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High-level disinfection of ultrasound probes

A large population-level study has revealed an unacceptable risk of infection following endocavitary ultrasound procedures. Nanosonics is intent on ensuring that vulnerable patients are protected from the risk of cross-contamination.

Support for the development of this advertorial has been provided by Nanosonics

Patients can be at risk from ultrasound associated infections when low-level disinfection (LLD) is the standard of care. In order to quantify this risk, Scotland's National Health Service undertook a retrospective analysis of microbiological and prescription data through linked national health databases. Patient records were examined in the 30-day period following semi-invasive ultrasound probe (SIUP) procedures.

The study analysed almost one million patient journeys that occurred during a six-year period from 2010.[1]

Of the 982,911 patients followed, 330,500 were gynaecological patients; and 60,698 of these gynaecological patients had undergone a transvaginal (TV) ultrasound procedure. These patients were found to be at a 41% greater risk of infection and a 26% greater risk of needing an antibiotic prescription in the 30 days following their transvaginal ultrasound procedure when compared to gynaecological patients who had not undergone a transvaginal ultrasound.

During the study period, 90.5% of facilities reported that they were performing low level disinfection for transvaginal ultrasound probes. These patients were at a greater risk of infection due to inadequate reprocessing and the study concluded that: "Hence failure to comply with existing guidance on [high-level disinfection] of SIUPs will continue to result in an unacceptable risk of harm to patients ."[1]

The diverse use of ultrasound probes is now prompting a renewed focus on correct probe reprocessing to ensure patient safety. To ensure best practice standards, decontamination experts and ultrasound users need to work together to reduce the risk of infection that is associated with using ultrasound probes.

Ultrasound procedures are performed in various inpatient and outpatient settings by a wide range of health professionals. This has increased the use of surface probes to guide procedures such as biopsies, cell retrieval, cannulation, catheterisation, injections, ablations, surgical aspirations, and drainages. Across these procedures, the probe has the potential to contact various patient sites – including intact skin, non-intact skin, mucous membranes and sterile tissue. This presents a complex challenge, as contact with these various body sites requires differing levels of disinfection or sterilisation between patient uses. Failure to adequately clean and disinfect medical devices like ultrasound probes between patients poses a serious risk to patient safety.

In 2012, a patient in Wales died from a hepatitis B infection – most likely caused by a failure to appropriately decontaminate a transoesophageal echocardiography probe between patients. As a result of this fatality, a Medical Device Alert was issued by the Medicines and Healthcare Products Regulatory Agency (UK) advising users to appropriately decontaminate all types of reusable ultrasound probes.[2]

The UK and European guidelines require ultrasound probes that come into contact with mucous membranes and non-intact or broken skin to be high-level disinfected. In particular, automated and validated processes for ultrasound reprocessing are preferred. This is supported by a study relating to manual disinfection methods, which found that only 1.4% of reprocessing systems were fully compliant when using manual methods, compared to 75.4% when using semi-automated disinfection methods.[3]

The Spaulding classification system

The Spaulding classification system[4] must be applied before a procedure commences so that information about what tissues or body sites may be contacted is taken into account.

This classification system is a widely adopted disinfection framework for classifying medical devices, based on the degree of infection transmission risk, and requires the following approaches:

- Critical devices are defined as those that come into contact with sterile tissue or the bloodstream. Probes in this category should generally be cleaned and sterilised. Where sterilisation is not possible, high-level disinfection is acceptable with the use of a sterile cover for ultrasound probes.
- Semi-critical devices contact intact mucous membranes and do not ordinarily penetrate sterile tissue. Ultrasound probes scanning over non-intact skin are also considered semi-critical. Semi-critical ultrasound probes include endocavitary probes, which should be used with a cover in addition to being high-level disinfected.
- Non-critical devices only contact intact skin. This category also includes contact surfaces that are not intended for patient contact in health settings. These devices and surfaces should be cleaned and low level disinfected.

It is important to note the difference between cleaning and low-level disinfection. Cleaning is the removal of soil and visible material until the item is clean by visual inspection. Low level disinfection is the elimination of most bacteria, some fungi and some viruses.

A final and important point for consideration is the use of probe covers.

While many ultrasound users and sonographers believe that their transvaginal ultrasound patients are protected from infection risk by using barrier shields and/or condoms, research has shown that up to 13% of condoms fail and up to 5% of commercial covers fail. Probe covers may have microscopic tears or breakages which can allow microorganisms to pass through.[5]

Conclusion

Ultrasound users should work with their decontamination colleagues to understand the current UK and European guidelines for reprocessing ultrasound probes. There are patient risks associated with ultrasound usage when proper disinfection procedures are not followed, as well as from ancillary products such as contaminated ultrasound gel. While the increased use of ultrasound has brought many benefits for patients, effective education and disinfection protocols are required to minimise the risk of infection.

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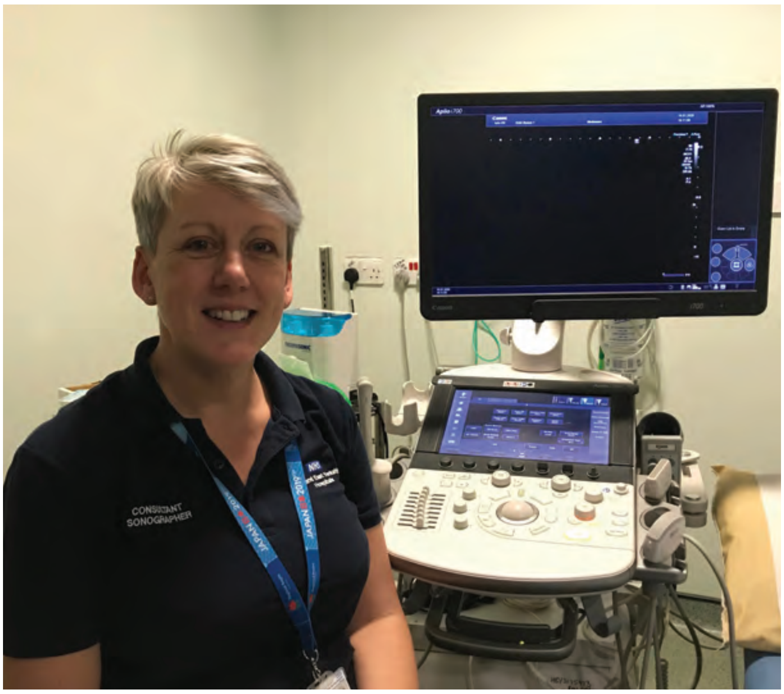
The world of medical ultrasound – A President's perspective

Pamela Parker
President, British Medical Ultrasound Society; Department of Radiology, Hull & East Yorkshire Hospitals NHS Trust, UK

There can be no one truly unaffected by the COVID-19 pandemic. This ongoing international health crisis has impacted on lives around the world; arguably, none more so than those of front-line health care workers. Speaking as a sonographer based in a large teaching hospital in the north of England, I have experienced first-hand the significant impact the pandemic has had on service delivery, my colleagues and, most of all, our patients. However, as an optimist, I like to believe that with every dark cloud a silver lining can be sought. Therefore, as an optimist, one opportunity the pandemic presents is the opportunity to reset normal within our clinical and professional landscapes. In some instances, of course, this happened rapidly and without time to pause and reflect. However, there has been an opportunity to review those services that were stopped and an opportunity to redesign as we move to restart planned care. Indeed, in my own institution, entire pathways have been remodelled, placing ultrasound imaging at the very core of where it was once an afterthought and poorly resourced or acknowledged. This has provided an ideal opportunity for modern ultrasound imaging to be showcased; those technological developments that have gradually become integral in diagnostic ultrasound imaging are now being recognised as essential to providing a powerful first-line core test for many patients, particularly those with delayed presentation and for whom swift assessments and management plans are required.

The British Medical Ultrasound Society
The British Medical Ultrasound Society (BMUS) has the core objectives: "to promote the advancement of the science and technology of ultrasonics as applied to medicine" and "to ensure the highest standards in practice are maintained". Coupled with the changing role of ultrasound in patient pathways, BMUS has developed and provided education and guidance to all professionals working in the field of medical ultrasound. For BMUS, as the premier ultrasound society in the UK, the annual scientific meeting has been the stage to present developing best practice, new and emerging technology, and provide an opportunity to discuss research and development with like-minded professionals. Face to face events have clearly been impossible to hold during the pandemic, and difficult to consider planning in the immediate future. This, too, has led to the organisation pausing, reflecting, and redesigning what can be delivered. The need for support for ultrasound professionals has not diminished; indeed, with increasing role development, it can be argued the need is greater than before. A virtual webinar programme was developed by BMUS during 2020 to provide relevant, and pertinent, education and standard setting in line with the objectives of the organisation; a journal club via Twitter established, and now plans are well underway for a full virtual online conference. None of these are likely to have developed without the dark cloud of the COVID-19 pandemic causing much disruption.

