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One of the most remarkable technological developments that have taken place over the last few years in the field of medical imaging has been the steady decline in the levels of ionizing radiation that are currently needed in modalities such as CT. Advances such as the use of low kV protocols coupled with more and more powerful iterative reconstruction algorithms have resulted in an inexorable driving-down of doses used in typical CT examinations, while still maintaining diagnostically acceptable image quality. This achievement has been almost wholly the result of intensive effort on the part of industry who have stepped up to the plate to meet the challenge of reducing ionizing radiation. Much remains to be done however, for example in the frustratingly large differences that still remain between dose levels actually used for the same indication, using the same scanner. The individual characteristics of each patient can account for some of such differences, but the use of inappropriate protocols is also largely responsible. Notwithstanding these remaining frustrations, the trend of radiation dose per image acquired is reassuringly downwards. So far, good news. The bad news, however, is that as far as the collective/ population level trend of radiation use in diagnostic imaging in the clinic is concerned, this is inexorably increasing. Not only are more patients being imaged, but more images are being acquired per patient. The obvious, troubling question is raised, namely as to whether all these additional imaging examinations are really necessary? And it is not just CT that’s involved — the number of MRI examinations and those carried out with other imaging modalities are also increasing.

While such statistics may (for radiologists) reassuringly underline the increasingly central role that medical imaging occupies in modern medicine, it is clear that, by definition, unnecessary imaging does not materially affect diagnostic accuracy but does increase healthcare costs.

A recent JAMA viewpoint paper ([Oren O, Kebebew E, Ioannidis JPA. Curbing Unnecessary and Wasted Diagnostic Imaging. JAMA. 2019. doi:10.1001/jama.2018.20295](https://doi.org/10.1001/jama.2018.20295)) highlights the problem of unnecessary imaging. In the U.S., the population rate of CT examinations carried out annually is 245 per 1000 population; for MRI the rate is 118 per 1000 population. In Finland, these rates are respectively five and three times lower, without any perceptible decrease in the quality of population-level patient outcome. More aggressive use of imaging in the Unites States appears to only slightly increase the yield of useful information.

Against the background of the present need for diagnostic accuracy (and the fear of errors) it is all too easy to understand the reflex of ordering even more images (paradoxically perhaps) encouraged, at least as far as CT is concerned, by the perception that anyway with modern technology the radiation dose is now so low that radiation exposure is no longer an issue). Worthy campaigns such as “Image Wisely” have had only a modest effect on the issue of unnecessary diagnostic imaging, so the question remains as to how best to combat the problem.

One suggestion, amongst several, is that the use of certain modalities could be restricted to cases approved by radiology specialists, similar to the use of some high-potency antibiotics requiring approval by infectious disease specialists. With marked improvements in the sensitivity and specificity of automated reading of images, there will be less demand for radiologists to interpret some imaging tests. The specialty of diagnostic radiology may thus need to change focus: instead of training radiologists primarily to read images, they may need to be trained as “gatekeepers” who mostly regulate or are consulted about what tests should be ordered and, even more so, which ones.

Against the background of the ever-present grind of the routine workload and, especially in the light of the ever-present background of the routine workload of ever-increasing images, which, once acquired, still need to be interpreted.
THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) IN MODERN MEDICINE

Artificial Intelligence (AI) is being embraced by the medical community; however, there are still some barriers to widespread adoption. This article shows the growing application of AI in modern healthcare and the benefits to patients and clinicians, whilst also looking at what is needed to confirm its place in medical diagnosis.

COVER STORY

FEATURING

Vacuum assisted procedures have revolutionised the diagnosis and therapy of both benign and malignant breast pathologies and can be used under sonographic, mammographic, and magnetic resonance imaging guidance.

The use of a new hand-held mobile system to control chest CT resulted in the radiographers spending much more time in proximity to the patient than with conventional CT workflows.

In the new world of radiology department economics, CT is a key enabler in addressing some of healthcare’s most pressing challenges from a clinical, operational and business standpoint.

