medical community and public

Hounsfield and Ambrose start lecture tours around UK and USA

Second generation system developed, using small X-ray fan beam. Still solely used for head imaging.

INTERESTING FACT
EMI signed The Beatles in 1962 and used their sales from the 60s to fund the research that produced the CT scanner

1973 First clinical CT scanners installed in USA

1975 Third generation systems developed: ACTA and Delta scanners can scan whole body. Contain full X-ray fan beam covering complete field of view, with a rotating tube and detector array.

1976 Rapid development of CT with >15 companies involved in production. Scan times of 5 sec.

1979 Nobel Prize in Physiology or Medicine jointly awarded to Hounsfield and Cormack for the development of CT

1980 Number of CT scans performed annually reaches 3 million. Scan times of 3 sec.

INTERESTING FACT
Hounsfield adopted two mathematical theories, Radon transform (1917) and algebraic reconstruction technique (1937), to create the CT scanner

1989 Introduction of spiral (continuous) CT scanning allows acquisition of volume data without risk of mis- or double registration of anatomical details

1992 CT system with two detector rows developed

1998 Multi-slice CT systems produced; 4-row detector arrays at rotation time of 0.5 sec. Slice number becomes most important performance characteristic of CT scanner.

2004 Next generation MSCT introduced with 32, 40, or 64 slice-scanners

2005 Dual-source CT developed, increasing scan speed and double temporal resolution

68 million CT scans performed annually

2006 Dual-energy CT developed; two different X-ray energy spectra to improve material differentiation

2008 Functional analysis of the heart possible using four-chamber heart modelling and automatic segmentation for 3D cardiac CT volumes

INTERESTING FACT
First CT scan took 160 parallel readings through 180 angles, 1° apart, in ~5 min. Algebraic reconstruction techniques processed scans on a computer in 2.5 hours. This first generation system consisted of a single photomultiplier detector and operated on the Translate/Rotate principle.

2010 Tin filtration introduced within X-ray tube; used in unenhanced CT high contrast studies of sinus and chest

2016 First human study on abdominal imaging using contrast enhanced photon counting CT

2018 AI detects acute neurological occurrences (e.g., stroke) in CT within 1.2 sec, quicker than human radiologists

2019 **COVID-19 outbreak; chest CT used in diagnosis, detection of complications, and prognostication**

THE FUTURE OF CT

AI and deep learning will aid in noise and artifact reduction, and image reconstruction

3D printing from CT scan will help demonstrate anatomy and disease in clinical, research, and educational settings, aiding in surgical planning

Photon counting CT will provide high spatial resolution, less artifacts and noise, and intrinsic spectral sensitivity

Source: Ai et al., 2020; Alexander and Gunderman, 2010; Booij et al., 2020; European Commission, 2019; ISCT, 2016; Kohl, 2005; Kratochwil et al., 2019; Lell et al., 2015; The Nobel Prize, 1979; Otton et al., 2017; Pourmorteza et al., 2016; Siemens Healthcare, 2015

NUMBER OF CT SCANS PERFORMED PER 1,000 INHABITANTS

- **>275**: USA
- **225-250**: Iceland, Turkey
- **200-225**: Belgium, Greece, Luxembourg
- **175-200**: Austria, Denmark, France, Latvia
- **150-175**: Canada, Cyprus, Germany, Slovak Republic
- **125-150**: Estonia, Hungary, Israel
- **100-125**: Croatia, Czech Republic, Lithuania, Spain, Switzerland, U.K
- **75-100**: Italy, Malta, Netherlands, Poland, Slovenia
- **50-75**: Bulgaria, Finland, Serbia
- **25-50**: Liechtenstein, North Macedonia, Romania

Data collected between 2017–2019

Source: Eurostat, 2020; Statista, 2019

EVOLUTION OF THE CT SCAN

CT scanner evolution

A Axial scanning Single-detector CT
Multiple breath holds

B Spiral scanning Single-detector CT
2 breath holds

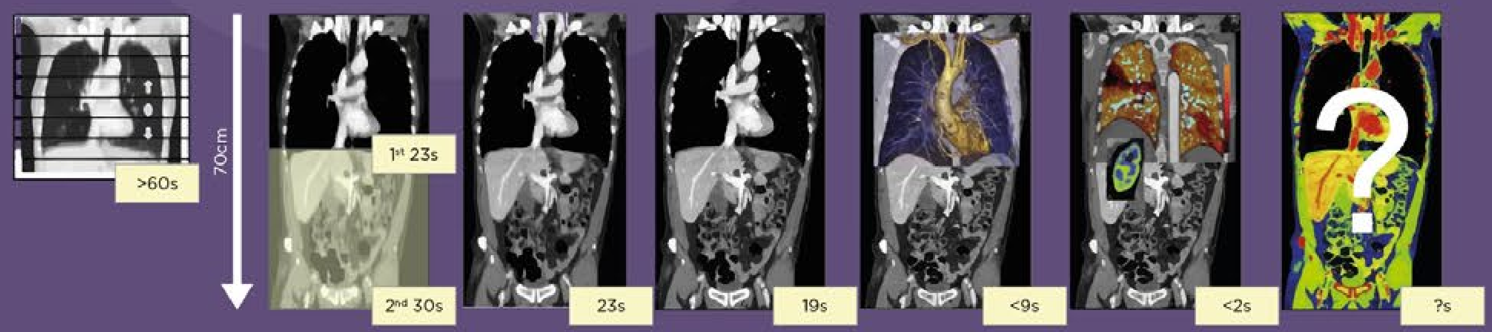
C Spiral scanning 4-multi-detector CT
1 breath hold (volume)
2 breath holds (detail)
CTA & postprocessing

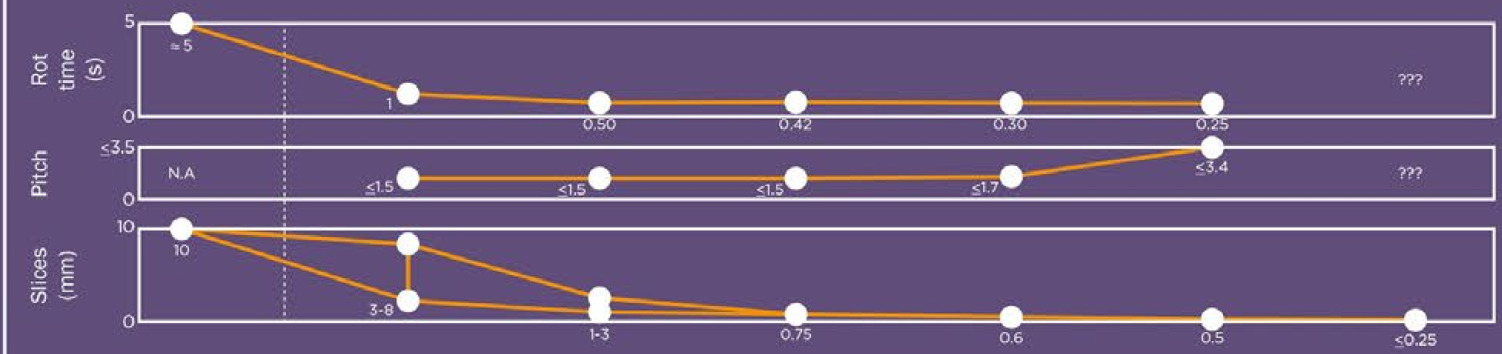
D Spiral scanning 16-multi-detector CT
1 breath hold (volume & detail)

E Spiral scanning ≥64-multi-detector CT
1 breath hold
Low kV imaging
Robust low HR cardiac CT

F Dual Source scanning ≥128-multi -detector CT
Free breathing
Dynamic imaging
High HR cardiac CT
Dual energy

G Future scanning Photon counting CT
Spectral imaging
AI-operation
AI-reconstruction
AI-analysis





Graphical representation of the evolution of third generation CT scanner technology from a single detector row design to expected future technology

Source: Booij et al., 2020

Artificial Intelligence in Radiology: An Exciting Future, but Ethically Complex

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Disclosure: The author has declared no conflicts of interest.

Received: 19.01.21

Accepted: 25.02.21

Keywords: Artificial intelligence (AI), machine learning, medical ethics, radiology, radiomics.

Citation: EMJ Radiol. 2021;2[1]:54-57.

BACKGROUND

"Let me start by saying a few things that seem obvious. I think if you work as a radiologist, you're like the coyote that's already over the edge of the cliff but hasn't yet looked down, so doesn't know there's no ground underneath him. People should stop training radiologists now. It's just completely obvious that within 5 years, deep learning is going to do better than radiologists, because it's going to be able to get a lot more experience. It might be 10 years, but we've got plenty of radiologists already. I said this at a hospital, and it didn't go down too well." [1]

With those words at a 2016 Creative Destruction Lab (CDL) seminar on 'Machine Learning and the Market for Intelligence' in Toronto, Canada, Dr Geoff Hinton provided radiologists the world over with an uncomfortable prediction of their obsolescence (and provided a piece of video that always gets attention from audiences during speeches about artificial intelligence [AI] and radiology). Dr Hinton, an English/Canadian cognitive psychologist and computer scientist, is, fittingly, the great-great-grandson of George Boole.

There have been many other such predictions in recent years, some from sources that know less about the subject than Dr Hinton. In October 2020, the Dutch Finance Minister, Wopke Hoekstra, said: "The work of the radiologist to a significant extent has become redundant, because [...] a machine can read the images better than humans who studied 10 years for it." He also commented that the same changes were occurring with supermarket checkout operators.[2]

Whatever one thinks about the value of such apocalyptic prognostications for the demise of the specialty (or about the lack of understanding of the work that underpins them), it is true that the advent of AI tools will change (indeed, is already changing) radiology practice. The era of spending long periods painstakingly perusing hundreds of images to identify tiny lung nodules on a chest CT will soon be past, and unlamented. AI will automate many tedious and imperfect aspects of radiologists' work and allow for the focus of more time and effort on higher-level cognitive tasks (such as deciding which of the many lung nodules identified by the AI tool are significant and what they mean) and collaborative input into diagnosis and management of patients, the components of radiologists' jobs that many glib commentators do not recognise or understand.

CAN WE DEVELOP ARTIFICIAL INTELLIGENCE ETHICALLY?

So, can we assume that AI in radiology will be a boon to radiologists, to patients, and to society as a whole? That depends on who develops and integrates it, how they do it, and their motivations.

AI developments in all disciplines are led by innovative, intelligent, and dedicated researchers or software developers. These people need support and encouragement. They also need practical financial resources and these are frequently supplied by large data companies, directly or indirectly. The rapid movement of 'big tech' players into healthcare AI indicates the importance they attach to these developments and, not incidentally, the monetisable value they foresee arising from access to and use of healthcare data. Developing AI tools that perform accurately and effectively requires access to large amounts of verified 'ground truth' data, which can be used to train and validate algorithms. In radiology this usually involves large numbers of labelled imaging studies, upon which the machine learning algorithm practises and hones its functions. Obtaining the necessary imaging data and labelling its contents can be a very resource-intensive task; the huge resources of big data companies can be a perfect match for this need. However, the means by which the data are obtained, manipulated, and used must be controlled to avoid inadvertent or deliberate ethical missteps. Under the provisions of the General Data Protection Regulation, all European Union (EU) citizens own and control their own sensitive, personal, and identifiable data. If patients' imaging data are to be made available to AI developers, patients' privacy and data ownership rights must be protected, their consent to use of their data must be solicited and secured, and they must agree to any possible financial ramifications of their information being used to develop potentially profitable outputs. They also need to be sure that their personal information is secure (or ideally irreversibly removed from the data) and will not be used by data companies to target them in ways that have nothing to do with the stated use for which they have consented.

Moving beyond the issues of access to and anonymisation of imaging data, another ethical issue that arises in AI in radiology is data bias. This is usually inadvertent, arising from an algorithm having been trained on data that doesn't accurately represent the population on which the tool is ultimately deployed, whether because of under- or over-representation of particular population subsets in training data or fundamental differences between populations. Examples abound of AI tools performing outstandingly in training but failing when applied to populations with different demographics or characteristics.[3] Frequently, these difficulties cannot be identified in advance but their possibility should always be considered and anticipated when developing AI programmes.

SHOULD ARTIFICIAL INTELLIGENCE BE TRANSPARENT AND UNDERSTANDABLE?

The very nature of machine learning makes it difficult, if not impossible, for humans to follow and understand every step that takes place during the process whereby an AI algorithm arrives at an outcome (i.e., a 'decision'). This has been referred to as the 'black box' situation, whereby inputs are provided to the algorithm, an output is delivered, but we cannot follow how that output was arrived at. Interpretability, explainability, and transparency seem like attractive attributes for an AI algorithm if its developers want to engender public trust, representing, respectively, the ability to understand the workings of the AI model, to explain in understandable terms what happens when the model makes a decision, and the capability of an outside observer to visualise and understand what happens within the model. Unfortunately, these are not necessarily always viable or desirable goals. If we can follow and understand every step of an AI process, we surrender some of the potential benefits of machine learning, including the capacity of the algorithm to achieve goals that are beyond the conscious mind. Furthermore, the more transparent an AI model is, the more subject it is to malicious attack and the less secure is its intellectual property, potentially reducing its commercial value to developers. There are ethical trade-offs inherent in developing and marketing useful AI products, balancing the need for understanding of the people on whom the product will ultimately be used, against the advantages of harnessing computing power to augment human capability.

Public acceptance of the use of AI in medical care should not be taken for granted. Most would not be comfortable to accept without question that decision-making about their healthcare should be devolved to algorithms, without human oversight. Public knowledge of the role AI may play in future life is, as yet, underdeveloped. Sixty-five percent of American adults have been shown to be uncomfortable about delegating the task of making a medical diagnosis to a computer with AI.[4] When asked about autonomous vehicles (AV; self-driving cars), in general, the public approve of AV that would sacrifice passengers for the greater good if faced with the choice of either running over pedestrians or sacrificing the occupants, and would like others to buy them. However, most people would themselves prefer to travel in AV that protect passengers at all costs.[5] This level of inconsistency augurs poorly for public understanding and acceptance of AI in healthcare.

ETHICAL DANGERS IN ARTIFICIAL INTELLIGENCE

At a practice level, AI tools offer potential for misuse. It is not difficult to imagine a healthcare provider adapting an algorithm to drive medical decisions which will increase utilisation and profit, rather than be solely based on patient welfare. Equally, better-off patient groups could derive advantages over other subsets of the population from AI resources, which they can afford to access (the term 'liberal eugenics' has been used to describe this scenario). To some extent, these dangers also exist in conventional healthcare. Nonetheless, we should guard against increasing the potential for their occurrence.

Other practice-based ethical dangers of AI also exist. If something goes wrong after AI use in medicine, who is liable? Is it the doctor who used the tool, the institution that bought it, or the developer who brought it to market? Doctors' involvement in AI model development is desirable and beneficial; after all, we understand best how these tools may be applied in patient care. But this involvement opens up the possibility of decisions about which AI tools to use, and how to use them, being exploited for personal commercial gain.