Webinars and e-learning, in the world of medical ultrasound at least, have developed at a pace in the last 18 months. Having a creative and innovative team supporting an online training programme has been essential and has unearthed hidden talents within the BMUS administrative team as well as the multitude of professionals who have supported and volunteered to provide the education programme. As with many professional charitable organisations, BMUS is reliant on volunteers who are willing and able to share their time and knowledge with peers. Despite the difficulties we have all faced, the willingness of our clinical colleagues to support the ongoing education and professional guidance output of BMUS has been phenomenal, and yet, despite this wealth of readily available material, attracting new members and minimising attrition of existing members remains as very real challenge. It is pleasing to note that the sonographer membership of BMUS has marginally increased recently, but attracting medical colleagues, in particular radiologists, to support the organisation remains difficult. BMUS prides itself on being a multi-disciplinary organisation and there to support any professional using medical ultrasound within their scope of practice. In the UK, by far the largest professional group is sonographers who primarily use ultrasound in their everyday clinical practice. Essentially, a sonographer is medical ultrasound! Radiologists learn ultrasound as a core skill during their training but, and as is common in larger establishments, radiologists are specialty-focused and many use



cross-sectional imaging modalities or interventional suites that are now far removed from the hands-on image acquisition, interpretation and reporting of ultrasound imaging. Increasingly, there are numerous non-radiology professions using medical ultrasound as a tool to enhance their clinical practice and to guide patient management. Indeed, many Royal Colleges now have specific ultrasound training programmes and competency assessments that their members are expected to complete to be able to deliver this point-of-care ultrasound (PoCUS). The importance of PoCUS cannot be overstated. As such, publications produced by our emergency medicine, chest, and intensive care colleagues ensured shared learning of the signs of COVID-19 on lung imaging, which became critical as hospital admissions rose in the first and second waves. The aim of BMUS is to bring this multi-disciplinary family together and recognise the benefits of sharing knowledge and skills but, at the same time, not alienating those for whom medical ultrasound is a professional career choice; sonographers, physicists, and radiologists alike.

BMUS has had, as do many societies, sub-committees whose roles are to ensure the objectives of the organisation are met. Longstanding and hardworking committees such as the physics and safety, publications and education committees have been the workhorses of the society since its inception. Latterly, new committees have been set up to reflect the changing professional landscape and, the now more diverse, users of medical ultrasound. PoCUS and obstetric clinical imaging groups have been established to support improvements in these critical fields of medical ultrasound. The professional standards group was established to better nurture and enhance working relationships with like-minded professional bodies and organisations. A consultant sonographer interest group has been established to promote career development for non-medical ultrasound practitioners and show case the very best in ultrasound innovation. However, membership of the society and an engaged workforce, from whatever background, is essential to the future success of these committees and the wider BMUS family. BMUS upholds the highest standards of practice and, it is with this aim, that the society engaged with Health Education England (HEE) in a project to increase the sonography workforce. BMUS, in collaboration with the Consortium for Accreditation of Sonographic Education, the Royal College of Radiologists and the Society of Radiographers has been integral member of this HEE sonographer workforce project group and progress is slowly being made. Every arm of health care is under pressure to increase activity, improve turn-around-times, and deliver safe and effective care. There is no profession that is not struggling with workforce capacity, with vacancy rates well documented; radiology and sonography are no different, and solutions have needed. While BMUS has no remit to act as a trade union or provide workplace advice, it does have a remit to ensure standards of practice are optimised, safe and of high standards. The multi-disciplinary nature of its membership ensures BMUS is well-placed to offer opinion, advice and guidance as part of this collaborative approach to HEE as the path of defining and developing an ultrasound / sonography career framework emerges.

Whilst there have been significant challenges, in the workplace, professionally and personally over the last 18 months there has been opportunity to reflect and set a new or revised course for the future. The publication of the Richards Report in 2020[1] and NHS Long Term Plan in 2019[2] has provided an opportunity for the role of sonography, and the role of medical ultrasound within healthcare, to be established as essential in first line investigations in critical, acute and planned care, the improvement of obstetric outcomes, and in guiding interventions within an out-patient setting. Professionals working with medical ultrasound, as a career path or using it as a tool, have the opportunity to embrace new ways of working and new pathways. Supporting national organisations, such as the BMUS, provides the opportunity for professional societies to have a voice around the table at national discussions and highlight the benefits of a highly trained, well-motivated, recognised workforce. There are challenges ahead but none that cannot be faced together.

I am proud to represent BMUS and my multi-disciplinary ultrasound colleagues and will work hard in my tenure as President to turn those challenges into golden opportunities as we head into the new normal of 2021 and beyond.

About the author
Pamela Parker is a consultant sonographer working within radiology of the Hull University Teaching Hospitals NHS Trust. Pamela has over 25 years' experience in the field of medical ultrasound. Her specialist interests are uro-genital ultrasound, contrast and fusion-guided imaging. She has established the first sonographer-delivered fusion and transperineal prostate biopsy service within radiology in the UK. Pamela is studying part-time for a PhD investigating the role of ultrasound within the active surveillance of prostate cancer.

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Meet the Expert: Paul Sidhu

Paul Sidhu is Professor of Imaging Sciences at King's College London and consultant radiologist in the Department of Radiology at King's College Hospital. His research interests have focused on ultrasound and interventional radiology. Here he shares his thoughts with *Hospital Healthcare Europe* on ultrasound and how this technique has evolved and will continue to develop in the future.

On how radiology services are organised at King's

Professor Sidhu described how King's is a large tertiary, general hospital in southeast London serving a population of over 2.2 million people in a largely deprived area. King's has several different sites that cover various services, including paediatric, neonatal, cardiothoracic, neurosurgery, breast cancer screening, and liver transplantation. There is one centralised, very large, radiology department employing around 80 consultant radiologists and up to 700 staff. The department is also involved in the provision of training for radiologists and radiographer staff. Although radiologists are qualified doctors, their path towards becoming a radiologist is a long one that can take up to 12 years. In contrast, radiographers, who are the individuals responsible for taking images, still need to undergo degree level training although their role has greatly expanded in recent years. At King's for example, radiographers manage all aspects of imaging for CT and MRI scans imaging in interventional radiology and some radiographers have become sonographers involved in the scanning and issuing of medical reports. All aspects require several years of training to become established within these roles.

Ultrasound is available and employed in many different specialities by experienced and competent individuals. Professor Sidhu explained how there remains strict controls on who can perform scans that involve exposure to radiation and particularly in nuclear medicine, with the administration of radioactive isotopes. Administrators are required to have a specific ARSAC licence. All hospitals that undertake examinations with radiation exposure will have a radiation protection officer. In contrast, while there are no specific controls on who can perform either an MRI and ultrasound scan, he highlighted how MRI equipment is prohibitively expensive and ultimately is best reserved for the radiology department. Nevertheless, according to Professor Sidhu, the position is rather different with respect to ultrasound. While in the past, ultrasound has been the responsibility of the radiology department, as Professor Sidhu explained, things are rapidly changing with much ultrasound, particularly point-of-care, becoming performed outside of radiology. For instance, chest physicians will use ultrasound to identify pleural effusions that need to be drained, and rheumatologists will make use of ultrasound to examine the small joints of the hands. The evolution of ultrasound in other specialties has been considerable and radiologists no longer have either the time or perhaps inclination to perform such scans. Despite these developments, as Professor Sidhu described, it is safety regulations, focused on the patient, that keep radiology departments together. However, while the use of ultrasound has now extended beyond the realms of the radiology department, he felt that the radiology community was not overly concerned about this direction of travel, especially given that in the UK, there is a shortage of radiologists, and this delegation has to some extent been welcomed. In fact, he now believes that no single speciality effectively "owns" ultrasound and in many radiology departments, the ultrasound scanning is performed by sonographers and the radiologists themselves have moved on to becoming more focused on the interpretation of specialised scans. As a passing thought, he felt that while radiologists were likely to be the most competent individuals to perform and interpret scans, if an ultrasound was being used as a point-of-care service for a specific indication, provided that an individual healthcare professional appropriately interpret a scan, he had no objection to these developments.

On the ESR subcommittee on ultrasound, his work as Chair, and future plans

Professor Sidhu mentioned how he had been a member of the European Society of Radiologists (ESR) ultrasound subcommittee for several years during which time, it had produced a number of different position papers. He cited what has become a very successful position paper on infection control and prevention from 2017,[1] highlighting the importance of good hygiene measures, especially with transducers and how these should be cleaned after each use. More recently in 2020, the group have published best practice recommendations and imaging use.[2]

This latest paper was an update of an earlier 2009 position paper on ultrasound.[3]
As Professor Sidhu clarified, the newer version provides a series of recommendations on appropriate standards for the use of ultrasound in radiology from the perspective of the ESR.

For instance, the position paper, defines the essential requirements for equipment, practice aspects of use, infection control, requirements for training, certification and competence. He noted that while not all ultrasound operators would necessarily conform to the standards delineated in the position paper, it did define the professional standards which would be expected if the service were delivered by a radiologist. Professor Sidhu explained that an important aim of the position paper was to hopefully clarify for any non-radiologists, the anticipated standards which should be followed, in a sense, a standard operating procedure for undertaking ultrasound, which had the support of the ESR and therefore credibility. Professor Sidhu described how it was important that the position paper provided the necessary guidance because when using ultrasound, it is not the machine which does the job but the operator. If the operator is not competent, neither is the output from the machine! In short, it is vital that operators will need to practice, learn and develop all the time to perfect the technique to ensure that they get the best use from the device.

In terms of ensuring continued best practice, Professor Sidhu outlined documents produced by the ESR were designed to support non-radiologist operators. This advice encouraged participation in audits of their service but additionally and equally important, was that non-specialists needed to maintain their skills and competence through an examination of the practice all the time, together will ensuring equipment maintenance, the environment used to perform imaging and how best to manage patient throughput, all of which were essential for adherence to professional standards. Professor Sidhu hinted that with a rapid pace of development in ultrasound technology, it is highly likely that the professional standards of today would require updating in the near future. He pointed to the fact that equipment was becoming smaller, so that handheld devices are able to do a reasonable job and ultrasound technology is also available for use on smartphones and an iPad for scanning.