FEATURE ARTICLES

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IN THE NEXT ISSUE

Cardiovascular Imaging
New PET tracer identified for imaging Tau in Alzheimer’s disease patients

In the diagnosis of Alzheimer’s disease and the search for effective treatments, tau tangles in the brain have joined amyloid build-up as markers of the disease and potential therapy targets. A recently-published paper reports on the identification of a promising second-generation positron emission tomography (PET) tracer for imaging and measuring such tau pathology (Wong DF et al. Characterization of 3 Novel Tau Radiopharmaceuticals in Healthy Controls and in Alzheimer Subjects. J Nucl Med. 2018 Dec;59: 1869).

“Compared three novel tau-specific radiopharmaceuticals — \(^{11}\)C-RO-963, \(^{11}\)C-RO-643, and \(^{18}\)F-RO-948 — that showed pre-clinical in vitro and in vivo promise for use in imaging human tau,” explained Dr. D. F. Wong, Johns Hopkins University professor of radiology, neurology, psychiatry and neurosciences.

In this first human evaluation of these novel radiotracers, healthy humans and patients with Alzheimer’s disease (AD) were studied using an innovative study design to perform head-to-head comparisons of the three compounds in a pairwise fashion. Wong states, “This design allowed us to select one radioligand, \(^{18}\)F-RO-948, as the most promising second-generation tau radiopharmaceutical for larger scale use in human PET tau imaging.”

Over all brain regions and subjects, the trend was for \(^{18}\)F-RO-948 to have the highest standardized uptake value (SUVRpeak), followed by \(^{11}\)C-RO-963 and then \(^{11}\)C-RO-643. Regional analysis of SUV ratio and total distribution volume for \(^{11}\)C-RO-643 and \(^{18}\)F-RO-948 clearly discriminated the AD group from the healthy control groups. Compartmental modeling confirmed that \(^{11}\)C-RO-643 had lower brain entry than either \(^{11}\)C-RO-963 or \(^{18}\)F-RO-948 and that \(^{18}\)F-RO-948 showed better contrast between areas of high versus low tau accumulation.

Subsequent analysis therefore focused on \(^{18}\)F-RO-948. Both voxelwise and region-based analysis of \(^{18}\)F-RO-948 binding in healthy controls versus AD subjects revealed multiple areas where AD subjects significantly differed from healthy controls. Voxelwise analysis also revealed a set of symmetric clusters where AD subjects had higher binding than healthy controls. “Importantly, this new tracer appears to have much less off-target binding than was reported for existing tau tracers,” notes Wong. “Especially, it has less binding to the choroid plexus adjacent to the hippocampus, which has confounded interpretation of mesial temporal tau measured by first generation PET Tau tracers.”

He points out, “The significance of this research is that we describe in detail the selection and quantification of a second-generation tau PET imaging as a complement to amyloid imaging, allowing us to accurately measure tau pathology in living people and contributing to our understanding of the pathophysiology of Alzheimer’s and related dementias. Better Tau PET radiopharmaceuticals also provide the promise of improved target engagement and monitoring of anti-tau treatments in future Alzheimer’s clinical trials.”

Collaboration has been key to this research process. Wong emphasizes, “These findings demonstrate the impact of the complementary strengths of preclinical, translational and clinical research with university PET and memory experts, NIH aging experts and dedicated imaging neuroscientists in the pharmaceutical industry to approach one of the greatest global public health challenges—i.e., Alzheimer’s disease, where there is still no definitive cure. Improved biomarkers such as PET imaging of tau and, in the future, other dementia-implicated proteins are vital to reducing the enormous costs of drug development and eventually understanding and treating Alzheimer’s.”

doi: 10.2967/jnumed.118.209916

Liver disease could be detected sooner by nurse-led ultrasound tests in GP surgeries

Research carried out by scientists at the University of Southampton, UK has shown that simple ultrasound – based tests in GP surgeries could potentially double the diagnosis rate of liver disease in asymptomatic patients (El-Gohary M et al. Local care and treatment of liver disease (LOCATE) - A cluster-randomized feasibility study to discover, assess and manage early liver disease in primary care. PLoS One. 2018 Dec 21;13:e0208798. doi: 10.1371/journal.pone.0208798. eCollection 2018)