AI is, at heart, a mathematical function. As such, it can perform very well in classification tasks. It's less well-suited to more abstract concepts, such as determination of fairness, equality, and context. Writing code to embed the ability to weigh up the consequences of a decision or management recommendation for a patient or a patient's family, with all the associated calculations and choices that can depend on very individual circumstances, is difficult. Simultaneously ensuring that AI-supported decision-making always follows ethical principles adds another layer of complexity.

CONCLUSION

This paper attempts to outline some, but by no means all, of the ethical issues that arise when AI algorithms are in development and use in clinical practice. None of these issues is insoluble. Equally, none of them is simple or easy to resolve. Many of these potential problems can be lost sight of in the excitement of developing and implementing new tools, which have the potential to greatly benefit patients and to change medical practice for the better. We can best guard against deliberate or inadvertent unethical actions by educating all involved in AI about the moral risks that exist in the use of AI. To this end, in 2019, a joint group representing the European Society of Radiology (ESR), the American College of Radiology (ACR), the Radiological Society of North America (RSNA), the Canadian Association of Radiologists (CAR), the European Society of Medical Imaging Informatics (EuSoMII), the Society for Imaging Informatics in Medicine (SIIM), and the American Association of Physicists in Medicine (AAPM) published a comprehensive statement on the ethics of AI in radiology.[6,7] This statement tries to explain the issues in detail. We do not yet have all the solutions to these ethical considerations, but acknowledging and understanding the problem is the first, necessary step to ultimately get the implementation of AI in radiology right, using its power for the benefit of individual patients and society, without harm or bias.

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An Ultrasound Phantom for Stenosing Flexor Tenosynovitis

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Disclosure: The authors have declared no conflicts of interest.

Received: 09.10.20

Accepted: 10.02.21

Keywords: Medical education, musculoskeletal ultrasound (MSUS), stenosing flexor tenosynovitis, trigger finger, ultrasound simulation.

Citation: EMJ Radiol. 2021;2[1]:58-64.

INTRODUCTION

Stenosing flexor tenosynovitis, often referred to as a trigger finger or trigger digit, is among the most common causes of hand pain in adults and often presents as a painful clicking or locking of a finger or thumb with movement.[1] Trigger finger most often occurs in adults between the fourth and sixth decade of life and is more common in females than males.[2] It can also be seen in children, typically prior to 8 years of age.

In the absence of pathology, flexion of the digits occurs smoothly as the flexor tendon glides within a system of annular and cruciform pulley sheaths. The pulley system prevents separation of the flexor tendon from the bone. Chronic repetitive friction is thought to cause most cases of primary idiopathic trigger finger by leading to thickening of the pulley sheath.[1,3] The first annular (A1) pulley is most affected, and this is due to its receipt of the greatest degree of force during digital flexion.[4]

Trigger finger is considered a clinical diagnosis, but ultrasound assessment has been described as a useful adjunct in both diagnosis and treatment.[5] Treatment for a trigger finger depends on severity and duration of symptoms. Noninvasive options include a combination of nonsteroidal anti-inflammatory drugs, heat, ice, massage, and splinting.[2] If noninvasive treatment fails, a corticosteroid injection (CSI) of the tendon sheath is suggested prior to consideration of surgical release of the pulley (Figure 1A and 1B). A single CSI was shown to provide up to 10 years of relief in 56% of female patients who presented for the first time with a trigger finger.[6]

Typically, a landmark-based CSI is performed, but a prospective study showed that only 37% of patients received all the injection within the sheath and 17% received no medication within the sheath.[7] Ultrasound guidance has also been used and is considered the most accurate method.[8-10] The efficacy of ultrasound-guided A1 pulley CSI was evaluated in a prospective study of 50 consecutive trigger fingers from 24 patients.[7] The patients who received the ultrasound-guided CSI showed complete resolution in 94% of fingers at 6 months. There are no large, blinded, randomised studies comparing the efficacy of ultrasound-guided to landmark-based injections in trigger fingers; however, a smaller, unblinded, randomised trial showed no difference in efficacy between ultrasound-guided and landmark-based CSI of trigger fingers.[10]

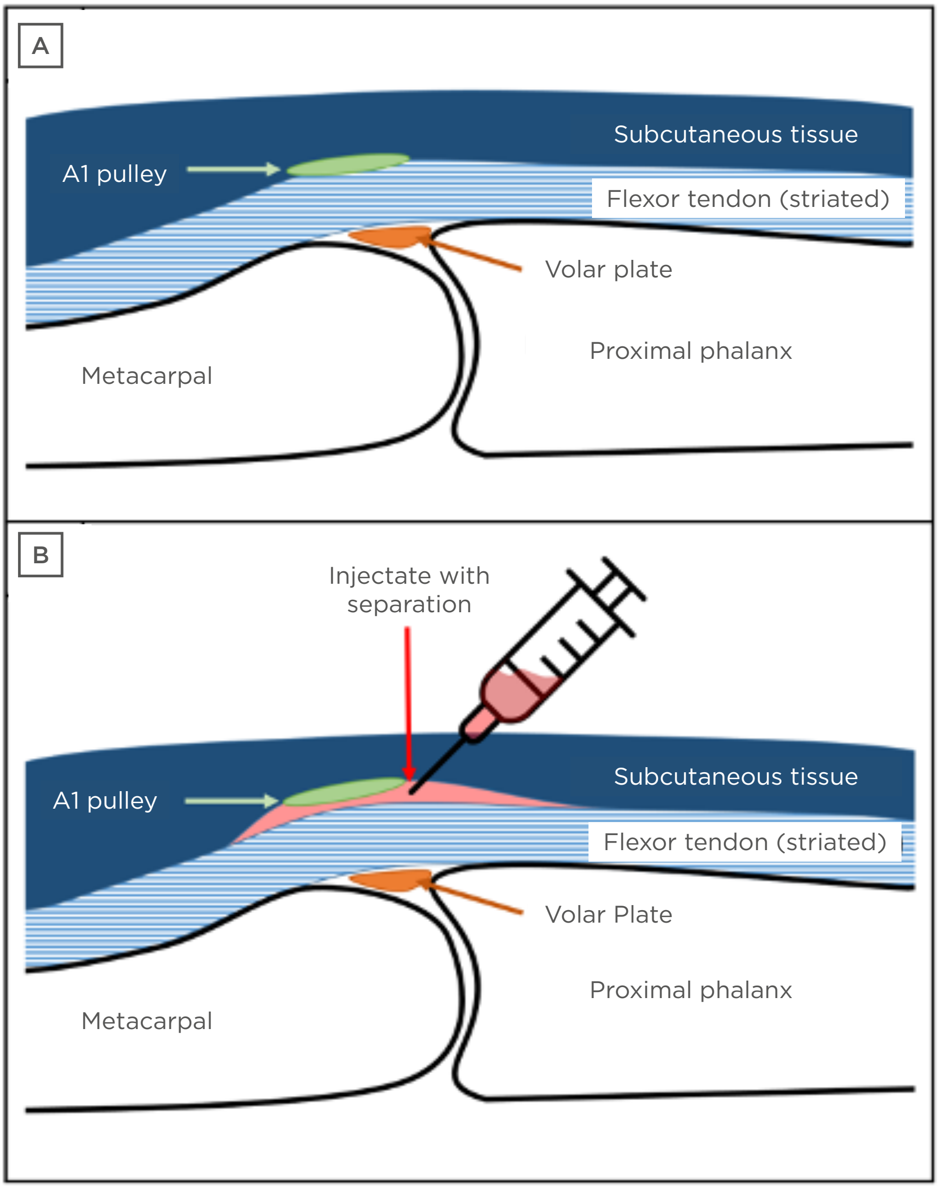

Figure 1: Schematic of the metacarpophalangeal joint with A) surrounding soft tissue structures and B) separation after the injection.

A1: first annular.

Ultrasound procedural phantoms have been developed to supplement education and allow for training prior to attempting a procedure on a patient.[11-13] Simulation trainers used within a standardised curriculum of procedural instruction have also been shown to significantly improve participants' medical knowledge and technical skills.[14] Commercial ultrasound training phantom models may be prohibitively expensive; however, low-cost homemade and three-dimensional (3D) printed models have more recently been developed.[12,15] The authors herein propose a 3D-printed anatomical finger model embedded in ballistic gelatin as a low-cost ultrasound training phantom for procedural guidance of trigger finger injection.

MATERIALS AND METHODS

The finger models were created using a computer-aided design software (Autodesk Fusion 360 Student Edition, Autodesk, San Rafael, California, USA), a Creality Ender 3 Pro Fused Deposition Modeling (FDM) 3D printer (Creality, Shenzhen, China), ballistic gelatin, and household materials.

1. The distal, middle, proximal phalanx, and metacarpal bones were obtained through the database Thingiverse. The models were initially in the 'OBJ' format, which had to be converted to a solid model using the 'Mesh to BRep' command in Fusion 360 to allow the models to be edited prior to printing. The various models of the bones were then arranged and scaled appropriately in Fusion 360.

2. The bone model was scaled to the appropriate size within Fusion 360 according to a standard human finger.

3. After scaling, the hand was reduced to contain only the proximal phalanx and a portion of the distal metacarpal using the 'Cut' command in Fusion 360. The finger bone model was placed into a scaffold piece (Figure 2A), which allowed proper orientation for scanning and provided a method for attaching the tendon to the model via small holes.

4. A rectangular box model was created to allow for pouring of ballistic gelatin around the model (Figure 2B).

5. The scaffold and mould were modelled with features to create the proper thickness of the finger model (Figure 2C). The scaffold itself contained a ridge that indicated the intended height of the tendon, while the top of the mould indicated the thickness of the subcutaneous tissue in the average finger.

6. The mould and finger models were printed using the Creality Ender 3 Pro FDM printer using a 0.16 mm layer height with 0% infill (hollow) and 2 perimeters using SUNLU PLA Plus 1.75 mm 3D printer filament (Sunlu, Zhuhai City, China) with stock printer settings. Both models were sliced using PrusaSlicer to generate the file, or 'gcode', that allowed the 3D printer to print the model. These settings were chosen after various attempts with other infill settings in combination with previous literature recommendations.[16]

7. Flexor digitorum tendon models were assembled by wrapping Stren Magnathin Monofilament fishing line (Pure Fishing, Columbia, South Carolina, USA) around the finger bone model until a thickness of approximately 5 mm was achieved (Figure 2C). The monofilament fishing line was made of nylon, had a 4 lb test strength, and a 0.17 mm diameter. The line was tied into the model with holes for tight wrapping. The bundled strands were used to resemble the striated appearance of the flexor digitorum profundus and superficialis tendons (Figure 2D).

8. Ballistic gelatin was prepared as previously described[17] with the following modifications: 1.5 g of gold mica powder was added to the dissolved ballistic gelatin prior to pouring to increase echogenicity.

9. The 3D-printed model was then attached to the tendon model. A thin layer of ballistic gelatin without mica powder was added onto the tendon above the metacarpophalangeal joint to resemble the A1 pulley.

10. The finger model was placed into the 3D-printed rectangular mould and liquefied ballistic gelatin was poured into the mould to a level just above the tendon, covering the entire tendon from all sides (Figure 2E).

11. A second mixture of gelatin was created and poured into a separate rectangular mould to a height of 0.6 cm to serve as the subcutaneous tissue for the model. This gelatin was prepared by mixing 1.5 g of modelling clay into 25 mL of ballistic gelatin.

12. Once cooled and solidified, the hyperechoic gelatin layer was added to the ventral surface of the 3D-printed finger model (Figure 2F). Heated ballistic gelatin was applied on the edges of the gelatin layer to seal the perimeter of the two gelatin layers in the model. This created a potential space between the two layers to serve as the reservoir for the injectate.

13. Ultrasound transmission gel was used as the injectate due to its greater viscosity compared to water.

14. A 22 Gauge needle with a length of 1 inch was used for the simulated procedure.

Ultrasound images of the phantom were captured with a GE M12L linear transducer on a GE Venue 40 system (GE Healthcare, Chicago, Illinois, USA). The ultrasound machine was set to the 'Musculoskeletal (MSK)' preset and scans of the phantom were captured during an in-plane, long-axis injection.

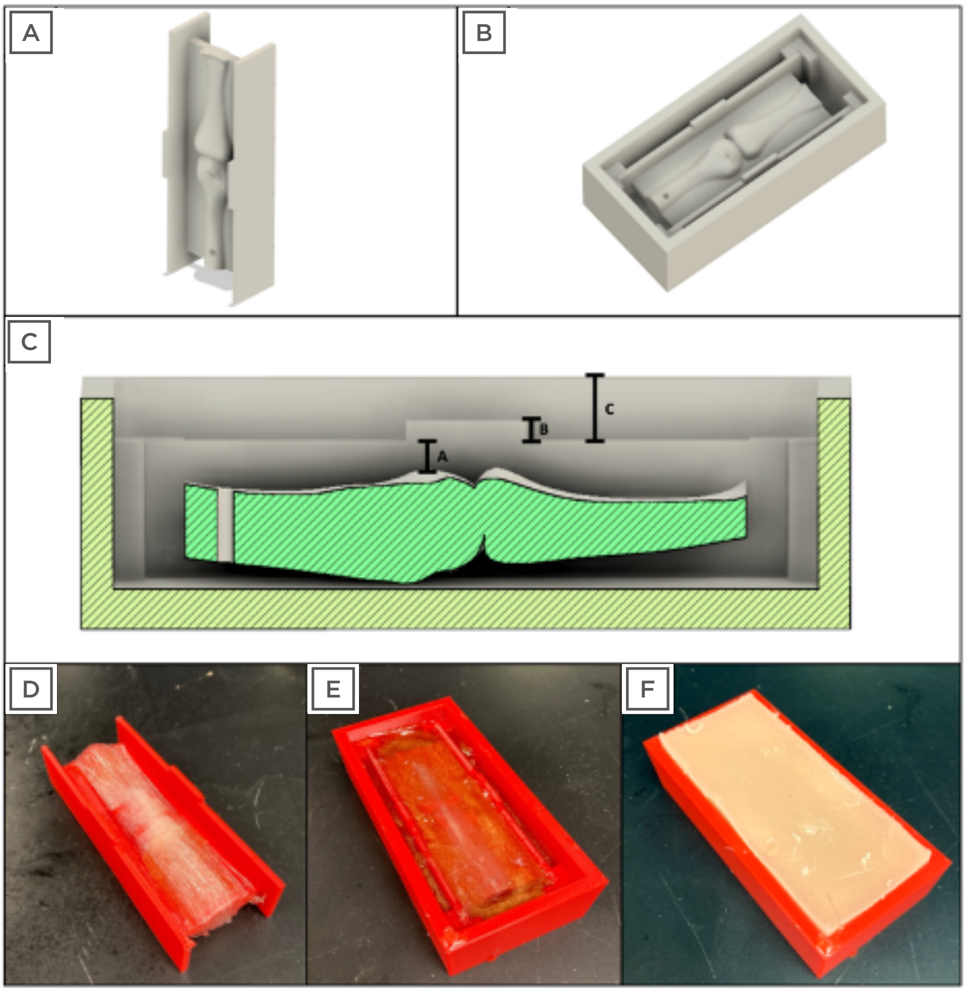

Figure 2: Computer-aided design and 3D-printed model of ultrasound phantom.