Future plans

Professor Sidhu indicated that one of his aims for the ESR over the next few years was to define the place of ultrasound within radiology more clearly. He remarked on how the position of ultrasound within radiology is far less clear cut than say 20 years ago and that is often seen as the 'Cinderella' modality in radiology. He noted for instance how today, a lot of younger radiologists were more interested in CT and MRI scanning because this was perceived as being more cutting edge and that ultrasound is often seen as harder work than the other modalities. After all, clinicians must operate the device, sit with the patient, and scan them, whereas there is no direct patient contact with MRI and CT, with the hard work coming from the ability to form a diagnostic image, readily interpretable. He revealed how for the next ESR meeting in 2022,[4] the committee is preparing a session dealing with where they believe ultrasound will sit in 20 years' time. He stated that there are

plans for three speakers at the meeting and who will discuss different models of ultrasound practice. Firstly, there is the German model, in which many GPs perform ultrasound as well as having a centralised hospital department run by radiologists, but with other medical specialists effectively dipping into the service. Second is the Russian model, whereby both radiologists and other physicians only do ultrasound and no other imaging modality. The third, and often perceived as a controversial model, is the one deployed in the UK, where it is the radiologists who performs less scanning, taking on more specialised examinations (e.g. MSK) and delegating the sonographers to effectively undertake most of the scanning, and providing diagnostic reports. He felt that a discussion of the different models would undoubtedly provoke a lively debate. Professor Sidhu mentioned that tied in with this debate will be a position paper on where the ESR believes ultrasound should sit within radiology and how the speciality should evolve over the coming years. Professor Sidhu, though not the final arbiter on any decisions, felt that in the future, perhaps radiologists should not see themselves as guardians of the ultrasound world. He added that anyone from whatever subspecialty and who has an interest and can demonstrate competency and safety in their practice should be encouraged to use ultrasound. Professor Sidhu believed that there was nothing inherently wrong with, for example, a rheumatologist upskilled in the use of ultrasound, if they saw the benefit of the imaging modality in their assessment of a patient. He also thought it possible that radiologists could retain ultrasound within their departments but allowing access to physicians from different specialities with an overarching goal of improvements in patient care.

A further advantage of ultrasound

highlighted by Professor Sidhu was the flexibility of the modality. In contrast to the static imagery of an MRI or CT scan, ultrasound was performed in real-time. Consequently, it was possible during the scan to enquire as to whether the patient experienced any pain or discomfort, particularly if the imaging indicated a potential cause for the pain. Alternatively, the patient may offer a snippet of history during the scanning, and which helps to confirm the diagnosis, neither of which are available to radiologists when interpreting other imaging modalities.

On the impact of the pandemic on imaging

Professor Sidhu described how King's was very busy during the first and second waves of the COVID-19 pandemic.[5] With the global cancellation of routine imaging during the first wave, the radiology department was quiet with ultrasound becoming extremely useful within the intensive care unit as a point-of-care for imaging of patients' lungs; this was done predominately by the pulmonary physicians although radiologists did perform some abdominal scans. He added that during the second wave, the department was a lot more prepared and continued with as much routine scanning, if patients could safely attend the hospital, but suspects that this has resulted in a huge backlog of imaging awaiting to be undertaken. While the magnitude of this backlog remains uncertain, Professor Sidhu remarked that there are still a lot of patients waiting to be scanned.

On the key learnings since the pandemic

Professor Sidhu thinks that an important learning from the pandemic is that services need to become more patient centric and that the provision of imaging services should become easier and more accessible for the patient. With this idea in mind, there is likely to be a wholesale shift of routine outpatient scanning out of the acute hospital and make greater use of community-based imaging, a move he says which has been supported by government. He mentioned that although this change had been under discussion for several years, it was really brought into sharper focus as a consequence of the pandemic. After all, he reflected on how it has been ludicrous to bring large numbers of patients into a busy hospital for routine/GP imaging. Consequently, there is now a move in progress to establish diagnostic hubs, adjacent or close to the hospital and introducing agreed patient pathways to ensure that only those patients who need further management must visit the hospital. Professor Sidhu felt over the next few years, elective imaging could be undertaken within the hub and that this would release capacity with the hospital, allowing time to see acute patients and those who required other forms of interventional or complex imaging, with the important caveat, that the hospital service is accessible for patients when needed.

On the current exciting technological developments

Professor Sidhu noted how there were enormous developments in ultrasound technology, and which were of huge benefit. He mentioned that a difficulty was that many people still see ultrasound as only black and white, but that this is no longer the case and ultrasound has a far greater capability for imaging that all other modalities. He cited how multiparametric ultrasound imaging can be used to assess patients with steatotic livers[6] and that other innovations such as colour Doppler ultrasound, contrast ultrasound and elastography ultrasound,[7] which looks at the stiffness of the liver, the amount of fibrosis and scarring have all proved to be of value in patient care. He added that a further advantage of the developments in ultrasound was that the technology was less expensive than other modalities and safe. He sensed that in the next couple of years there would be many further innovations with ultrasound-based technology and that these would continue to be patient-friendly. Using the example of scanning the liver of a two- or three-year-old child, Professor Sidhu described how for an MRI scan, the child needed to be sedated perhaps, given the contrast agent gadolinium, and kept still. However, for an ultrasound scan, the child remains awake, and the parents can also be present to help with any possible anxiety. He thought that as an imaging modality, radiologists would be ultimately unwise to give up on ultrasound, adding that the technology is now at a level where the device does almost everything for the operator, adjusting the parameters automatically to produce the best image.

Another development that had made a considerable impact on ultrasound mentioned by Professor Sidhu was artificial intelligence. The technology can recognise the organs under investigation, identifies any abnormalities as well as providing a differential diagnosis. He added that it even writes the report for the operator although currently, it still needs a clinician to interpret the results of the scan.

On the skills that radiologists will require in the future

Professor Sidhu thinks that will all the emerging technologies, some radiologists have been left behind simply because the developments in ultrasound are largely driven by physicians in other specialties; in particular, hepatologists. He explained how a key driver is not so much that other specialists embrace the technology but more that unlike radiologists, hepatologists and other specialties do not have routine access to CT and MRI, ensuing the best aspects of ultrasound are utilised constantly, before reverting to another imaging modality.

Even though in the future ultrasound might well move outside of the sphere of radiology, Professor Sidhu still believes that there will always be a need for radiologists to be skilful in ultrasound. As a profession, they possess the necessary skills to match up the results from all the other scans and images and in doing, so will continue to make an important contribution to patient care.

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Meet the Expert: Neelam Dugar

After specialising in oncology imaging at Manchester, Neelam Dugar is now a consultant radiologist at Doncaster and Bassetlaw NHS Trust and also Chair of the Radiology Informatics Committee at the Royal College of Radiologists. *Hospital Healthcare Europe* had the pleasure of speaking with her about her career to date and to discuss recent documents produced by the College on the use of artificial intelligence in radiology and the development of a vetting procedure for inappropriate scan requests.

Organisation of services at the Trust

Dr Dugar's department has approximately 16 radiologists and, with a newly purchased third CT scanner, the department is extremely busy, operating on an almost conveyor belt-like basis. In a typical day, radiographers will perform around 1000 imaging investigations including those for elective, acute and ward patients. As there is a requirement to have A&E CT scans reported on within an hour, Dr Dugar emphasised the importance of prioritising the workload within the team. Hence, one radiologist is always allocated to report emergency scans, and while others do elective work. During the evening and weekends only one radiologist is available for undertaking emergency CT and MRI scan reporting. Night-time emergency radiology has now been outsourced to Australia. Since starting her role over 17 years ago, the workload had expanded considerably due to a combination of increased expectations and national guidelines that often recommend the use of imaging. For example, she described how 17 years ago, during a typical Sunday, she might be called upon to report one emergency scan but on a recent weekend shift, her hospital performed 100 emergency CT and MRI scans. She feels that no other specialty has experienced that kind of explosion in workload.

On the work of the RCR Informatics Committee and her role as Chair

Dr Dugar emphasises that technology is the backbone of radiology and had a desire to make best use of technological advances as a means of enhancing patient care. She explained that she was appointed as informatics advisor in 2015, because of an interest in the topic coupled with the fact that she had led the development of digitisation in her own department. She suggested that the Royal College of Radiologists (RCR) felt that it was necessary to have a committee that was able to set the standards of what should be achieved by all radiology departments implementing informatics. In other words, the RCR Informatics Committee was tasked with defining the standards and hence, best practice, which should be achievable through hospitals' information technology (IT) systems.

Out of this work came the publication Integrating artificial intelligence (AI) with the radiology reporting workflows (see later in the supplement for a summary of guidance). The guidance defined the standards for how AI should be incorporated into the radiology information (RIS) and picture archiving and communication systems (PACS). Dr Dugar highlighted how, in some respects, AI is considered a very broad term and can be interpreted differently depending on the context. For the present document, the RCR informatics group considered AI in the narrow context of 'computer vision' used for radiology image pre-analysis. As Dr Dugar explained, because AI systems have already been developed for facial recognition, given that the role of a radiologist is to visualise images and to make interpretations to inform the ongoing care of patients, it seemed only right that this should be the area to focus upon.

However, a primary focus was to ensure that IT vendors could develop the necessary infrastructure to incorporate AI systems with different hospitals. A further consideration for the implementation of AI was the apparent national shortage of radiologists in the UK. For instance, in a 2018 report,[1] it was noted how in the UK, only one in five UK Trusts and health boards had enough interventional radiologists to provide safe 24/7 services to perform urgent procedures.

Dr Dugar defined how the AI workflow guidance should work in practice, explaining that the AI system would initially review the image before it was seen by a radiologist. The AI system algorithms were such that it was able to highlight any relevant features, which is also within the remit of radiologist. Nevertheless, whereas the AI systems are capable of detecting some abnormalities, the radiologist would then combine these findings with other test/imaging results, and any other relevant clinical findings, to create a more personalised report for the patient.

Will AI replace radiologists in the future?