Chronic liver disease is an escalating problem worldwide. In the UK mortality rates have risen sharply and it is now the third most common cause of early death. The disease progresses silently, with few symptoms appearing before serious liver scarring (cirrhosis) develops. The increase is predominantly due to alcohol, however the increasing prevalence of non-alcohol related fatty liver disease both in the UK and elsewhere is also of concern. The objective of the research was to identify previously undiagnosed liver disease in primary care using a nurse-led specialist liver clinic. Ten
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GP practices were allocated to either intervention (where patients were tested by a specialist liver nurse) or care as usual. Participants recruited to the intervention practices had a full liver assessment which involved a simple examination; the taking of a blood sample and the measurement of liver stiffness using a portable FibroScan ultrasound device. All participants had their case notes reviewed by a consultant hepatologist and were ascribed as ‘no fibrosis’, ‘liver warning’, ‘progressive fibrosis’ or ‘probable cirrhosis’. Of the 910 participants seen in the nurse-led clinic nearly half were found to have some form of liver disease. 44 of these patients (4.8%) had probable cirrhosis, 141 (15.5%) had progressive fibrosis, and 220 (24.2%) had liver warnings. Overall the nurse-led clinic diagnosed twice as many cases as the care as usual clinics.

Lead Author Dr Magdy El-Gohary said: “Incorporating a liver nurse within Primary Care was simple to arrange and yielded a much higher number of new diagnoses of liver disease compared to usual care. The next step is to roll this service on a larger scale so that we can show whether early diagnosis is able to prevent the liver disease developing to the stage where an emergency admission to hospital is required.”

The aim of this programme of work is to reduce the number of avoidable premature deaths from undiagnosed liver disease. Offering a specialist liver clinic within Primary Care means that patients can be assessed and diagnosed quickly and may reduce or halt the progression of liver disease.

doi: 10.1371/journal.pone.0208798.

**DTI MRI scans show promise in predicting dementia**

MRI brain scans predicted with 89 percent accuracy who would go on to develop dementia within three years, according to recently published research from Washington University School of Medicine in St. Louis and the University of California San Francisco.

The findings of this work were presented at last year’s RSNA meeting and suggest that it may be possible one day to use widely available tests to tell people their risk of developing dementia before symptoms arise.

“Right now it’s hard to say whether an older person with normal cognition or mild cognitive impairment is likely to develop dementia,” said lead author Dr. Cyrus A. Raji, of Washington University’s Mallinckrodt Institute of Radiology. “We showed that a single MRI scan can predict dementia on average 2.6 years before memory loss is clinically detectable, which could help doctors advise and care for their patients.”

“Alzheimer’s disease is the most common cause of dementia in the world and is expected to increase globally, as the population gets older. As we develop new drug therapies and study them in trials, we need to identify individuals who will benefit from these drugs earlier in the course of the disease.”

Common predictive models like standardized questionnaires used to measure cognition and tests for the APOE4 gene, the gene variant associated with a higher risk of Alzheimer’s disease, have limitations and—with accuracy rates of about 70-71 percent—fail to identify many people who go on to develop the disease.

MRI exams of the brain using diffusion tensor imaging (DTI) are a promising option for analysis of dementia risk. These exams assess the condition of the brain’s white matter.

“With DTI you look at the movement of water molecules along white matter tracts, the so-called telephone cables of brain,” Dr. Raji said. “When these tracts are not well connected, cognitive problems can result.”

DTI provides different metrics of white matter integrity, including fractional anisotropy (FA), a measure of how well water molecules move along white matter tracts. A higher FA value indicates that water is moving in a more orderly fashion along the tracts, while a lower value means that the tracts are likely damaged.

For the new study, Dr. Raji and colleagues set out to quantify differences in DTI in people who decline from normal cognition or mild cognitive impairment to Alzheimer’s dementia compared to controls who do not develop dementia. They performed brain DTI exams on 61 people drawn from the Alzheimer’s Disease Neuroimaging Initiative, a major, multisite study focusing on the progression of the disease.