A) Render of the finger model placed into the scaffold prior to adding the tendon; **B)** render of the scaffold seated inside of the rectangular mould; **C)** cross-section of the finger model with key thicknesses indicated: A: thickness of the tendon between the bone and the subcutaneous tissue; B: thickness of and location of injectate; C: thickness of subcutaneous tissue; **D)** 3D-printed finger model with tendon made of fishing line; **E)** 3D-printed finger model after pouring of initial ballistic gelatin; **F)** layer of ballistic gelatin and modelling clay mixture layered on top of the initial 3D-printed finger model.

3D: three dimensional.

RESULTS

The 3D-printed finger phantom appeared anatomically and sonographically similar to images observed in a human finger both pre- and post-injection (Figure 3).

The pre-injection images had the following anatomical landmarks: metacarpal, proximal phalanx, volar plate, flexor digitorum complex (which included the tendons of flexor digitorum superficialis and flexor digitorum profundus), subcutaneous tissue, and the A1 pulley. Additionally, the depth of each anatomical landmark was similar across all images (Figure 3E and 3F). The fishing line was able to create recognisable striations similar to the fibrillations in a human tendon. Additionally, the A1 pulley was visible in the phantom model, although slightly more hyperechoic than seen in a human finger.

Injection and separation were achieved, which resulted in a sonographic image similar to that of a human finger (Figure 3E and 3F). The separation was evident (Figure 3D), which indicated a successful injection.

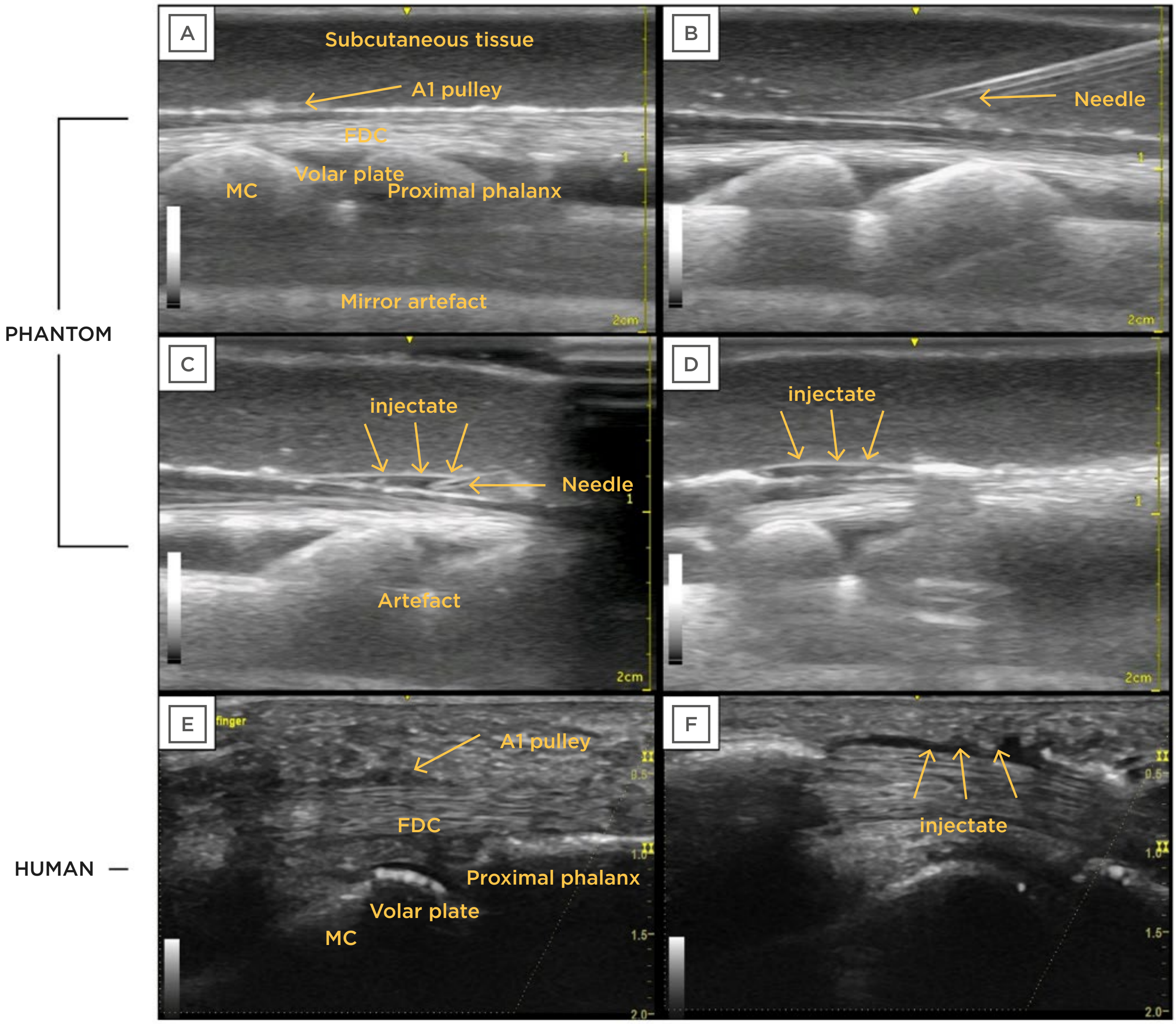

Figure 3: Pre- and post-injection ultrasound images of the 3D-printed phantom compared to a human finger, with all relevant anatomical features labelled.

A) Finger phantom with all relevant labels; **B)** needle approaching injection location; **C)** injection into location; **D)** phantom model post-injection with injectate and separation; **E)** human model pre-injection; **F)** human model post-injection with injectate and separation.

A1: first annular; FDC: flexor digitorum communis; MC: metacarpal.

DISCUSSION

The major strengths of the phantom were its sonographic similarity to a human finger, low cost, and relative ease of preparation.

For an ultrasound phantom to improve the skills of its trainees, it must mimic its human counterpart in its anatomy and echogenic appearance. By creating a finger model using computer-aided design software and 3D printing methods, the dimensions of the bony components were precise, with limited undesirable artifacts that could have been created using other construction methods.

Imaging of the metacarpophalangeal joint in long-axis showed soft tissue and bony landmarks sonographically similar to those in a human finger. The in-plane, long-axis injection technique was comparable to that often used in patients. The visual–spatial and tactile awareness required to perform the injection under ultrasound guidance was also similar between the human and phantom. The authors were unaware of any commercially available trigger finger models. The cost of the 3D-printed model presented in this study was less than $20 USD.

Many universities have 3D printers available for use, which provides an accessible means of production. Additionally, all software was open-source or free to use under educational licensing agreements. Because the only area of the phantom that could be punctured was the ballistic gelatin outer portion, the 3D-printed bones and soft tissue components remained intact. Repeated needle insertions and injections created faint needle tract tracings after several injections, and the use of a hair dryer resolved the needle tracts. The PLA-printed finger bones in this setting have a near-unlimited lifespan and can be reused indefinitely.

LIMITATIONS OF THE THREE-DIMENSIONAL-PRINTED FINGER PHANTOM

While this study showed that a sonographically similar finger phantom model can be created using 3D printing, the experiment did have some noteworthy limitations. The final model created in this study was not physically similar to a human finger as the model was rectangular in shape and embedded within a mould. The authors believe that the rectangular model can be altered in a way that more closely resembles a finger, but the ability to create a potential space within such a finger prevented physical similarity. Further, given the shape of the mould, out-of-plane or transverse injection techniques were not performed.

As this project was carried out in a medical school environment, the ultrasound transducer selection was limited to a linear 12 MHz transducer. Compact linear probes are often used for small-joint imaging and injections, and they typically have higher frequencies with improved near-field resolution. The overall sonographic appearance was unlikely to be affected by these differences, however.

As expected, the use of multiple materials created artefacts. The artefacts were likely reflections of the ultrasound waves between the hollow layers of the model. Scattering due to the mica powder was also noted. Ultrasound gel was used as the injectate due to the need for increased viscosity for tissue separation. Lower-viscosity fluids travelled back through the needle puncture site, which resulted in the fluid ejecting from the model. Fortunately, the ultrasound gel was anechoic and similar in sonographic appearance to a liquid injectate.

CONCLUSION

Ultrasound phantoms are a valuable training tool for both novices and experienced sonographers because of their nearly limitless versatility and, if home-made, low cost. The use of phantoms also supplements ultrasound education programmes. This manuscript describes a versatile and rather simple method for producing a low-cost, reusable finger phantom. Further studies are needed to validate the phantom model.

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Looking for a new job opportunity?

Giant Cell Arteritis: Navigating Beyond the Headache

EDITOR'S PICK

With the growth of innovative imaging techniques in the field of radiology, several procedures are now used in the diagnosis of vasculitis. In the Editor's Pick, Harkins and Conway explore the recent significant advancements that have been made in the diagnosis of giant cell arteritis. The authors walk through the currently available and recommended diagnostic techniques for both large vessel and cranial giant cell arteritis: temporal artery biopsy, colour Doppler ultrasound, PET scanning, CT, and MRI/magnetic resonance angiography. In addition to the different imaging pathways currently in use, the authors also discuss the unmet challenges in the diagnosis of systemic vasculitis.

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Disclosure: The authors have declared no conflicts of interest.

Received: 05.06.20

Accepted: 02.11.20

Keywords: Giant cell arteritis (GCA), temporal arteritis, temporal artery biopsy (TAB), temporal artery ultrasound, vasculitis.

Original citation: EMJ Radiol. 2021; DOI/10.33590/emjradiol/20-00146

Corrigendum: The article by Harkins and Conway et al. in an article of EMJ Radiology was originally published on 18.01.21. Since then a corrigendum has been made. The corrigendum can be seen here.

Abstract

Giant cell arteritis (GCA) is the most common systemic vasculitis. In the past two decades there have been significant advancements in our understanding of the pathophysiological mechanisms underlying the disease, and consequently the management of GCA is evolving. GCA is a medical emergency because when left untreated it can lead to devastating complications including irreversible visual loss. Thus, prompt diagnosis is imperative to ensure appropriate treatment and prevent ischaemic events. However, uncertainty remains over diagnostic pathways, including appropriate modalities and standardisation of findings. Temporal artery biopsy has been considered the gold standard diagnostic test but has significant limitations in terms of false negative results. In recent times, several new diagnostic modalities have been proposed in GCA including temporal artery ultrasound, CT angiography, magnetic resonance angiography, and PET. In this paper, the authors review the advantages and limitations of current diagnostic modalities in GCA.

INTRODUCTION

Giant cell arteritis (GCA) is an idiopathic granulomatous vasculitis involving medium and large calibre arteries.[1] It is the most common systemic vasculitis, with a female preponderance, and occurs almost exclusively in those >50 years of age.[2,3] It occurs mainly in Caucasian populations, with the highest incidence in those of Northern European descent.[4] With the worlds ageing population, the number of patients diagnosed with GCA by the year 2050 is predicted to be in excess of 3 million, of whom approximately 500,000 will be visually impaired.[5] The systemic nature of GCA was noted as far back as 1938 in a paper by Jennings;[6] however, the traditional description of GCA has focussed on cranial symptoms resulting in its misclassification as a 'headache disease.'[7] In the past two decades the importance of the overlapping GCA phenotype, including cranial GCA and large vessel GCA (LV-GCA), has been recognised.[4] Although advances in imaging modalities have raised awareness for the frequency of LV-GCA, there remains a paucity of data guiding the modality of choice in both diagnosis and disease activity assessment.

GCA remains a clinical diagnosis, supported by laboratory and imaging investigations. The most recent British Society for Rheumatology (BSR) guidelines highlighted the importance of clinical acumen in stratifying further investigation, emphasising the importance of pretest probability in guiding the diagnostic pathway.[8] A new-onset headache is the most common systemic symptom,[9] with jaw claudication being the most specific presenting symptom.[9-11]

Early and accurate diagnosis of GCA is imperative. Failure to accurately diagnose and expeditiously treat GCA may lead to devastating complications, including permanent visual loss, which occurs in 15–20% of patients.[12] Misdiagnosis, on the other hand, can lead to inappropriate glucocorticoid use and the toxicities associated with this.[13]

TEMPORAL ARTERY BIOPSY

Temporal artery biopsy (TAB) for histological analysis has traditionally been the gold standard for the diagnosis of GCA.[14,15] Typical histological features in GCA include granulomatous inflammation in all layers of the muscle wall, with a predominantly T-lymphocyte and macrophage-rich population localised between the media and adventitia.[7] Other, less frequently identified histological patterns include inflammation limited to the vasa vasorum, the adventitia, or inflammation targeting small periadventitial vessels with no muscular coat, which therefore spare the temporal artery (TA) itself.[16]

When present, multinucleated giant cells are usually localised in close proximity to a fragmented internal elastic lamina; the presence of neutrophils, eosinophils, and plasma cells are rare.[7] Although highly specific, it is not a perfect test as it is relatively invasive and has poor sensitivity, with false negatives reported in up to 61% of patients compared to a clinical diagnosis of GCA.[17] This can be partly attributed to the segmental nature of the vasculitic involvement by GCA with so called 'skip lesions'.[18] To account for this, the BSR recommends that all TAB specimens be at least 1 cm in length postfixation.[19] There is at least a 10% shrinkage rate of TA segment length reported after formalin fixation[20] and therefore, optimal TAB length should be at least 1.5 cm.[21]

To date, ultrasound-guided biopsy has failed to demonstrate improved sensitivity or yield of TAB,[22] and biopsy of the contralateral TA has been reported to only provide a modest improvement in diagnostic yield and so is not routinely recommended.[23] Furthermore, the administration of glucocorticoids may affect the sensitivity of TAB results. In the TABUL study, sensitivity fell from 48% to 33% when TAB was performed within 3 days of glucocorticoid commencement versus within 7 days of glucocorticoid commencement, respectively.[24] However, Maleszewski et al.[25] demonstrated histologic activity at 420 days post glucocorticoid initiation.

With increasing knowledge of the diverse phenotypic nature of GCA, and the understanding that the temporal arteries can be spared in up to 40% of cases of extracranial LV-GCA, coupled with the issues outlined above, there has been a transition to other diagnostic modalities to optimise diagnosis in GCA. The most recent European League Against Rheumatism (EULAR) consensus proposes the use of colour Doppler ultrasound (CDUS) in the first-line in patients with suspected large vessel vasculitis, in particular cranial GCA (cGCA), provided it is promptly available and the test is performed and interpreted by a trained, experienced specialist using the appropriate machine settings and protocols.[25] The BSR guidelines also recommend CDUS in the first instance, with the necessity of TAB being determined by clinical pretest probability.[8]

COLOUR DOPPLER ULTRASOUND

A growing body of literature over the past two decades have provided robust evidence for the routine use of CDUS in the diagnosis of GCA. It allows assessment of the whole length of the superficial temporal arteries, potentially overcoming the issue of skip lesions affecting histological results.[10] Furthermore, unlike TAB, which is limited to one anatomical region, CDUS can be used to evaluate accessible cranial and extracranial vessels, increasing the diagnostic yield for this systemic pathology.