If the AI system can do the essential job of a radiologist, surely these individuals can be easily replaced? Dr Dugar disagrees. She revealed how in 2016 AI pioneer, Geoffrey Hinton, had said "we should stop training radiologists now. It's just completely obvious that within five years, deep learning is going to do better than radiologists."[2] At the time, she said this created a major staffing crisis,

especially in the US, which saw a downturn in doctors choosing radiology as a career, fearing that they would be deemed superfluous in the near future. But, as Dr Dugar added, medicine is not maths – if it were then there would be no need for a radiologist! She feels that it is virtually impossible to create an 'artificial' radiologist simply because of the huge number of algorithms that would be required to emulate the thought-processing of a radiologist.

Dr Dugar believes that having an AI system evaluating a scan goes some way towards the need for two independent reviewers of a scan result. This is considered as best practice, lending support to the metaphor that "two heads are always better than one". As she said, this is the current recommendation for breast cancer screening. She stressed that having two independent reviews was necessary because even though individual radiologists are highly trained, they are fallible. Thus, from a safety perspective, dual review is the ideal standard.

The integration of an AI system was also important but for a very different reason. Dr Dugar highlighted that, in reality and with a national shortage of radiologists, it becomes impossible to achieve the two-reporter standard for images. One of the key reasons for a second reporter was to the minimise the phenomenon of satisfaction of search, which describes the situation where some lesions remain undetected after an initial lesion. As Dr Dugar illustrated, when a radiologist finds an abnormality, they become fixated on that particular problem and start to process this finding within the context of other clinical information and sometimes ignore other findings. With an AI system able to review the image prior to the radiologist, it effectively becomes that second reporter and a helper, alerting the radiologists to the full range of abnormalities present on the image. In discussion with colleagues, a barrier to greater use of AI is the perception among some radiologists that the system is very sensitive but not specific. Using the example of the assessment of a lung scan, Dr Dugar explained that while the AI system would report on the presence of tiny nodules, the focus of the radiologist was in looking for metastases. With greater knowledge of the patient's clinical history than the AI system, the radiologist can potentially discount the relevance of these nodules and advise accordingly. In contrast, the AI system simply identifies any abnormality and is unable to make a subjective judgement within the context of any other clinical findings. Dr Dugar labelled the AI system as a 'junior radiologist', i.e., it was able to provide a limited role as a preliminary reviewer on images. Nonetheless, she did believe that in the future, with improvements in AI occurring, the input from a radiologist might be unnecessary, especially for simple imaging, e.g., reporting on the presence/absence of a fracture. However, radiologists would still be required to interpret more complex imaging from MRI or CT scans. She added that while an AI system could identify a filling defect in the lungs and report the most likely cause to be a pulmonary embolism, as a radiologist, you are always thinking laterally about other differential diagnoses.

On the vetting and cancellation of inappropriate scan guidelines

As Dr Dugar described, being both medically qualified and trained in radiology allowed her and her colleagues to assess whether or not a particular imaging request was appropriate. She emphasised how often both junior doctors and those from other specialities, may not be completely clear on which imaging tests were correct. The vetting (triaging) and cancellation of inappropriate radiology requests document was introduced simply to help manage the workload within radiology departments. An important part of Dr Dugar's role is to always vet or triage any requests for imaging that reach the department. This vetting process, she added, was crucial because of the high workload of the department, which makes it impossible to perform every exam request.

While the vetting process amounts to a clinical assessment task in itself, Dr Dugar highlighted how within her department over 90% of the vetting process was undertaken by the radiographers rather than the radiologists. This had been made possible through the introduction of a protocolised approach for the radiographers. Moreover, Dr Dugar believes that radiographers can quickly acquire the necessary vetting skills and then approve and book a scan or reject the request. A further advantage to radiographer-based vetting, is that, as these individuals are involved in performing the imaging, they are able to quickly assess, and then cancel, any duplicate requests and in some cases, even determine if the request would be of additional value, i.e., if the request is for a broadly similar scan. A difficulty for radiographers, however, is that without the necessary medical training, they may feel uncomfortable cancelling an imaging request that was requested on clinical grounds and in such instances, the protocol would dictate that the request is forwarded to the radiologist.

As a consequence of introducing the vetting process in her department, Dr Dugar felt that on a typical day, she might be asked to vet up to 30 requests and allocates up to 30 minutes of her day to this task. She thinks that such vetting is a key task given that the department performs around 1000 scans each day. Although some of the requests passed to her from radiographers can be challenging, in many cases, it can sometimes be very straightforward and require simply altering the request to a more appropriate imaging modality. For more complex cases, she will need to review the patient's medical history or initiate a discussion with the referring clinician to discuss the best option. In cases where the request is rejected, Dr Dugar ensures that the requesting clinician is informed of her decision and the rationale behind the cancellation. She thinks that the departmental system, being fully electronic has streamlined the whole request/cancellation process.

Dr Dugar expressed the view that the vetting document was desperately needed because in some radiology departments, no vetting process was in place. She realised that part of the reason behind this lack of vetting was largely due to a lack of functionality within the hospital's internal IT system. The purpose of the vetting guidance was thus to ensure that while not all NHS Trusts employed the same vendors, these vendors would modify the IT infrastructure to enable electronic communication for the vetting process. As Dr Dugar said, in discussion with radiologists from outside of her own department, the cancellation process was often not communicated to the original requesting clinician and this led to internal friction and, in some cases, the radiologists in an attempt to appease the requesting clinicians, decided to no longer triage requests, with a resultant increase in their workload. Although it seems unusual that the whole of the NHS must deal with different IT vendors, Dr Dugar is against the idea of a national vendor. She thinks that with such a huge monopoly, there would be little incentive to innovate. What is more important she feels, is that the same workflow processes should be adopted in the different NHS Trusts, to improve the efficiency of radiology departments, even if this occurs through dissimilar IT systems.

On the impact of the pandemic on imaging services

Dr Dugar said that for her, radiology services did not stop during the pandemic although the focus shifted to COVID patients. She felt that her own work, which is either cancer or emergency-based, did not slow during the pandemic. She believed that one of the greatest changes because of the pandemic was the digital transformation within the NHS. She thinks this was of enormous benefit, enabling more virtual meetings which were a great advance compared to teleconferences. Another important development for work–life balance was allowing radiologists to have workstations at home.

Dr Dugar says that having an interest in digital technology, she had tried to implement greater home working for some time, but her request was always denied due to lack of funding. However, she also thinks in the future, this innovation of homeworking and virtual meetings will not revert to pre-pandemic times but there will still be a balanced need for office working.

On the evolution of the imaging landscape over the next few years

Dr Dugar believes that AI algorithms will develop in the next two to five years and become a much better preliminary reporter on many more things such as fracture detection, lung nodule detection etc. She mentioned how AI is already being used in brain imaging for strokes.

She worries, however, that future innovations in AI by computer scientists will require additional funding, and that this should not be at the expense of a radiologist training.

Another potential growth area she feels is in the evolution of enterprise imaging[3] and revealed how all her own radiology department's images have already been archived and made available throughout the enterprise. An important current problem, she explained, was how various medical images from other specialties/departments have been generated but are stored in different locations and formats without the correct patient identifiers etc. and are not indexed properly (e.g., endoscopy images, ECG, audiometry, sleep studies etc). Incorporation of all the images and graphs in a single and accessible location will be of enormous value, not only to radiologists but also all treating physicians. With the ability to review all images, and together with other pieces of clinical data, it will allow radiologists to create a much more personalised report for the patient.

Although improvements in smartphone technology allow for image review, Dr Dugar thinks that at the present time, the quality of the images is not of sufficient quality for diagnostic purposes. Furthermore, from a medico-legal perspective, she would not use the images reviewed on a smartphone for reporting. She also felt that while mobile scanning units for MRI and CT scans were available and could be utilised for elective work, these imaging modalities would still need to remain within the hospital premises, where the equipment was needed for emergency scans.

Image acquisition and interpretation were separate, and Dr Dugar believes that she does not need to be present at a mobile scanning unit and can remain either in the office or at home to undertake her interpretive role for the images. However, radiologists (whether remote or on-site) must continue to work closely with the radiographers operating the scanners to provide support and advise on appropriateness and vetting/triaging support. Radiologists and radiographers must always work as teams to improve patient care.

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3 Petersilge C. The evolution of enterprise imaging and the role of the radiologist in the new world. www.ajronline.org/doi/full/10.2214/AJR.17.17949 (accessed June 2021).