About half of the patients went on to develop Alzheimer’s disease, and DTI identified quantifiable differences in the brains of those patients. People who developed the disease had lower FA compared with those who didn’t, suggesting white matter damage. They also had...
statistically significant reductions in certain frontal white matter tracts.

“DTI performed very well compared to other clinical measures,” Dr. Raji said. “Using FA values and other associated global metrics of white matter integrity, we were able to achieve 89 percent accuracy in predicting who would go onto develop Alzheimer’s disease. The Mini-mental State Examination and APOE4 gene testing have accuracy rates of about 70–71 percent.”

The researchers conducted a more detailed analysis of the white matter tracts in about 40 of the study participants. Among those patients, the technique achieved 95 percent accuracy. While more work is needed before the approach is ready for routine clinical use, the results point to a future role for DTI in the diagnostic workup of patients at risk for Alzheimer’s disease. Many people already receive MRI as part of their care, so DTI could add significant value to the exam without substantially increasing the costs.

Perhaps most importantly, MRI measures of white matter integrity could speed interventions that slow the course of the disease or even delay its onset.

“Research shows that Alzheimer’s disease risk can be reduced by addressing modifiable risk factors like obesity and diabetes,” Dr. Raji said. “With early detection, we can enact lifestyle interventions and enlist volunteers into drug trials earlier.”

https://tinyurl.com/Raji-Presentation

Financial analysis of free lung cancer screening program

Lung cancer screening with low-dose computed tomography (LDCT) chest scans in high-risk populations has been established as an effective measure of preventive medicine by the National Lung Screening Trial. However, the sustainability of funding a program is still controversial. A recently published report from the United States shows that a free, simple screening for lung cancer can save a patient money, while building a healthy relationship for any medical needs they may have in the future (Chung JM et al. Financial Analysis of Free Lung Cancer Screening Program Shows Profitability Using Broader NCCN Guidelines. Ann Thorac Surg. 2018. doi: 10.1016/j.athoracsur.2018.09.056).

The study shows that the partnership can be beneficial for patients looking for cardiology specialists, family medical care and other health-related issues, as well as for medical facilities that offer the free screening. “Our mission is to find lung cancer earlier,” said Dr. Carsten Schroeder, thoracic surgical oncologist at the Georgia Cancer Center and Medical College of Georgia at Augusta University. “If we find a nodule in the lung that’s in the later stages, survival rate is much worse than if we find it earlier.”

Schroeder and his team analyzed fiscal years 2015-17 to evaluate indirect cost, direct cost and adjusted net margin per case after factoring downstream revenue from treating patients with positive scans and other findings. Costs from a total of 705 scans. Of that 705, 418 patients were referred for follow-up procedures and specialist evaluations. The adjusted net margin per case was -$212 in the first year but turned positive to $177 in the third fiscal year.

“In all, we have 1,600 people on the screening list,” Schroeder said. “Of those, 1,200 have actually had a scan. In just over 2 percent of those patients, we found lung cancer. The remaining 400 people do not meet the necessary criteria.”

The idea to develop the free lung screening program started after a major research paper was published in the summer of 2011. The National Cancer Institute’s National Lung Screening Trial, which included 50,000 people, showed a computerized tomography (CT) screening is better than chest x-ray for screening for lung cancer.

“There was a 20 percent increase in the survival rate for those patients who had the CT screening,” Schroeder said. “This paper was the one that served as a catalyst for the Centers for Medicare and Medicaid Services to start covering the cost of the screening for patients.”

While patients do not need to have health insurance to qualify for the lung screening program, there are some defined criteria they must meet.

For his research, Schroeder and his team looked at the

FEB/MARCH 2019
The death of Nancy Cappello, an energetic campaigner for increased awareness of the implications of dense breasts, was announced end of last year, with the cause of death being secondary Myelodysplastic Syndrome (MDS), attributed to the side-effects of radiation therapy and aggressive chemotherapy that she had received as treatment for the breast cancer, with which she was diagnosed nearly 14 years ago.