When examining the TA in a suspected case of GCA, it is recommended that the complete length of the common superficial TA, with its frontal and parietal branches in transverse and longitudinal planes, be examined bilaterally.[26] In addition to this, studies have demonstrated that the axillary arteries (AX) are the most frequently involved extracranial vessels accessible by CDS, and that when affected the inflammation is often present bilaterally. Therefore, examining the AX and TA bilaterally can increase the diagnostic yield in GCA and is recommended in all cases.[27] Further arteries may be examined if the diagnosis remains unclear or if the clinical assessment of patient history and examination points to the involvement of other arterial territories, such as lower limb intermittent claudication and involvement of the femoral or popliteal arteries.

While promising efforts have been made recently to devise quantitative CDUS criteria for the diagnosis of GCA, they have thus far failed to be incorporated into guidelines or to gain momentum in clinical practice.[28,29] Instead, qualitative assessment measures for interpreting CDUS findings have continued to be used. A normal intima–media complex on TA ultrasound examination reveals a homogenous, hypoechoic, or anechoic structure delineated by two parallel hyperechoic margins.[30] Upon CDUS examination of an affected TA in GCA, the hallmark ‘halo sign’ is diagnostic, defined as a homogenous, mostly concentric, hypoechoic wall thickening, well delineated toward the luminal side, visible in both longitudinal and transverse planes (Figure 1).[13]

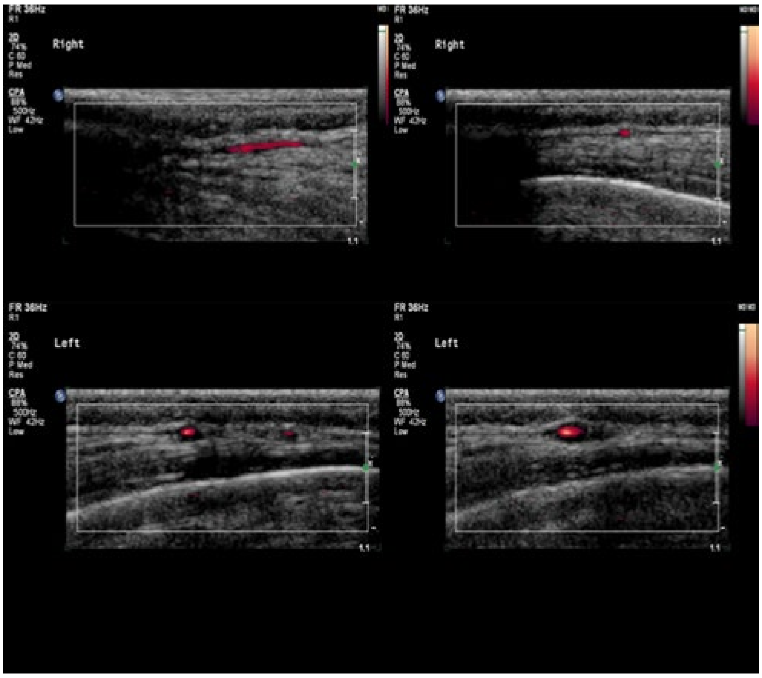

Figure 1: Colour Doppler ultrasound examination of a normal and an affected temporal artery in giant cell arteritis.

A unilateral halo sign has a sensitivity of 68% and a specificity of 91%, with this increasing to a specificity of 100% with the presence of bilateral halos.[31]

The thickened wall of a vasculitic artery remains persistently visible upon compression of the lumen with the ultrasound probe, giving rise to the so called 'compression sign'. This demonstrates excellent interobserver agreement, with a sensitivity of 75–79% and a specificity of 100% for the diagnosis of GCA.[32,33] The external validity of these more specialised tests requires further assessment. The presence of the halo and compression signs have been regarded by the OMERACT Large Vessel Vasculitis Ultrasound Working Group as the most important CDUS findings suggestive of vasculitis, and the presence of the halo sign is also specified as a minimum requirement for the diagnosis of GCA.[15] The presence of stenosis and occlusion were previously thought to aid the diagnosis of GCA; however, with advancements in the resolution of ultrasound equipment, these findings have been demonstrated to be neither sensitive nor specific.[12,34]

Compared to TAB, CDUS is a safe, well tolerated, noninvasive bedside procedure, that affords the advantage of almost instant results. Furthermore, versus all imaging modalities employed in the diagnosis of vasculitis, CDUS has the highest resolution (100 µm).[35]

Images and videos taken during CDUS examination can be stored and readers of these have been shown to achieve the same reliability as that of a pathologist evaluating a biopsy specimen.[9] However it is very much operator dependent and requires skilled sonographers with expertise in the area of temporal artery CDUS.[36] Similar to other diagnostic modalities, the sensitivity of CDUS in the diagnosis of GCA diminishes upon initiation of glucocorticoids.[37] The TABUL study demonstrated a significantly smaller halo size in those who had received >4 days of glucocorticoid therapy versus those who had received up to 4 days of glucocorticoid therapy.[9] It is thus imperative that CDUS be performed as close to the initiation of glucocorticoids as possible. This has led to the development of 'fast track clinics' in centres with expertise in the management of GCA, where patients are ideally seen within 24 hours of initial suspected GCA presentation.[22,38,39] They undergo a clinical assessment, including structured history and clinical examination, in addition to an ultrasound examination of the TA and AX by an experienced rheumatologist.

One of the main advantages of this clinic is its ability, in the majority of cases, to either exclude GCA, or provide a rapid and clear diagnosis of GCA and thus initiate prompt and appropriate specialised care. This reduces the exposure to harmful complications of unnecessary glucocorticoid treatment, but also has been shown to optimise patient outcomes in those with GCA. Two retrospective studies have demonstrated how, with the inauguration of fast track clinics, the rate of permanent vision loss fell dramatically from 37% to 9%[39] and from 19% to 2%.[40] The recent TABUL prospective multicentre cohort study assessing CDUS performance in a rigorously controlled setting reported a CDUS sensitivity of 54% and a specificity of 81% compared to physician diagnosis at 6 months.[19] Although superior to prior studies, it similarly focussed on a specialist centre with experienced operators; thus, it potentially fails to capture a real-world assessment of CDUS performance. The authors highlighted this in a recent study where they assessed the CDUS performance characteristics of TA in routine clinical practice with a heterogenous patient population with variable delays between symptom onset, treatment initiation, and diagnostic imaging.[40] They showed a CDUS sensitivity of TA of 52.8%, with a specificity of 71.8%. The sensitivity of testing significantly increased to 78.9% when TAB was used with CDUS of TA, with no change in specificity. Although more reflective of real-world performance, this study also used experienced operators of CDUS in the diagnosis of GCA and so arguably fails to represent the majority of centres, in which CDUS will be performed by radiologists whose skills are also required in multiple competing areas. Therefore, both these findings and those of TABUL stress that, whilst valuable in the diagnosis of GCA, CDUS should be used with caution and by those highly experienced in the assessment of GCA.

Contrast-enhanced ultrasound (CEUS) is evolving as an increasingly popular technique in vascular imaging and the potential use of carotid CEUS in the diagnosis of large vessel vasculitis (LVV) has recently been explored.[41-43] A small prospective study demonstrated the use of carotid CEUS in the assessment of carotid wall neovascularisation and its ability to act as a potential surrogate marker of disease activity in those with LVV.[45] Furthermore, when compared with PET imaging, carotid CEUS demonstrated a strong correlation in identifying and grading vascular inflammation in a small population with LVV.[44] Although further studies with a higher power are required, this is a potentially exciting noninvasive method to detect and monitor disease activity in those with GCA.

PET SCANNING

PET is a technique employed since the late 1990s in the diagnosis and assessment of LVV. It is a functional nuclear medicine imaging technique which uses fluorine-18-fluorodeoxyglucose (F-18-FDG), a positron-emitting radionuclide, that shows increased uptake in metabolically active cells such as those in infection, malignancy, and inflammation.[45] F-18-FDG does not accumulate in normal vascular structures, and so any evidence of uptake within the vasculature tree is considered abnormal, with increased F-18-FDG uptake in the vessel wall being the hallmark of vasculitis in PET. F-18-FDG uptake typically following a symmetrical pattern in GCA and bilateral arteries tends to always be involved to the same extent.[46] In current practice, PET is almost exclusively combined with CT (PET-CT), working synergistically to assess the morphological structure and metabolic function of the vascular territories.[47] In more recent times, PET has also been combined with MRI (PET-MRI).

The EULAR Recommendations Working Group for the use of imaging in LVV recommend the use of PET (or ultrasound, MRI, or CT) for the detection of mural inflammation in extracranial arteries to support the diagnosis of large vessel GCA.[10] A major limitation of PET in the diagnosis of GCA has been the lack of spatial resolution to distinguish small branches of the external carotid artery, including the TA, from the background high physiological uptake in the brain. However, improved PET/CT technology allows time of flight (TOF) reconstruction, which improves image quality and provides a greater signal to noise ratio, allowing for arteritis detection in the smaller extracranial arteries of the head and neck, including the TA.[48-50] Thus, TOF PET/CT can now be used to diagnose areas of arteritis in the whole body, including the previously beyond-resolution small branches of the external carotid artery, while also reducing radiation exposure and scan time.[51]

The GCA and PET scan (GAPS) study, a double-blinded, prospective, cross-sectional study utilising a TOF scanner with 1 mm CT reconstruction, aimed to assess the use of PET as a first-line diagnostic tool in GCA.[40] It demonstrated that, versus TAB, the sensitivity and specificity of PET/CT was 92% and 85%, respectively, with a negative predictive value of 98%. Compared to clinical diagnosis, PET/CT had a sensitivity of 71% and a specificity of 91%. The finding of a negative predictive value of 98% demonstrated the use of this imaging technique in ruling out GCA in those considered lower risk. It is also worth noting how, whilst ruling out GCA, PET/CT has the ability over other diagnostic methods of detecting vasculitis mimics, infection, and malignancy, and has demonstrated a clinically relevant incidental finding in 20% of those enrolled in the study.[40] Furthermore its use in the identification of a clinically silent LVV in those with polymyalgia rheumatica has been demonstrated in numerous studies, with PET/CT revealing LVV in up to one-third of those with perceived isolated polymyalgia rheumatica, particularly refractory and atypical cases.[52-54] To date, there is no definitive internationally-accepted consensus criteria to define and interpret the presence of vascular inflammation using FDG-PET in GCA.[55] To optimise the performance of this diagnostic tool, in addition to ensuring optimal comparison between centres to facilitate future multicentre trials, there is a pressing need for a standardised scoring system for vascular uptake. Visual, qualitative, semiquantitative, and quantitative methods of interpretation have all been proposed. There is no 'gold standard' but a time-honoured method of interpretation has been the Meller scale: a semiquantitative four-point scale grading the vascular uptake with respect to that of the liver.[56] It includes the following grades: Grade 0 (no vascular uptake), Grade 1 (vascular uptake less than the liver), Grade 2 (vascular uptake similar to the liver), and Grade 3 (vascular uptake higher than the liver). A high interobserver agreement has been demonstrated in Meller Grade 3, but not in Grade 2 or 1.[57] Another issue is that although increased vascular uptake is suggestive of vasculitis, it is not pathognomonic for it, with atherosclerosis also causing increased uptake. This compromises the diagnostic accuracy of FDG-PET, particularly in the case of Grade 1, and less commonly Grade 2, uptake.[58] Typically, atherosclerosis has a 'patchy' irregular uptake pattern, with vasculitis uptake usually smooth and linear, involving long segments. Like other diagnostic methods in GCA, the shorter the interval to PET acquisition from glucocorticoid commencement, the higher the diagnostic potential.

In a recent study, 3 days of prednisolone 60 mg/day did not substantially attenuate FDG-PET results; however, 10 days of the same treatment resulted in a significant loss of vascular FDG uptake.[59] Furthermore, the use of glucocorticoids has been shown to increase FDG uptake in the liver, which may result in an underestimation of vascular FDG uptake if using the liver as a comparison.[60] Therefore it has been recommended that PET ideally be performed within 72 hours of glucocorticoid commencement to ensure high diagnostic potential; whilst this may be feasible in some centres, in the majority of centres the acquisition of PET scans within 3 days may not be as accessible and so may limit the use of this diagnostic tool.

CT AND MRI/MAGNETIC RESONANCE ANGIOGRAPHY IN CRANIAL GIANT CELL ARTERITIS

CT angiography (CTA) and MRI/magnetic resonance angiography (MRA) are alternative imaging modalities that identify arterial wall abnormalities reflective of vascular inflammation, such as oedema and contrast enhancement, in addition to assessing the arterial lumen for associated structural abnormalities, such as stenosis or aneurysm formation.

For those with predominantly cranial symptoms, high-resolution MRI has shown high sensitivity in the detection of cranial arteritis.[61-64]

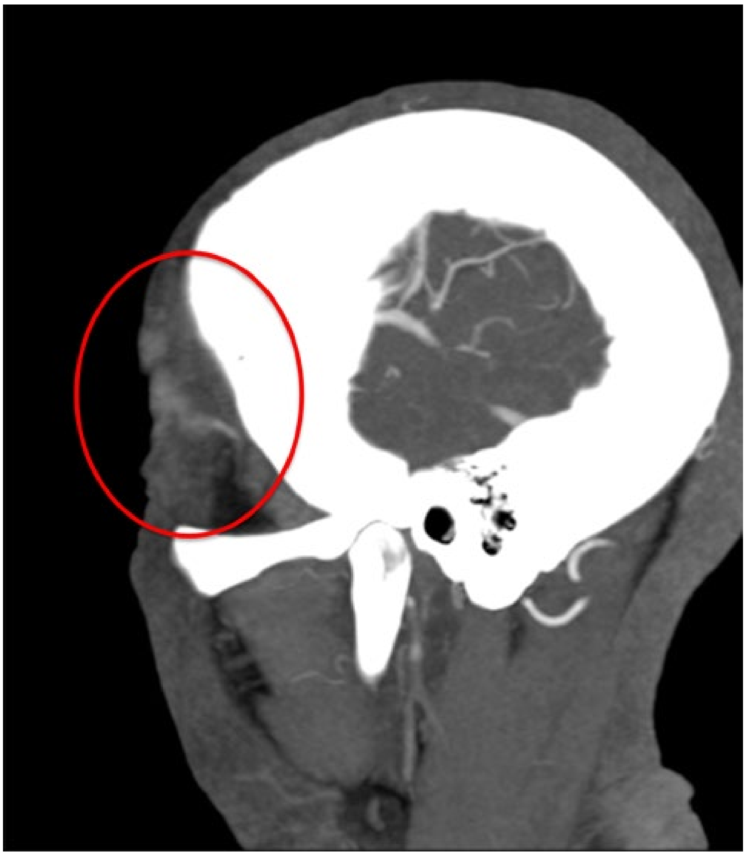

Figure 2: The characteristic appearance of giant cell arteritis of temporal artery on CT angiogram.