Integrating artificial intelligence with the radiology reporting workflows

This guidance from the Royal College of Radiologists sets out the standards that a department should meet when integrating artificial intelligence into already established systems, producing a safe seamless system with the patients at the centre

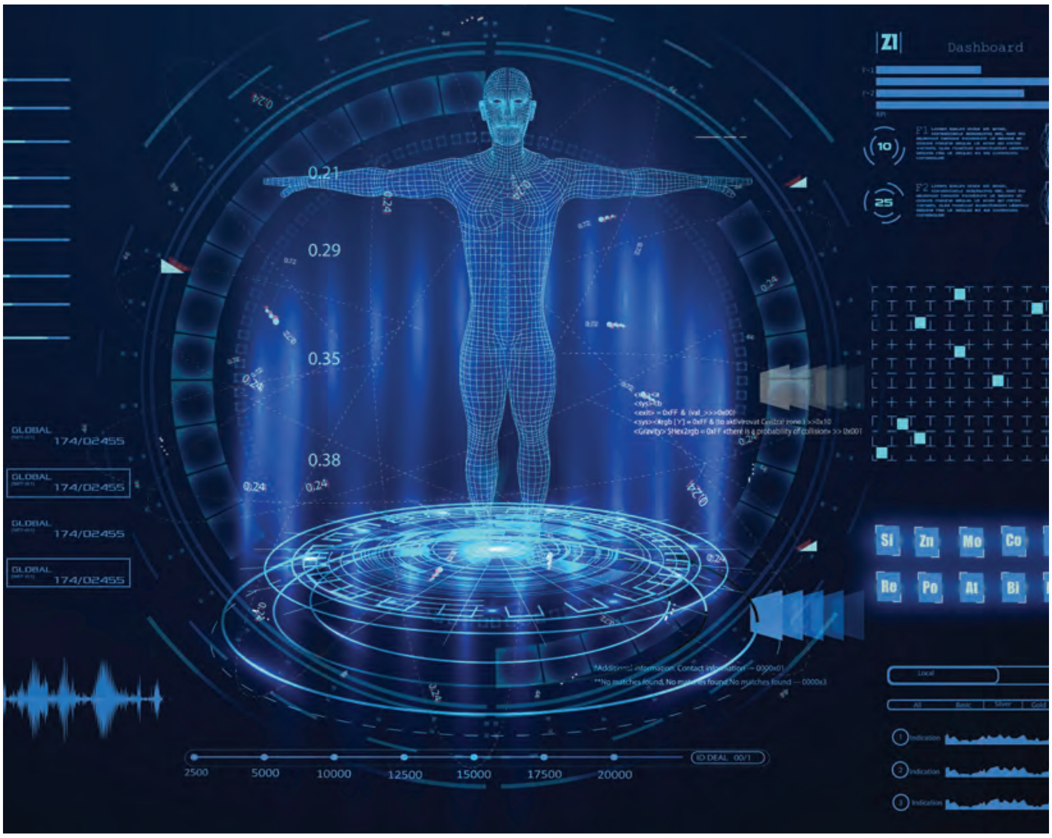
The fast pace of developments in artificial intelligence (AI) means that the technology will have an important role to play in many clinical specialities, including radiology and will change, hopefully in a positive direction, the way in which patient care is delivered.

AI platforms and algorithms are designed to work in collaboration with existing technologies and have a wide range of potential uses in radiology. For example, in magnetic resonance imaging (MRI), an AI algorithm can detect multiple sclerosis, strokes, brain bleeds etc. Within the arena of computed tomography (CT), AI systems are designed to detect skull fractures, brain haemorrhages, infarcts, and tumours. In body CT, the introduction of AI has a role in mammography, allowing for the detection of both suspicious lesions and calcification.

Once an image has been captured by the radiographer, the AI will perform a 'pre-analysis' of the image, and, if an abnormality is detected, the system will query and retrieve a prior similar image from the picture archiving and communication system (PACS) for comparative analytical purposes. A further advantage of using an AI system, is 'computer-assisted triage', which helps with the prioritisation of reporting worklists once an abnormality has been detected.

Nevertheless, the RCR report emphasises the importance of radiologists acknowledging the limitations of an AI system report, i.e., its sensitivity and specificity, and what these figures mean in the context of the specific pathology. In other words, the AI system is simply a supportive tool and radiologists should not become overly reliant upon on the AI findings and assume that these findings will be 100% accurate all the time.

The overarching aim of the RCR report is firstly to ensure that any innovations in AI are fully integrated into existing reporting systems and secondly, to define the necessary standards



required to enable radiology service providers to facilitate this integration without creating additional burden for staff.

The report does not make any specific recommendations about which AI system should be purchased, or any ethical considerations related to the use of AI, and finally discusses the issue of AI solutions for workflow and radiology management efficiency. The report is directed more towards defining the parameters within which an AI platform should operate.

Standards

The report begins with a series of standards for the use of AI systems.

1 AI must be integrated seamlessly with existing radiology information systems (RIS) and PACS without creating an additional burden for radiologists.

2 The accuracy of the AI algorithms must be clearly declared to both the radiologist and others involved in patient management.

3 The AI finding should be communicated to the RIS and PACS through existing and global technical standards.

4 The department workflow should be sufficiently robust to ensure that the AI analysis is complete and available on PACS before being viewed and interpreted by a human.

An important element of the report is the necessity to ensure that all instrumentation, e.g., scanners, RIS, PACS and the AI platform, all work cooperatively within the radiology department. It is also necessary that the AI platform only begins the analysis once the radiographer has completed the examination and has sent the information to the AI system, i.e., that the imaging should be 'pre-analysed' before reaching the PACS for displayed.

General standards for data output

Any AI platform adopted should have standard output, and which must include:

Graphical representation of the region of interest (of the detected abnormalities) or mark-up/pointers using global technical standards (DICOM) so that images can be viewed in the PACS viewers.

- AI detected abnormalities should be output as text e.g., fracture, infarct etc.
- A notification that the image analysis has been completed.
- Some AI alerts may be defined as critical within the system and should be pre-specified by the radiologist.
- A declaration or disclaimer should be sent out including the list of any abnormalities which were evaluated by the AI system. This might, for example, include a CT scan that detected a brain haemorrhage. It is also necessary to include the sensitivity and specificity (or true/false positives or negatives) of the applied algorithm for each of the abnormality being evaluated.

With the RIS, it will be necessary to incorporate additional data fields which capture AI abnormalities and any alerts.

The report concludes on a positive note saying that: "AI image pre-analysis is likely to have a very positive impact on radiologists' future working lives if properly integrated into the reporting workflow".

A copy of the full guidance can be viewed here. www.rcr.ac.uk/publication/integrating-artificial-intelligence-radiology-reporting-workflows-ris-and-pacs

Vetting (triaging) and cancellation of inappropriate radiology requests

Radiologist review of imaging requests prevents exposure to unnecessary radiation, reduces inappropriate and duplicate examinations and makes the overall delivery of services both safer and more efficient. Recent RCR guidance advises on setting up efficient processes for vetting and communication

An often under-recognised role of radiologists is that of reviewing imaging requests. Such input can lead to the avoidance of inappropriate requests, unnecessary radiation exposure for patients and the potential to avoid duplication of examinations, which increases the workload burden of radiology departments. Moreover, communication with the original referrer as to why a request has been declined provides an opportunity for informative feedback and hence the effectiveness of any vetting procedure is reliant on the establishment of a robust communication network.

Because radiologists are themselves qualified medical practitioners, they often have a good understanding of the appropriate imaging modalities required for specific conditions and in particular age groups, after a consideration of any prior tests (both radiological and non-radiological). Thus, there is much to be gained through incorporation of radiologists as members of the multi-disciplinary team (MDT), to enable alignment of investigations and preferences for the mode of imaging. A further and relevant benefit of radiologist involvement with MDTs is that it can serve to improve the overall efficiency, cost-effectiveness, safety and delivery of radiology services.

The role of radiologists is becoming more patient-focused, and this is likely to be expanded in the years to come with the development of rapid access diagnostic centres and one-stop imaging/biopsy/clinical pathways, especially where diagnostics become a first step within many patient pathways.

Staff involved in vetting requests

The report includes a section discussing the vetting process and who should be involved. While an important aspect of their work, the vetting process undertaken by radiologists is often not fully recognised as a clinical task and unfortunately there is no national benchmarking of vetting activity. The report suggests that vetting should be used as a benchmark to ensure that it supports the specific recommendations for radiologists detailed in the National Health Service (NHS) document, *Choosing Wisely* (https://www.choosingwisely.co.uk/).

The Royal College report suggests that modality-based radiographers, using appropriate protocols and with suitable training, can undertake vetting of requests for computer tomography, magnetic resonance imaging and ultrasound. Such individuals are likely to be much more comfortable cancelling, for example, a duplicate request, but given that radiographers are not medically qualified, they are less likely to refuse a test on clinical grounds. Under such circumstances, the report advises that requests for more specialist or complex imaging, are best left to a radiologist or special interest radiologist, to ensure that the request is appropriate. In addition, where a radiographer has any concerns or is uncertain about whether to decline a test, the request should be forwarded to the radiologist. Thus, good communication within the radiology department is a prerequisite to ensuring that an appropriate protocolling and vetting procedure is introduced.

Technology requirements for vetting

On a practical level, the report recommends that an effective vetting process is carried out using the radiology information system (RIS), which is the most commonly used system in the NHS. However, while the structure of systems may differ across the NHS due to the presence of different vendors, the report defines the process which should be available to radiology departments, despite the presence of different vendors. Using RIS, it should be possible to communicate the reason for cancelling a scan and in making such decisions, radiologists should have access to the full local imaging history and should be able to have their vetting workload recognised as an activity.

In an appendix to the document, there is a RIS specification for the vetting and protocolling workflow.

The full document can be found here: www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr214-vetting-triaging-cancellation-inappropriate-radiology-requests.pdf

European Radiology Society best practice guidance for lung ultrasound in COVID-19

With the attributes of portability and ease of use, lung ultrasonography has become the 'go to' imaging modality for lung and pleura and recognised as being able to make a substantial contribution to the care of patients with COVID-19.

While computer tomography (CT) has become the mainstay of diagnostic imaging evaluation of thoracic disorders, in the hands of an experienced radiologist, lung ultrasonography has much to offer according to guidance issued by the European Radiology Society (ERS). Within an intensive care setting, for example, point-of-care ultrasonography enables direct, bedside examination of the lung and pleural space and has been found to reduce the need for chest radiographs and CT scans. Although the standard of care within an intensive care unit is the chest X-ray, in an assessment of the comparative diagnostic performance of auscultation, chest radiography and lung ultrasonography, the latter was deemed to be highly sensitive, specific and reproducible for diagnosing the main lung pathologic entities in patients with acute respiratory distress syndrome (ARDS), which is a recognised complication of infection with COVID-19. More recently, compared with X-rays and CT scans, point-of-care ultrasound of the lungs of patients with COVID-19 has been found to offer similar performance to CT and superior to X-ray, in evaluating pneumonia and ARDS. In fact, the authors of this latter study commented on how lung ultrasound played an important role within the emergency room and intensive care unit, reducing exposure to radiation and minimised transport of high-risk patients.