Nancy Cappello was an extremely health-conscious person, so regularly followed the recommended mammography screening program then operating in her state, Connecticut, USA. After a decade of receiving all-clears from the routine mammography she underwent, a palpable lump was discovered in one of her breasts, which was identified by ultrasound to be suspicious, and confirmed by biopsy to be malignant. The final diagnosis was a stage 3C breast cancer, with metastases, even though the lesion was still undetectable by mammography. Cappello was informed by her radiologists that the reason for the lack of detection of the lesion by the routine screening mammography was the fact that her breasts were dense, which not only contributed to a significant decrease in the sensitivity of the mammography examination, but, in addition, was in its own right an increased risk factor for the development of breast cancer.

Cappello was outraged that for the years during which she dutifully followed the recommended screening mammography, no-one had seen fit to inform her, the patient, of the implications of dense breasts. As she herself famously put it, “My radiologist knew I had dense breasts. My doctor knew I had dense breasts. The only person who did not know was me: the woman with the dense breasts.”

She then threw herself into an energetic campaign to broaden the awareness of breast density, even while she was being treated for malignant breast cancer. Cappello was an indefatigable crusader for the dense breast awareness cause and a frequent invited speaker at breast cancer conferences, where the majority of health professionals were motivated and inspired by her presentations, being reminded in an eloquent and powerful way of the implications of breast imaging as seen from the patient’s point of view. It should be noted however that some radiologists and breast oncologists considered her a thorn in their side for revealing the “Inconvenient Truth” regarding the significance of dense breasts. Undeterred, she founded the “Are You Dense?” movement which has advocated for more than a decade for the reporting of dense breast tissue as part of mammography reporting results directly to patients through U.S. state law, federal law, and FDA regulatory efforts.

The first major tangible result of her energetic campaign was in 2009, when Connecticut became the first state in the United states to pass a law obliging radiologists to report dense tissue to women as part of their mammography reporting results. Since then, a total of 36 U.S. states have enacted density reporting legislation.

Although hailed by patient advocate groups, such moves have not been met with equal enthusiasm among other stakeholders. The language dictated by state-level reporting laws has been criticized for its readability levels and differences across states, for the potential for additional costs and overdiagnosis, physician unpreparedness, and for contributing to patient and provider confusion. Nevertheless, the intended goals of increasing awareness of breast cancer risk and informing women regarding options for supplemental screening remain. In a recent paper in which she was lead author Cappello described the results of an objective study of the effects of the legislation she had been instrumental in instigating. (Cappello NM et al. The Impact of Breast Density Reporting Laws on Women’s Awareness of Density-Associated Risks and Conversations Regarding Supplemental Screening With Providers. J Am Coll Radiol. 2018 Sep 17. pii: S1546-1440(18)31002-0. doi: 10.1016/j.jacr.2018.08.009). It was found that density reporting laws are associated with increased breast density awareness and higher rates of conversations between women and their providers regarding supplemental screening. However, although most women are now familiar with the masking effect of dense breasts on mammography, they are less aware of density’s inherent increased breast-cancer risk. Radiologists and referring clinicians are both involved in engaging women to inform them of their density and risks.

The “Are you dense?” movement continues as purposefully as ever after Cappello’s death.

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**Diagnostic Imaging Systems**

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Novel imaging technique brings diagnostic potential into the operating room

Using a new portable optical imaging system, a team of researchers led by Prof. Stephen Boppart has successfully visualized the tumor microenvironment of human breast tissue shortly after it was surgically removed from a patient in the operating room. This work, which was reported recently (Sun Y et al. Intraoperative visualization of the tumor microenvironment and quantification of extracellular vesicles by label-free nonlinear imaging. Sci Adv. 2018; doi: 10.1126/sciadv.aau5603.), has been described as a major step toward providing cancer researchers with a new tool for tracking tumor progression and physicians new technology for tissue pathology and diagnostics.

“We believe that capturing the dynamic cellular and molecular features in freshly removed or biopsied tissue specimens contains valuable diagnostic and prognostic information that is currently lost when specimens are placed in a fixative and essentially killed quickly in order to preserve structure,” said Boppart.