MRI allows for simultaneous and continuous evaluation of the cranial artery segments.[58] Using TAB as the diagnostic gold standard, MRI was demonstrated to be 94% sensitive with a specificity of 78% in the diagnosis of GCA.[56] Notably, in the same study, the negative predictive value of MRI was 98% raising the possibility of a negative MRI eliminating the need for TAB.[56]

However, when using the diagnostic reference standard of clinical diagnosis, the sensitivity of MRI fell to 39%, with a specificity of 82%.[56] This highlights the need for improved standardisation of a diagnostic reference standard in GCA. MRI of the TA has been included in the recent EULAR recommendations for imaging in GCA as a second-best alternative to CDUS to assess the cranial arteries.[26]

CTA has been shown to detect superficial TA abnormalities in GCA.[65] The authors demonstrated, in a retrospective case control study, how CTA has a sensitivity of 71% and a specificity of 86% for the diagnosis of cGCA. The characteristic appearance of GCA in the study was of a well-defined normal vessel disappearing into an abnormal, ill-defined area of hyperenhancement, reminiscent of smoke arising from the end of a cigar (Figure 2). Like CDUS, the findings of stenosis and occlusion appeared to be nonspecific in this group.

CT AND MRI/MAGNETIC RESONANCE ANGIOGRAPHY IN LARGE VESSEL GIANT CELL ARTERITIS

There are currently no guidelines addressing the screening need for large-artery disease and complications in GCA. In clinical practice, MRI/MRA and CTA are commonly used interchangeably to detect large vessel involvement. CTA can evaluate mural thickening, stenosis, and aneurysm formation of the aorta and branch vessels.[52] It has a reported sensitivity of 73% and a specificity of 78% for the diagnosis of LV-GCA.[66] Although limited by the risk of contrast and radiation exposure associated with its use, CTA has the ability to detect structural lesions with a higher resolution and shorter scanning time than MRA.[67]

MRA may be particularly advantageous in this setting due to its ability to simultaneously assess vascular morphology, detect oedema, and contrast uptake using specific weighted sequences, without radiation exposure.[47] This, combined with its good reproducibility, may suggest a role for MRI/MRA in disease monitoring in GCA, including screening for complications such as aneurysm. One study compared the role of MRA and PET in the diagnosis of LV-GCA and highlighted how each of these modalities contributes separate but complementary information regarding disease presence and extent.[68] MRA was superior to PET in assessing disease extent due to detection of both arterial wall and luminal abnormalities. However, PET was shown to be more reliable than MRA in the assessment of disease activity. Of note, oedema on MRA was the strongest correlate of PET scan activity, and oedema in an increasing number of arterial territories was most predictive of an MRA being interpreted as 'active', providing a potential surrogate for PET scan activity in cases where PET is unavailable or contraindicated.[68]

Similar to the other diagnostic modalities outlined above, the performance characteristics of CTA and MRI/MRA are affected by the initiation of corticosteroids.[63,6970]

CONCLUSION

While significant advances have been made in recent times in the diagnosis of GCA, this is still an evolving field with a large number of unmet needs. Much uncertainty still surrounds the optimal diagnostic modality and, despite diagnostic guidelines from both EULAR and BSR, the diagnostic pathway remains challenging.

Pretest probability should be used to guide the diagnostic pathway, with modalities chosen based on local availability and centre expertise. In both the diagnosis of cGCA and LV-GCA, there is an urgent need for standardisation of imaging-based measurements of vascular activity to improve patient outcomes and advance clinical research. Furthermore, a definitive biomarker for GCA diagnosis and assessment of disease activity is required, with a number of serological markers and novel PET ligands demonstrating future promise.

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Breast Lesion Characterisation with Diffusion-Weighted Imaging Versus Dynamic Contrast-Enhanced-MRI: A Prospective Observational Study in a Tertiary Care Hospital

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Disclosure: The authors have declared no conflicts of interest.

Received: 22.02.21

Accepted: 10.03.21

Keywords: Diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE)-MRI, kinetic curves, MRI breast.

Citation: EMJ Radiol. 2021;2[1]:75-82.

Abstract

Purpose: Dynamic contrast-enhanced (DCE)-MRI has a promising role in breast cancer detection and lesion characterisation. Diffusion-weighted imaging (DWI) acts as an adjunct in the differentiation between benign and malignant lesions. The purpose of the study was to evaluate the efficacy of DCE-MRI and DWI in differentiating benign and malignant lesions.

Methods: In a prospective study conducted between March 2019 and February 2020, 60 patients with breast lesions underwent DWI combined with DCE-MRI of the breast. The time–intensity curves were plotted. Lesions were classified according to the latest American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS; 5th edition). The results were compared with the histopathological diagnosis. The sensitivity and specificity of DWI, DCE-MRI, and combined DWI and DCE-MRI were calculated for detection of benign and malignant breast lesions.

Results: Sixty patients underwent breast MRI in which 78 lesions were detected, out of which 28 were benign and 50 were malignant. Quantitative apparent diffusion coefficient measurement revealed 96% sensitivity and 82% specificity, with a positive predictive value of 92% and negative predictive value of 96%, for differentiating benign from malignant lesions. DCE-MRI findings showed 96% sensitivity and 78.5% specificity. The sensitivity of combined DWI and DCE-MRI was 98% and specificity was 86%, which was higher than DWI and DCE-MRI alone.

Conclusion: Multiparametric MRI of the breast has very high sensitivity for detecting and characterising breast lesions as benign or malignant lesions. DWI had higher specificity than DCE-MRI, and the combined use of DWI and DCE-MRI had greater efficacy than DWI and DCE-MRI alone.

INTRODUCTION

Breast cancer is a leading cause of morbidity as well as mortality. It remains a matter of interest for both clinicians and investigators. Increased understanding, regular physical check-ups, and diagnostic radiological procedures have resulted in a timely diagnosis of carcinoma of the breast and have resulted in improvement in the prognosis of malignancies of the breast.[1-3] Early diagnosis of breast cancer is essential for a more conservative surgical approach towards management of the disease. The triple assessment protocol has been established as a diagnostic protocol for the management of palpable masses of breast; the triple assessment consists of regular physical check-ups, radiological investigations, and histopathological examination.[4]

Although ultrasound breast is a well-recognised modality for the detection of breast pathologies, various studies have shown that dynamic contrast-enhanced (DCE)-MRI has a promising role in the detection of various breast masses, along with characterisation of the lesion.[5,6]

In addition to DCE-MRI, the use of diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values help to distinguish benign breast lesions from malignant breast lesions; they also aid in early detection and diagnosis of the breast malignancies. Therefore, DWI can also be used to detect carcinoma of the breast without injecting contrast or as an adjunct to it, specifically for patients with deranged renal function tests or prior history of contrast reactions.[7]

MRI offers accurate visualisation of posterior breast tissue, axillary lymph node involvement, multiplicity in the same as well as opposite breast, and can assess contiguous involvement better than conventional imaging, so aids preoperative imaging of carcinomas.

PURPOSE

The purpose of this study was to evaluate the efficacy of DWI and DCE-MRI in differentiating benign and malignant breast lesions.

METHODS

A prospective, single-centre, observational study was conducted of 60 patients who had a clinically palpable breast lump or mass lesion detected on breast ultrasound breast March 2019 to February 2020, after obtaining approval from the institutional ethics committee/review board. Informed and written consent was taken from each patient. Female patients who presented with a breast lump on self-examination or clinical examination, or those with lesion detected on ultrasound breast, were part of the study group in the present study. Patients with contraindications to MRI and those with a history of allergic reaction to contrast media were not included. Patients with any history of previous interventional procedure or any surgery in the 3 months preceding the examination were also not included in the study.

Breast MRI

All the patients included in the study group had MRI examination with Achieva dStream 1.5T MRI (Philips, Amsterdam, the Netherlands). The dedicated breast coil was used. All metallic objects related to the patients' bodies were removed. Intravenous access was secured for gadolinium contrast injection. The patients were instructed to lie in prone position and both breasts were placed into the breast coil. Both the breasts were placed deep and centrally in the coil, with the nipple facing downwards. Patients were advised to stay immobile until the completion of scan.

The standard imaging protocol included:

1. T1-weighted pulse sequence. Axial and coronal non-fat-saturated T1-weighted images were acquired by turbo spin echo imaging, by using the subsequent imaging parameters: repetition time (TR) 425–475 ms, echo time (TE) 14–18 ms, and field of view (FOV) 200x340 mm^2 for axial and 300x379 mm^2 for the coronal plane.
2. Short T1 inversion recovery (STIR). Axial and coronal STIR images were obtained with the following imaging parameters: TR 3,500–4,500 ms, TE 70–90 ms, and FOV 200x340 mm^2 for axial and 300x379 mm^2 for coronal plane.
3. DWI. DWI was obtained before DCE-MRI. ADC values were obtained using b values at 0, 350, 700, and 1,000.

4. Dynamic study. All dynamic studies were performed in the T1-weighted sequences by applying fat-saturated pulses. Dyn thrive was used for contrast-enhanced images with the following parameters: TR 450–500 ms, TE 40–50 ms, and FOV 200x340 mm^2. DCE-MRI study was conducted by injecting 5–8 mL of gadolinium chelate (Gadovist®, Bayer, Leverkusen, Germany) intravenously followed by 10 mL of normal saline. Kinetic curves were obtained based on the DCE-MRI study. Dynamic study consisted of one precontrast and five postcontrast series; each of the sequences was captured in approximately 45 seconds, with an approximate time gap of 20–40 seconds between the pre- and postcontrast sequences as well as the individual postcontrast sequences.

Image Post-Processing

Subtraction images were acquired by subtracting each of the precontrast images from the postcontrast images. Kinetic curves were generated for enhancing lesions and maximum intensity projection images were also generated.

Time–Intensity Curves

After administration of intravenous gadolinium contrast, three types of enhancement kinetic curves are possible for an enhancing lesion in the breast parenchyma (Figure 1):[8]

- Type I curve (rising enhancement pattern): typically shows a continuous increase in signal intensity throughout time. Most of the lesions are benign; only a small proportion of malignant lesions show this pattern.
- Type II curve (plateau pattern): initial uptake is followed by the plateau phase towards the latter part of the study. This pattern is suspicious for malignancy.
- Type III curve (washout pattern): initial rapid uptake, then shows washout of contrast towards the later part of the study. This pattern is strongly suggestive of malignancy.

MRI Image Analysis

Initial detection of the lesions was first completed on STIR images. Morphologic characteristics (shape and margins) of all detected lesions were analysed on STIR and T1-weighted images. The enhancement characteristics of the lesions were assessed on DCE-MRI by plotting the kinetic enhancement curves, which were characterised as kinetic curve Type I, kinetic curve Type II, or kinetic curve Type III on the basis of their delayed-phase enhancement.

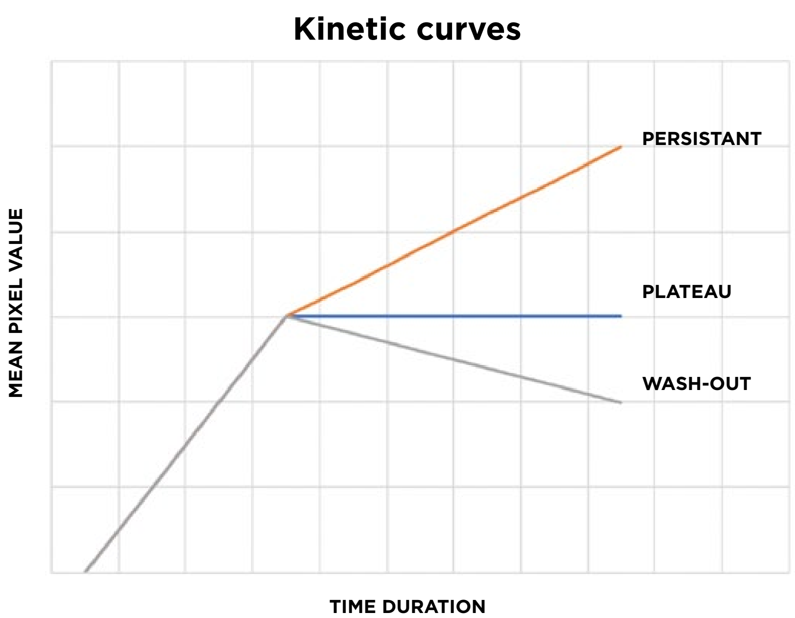

Figure 1: Diagrammatic representation of the types of kinetic curves according to wash-out patterns in dynamic contrast-enhanced MRI study.

DWI characteristics and corresponding ADC values were evaluated using b values of 0, 350, 700, and 1,000. The region of interest was chosen for the part of the lesion that demonstrated the highest signal intensity on DWI image. ADC value of $\leq 1.1 \times 10^{-3}$ mm^2/sec was taken as the cut-off value for diffusion restriction.

American College of Radiology Breast Imaging Reporting and Data System (ACR BI-RADS; 5th edition) lexicon criteria were used to classify lesions that were detected on MRI breast. Two certified radiologists with 10 years of experience in MRI simultaneously evaluated the MRI findings. Percutaneous core needle biopsy was performed in the patients with lesions labelled as BI-RADS ≥3 according to the study protocol and were taken as gold standard. Biopsies were performed within 30 days of the breast MRI in all cases. The lesions that were classified as BI-RADS 2 and 3 were considered benign lesions, while the lesions classified as BI-RADS 4 and 5 were considered to be malignant. The MRI findings were also compared with the histopathological findings.

Statistical Analysis

The lesions that were classified as BI-RADS 4 or 5 were considered as a positive test (MRI evaluation) result, while the lesions that were classified as BI-RADS 2 or 3 were considered as a negative test (MRI evaluation) result. The sensitivity and specificity of DWI and DCE breast MRI were calculated in the detection and diagnosis of cancerous lesions of the breast. Positive predictive value and negative predictive value were also calculated.

Statistical assessment was carried out using SPSS® 23.0 version (IBM®, Armonk, New York, USA). Chi-squared test was used to find connotation in categorical data. A probability threshold of 0.05 was considered as noteworthy.

RESULTS

The present study included 78 breast lesions among 60 female patients with ages ranging from 25 to 73 years. The mean age of those with benign breast lesions was 31 years and of those with malignant breast lesions was 46 years. All the cases (BI-RADS ≥3) were confirmed by percutaneous core needle biopsy.

The malignant lesions were most common in the upper outer quadrant (42%), followed by the upper inner quadrant (20%). These were followed by the lower outer quadrant (20%) and lower inner quadrant (14%). Only 4% of the lesions were detected in the retroareolar region.

The description of MRI breast findings was completed using the latest ACR BI-RADS lexicon, which included the basic morphological criteria (shape, margin, enhancement, and kinetic curve). On MRI breast, 22 benign lesions (78.5%) were categorised as BI-RADS 2 and 3. Only six benign lesions were categorised as BI-RADS 4. Fifty malignant lesions (100%) were characterised as BI-RADS 4 and 5 (P=0.001).