With the potential benefits of ultrasonography clearly defined, the ERS has released, what it hopes, will be the definitive guide on the role of lung ultrasound in patients with COVID-19. The guidance covers the fundamentals of ultrasonography examinations, the different types of available transducers, including appropriate methods of cleaning and system set-up and concludes with advice on how to perform a lung examination and examples of the typical findings seen in patients with COVID-19.

The guidance defines how when using ultrasound for the diagnosis of lung pathologies, the presence of two artefacts can provide invaluable information. In fact, the document provides several illustrative imaging examples. The first, described as "A-lines" are reverberation artefacts triggered by oscillating tissue with an air interface and which can be seen as parallel, repetitive horizontal lines of the pleural surface. This A-profile is shaped by intact ('dry') lung parenchyma containing air when it is combined with normal lung sliding. If sliding is absent, however, it is intensely suggestive of a pneumothorax. In contrast, "B-lines" are vertical hyperechoic artefacts and arise from areas of pleural consolidation and are indicative of accumulation of fluid in the pulmonary interstitial space or alveoli. According to the ERS guideline, although one or B lines might be considered as normal, any increase in number or spread in one zone represents severe pulmonary interstitial oedema.

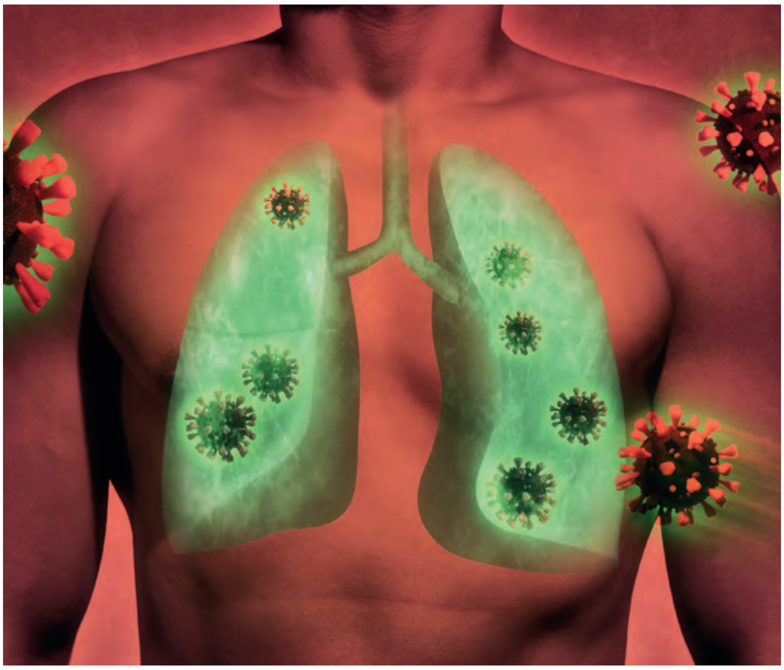
In a discussion of the different transducer devices, e.g., high and low frequency linear, curvilinear devices, the guidance suggests that high-frequency probes will offer a better solution to observe lesions in the pleural line. Nevertheless, it also makes the important point that ultimately, the performance and interpretation of results is not probe-specific. With respect to cleaning, the guidance indicates that though immersion of the probes in a strong disinfectant is desirable, in the longer term, repeated cleaning could damage the probe. In fact, the recommendation is that the use of advanced cleaning solutions should be discussed with local infection teams and vendors supplying the machine.

The document ends with some general advice on basic lung examination and the typical findings observed in patients with COVID-lung disease. It notes how pleural effusions are uncommon and that these are more likely among those who are critically ill. The guidance records how lung ultrasonography can reveal the typical patterns for interstitial pneumonia, which in COVID-19 is mainly seen in the peripheral pulmonary zones.

Finally, the guidance notes that while CT may be needed for follow-up of cases in which ultrasonography is unable to provide a specific answer, the portability of the imaging modality avoids the need to transport high-risk patients while at the same time, can provide a prompt and accurate evaluation of the severity of COVID-19 pneumonia as well as permitting tracking of the disease during follow-up.

Citation
European Society of Radiology. The role of lung ultrasound in COVID-19 disease. Insights Imaging 2021. https://doi.org/10.1186/s13244-021-01013-6

Deep learning ultrasound algorithm predicted prognosis of COVID-19 as well as clinicians



A deep learning algorithm for lung ultrasound with the ability to identify patients with COVID-19 at high risk of clinical worsening showed good agreement with the view of clinicians.

Although the diagnostic assessment of patients with COVID-19 is undertaken with a PCR test, diagnostic imaging using computed tomography (CT) has a reported sensitivity and specificity ranging between 61% and 99% and 25% and 33% respectively. However, because CT imaging is not portable, other solutions are required. One such alternative and portable imaging modality is lung ultrasound (LUS). The technique provides real-time imaging and has the benefit of portability and is widely available. Moreover, LUS which can be used to identify changes in the physical state of superficial lung tissue and may be of potential value in the assessment of patients with COVID-19. However, LUS is generally restricted to visual inspection and interpretation of imaging artefacts and is thus qualitative and subjective although quantitative scoring systems have been proposed. In recent years, deep learning (DL) algorithms using automatic scoring and semantic segmentation have been developed to classify each LUS frame.

Whether a deep learning algorithm could be used to evaluate LUS videos and provide a score as well as semantic segmentation for each frame that was of prognostic value in patients with COVID-19 was the subject of a study by a team from the Diagnostic and Interventional Ultrasound Unit, Valle del Serchio Hospital, Lucca, Italy. The team are the first to report on the development of a standardised imaging protocol and scoring system and which utilised a DL algorithm that was able to evaluate LUS videos and which provided, for each frame, a score as well as semantic segmentation. The team then sought to evaluate the prognostic value of this approach by comparing the level of agreement between the output from the DL and the interpretation from expert clinicians. All patients were examined using LUS and according to a standardised acquisition protocol that involved 14 scanning areas. All videos acquired by the scans were independently evaluated by two clinicians and who assigned a score ranging from 0 to 3 for each video. This scoring system has been described previously such that a score of 0 = high reflectivity of the normal aerated lung surface and a score of 3 = a pleural line that is highly irregular and cobbled. The acquired videos were also fed into the DL algorithm.

Findings

The team analysed data from 82 patients (43 male) with a mean age of 61.1 years, all of whom had a PCR confirmed diagnosis of COVID-19. A total of 1488 LUS examinations were performed (note that some patients were scanned multiple times) which generated 314,879 frames. When comparing the level of agreement between the DL system and the clinical experts, the resulted showed a percentage agreement of 85.96% in the stratification between patients at a high risk of clinical worsening of COVID-19 and patients at low risk. Despite this high level of agreement, there were instances where the DL misclassified scores. For example, in 14% of cases the DL misclassified a score of 3 as 2.

In a discussion of their findings, the authors stressed that for LUS to be a reliable means of patient evaluation, a standardised protocol is required. They concluded that the results were encouraging and demonstrate the potential value of using DL models for the automated scoring of LUS and stratification of the risk of disease progression in those with COVID-19.

Citation

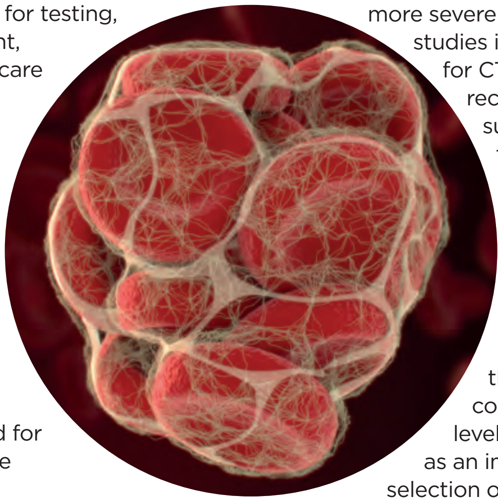
Mento F et al. Deep learning applied to lung ultrasound videos for scoring COVID-19 patients: A multicenter study. J Acoust Soc Am 2021;149(5):3628–34. https://asa.scitation.org/doi/10.1121/10.0004855

CTPA detection of pulmonary embolism guided by D-dimer levels in patients with COVID-19

CT pulmonary angiography (CTPA) is the preferred imaging modality to detect pulmonary embolism (PE) but whether D-dimer levels can guide selection for CTPA is uncertain.

Emerging evidence has indicated a high incidence of thromboembolic events, including pulmonary embolism (PE) in patients with COVID-19. Moreover, computed tomography pulmonary angiography (CTPA) is the current and preferred standard of care form of imaging to detect a PE. Nevertheless, the true incidence of PE in patients with COVID-19 remains to be determined and it is therefore unclear which patients should be referred for CTPA for diagnostic confirmation. While it has been suggested that the threshold for CTPA should be lowered, and based on grossly elevated D-dimer levels, the overall value of this approach requires further clarification.

Given this uncertainty, researchers from the Department of Radiology, Zuyderland Medical Centre, Geleen, The Netherlands, undertook a meta-analysis of the frequency of PE in patients with COVID-19 to determine whether D-dimer levels served as a useful guide to the selection of patients for CTPA. Using both MEDLINE and Embase, the researchers sought to identify studies which reported on the frequency of PE on CTPA scans in at least ten patients. Furthermore, the team manually searched for relevant articles in the journal Radiology: Cardiothoracic Imaging, which is not available via either MEDLINE or Embase. For identified studies, the researchers extracted data on the country of origin, location for testing, i.e., emergency department, general ward or intensive care unit, patient inclusion criteria, indications for CTPA (and who interpreted the results of the imaging) together with the location of the PE (i.e., main, lobar, segmental and subsegmental pulmonary arteries). In addition, mean values of D-dimer levels were also extracted and the authors contacted for this data if it was not in the published article.