“Our imaging platform and methodology allow us to extract this new information in real-time, at the point-of-procedure.”

Boppart’s portable optical imaging system uses precise light pulses to simultaneously image tissue in four modalities, enabling his team to study concurrent processes within cells and tissue that make up the tumor microenvironment. For example, collagen fibers appear in green; elastin fibers and flavin adenine dinucleotide-containing cell cytoplasm appear in yellow; cell membranes, lipid boundaries, and extracellular vesicles (EVs) appear in magenta; and nicotinamide adenine dinucleotide in the cells and lipids appears in cyan.

The team demonstrated the viability of their imaging system in the operating room during breast cancer surgeries. Within 30 minutes of the diseased tissue being extracted, the researchers were able to identify specific tissue features, including molecular signatures associated with metabolic activity inside individual cells that make up the tumor microenvironment. The researchers were also interested in measuring tumor-related extracellular vesicles (EVs), which are known to promote the spread of cancer. “EVs do play an essential role in cancer progression,” said graduate student Yi Sun, the lead author of the research paper.

“Quantifying EV densities may be developed as a potential biomarker for future cancer diagnoses.”

As part of their studies, they also collected and imaged healthy breast tissue that surgeons had removed from cancer-free patients during breast reduction procedures.

In a comparison of the two types of tissue, they found a clear difference in EV density between the cancerous and healthy tissue. For example, the cancerous tissue exhibited increased EV densities and had shorter tumor-to-margin distance.

“What we observed about the extracellular vesicles is significant but it could only be accurately determined with our new system,” said Sun, noting how other portable optical imaging systems deployed in the operating room all alter the tissue samples either with fluorescent dyes or toxic ultraviolet light. “Our imaging technique works well with current cancer treatment routines and is free of any form of perturbation.”

doi: 10.1126/sciadv.aau5603.

MRI cardiac stress test shows promise at identifying fatal heart disease

The use of MRI to determine heart function has been slow to catch on, but a recent study from Duke Health researchers shows that stress cardiac MRI not only diagnoses disease, but can also predict which cases are potentially fatal (Heitner JF et al Prognostic Value of Vasodilator Stress Cardiac Magnetic Resonance Imaging: A Multicenter Study With 48 000 Patient-Years of Follow-up. JAMA Cardiol. 2019. doi: 10.1001/jamacardio.2019.0035)

Results from a large, multi-center study suggest that cardiac magnetic resonance CMR, has potential as a non-invasive, non-toxic alternative to stress echocardiograms, catheterizations and stress nuclear exams in identifying the severity of coronary artery disease.”We’ve known for some time that CMR is effective at diagnosing coronary artery disease, but it’s still not commonly used and represents less than one percent of stress tests used,” said senior author Dr. R Judd of the Duke Cardiovascular Magnetic Resonance Center.

The use of MRI to determine heart function has been slow to catch on, but a study from Duke Health researchers shows that stress cardiac MRI can also predict which cases are potentially fatal.

Picture courtesy of Duke Health

“One of the impediments to broader use has been a lack of data on its predictive value — something competing technologies have,” Judd said. “Our study provides some clarity, although direct comparisons..."
between CMR and other technologies would be definitive.”

Judd and colleagues analyzed data from more than 9,000 patients who underwent CMR at seven U.S. hospitals, encompassing up to 10 years of follow-up. For patients without any history of heart disease and at low risk based on traditional clinical criteria, those with an abnormal CMR scan were 3.4 times more likely to die compared to patients with a normal CMR scan. For the entire patient population, the researchers found a strong association between an abnormal stress CMR and mortality, even after adjusting for patient age, sex, and cardiac risk factors. “Noninvasive cardiac stress testing is a cornerstone in the clinical management of patients with known or suspected coronary artery disease,” Judd said, noting that CMR works as well or better than other exams at identifying heart wall motion, cell death and the presence of low blood flow. In addition, the technology does not require any radiation exposure, which is essential in nuclear stress tests that are by far the most commonly used in the U.S.