Contrast enhancement was assessed following gadolinium contrast injection and time–intensity curves were evaluated. Type I enhancement kinetic curve (rising curve) was noted in 20 benign lesions (71.4 %) and none of the malignant masses. Type II enhancement kinetic curve (plateau curve) was observed in only two benign lesions (7.1%) and two malignant lesions (4.0%). Type III enhancement kinetic curve (washout curve) was noted in six benign lesions (21.4%) and 48 malignant lesions (96.0%) (P=0.001).

DCE-MRI findings showed 96% sensitivity and 78.5% specificity, whereas quantitative ADC measurement revealed a sensitivity of 96% and specificity of 82%, and a positive predictive value of 92% and negative predictive value of 96%. The sensitivity of combined DWI and DCE-MRI was found to be 98% and specificity was 86%.

The determination of final ACR BI-RADS category of each lesion was made including all the above criteria.

DISCUSSION

Breast MRI is well known for its high capability and increased potential for the detection of breast masses. However, MRI breast is an expensive imaging modality, and it cannot be used in patients who have contraindications to MRI or any history of reaction to intravenous contrast media.

Lee[9] conducted a study that found that breast cancer is more frequently detected in the upper outer quadrant of the breast, which might be because more breast parenchymal tissue is present in the upper outer quadrant or because of the overuse of underarm cosmetics. In the present study, it was also found that the malignant lesions were more common in the upper outer quadrant.

In the present study, it was detected that the mass lesions that had well-delineated and well-defined margins were mostly benign (89.2%), whereas the lesions that had irregular and spiculated margins were diagnosed to be malignant in most of the cases (94.0%). These findings were in concordance with the study performed by Macura et al.,[10] who concluded that the description of the margin of a focal lesion is one of the most foretelling characteristic features of the MRI breast analysis. They also found that irregular margins raised greater suspicion for the lesion to be malignant (Figure 2).[10]

The internal enhancement characteristics of a focal mass lesion are one of the most efficient diagnostic measures for the differentiation of benign lesions from malignant lesions, as described by Rausch et al.[11] Shah et al.[12] also concluded that heterogeneous internal enhancement was the most commonly seen morphological finding among all the studied malignant lesions. In the present study, 47 of the enhanced lesions showed heterogeneous postcontrast enhancement on DCE-MRI, with the majority turning out to be malignant (90%; Figure 3).

Along with precisely describing the morphological characteristics of the lesion, MRI also determines the dynamics of the contrast medium by forming the signal intensity curve, signifying the degree of vascularity inside the lesion.

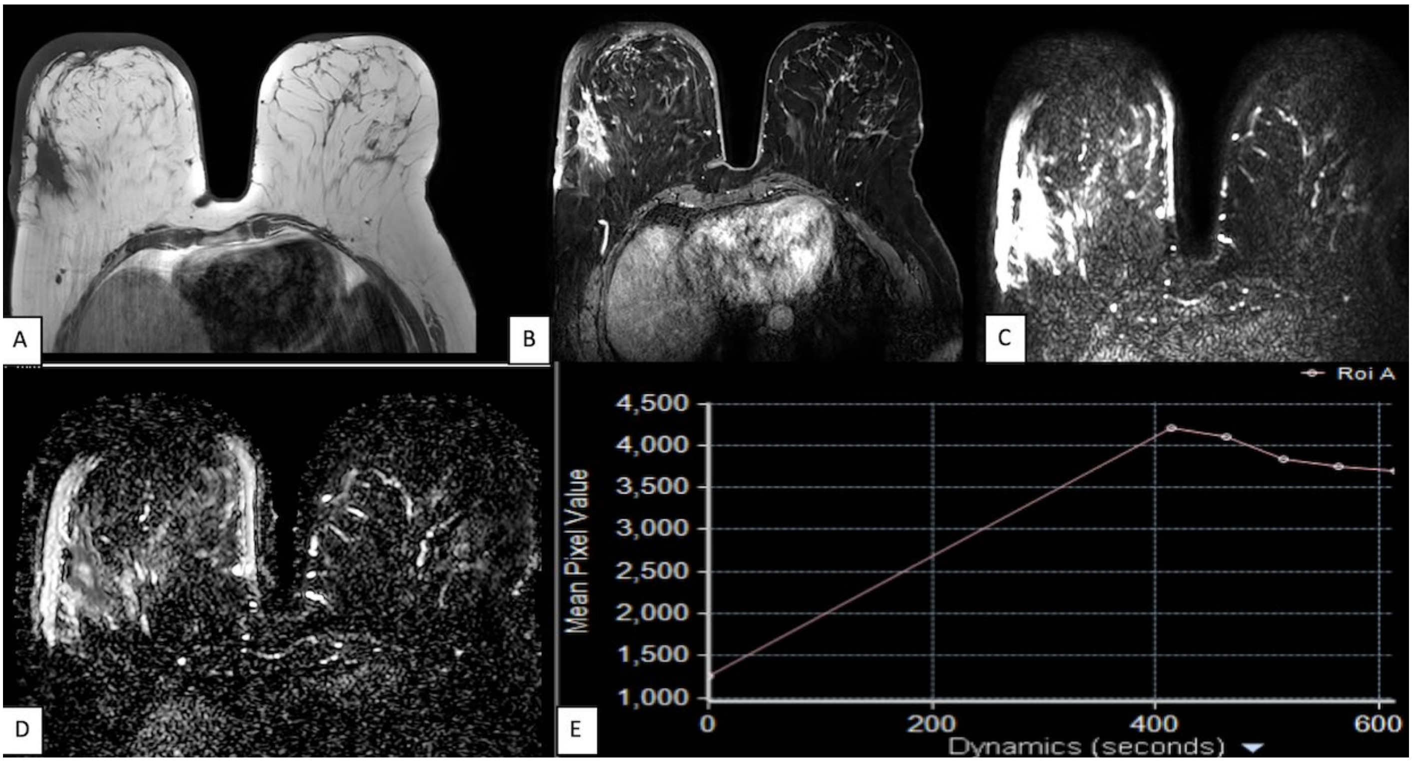

Figure 2: A 57-year-old female presented with a painless lump in the right breast, accidentally palpated 1 month prior. **A and B)**: Axial T1-weighted and axial STIR images reveal an ill-defined, irregular-shaped lesion in the upper outer quadrant of the right breast, appearing hypointense on T1-weighted images and heterogeneously hyperintense on STIR images. **C and D)** DWI and ADC images show diffusion restriction, with minimum ADC value of 0.714×10^{-3} mm^2/sec. **E)** Postcontrast images show heterogenous enhancement with washout type (Type III) of enhancement curve.

This lesion was labelled as BI-RADS 5 and was found to be invasive ductal carcinoma on histopathology.

ADC: apparent diffusion coefficient; DWI: diffusion-weighted imaging; STIR: short T1 inversion recovery.

In the present study, Type I enhancement kinetic curve (rising curve) and Type II enhancement kinetic curve (plateau curve) were seen in 22 benign lesions (78.6%). Type III enhancement kinetic curve (rapid wash-in and wash-out curve) was seen in 48 malignant lesions (96%). This was in agreement with various previous research studies that described and assessed the importance of the various enhancement kinetic curves in differentiating between malignant and benign breast lesions. Imamura et al.[13] reported that the use of enhancement kinetic curves of time–signal intensity resulted in markedly increased differentiation of benign from malignant breast lesions. Roganovic et al.[14] also showed that the enhancement kinetic curve of a persistent type is more in favour of benign changes and a Type III wash-in wash-out curve is more in favour of malignancy, as their study showed that 86% of malignant lesions had a wash-out type of enhancement kinetic curve, 14% had a plateau type of enhancement kinetic curve, and none had a persistent type of enhancement kinetic curve.[14] Most of the patients with triple-negative breast cancer in the research conducted by Azzam et al.,[15] also showed malignant-pattern kinetic curves.[15]

In the present study, 53 lesions showed restricted diffusion, out of which 48 lesions (96%) were malignant. This is in accordance with the results of Youssef et al.,[7] which proved that DWI further enhances the capability of the DCE-MRI for diagnosing breast lesions.[7]

The present study also analysed the ADC value using three separate b values (350, 700, and 1,000). No statistically significant difference was exhibited between the ADC values perceived at various separate b values in providing differentiation between benign and malignant breast lesions. Similar observations have been confirmed in the research work by Chen et al.,[16] which showed that the conspicuity of breast lesions is not affected by varying the b values on DWI at 1.5T. Partridge et al.[17] also concluded that DWI has a promising role in characterising breast lesions in breast MRI and is not considerably restricted by the size or type of the lesion.

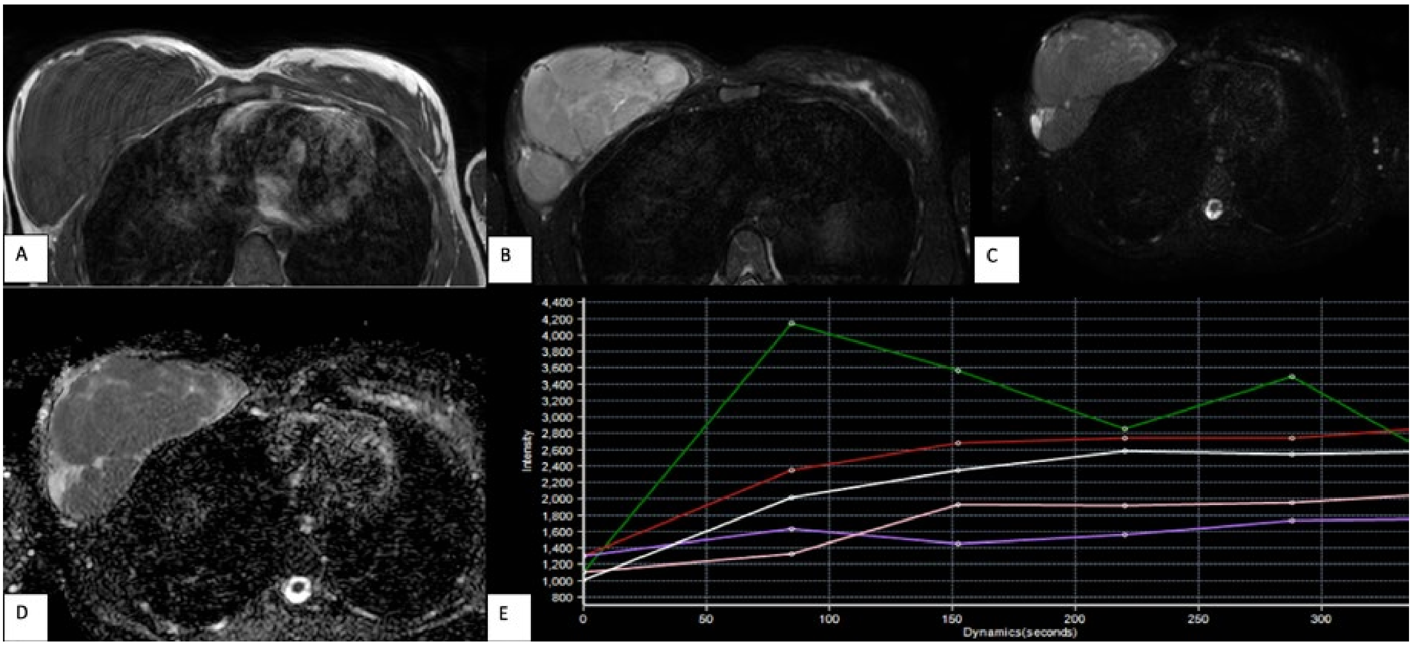

Figure 3: A and B) Axial T1-weighted and axial STIR images reveal a well-defined, lobulated mass lesion replacing the right breast parenchyma, appearing hypointense on T1-weighted images and heterogeneously hyperintense on STIR images, showing internal septations. **C and D)** DWI and ADC images reveal no restriction of diffusion. **E)** Postcontrast images show homogeneous enhancement with a rising type of enhancement curve (Type I; red and white curves; green curve represents normal vascular enhancement).

This lesion was labelled as BI-RADS 3 and was found to be atypical ductal hyperplasia on histopathology.

ADC: apparent diffusion coefficient; DWI: diffusion-weighted imaging; STIR: short T1 inversion recovery.

In the present study, quantitative ADC measurement and DCE-MRI alone had almost comparable sensitivities (96.0%); however, the specificity of DCE (78.5%) was much lower than that of DWI (82.0%). The concomitant use of DWI and DCE-MRI improved both sensitivity as well as specificity of diagnosing benign and malignant breast lesions, with sensitivity of 98% and specificity of 86%, which was greater than that of DWI and DCE-MRI alone. This is in accordance with the results of the research by Kul et al.[18] in which they evaluated the concomitant role of DCE-MRI and DWI as an imaging protocol in patients with suspicious breast lesions; 84 patients underwent MRI breast in their study. The efficacy of DCE-MRI, DWI, and combined MRI for diagnosis and characterisation of breast lesions were calculated. Sensitivity and specificity of ADC values in their study were 91.5% and 86.5%, respectively. DCE-MRI alone had sensitivity of 97.9% and specificity of 75.7%. The combination of DCE-MRI with DWI showed sensitivity of 95.7% and specificity of 89.2%.[18] In another research work performed by El Bakry et al.,[19] it was also revealed that the sensitivity for DCE-MRI alone was 91.7% and specificity was 84.2%. The DWI showed a sensitivity of 94.4% and specificity of 92.1% in their study. Sensitivity and specificity of breast MRI for the detection of breast tumours were increased in their study by the concomitant use of DCE-MRI and DWI.[19]

The limitations of the present study include a limited number of patients due to a relatively shorter time duration of the study. There were fewer patients agreeable to undergo MRI breast examination as a diagnostic modality who fit inclusion criteria. The main reason for this was the high cost, as well as a relative lack of awareness and knowledge about the utility of MRI for the timely detection and diagnosis of breast cancer.

CONCLUSION

Multiparametric MRI breast has very high sensitivity for detecting and characterising breast lesions as benign or malignant lesions. DWI alone has almost comparable sensitivity as compared with breast DCE-MRI; however, it is more specific. The concomitant use of DWI and DCE-MRI improved the sensitivity and specificity of breast MRI for characterising benign and malignant breast lesions, compared with DWI and DCE-MRI alone.

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Sonohysterography: A Formidable Diagnostic Tool in the Evaluation of the Caesarean Scar Defect in Comparison to MRI

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Disclosure: The authors have declared no conflicts of interest.

Received: 26.01.21

Accepted: 05.03.21

Keywords: Caesarean scar defect (CSD), niche, sonohysterography (SHG).

Citation: EMJ Radiol. 2021;2[1]:83-89.

Abstract

Introduction: The use of the caesarean section (C-section) in obstetric care has exponentially increased in the past few decades. The caesarean scar defect (CSD) is a potential complication of C-section and is associated with a wide range of problems. The purpose of this study was to compare the evaluation of the CSD in non-pregnant women by sonohysterography (SHG) and MRI.

Methods: This study was performed in patients having undergone a single C-section more than 6 months prior, presenting with abnormal uterine bleeding, dysmenorrhoea, or pelvic pain. Since ultrasonography and pelvic examination were inconclusive, these patients underwent MRI followed by saline infusion SHG. Measurements and characteristics of the 'niche' were acquired from both MRI and SHG and compared for analysis.