Findings

A total of 71 studies were included in the meta-analysis. The overall frequency of PE in all studies among those with COVID-19 was 32.1% (95% CI 28.5–35.9%). PE was more common in peripheral than in main arteries, with pooled frequencies of 65.3% compared with 32.9%, which suggested that a local thrombosis was a major factor. Furthermore, the pooled frequencies of PE in patients with COVID-19 was lowest at the emergency department, followed by general wards and intensive care units: 17.9%, 23.9% and 48.6%, respectively. In 55 (77.5%) of the studies, patient selection for CTPA was reported and CTPA interpreters were blinded to clinical information in 15 (21.1%) of studies, although in the majority (76.1%) of studies, it was unclear whether interpreters were blinded to the clinical data. Among two studies where CTPA was used routinely (and without a clinical suspicion of PE), the frequency of PE was 2.1% and 5.7%. However, in two other studies where CTPA was routinely performed within the intensive care unit, again regardless of clinical suspicion, the reported PE frequencies were 47.2% and 60%.

Patients with COVID-19 and PE had significantly higher D-dimer levels than those without a PE and cut-off levels for D-dimer to identify those with a PE varied from 1000 to 4800mcg/l.

Commenting on their findings, the authors reported that since the reported incidence of PE was highest within the intensive care setting, it is likely that the condition is associated with more severe disease. In addition, most studies indicated that the criteria for CTPA were generally recorded as a clinically suspected PE. Furthermore, the presence of elevated D-dimer levels was considerably higher than the conventional cut-off value of 500mcg/l which is used to screen the general public for venous thromboembolism. They concluded that a D-dimer level of 1000mg/l might serve as an important guide to the selection of patients for CTPA.

Citation
Kwee RM et al. Pulmonary embolism in patients with COVID-19 and value of D-dimer assessment: a meta-analysis. Eur Radiol 2021;1–19. doi: 10.1007/s00330-021-08003-8

Imaging modalities play a vital role in the assessment of patients with COVID-19

From the start of the COVID-19 pandemic, imaging modalities have proved to be of enormous importance in the diagnosis and management of patients.

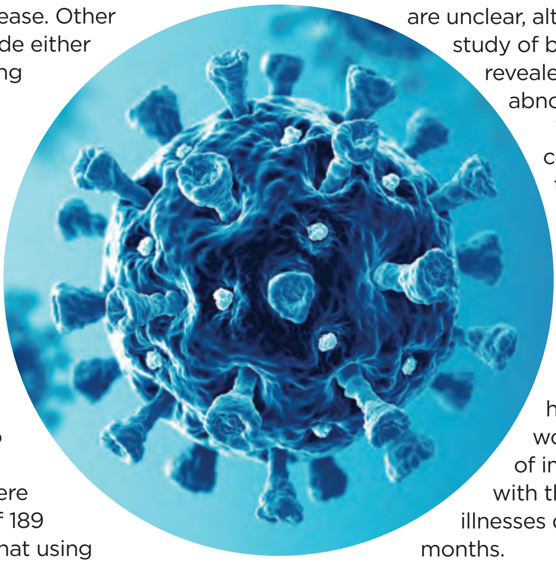
The importance of imaging in helping to identify lung abnormalities in those infected with COVID-19 became apparent very early in the pandemic. Since that time, a good deal of information has emerged on the radiological manifestations of the virus. However, a multinational consensus statement from the Fleischer Society in April 2020 had proposed that imaging was not indicated as a screening tool among asymptomatic patients, no requirement for daily chest radiography in stable, intubated patients but that CT scans were needed for patients with functional impairment, hypoxaemia or both after recovery from the virus.

In a review of the current state of knowledge of imaging use in COVID-19, a team from the Department of Radiology, University of Wisconsin, US, produced a comprehensive role of the clinical situations in which different imaging modalities have been used to help diagnose and offer advice on the management of patients infected with COVID-19.

One of the earliest reported uses of imaging, and a major focus of the review, were chest radiographs, although as the authors noted, CT chest imaging can be normal in up to 56% of patients within two days of symptom onset, indicating that a normal CT finding does not reliably exclude the disease. Other early findings can include either unilateral or bilateral lung opacities, often with a basilar and strikingly peripheral distribution. Some of the earliest work also revealed the presence of bilateral lower zone consolidation thath peaked at 10 to 12 days after symptom onset. A further valuable role for CT imaging is the ability to differentiate between patients with more severe disease. In one study of 189 patients, it was found that using a cut-off of 23% of lung involvement showed a 96% sensitivity and specificity for distinguishing critically ill patients. In addition, it has been determined from a meta-analysis of studies that the pooled sensitivity for detection of COVID-19 for CT was 94% but the specificity was only 34%. In a Cochrane review of thoracic imaging tests to diagnose COVID-19, it was found that when testing patients with known infection, chest CT was correct in 86% of cases, chest X-rays in 82% of cases, and lung ultrasound in 100% of patients. The use of artificial intelligence systems has also proved to be of value in identifying COVID-19 pneumonia with one large study in 3777 patients, finding a sensitivity of 93% and a specificity of 86%.

But imaging techniques such as CT pulmonary angiography have been successfully used to identify pulmonary embolism.

In addition, the use of MRI in patients recovering from COVID-19 have helped to identify abnormalities such as lowered ejection fraction, higher left ventricular volumes and pericardial enhancement. Moreover, abdominal CT imaging has revealed colorectal and small-bowel wall thickening, fluid-filled colon and infarction of the kidney, spleen and liver. Neuroimaging has revealed how patients with COVID-19 have various abnormalities including ischaemic and haemorrhagic stroke, encephalomyelitis and widespread white matter hyperintensities. Whether these changes are as a direct result of the virus, or a consequence of infection are unclear, although a retrospective study of brain MRI findings revealed a range of abnormalities.



The authors concluded that while the role of imaging in diagnosis and management had greatly increased during the pandemic, they did ponder the question of whether imaging could reduce hospital admissions and wondered how the role of imaging might change with the onset of respiratory illnesses during the winter months.

Citation
Kanne JP et al. COVID-19 Imaging: What we know now and what remains unknown. Radiology 2021 doi: 10.1148/radiol.2021204522

International radiologist survey identifies need for AI training

With little known about radiologists' views on the implementation of artificial intelligence (AI) and how this might impact on practice, an international survey sought answers on this important topic.

A 2019 international survey of radiologists revealed a limited knowledge of artificial intelligence (AI) and a genuine fear that the technology would lead to their replacement in the coming years. This fear was in part, found to be driven by a lack of understanding of the role of AI with the result that few expressed a proactive attitude towards the technology. Having identified several factors, a team from the Department of Radiology, University Medical Center, Utrecht, The Netherlands, decided to expand upon their earlier findings and further explore the expectations among radiologists regarding the potential implementation of AI systems, possible barriers to adoption and the perceived need for AI education during their residency training.

The team created a web-based survey that included 39 questions which sought to determine demographics, awareness and existing knowledge of AI, respondents' expectations of the technology and any hurdles to implementation. The survey was piloted with ten radiologists and then translated into English, French, German, Spanish, Italian, Dutch, Czech, Russian and Turkish and distributed electronically through the Italian, French and Dutch radiology societies, as well as the European Society of Medical Imaging Informatics and via social media.

Findings

A total of 1086 respondents from 54 countries, with a median age of 38 years (65% male) completed the survey. Most of the respondents (83%) were based in Europe although a small number came from Africa (1%), Asia (7%) and North America (6%). Among the respondents, the majority (66%) were radiologists and the remainder either fellows or residents. When asked whether AI would improve diagnostic radiology, the majority (89%) said maybe with only 10% believing that it would. Most respondents (89%) agreed that AI would help to improve diagnostic radiology and the majority (85%) also felt that AI would alter the future of radiologists. With respect to the expected role and benefits of AI in diagnostic radiology, the most frequently cited roles were as a second reader (78%) and workflow optimisation (77%). Interestingly, 47% reported that AI would serve as a partial replacement for radiologists with only 1% think that it would represent a complete replacement.

The potential hurdles to implementation cited included ethical and legal issues (62%), lack of knowledge among relevant stakeholders (56%) and limitations due to digital infrastructure (35%). Additionally, both the high cost of AI software development and the cost of the software itself, were seen as barriers to implementation by 35% and 38% of respondents respectively. Most respondents (79%) also felt that AI education should be incorporated into residency training programmes and this was more likely among older radiologists, although only a minority (23%) thought that imaging informatics and AI should become a radiology subspeciality. In addition, three-quarters (75%) of respondents stated that they were planning on learning about AI.

In discussing these findings, the authors noted how the many (82%) respondents expected that AI would cause a significant change to the profession within ten years but on a positive note, most felt that AI systems could serve as a second reader and assist with workflow optimisation within departments. They concluded that the data suggested how there was broad support across the radiologist community for the incorporation of AI into residency programmes while, at the same time, recognising that legal/ethical issues together with digital infrastructure constraints were an overlooked challenge.

Citation
Huisman M et al. An international survey on AI in radiology in 1041 radiologists and radiology residents' part 2: expectations, hurdles to implementation, and education. Eur Radiol 2021. https://doi.org/10.1007/s00330-021-07782-4

Combined PET/MRI scanning identifies features of sports-related brain injuries

Autopsies of patients with traumatic brain injury have found increased levels of tau aggregation and neuroinflammation but combining PET/MRI scanning has enabled the visualisation of these changes among living patients with sports-related injuries.