Results: Patients with a single C-section presenting with prolonged bleeding, spotting, and dysmenorrhoea were included in this prospective study. SHG and MRI were used to measure scar thickness, width, depth, and adjacent myometrial thickness, in which the findings concurred. The mean defect depth was greater in patients with postmenstrual bleeding.

Conclusion: SHG is noninferior to MRI, and SHG has the potential to assess the dynamic status of the CSD, with morphological clarity.

INTRODUCTION

The increase in the rate of the caesarean section (C-section) worldwide has raised concerns over the associated complications, such as the caesarean scar defect (CSD). The most alarming concern of the scar is its rupture during birth;[1,2] apart from dramatic obstetric issues, for instance placenta accrete, gynaecological sequelae such as secondary infertility, pelvic pain, ectopic pregnancy, and abnormal uterine bleeding (AUB) are other entities reported to be associated with CSD.[3] The potential for patients with these complications to undergo procedures such as uterine curettage, endometrial ablation, and hysteroscopy is only recently being explored.[4] Evaluation of the CSD is performed by transvaginal sonography (TVS), saline infusion sonohysterography (SHG), hysteroscopy, and MRI; however, no consensus has been reached for the assessment gold standard.[3-5] In this study, the authors compare the evaluation of the CSD in non-pregnant females by SHG and MRI, advocating for the ability of SHG to perform on par with MRI and for it to be utilised in low-resource settings.

MATERIALS AND METHODS

This study was conducted over a 2-year period in Srinagar, Jammu and Kashmir, India, on patients who had undergone a pelvic MRI for evaluation of symptoms such as AUB, dysmenorrhoea, and pelvic pain. It is pertinent to mention that these patients were referred for MRI after inconclusive ultrasonography, both transabdominal and transvaginal. The MRI was performed on the Siemens MAGNETOM Avanto 1.5T (Siemens Healthineers AG, Erlangen, Germany). T1 and T2-weighted images were acquired through standard planes. The sagittal T2-weighted scan of the uterus was examined for the presence of the caesarean scar. Only the cases with an identifiable scar on T2-weighted sagittal images were selected; these patients were educated on SHG and only those who agreed to the procedure were involved for further evaluation. Individuals excluded from the study were those who had undergone a C-section within the last 12 months, had undergone more than one C-section, were noncompliant, and those with possible contributory ancillary findings like fibroids, adenomyosis, and adnexal cysts, to exclude patient group variables. More than 300 pelvic MRI scans were evaluated and only 13 were selected for further assessment.

For the selected MRI examinations, the thickness of the scar was measured, i.e., the distance from the serosal surface of the uterus to the apex of the scar. The total myometrial thickness adjacent to the scar was also measured. In the case of a 'niche', the depth and width were measured (Figure 1).

SHG was performed on Days 8–10 of the menstrual cycle, either in the same cycle or the next feasible cycle, with the exclusion of patients who were pregnant.

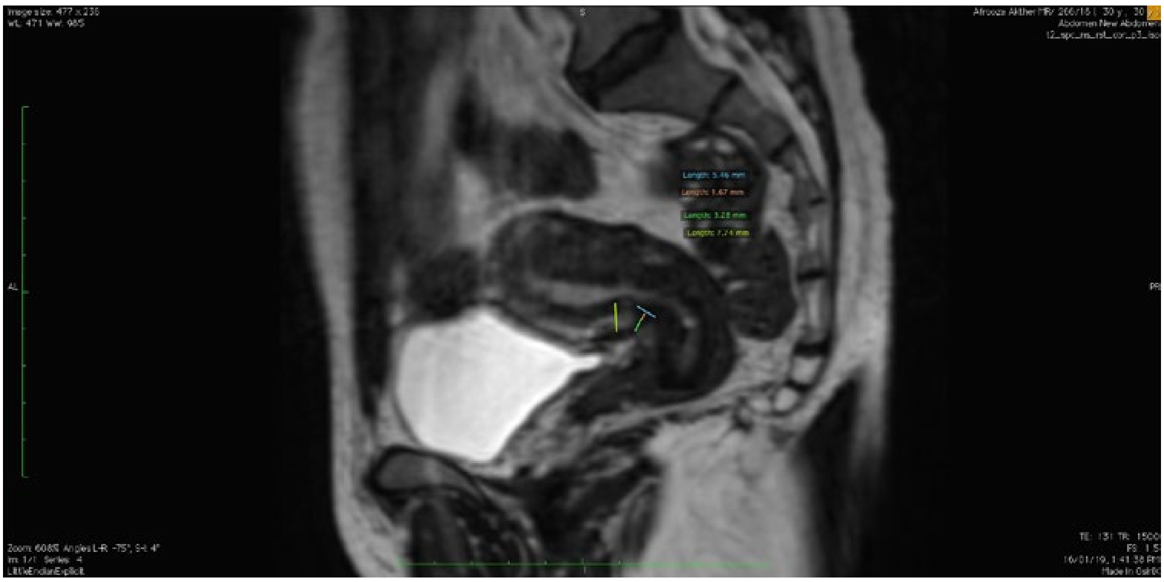

Figure 1: Sagittal T2-weighted MRI image depicting the uterus with callipers marking the 'niche' and its measurements.

The procedure was performed on the SonoSite M-Turbo® (Fujufilm, Bothell, Washington, USA). In the case of menorrhagia, SHG was performed (with informed consent) 2 days after cessation of bleeding by haemostatics. A Cusco's speculum was introduced, with the patient in the lithotomy position and the cervix swabbed with a solution of saline and povidone-iodine. A Foley catheter, 8 French units in diameter, was introduced via the external os and the balloon inflated; this was followed by the instillation of 20–50 mL of sterile saline into the uterine cavity under sonographic guidance with focus on the uterine scar. The thickness of the residual myometrium, the thickness of the myometrium bordering the scar (the anterior myometrium), and the depth of the niche (a triangular, anechoic area at the presumed site of incision) were measured (Figure 2).

RESULTS

The patient selection in this study allowed the authors to evaluate only those patients who had been symptomatic enough to have been referred for MRI. All the included patients had undergone a single C-section at least 12 months prior to the MRI.

Out of >300 pelvic MRI images, only 13 patients had measurable CSD on the T2-weighted sagittal MRI images (4.3%). Out of these, three had a history of two prior C-sections, one had coexisting multiple uterine fibroids, and one had adenomyosis; these patients were excluded from further study. The remaining eight patients had undergone a C-section more than 12 months prior. The mean age was 36 years. The most common symptom was prolonged cycles, defined as menstrual bleeding for >7 days (n=6) followed by postmenstrual spotting (a brown discharge at the end of the menstrual cycle) for at least 2 days (n=3). Other symptoms included dysmenorrhoea (n=5) and chronic pelvic pain (n=3). Emergency C-sections had been performed following prolonged labour (n=3) and for obstetric indications (n=4). None of the patients had previously given birth via vaginal delivery. Five patients had a history of gestational diabetes and an increased BMI of >28. Seven of these patients had anaemia during pregnancy. Five patients also reported having leukocytosis and fever postdelivery, which subsequently resolved.

On imaging, most of the patients had an anteverted uterus (n=6), while the others had a retroflexed uterus (n=3). The SHG and MRI findings correlated. An isthmocele was diagnosed when the CSD was at least 1 mm deep. The authors did not find any case with multiple defects. The mean defect width was 1 mm, while the mean defect depth was 3.4 mm with MRI and 3.6 mm with SHG. The mean scar thickness was 2.7 mm using MRI and 2.8 mm with SHG.

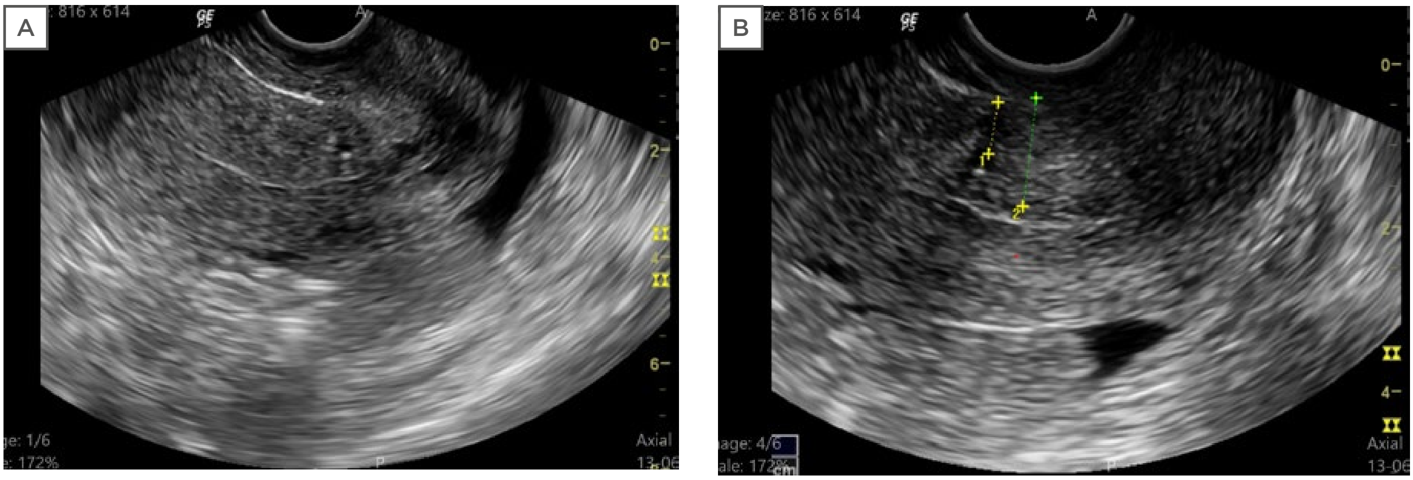

Figure 2: Imaging scans from a single patient. A) Transvaginal sonography showing the uterus in longitudinal section with thin endometrium and normal myometrium; **B)** saline hysterosalpingography showing the 'niche' with callipers marking the thickness of the residual myometrium (1) and adjacent myometrium (2).

The mean myometrium adjacent to scar thickness ratio was 28% with MRI and 30% with SHG. There was no significant difference in the measurement results from the MRI versus SHG. The only difference was in the better delineation of the CSD on the SHG. All the defects had a triangular shape with both MRI and SHG.

The mean defect depth was greater in patients with postmenstrual bleeding, with a Spearman's rank correlation coefficient of 0.87 ($p<0.05$). The rest of the correlations were not statistically significant (Figure 2A). On using the criteria of Osser et al.,[6] who defined a large defect as a scar myometrial thickness of <2.2–2.5 mm with SHG, only two patients had large CSD, both of whom had postmenstrual spotting and dysmenorrhoea (Figure 3).

DISCUSSION

When performed for the necessary reasons, the C-section, the most common global obstetric procedure, is a leading operation, having saved the lives of countless mothers and infants.[5-10] In India, as per the District Level Household and Facility Survey-3, the C-section rate is 28.1% in private sector health facilities and 12% in public sector, much higher than the recommended 10% by the World Health Organization (WHO);[7,11] this implies an increase in the incidence of CSD. It is reported that a rate higher than 10% may not provide further benefits but rather an increase in complications.[2,7,10] Other complications reported (though rare) include uterine rupture and ectopic pregnancy with CSD.[2,5-7,12] The prevalence of CSD have been reported with variations from 6.9–69.0%, and even up to 88.0%.[2,5-7,13] Due to the fact that most patients are asymptomatic, it is likely that reported numbers represent only the tip of the iceberg.[2,14]

The niche, pouch, or isthmocele of a CSD is a normal tissue response due to scarring at the site of a previous scar defect.[2,6,8-10,12,15-17] Its presence alone is not significant enough as it is commonly found after a C-section.[14,18] It may take at least 6 months for the scar to heal, during which time the site will be oedematous; healing may continue for a few months after this.[5,7] Additionally, vascular perfusion at the scar site may be affected by a range of factors including infection, diabetes, and nutritional status.[7,9,16] For this reason, the authors chose to invoke the 12-month prerequisite in an attempt to evaluate after healing was complete.[7]

CSD has been reported to be associated with multiple gynaecological issues. In a cross-sectional study, 63.8% of women with a CSD had postmenstrual spotting and 31.0% of these women had dysmenorrhoea and 39.6% had chronic pelvic pain. Additionally, dyspareunia and higher rates of failure in intrauterine device placements have also been ascribed to a CSD.[2,4,7,10]

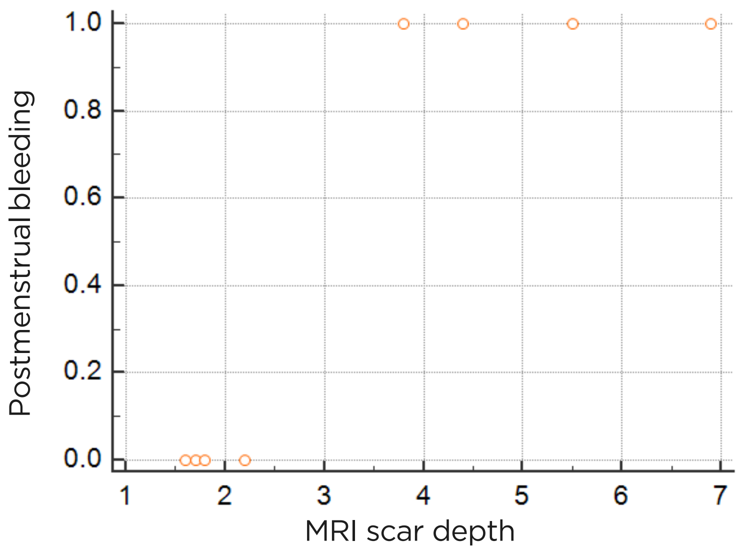

Figure 3: Scatter diagram of the scar depth in comparison to postmenstrual spotting.

Thurmond et al.[19] first reported abnormal bleeding with CSD by SHG evaluation. Postmenstrual spotting has been ascribed to have an independent relationship to the presence of a niche.[13] Surgical isthmocele treatment has shown to improve fertility outcomes.[2,16]

It is hypothesised that menstrual blood collects in the scar subsequent to its poor contractility and then leaks out after the menstrual flow has stopped, presenting as spotting or prolonged bleeding.[2,6,10,13,16,18] Morris et al.,[20] on pathologic examination of the uterus in patients with AUB and a history of at least one C-section delivery, found widening of the lower uterine segment in 75%, overhang of congested endometrium above the scar recess in 61%, polyps within the scar in 16%, lymphocytic infiltration in 65%, residual suture material in 92%, capillary dilatation in 65%, fragmented endometrium in 37%, and scar adenomyosis in 28%.[4] A chronic inflammatory environment can therefore contribute to AUB, chronic pelvic pain, and infertility.[2,6,13] This warrants a further evaluation of the niche, preferably dynamic in the non-pregnant individual.