Sports-related concussion (SRC) occurs when an external force is transmitted to the head and produces transient neurological symptoms. However, there is increasing evidence that individuals who have experienced repeated SRCs when examined at autopsy, are found to display an accumulation and aggregation of the protein, tau, which helps stabilise neurons combined with persistent neuroinflammation. In addition, traumatic brain injury (TBI) is a chronic disease, which leads to progressive white matter atrophy and persistent inflammation. It is possible therefore that repeated SRC might represent a harbinger of TBI but the evidence for this possible association is based on the findings from autopsies.

Is it possible therefore, wondered a team from the Department of Clinical Sciences, Lund University, Sweden, that imaging of the brains of individuals who have suffered SRCs and those with TBI might reveal similar changes?

The researchers recruited healthy young adults, who served as controls, athletes who had previously experienced SRCs and individuals with moderate-to-severe TBI. For the study, the researchers combined the use of positron emission tomography (PET) and magnetic resonance imaging to view images of the brains of their subjects. On the day of the scans, all participants were assessed using the repeated battery assessment of neurological status (RBANS), which provides a measure of attention, language, memory and visuospatial/constructive skills, i.e., overall cognitive skills with higher scores associated less cognitive impairment. Prior to the PET scans, participants were injected with two biomarkers; the neuroinflammation tracer, [11C]-PK11195, which was used to assess neurofilament-light (NF-L) levels, which is a measure of neuroaxonal damage, and later the tau tracer, [18F]-THK5317 that can assess for tau burden. The MRI scans were performed during PET scanning.

Citation
Marklund N et al. Tau aggregation and increased neuroinflammation in athletes after sports-related concussions and in traumatic brain injury patients – A PET/MR study. NeuroImage Clin 2021;30:102665. https://doi.org/10.1016/j.nicl.2021.102665

Findings

A total of 9 controls, 12 SRC and 6 TBI participants were recruited with a similar mean age (26 years) with 4 male patients in the control and TBI groups. Among the 12 SRC participants, 8 has been ice hockey players and the others were either footballers or Alpine skiers. Both the TBI and SRC groups had lower RBANS scores compared with controls, 75, 80 and 105.5, respectively ($p < 0.05$). Free tau levels were lowest in those with a TBI (reflecting greater aggregation) compared to controls and those with SRC (3.4 picog/ml, 4.0 picog/ml and 4.7 picog/ml, respectively). Similarly, the highest levels of NF-L (i.e., greater levels of neuroinflammation) were seen in those with TBI compared with controls and SRC (10, 6 and 8, respectively).

Discussing these findings, the authors outlined how on a group levels, both young athletes and TBI patients had increased levels of tau aggregation and neuroinflammation, even though the imaging had occurred six months, and up to several years, after the last SRC or TBI. They authors suggested that this implied a persistent pathology and thought that the reduced free tau levels might be a consequence of decreased release from damaged neurons.

They concluded that the presence of both increased tau aggregation and neuroinflammation among those with TBI and SRC implied a similar pathology, and that follow-up PET imaging was required to establish whether the observed changes persist over time and if such changes are associated with clinical symptoms.

Manganese enhances MRI imaging of viable tissue after myocardial infarction

After a myocardial infarction, assessing the extent of damage is essential but difficult. Now manganese-enhanced MRI offers an innovate approach to evaluate myocardial viability within one hour of an infarct.

The use of cardiac imaging has become an important tool in the assessment of heart disease although current imaging is unable to quantify one of the most important elements of patient morbidity, myocardial viability. Although gadolinium-enhanced magnetic resonance imaging is used to assess myocardial damage such as scar tissue, potential problems with its use include accumulation of chelated gadolinium within the infarct area and some evidence points to accumulation of the element in the brain. Alternatives such as PET scanning can be used to evaluate myocardial metabolism via the accumulation of the radioactive glucose analogue, [18F]-fluorodeoxyglucose within metabolically active cells, the analogue can also be taken up by immune cells present within the infarct. One factor which is highly sensitive to myocardial contraction is the metal calcium and contractility is regulated by changes in the levels of intracellular calcium. Unfortunately, intracellular calcium levels cannot be measured using non-invasive techniques. One solution is to use an alternative metal ion which is able to enter living cells using the same transport systems as calcium: such a metal ion is manganese, which is also used as an MRI contrast agent and for which levels can be quantified in vivo as a surrogate measure for calcium. In fact, studies have shown how manganese-enhanced MRI (MEMRI), using for example, the chloride salt, can be successfully used in cardiovascular MRI in humans.

Citation
Jasmin NH et al. Myocardial viability imaging using manganese-enhanced MRI in the first hours after myocardial infarction. Adv Science 2021. https://doi.org/10.1002/advs.202003987

Nevertheless, once within cells manganese acts competitively with calcium, reducing myocyte contractility hence potentially limiting its role. While a chelated form of manganese, Mn-DPDP (manganese dipyridoxyl disphophate) is approved for clinical imaging, chelation of manganese, while enhancing its safety profile, does reduce the extent to which it is desirable with respect to cardiac imaging. Moreover, studies have suggested that combining manganese with calcium gluconate has shown great promise for cardiac imaging.

For this study, a team from the Centre for Advanced Biomedical Imaging, University College, London, evaluated the real-time effects of manganese with or without the addition of the calcium gluconate on action potentials in vitro mouse and human cardiomyocytes and cardiac contractility in mice.

Findings

Initially, the team evaluated whether manganese affected in vitro beating rates and action potentials in cardiomyocytes and cardiac contractility in mice. Addition of manganese chloride reduced cardiomyocyte beating rates. However, when supplementing the manganese chloride with calcium gluconate, beating was restored. These data indicated that the cardio-depressant effect of manganese chloride can be negated if co-administered with a calcium supplement.

After inducing a myocardial infarction, the researchers investigated manganese uptake after the infarction. Quantitative T1 mapping-manganese-enhanced MRI revealed elevated and increased uptake of manganese in viable myocytes away from the area of the infarct.

Commenting on their findings, the authors reported on how their data suggest that manganese-enhanced MRI offers an important new method for evaluating myocardial viability in as little as one hour after an infarction. Although high doses of manganese reduced myocardial contractility, the use of a calcium gluconate supplement reduced these effects, indicating that the co-use of these metal ions could be employed as MRI contrast agents. The authors concluded that the use of a manganese-based contrast agent could potentially be used early after a myocardial infarction to evaluate the extent of remaining myocardial viability.

Real-time microscopic imaging allows for examination of flow characteristics during bioprinting

Bio ink flow dynamics can potentially damage cells during the process of bioprinting. Using a microscopy technique, researchers have directly observed ink flow to help identify conditions that could lead to cell damage.

Bioprinting enables the automated organising of living materials such as cells, layer by layer to create 3-dimensional (3D) structures such as organs and has a huge potential to revolutionise regenerative medicine. While there are several different approaches, one particular technique, extrusion-based 3D bioprinting has been widely adopted by the tissue engineering community, due to its great versatility and capacity to create numerous different tissues. In extrusion-based bioprinting, the substance is delivered via a hydrogel and through a thin capillary tube with diameters between 50 mcm and 1 mm. Consequently, during the extrusion process, the cells are subjected to mechanical forces, especially shear stress and which can result in considerable damage or even death of cells. Moreover, these forces are likely to be worsen, specifically if the capillary diameter is very narrow and ultimately affect the viability and functionality of the resultant tissue. In an attempt to reduce these forces, several hydrogels exhibit what has been described as a 'shear thinning' effect, although this is not always successful. One possible approach to understanding the impact of the mechanical forces exerted on cells would be continuous imaging of the extrusion process to help again a better insight of the flow dynamics and cell movements. Furthermore, the development of continuous imaging could serve as a means for process quality control.

In an effort to better understand the flow dynamics through the capillary tube, an international team led by the Department of Bioengineering, Imperial College, London, explored the use of light sheer fluorescence microscopy (LSFM) to quantify the real-time flow of cell-laden hydrogels through a capillary. The aim of their study was to provide quantitative information on the cell-hydrogel interplay in a capillary tube which served to mimic the portion of the extrusion bioprinting process in which cells were likely to be damaged.

Findings

Using the LSFM the researchers were able to

quantify the flow of cell-laden hydrogels through the capillary in real-time and the velocity of cell travel. This revealed how some cells appeared to roll on the surface of the capillary while others, not in contact with the capillary wall seemed to spin and those in the central portion spun faster. The LSFM essentially provided the team with information on the capillary viscosity and enabled a better understanding differences in cell viability. In addition, it was possible to image the hydrogel flow through the capillary, which indicated that the hydrogel separated into a solid and fluid phase with cells embedded in both phases. This created irregularly shaped solid phases suspended within the fluid phase and which, the authors felt, accounted for the variations in the calculated velocity measurements.

Cell survival was found to be dependent upon extrusion flow rates and cell viability was 2–2.5-times lower at higher flow rates.

In discussing their results, the authors indicated how the study had demonstrated the power of LSFM as a powerful imaging modality for the examination of flow dynamics through a capillary tube. Although this is the first study to explore the real-time imaging of capillary flow, the authors speculated that in the future, LSFM could be used to help with the design of the shape of capillaries to modulate cell viability during extrusion bioprinting.

Citation
Poologasundarampillai G et al. Real-time imaging and analysis of cell-hydrogel interplay within an extrusion-bioprinting capillary. Bioprinting 2021 https://doi.org/10.1016/j.bprint.2021.e00144

Andrea Porter, Content Director – Secondary Care
andreaporter@cogora.com

Rod Tucker, Clinical Assistant
rodtucker@cogora.com

James Depree, Art Director
jamesdepree@cogora.com

Shaun Matharu, Business Development Manager
shaunmatharu@cogora.com

Edward Burkle, Executive Director
edwardburkle@cogora.com

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