All of the defects found in this study were triangular in shape. In the literature, the most commonly reported shapes of the defect were triangular followed by round and oval.[2,7,13,17] Prior vaginal deliveries do not seem to elevate the risk of a CSD.[5,7] The ratio of the myometrial thickness at the scar to the thickness of adjacent myometrium indicates the degree of deficiency (>50%: severe deficiency).[2,4,5] In this study, this ratio was 28% with MRI and 30% with SHG; hence, none of the defects were categorised as severe. Larger defects may inherently have contents and therefore can be picked up on plain TVS. The deeper the niche, the higher the risk for complications.[2,15] Dehiscence extrapolates the occurrence of other complications such as scar pregnancy and placenta previa or accrete.[2,18] Even so, such niches are more susceptible to injury during gynaecological procedures such as dilatation and intrauterine device implantation, making the documentation of these of prime importance.[2]

Although retroflexed uteri have been reported to have more common and larger CSD, the findings from this study are not comparable with only three patients having a retroflexed uterus.[9,12] Obesity, prolonged pregnancy, peripartum infection, emergent C-sections, intraoperative complications, younger maternal age, prolonged duration of labour, advanced cervical dilatation, scar closer to the internal os, a retroflexed uterus, and a history of multiple C-section deliveries all increase the risk for a larger CSD.[2,4,6,7,9] The authors found an increased BMI in five of the patients (62%). It has been stated that every additional unit of BMI increases the risk of an isthmocele by 6%.[7] However, other studies have found no significant relationship between BMI and CSD.[9] Prolonged labour was seen in three patients, all of whom were managed via emergency C-sections. Seven out of eight patients in the study had a history of an emergency C-section. Though prolonged labour itself is an independent risk factor for the development of an isthmocele, it is reported that the incidence of CSD is much higher in the emergency group rather than the elective group.[7,9]

Anaemia was recorded in seven out of eight patients. A reduced haemoglobin state with the requirement of blood transfusions has been previously implicated with scar dehiscence.[6,9] The authors suggest the exploration of this association as anaemia was highly prevalent in the study set-up. The study also found a history of fever with leukocytosis postpartum in five patients. A possibility of infection can delay the healing of the wound and cause a future defect.[6,9]

TVS for the diagnosis of CSD has been reported since 1990 with an appearance of a wedge defect or a cystic mass between the bladder and lower uterine segment, which may be filled with debris.[2,4,6,8,12,17] However, TVS can be misleading as it can both miss, as well as underestimate, the size of the defect.[13,17,21] It is imperative to mention that in all the cases of this study, the niche had been missed on TVS. SHG has increased sensitivity and specificity for the detection of C-section scars by enhancing the defect and allowing its dynamic evaluation.[2] A comparison between TVS and SHG for diagnosis of CSD found facilitation in delineating the borders of defects on SHG.[4] Monteagudo et al.[15] found that even though the site of the scar is identifiable by TVS, its depth and width could not be assessed without saline enhancement.[13] Ofili-Yebovi et al.[12] defined the degree of severity of the defect on ultrasound using the ratio of the myometrial thickness at the scar to the thickness of the adjacent myometrium, i.e., severe defect is a ratio of <50%.[14] Though the first choice for screening, it seems plausible that symptomatic patients with negative TVS should invariably undergo SHG, as the defect can easily be missed with poor resolution or a low index of suspicion.[14]

MRI is not widely used as an investigative imaging tool for AUB, given its expense and low availability, especially in a low-resource setting.[2,14] A novel study using contrast enhanced-MRI was able to detect larger pseudocavities in the anterior wall with saline, enabling clear contrast between fluid and muscular fibre during MRI and the visualisation of larger and clearer CSD margins.[21] Wong et al.[14] found a CSD prevalence of approximately 6.3% on MRI performed for other pathologies. Fiocchi et al.[22] determined that the clinical value of 3T-magnetic resonance diffusion tensor imaging is better than ultrasound in predicting the thickness of the scar. The study also showed that the previous surgery in the anterior isthmus segment caused fibre disruption.[22] This study also indicates that MRI and SHG perform equally with respect to the measurement of the defect and the myometrial morphology. Although MRI allows no definite advantage, SHG can evaluate the defect dynamically with evidence of any potential diverticulum formation. This study did not have any case of diverticulum, most likely due to the fact that only patients with a single C-section were included. This study may pave the way for future large-scale evaluation of the CSD by SHG as a potential cause for a spectrum of gynaecological issues.

This study is intrinsically limited by the small positive sample size and an implicated selection bias, as only symptomatic patients were received. However, the authors explored a twilight zone of scarce prospective studies on this topic. What is more, the fact that the study was undertaken in a low-resource setting in a developing country means that it takes a certain tenacity to get a patient and machine to coalesce for a diagnosis, along with convincing a patient to take an MRI, its cost factor, and the logistics of organisation in a government set-up.

CONCLUSION

The CSD warrants evaluation in the symptomatic non-pregnant uterus. Even though fashionably complex, MRI lags behind SHG in the potential to assess the dynamic status of the CSD, with morphological clarity paralleling that of MRI. The authors recommend the use of SHG as a first line of investigation in such patients, and also aim to invigorate larger prospective studies with a probable evolution of the investigation with advancing technology, e.g., to predict the probability of scar rupture to allow for consensus regarding the best treatment of these patients in order to reduce AUB, improve fertility, and avoid scar pregnancies and scar rupture.

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Left Hemicolectomy for Intussusception of the Transverse Colon Caused by a Giant Benign Lipoma

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Disclosure: The author has declared no conflicts of interest.

Received: 05.12.20

Accepted: 03.02.21

Keywords: Colocolonic, diverticulitis, intussusception, lipoma, polyps.

Citation: EMJ Radiol. 2021;2[1]:90-93.

Abstract

Colocolonic intussusception, caused by submucosal lipomas, is extremely rare. These benign soft tissue tumours comprise mature adipocytes of mesenchymal origin. While the majority of patients with lipomas remain asymptomatic, large or giant size lipomas (>4 cm) have been shown to cause debilitating abdominal pain, alternating bowel pattern, and anaemia secondary to gastrointestinal blood loss. This necessitates intervention in the form of surgical resection or endoscopic removal. However, once lipomas increase beyond 2 cm in size there is a significant risk of complications with an endoscopic approach, and open surgery or laparoscopic resection with bowel re-anastomosis is warranted. In this case put forth, the patient underwent a successful transverse colectomy and primary anastomosis.

INTRODUCTION

Colonic lipomas are nonepithelial benign submucosal tumours, most commonly presenting in adults in their 50s and 60s.[1] CT is the gold standard imaging modality and is often used first-line given the clinical presentation and lipomas propensity to mimic colorectal carcinoma. Barium studies are nondiagnostic and require biopsy and histopathological staining for definitive diagnosis. Most often, patients with lipomas remain asymptomatic until the lipoma exceeds 4 cm in size, at which stage they can cause intermittent obstruction.[2]

CASE REPORT

A 47-year-old female with an established background of diverticulosis presented with left iliac fossa pain and haematochesia associated with nausea and bloating. This was her third admission to hospital in 3 weeks. Her previous stays were short and her symptoms were presumed to be attributed to recurrent episodes of diverticulitis. On each occasion these symptoms had settled relatively quickly with intravenous amoxicillin and metronidazole. She had subsequently been discharged and scheduled for an outpatient sigmoidoscopy.

Her past surgical and medical history included open appendicectomy, endometrial ablation, hypertension, and acne vulgaris. Notably, there were several inpatient stays for diverticulitis during the preceding years, and imaging had shown extensive diverticular disease of the sigmoid colon with inflammatory changes and mucosal thickening of the rectum and sigmoid. During one of these inpatient admissions 2 years prior, an incidental lipoma measuring 4.7 cm was seen at the distal transverse colon on CT imaging. Simultaneously, a polyp of about 2.5 cm in size and pedunculated at the rectus sigmoid junction was removed at colonoscopy; the helix pomatia agglutinin results revealed this to be a hypoplastic polyp.

Her blood panel on current admission showed the following: haemoglobin 110 g/L, mean cell volume 96 fL, white cell count 7.2×10^9/L, platelets 339×10^9/L, C-reactive protein 31 mg/L, and γ-glutamyl transferase 73 IU/mL. CT imaging of the abdomen and pelvis revealed an intussusception of the distal transverse colon into the descending colon. This intussusception was approximately 10 cm long, with the lead point being a large intramural lipoma measuring 6 cm in diameter (Figure 1 and 2). The proximal colon was normal in calibre and nondistended with no obvious small bowel obstruction evident. There was no fluid collection or free gas. Imaging was otherwise typical apart from multiple hepatic hypodensities which were consistent with cysts.

The patient underwent a left hemicolectomy and approximately 22 cm of colon with attached omentum was resected. This procedure best suited a laparoscopic approach but because the patient presented during the peak response of the coronavirus disease (COVID-19), local hospital policies precluded an aerosol generated procedure; therefore, it was carried out as open surgical procedure with full personal protective equipment precautions.

There were no intraoperative complications encountered and the patient made a swift postoperative recovery, apart from a sequential drop in haemoglobin to 54 g/L on the postoperative day, which required a transfusion of three units of packed red blood cells. A chest X-ray at this point showed normal pulmonary vasculature with no focal consolidation but mild right basal atelectasis. The patient was discharged home on postoperative Day 7.

The final pathology report described a firm bulge within the lumen measuring 55 mm x 40 mm x 40 mm, which was consistent with a large polyp; it had a smooth surface and was yellow at the tip, yet was more mottled and darker towards the base. The polyp was the locus of the intussusception. The mucosa around the base of the polyp was roughened and irregular. On sectioning, the polyp comprised solid fatty material with no haemorrhagic or cystic areas seen.

Histology of the sections from the polyp showed mature adipose tissue divided into lobules by fine fibrovascular septae. There were areas of necrosis within it and characteristics of a lipoma with no features to suggest malignancy. Histology of the mucosa overlying and surrounding the lipoma displayed focal regions of ulceration. Within these locations the mucosa also showed features of an ischaemic pattern of injury consistent with changes seen in intussusception with no dysplasia or malignancy. There were areas of fibrosis and increased vascularity within the serosa. Longitudinal resection margin showed a mild purulent exudate on the serosa that was otherwise typical. Histological analysis of sampled lymph nodes showed no primary or secondary tumour. The overall impression of the histological report was intussusception of the large colon around a lipoma within its wall.

DISCUSSION

The most common locations for colonic lipomas are the ascending colon (45.0%), sigmoid colon (30.3%), descending colon (15.2%), and with the transverse colon being the least common (9.1%). Almost 90% of colonic lipomas are localised to the submucosa with the rest confined to the subserosal or intramucosal layer.[3]

Secondary intussusception is defined as a pathological lesion of the intestinal wall that alters normal peristaltic activity and serves as a lead point, as in this instance (in the absence of a lead point it is classified as primary or idiopathic). Approximately 60–65% of intussusceptions in the large intestine have a malignant aetiology, making colonic lipomas much less common.[4] Clinically, they can present insidiously with nonspecific signs and symptoms, which can persist for years and lead to misdiagnoses unless otherwise meticulously investigated.

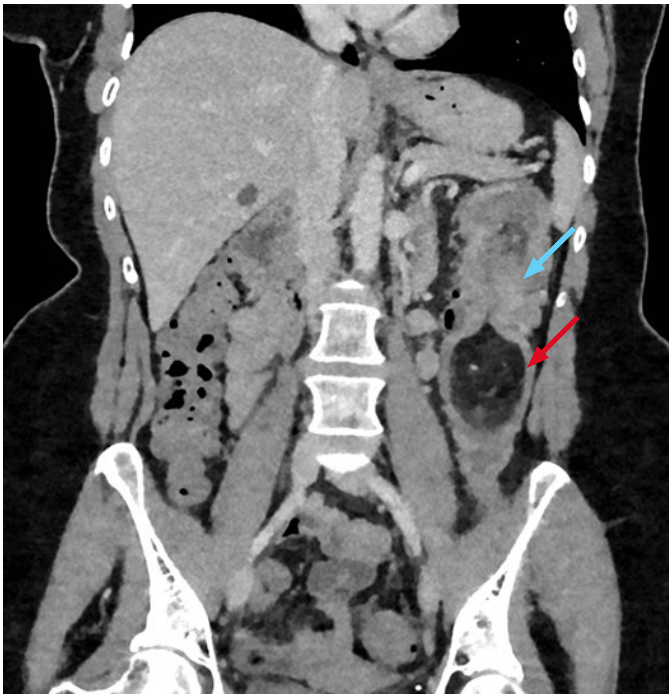

Figure 1: Coronal section of contrast enhanced abdominal CT showing intussusception (blue arrow) into the descending colon with lipoma as lead point (red arrow).

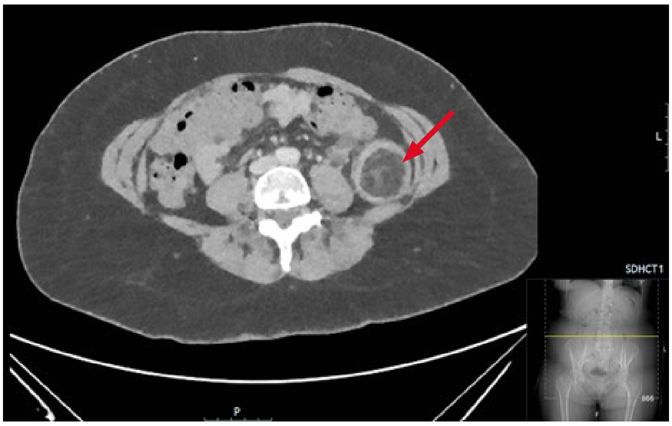

Figure 2: Axial view of soft tissue lipoma (arrow) filling the luminal space of the descending colon.

It is clear that fast growing colonic lipomas causing obstructive symptoms need to be removed. Ideally, lipomas <2 cm in diameter can be removed endoscopically by snare and laser techniques.[5] There are well-documented pathognomonic signs on endoscopic evaluation, such as the 'tenting' sign (mucosa grabbed over the lesion leaves a tented appearance) and the 'naked fat' sign (fat grossly extruded after biopsy).[6]

Giant lipomas (>4 cm in diameter) are more susceptible to complications such as superficial ulceration, haemorrhage, and obstruction. They can also undergo intermittent torsion and ischaemia. Therefore, these sizeable tissue masses require careful resection within the contained bowel segment and assiduous haemostasis with primary anastomosis, instead of submucosal lift techniques. Sessile polyps can prove difficult to ensnare. In addition, the low water content of fat can lead to prolonged electrocautery and risk of thermal damage. There is also a chance that the muscularis propria or serosal layer is involved. If so, these layers may become invaginated in the pedicle and increase the risk of perforation if endoscopic snare resection is used.[7] For these reasons segmental surgical resection is safer and has the added benefit of allowing local lymph node dissection if the diagnosis of colonic carcinoma is equally equivocal.

CONCLUSION

Invariably, due to the nonspecific presentation of colonic lipomas, diagnosis is difficult and can be delayed. From the outset, symptoms of a large colonic lipoma are viewed adversely as they can mimic malignancy. Giant lipomas (>4 cm) can be technically challenging to remove endoscopically with an associated increased safety risk to the patient. In order to avoid complications these giant sized lipomas are managed most appropriately by surgical resection.

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