“There are a number of reasons for the limited use of stress CMR, including availability of good quality laboratories, exclusion of patients who cannot undergo magnetization, and a lack of data on patient outcomes,” Judd said. “With the findings from this study suggesting that stress CMR is effective in predicting mortality, we provide a strong basis for a head-to-head study between stress CMR and other modalities.”


PET CT imaging agent shows promise for better diagnosis of acute venous thromboembolism

A first-in-human study reports that the novel positron emission tomography/computed tomography (PET/CT) tracer $^{18}$F-GP1 showed excellent image quality and a high detection rate for the diagnosis of acute venous thromboembolism, VTE (Kim C et al. Glycoprotein IIb/IIIa receptor imaging with $^{18}$F-GP1 positron emission tomography for acute venous thromboembolism: an open-label, non-randomized, first-in-human phase 1 study. J Nucl Med. 2018 doi: 10.2967/jnumed.118.212084).

Well-tolerated in patients, $^{18}$F-GP1 PET/CT also identified blood clots in distal veins of the leg below the knee, where conventional imaging has limitations.

Acute VTE is a disease that includes deep-vein thrombosis of the leg or pelvis and its complication, pulmonary embolism--which can be fatal. The highly variable and nonspecific symptoms and signs of VTE often result in delayed or inaccurate diagnosis. For acute VTE, timely and accurate diagnosis is critical to expedite the initiation of effective therapeutic strategy.

“Conventional imaging with ultrasonography, CT venography or CT pulmonary angiography is typically unable to distinguish old thromboemboli from new and potentially unstable thromboemboli,” stated Dr. Dae Hyuk Moon of the University of Ulsan College of Medicine in the Republic of Korea. “The $^{18}$F-GP1 tracer used in this study offers the unique ability to detect, characterize and track newly formed thrombi that have a high risk for embolization and further complication.”

Researchers conducted a prospective study to obtain clinical proof-of-concept for thrombus PET imaging with $^{18}$F-GP1. The safety and diagnostic performance of $^{18}$F-GP1 PET/CT were assessed in 20 patients with acute deep-vein thrombosis or pulmonary embolism (10 deep-vein thrombosis and 10 pulmonary embolism). Each patient had signs or symptoms of VTE and had one or more VTE foci confirmed by standard imaging.

Upon image review, researchers found that $^{18}$F-GP1 uptake in thromboemboli was easily distinguishable from the blood pool. Moreover, a positive correlation was observed between $^{18}$F-GP1 uptake and P-selectin expression on circulating platelets, which shows the presence of activated platelets and acute VTE. $^{18}$F-GP1 PET/CT detected thromboembolic foci in all 20 patients with deep-vein thrombosis or pulmonary embolism. Additionally, $^{18}$F-GP1 PET/CT showed an increased uptake in the distal veins of the leg in 12 patients that was not detected with conventional imaging.

“Incorrect diagnosis of VTE commits the patient to unnecessary anticoagulation and results in higher risk and costs, whereas incorrectly concluding that VTE is absent places the patient at high risk of potentially fatal pulmonary embolism,” said Moon. “Although the current studies are preliminary, $^{18}$F-GP1 PET/CT may provide not only more accurate anatomic localization, but also information on the risk of the clot growth or embolization. This may lead to changes in clinical intervention to the individual patient.”

In this article, we summarize the findings of our recent cost-effectiveness evaluation of lung cancer screening with low-dose computed tomography (LDCT) [1] in which we applied Australian health services costs and population-based survival data to the outcomes observed in the U.S. National Lung Screening Trial (NLST) [2] and assessed the impact of a range of screening scenarios on incremental cost effectiveness ratios (ICER) [1].

Our base case estimate was A$138,000 (± €87,000) per life-year gained and $233,000 (± €146,000) per quality-adjusted life year (QALY) gained.

Compared to an indicative willingness-to-pay threshold of A$30,000-50,000 (± €19,000 - €31,500) lung screening is not yet likely to be cost-effective in Australia. Variation in base-case parameters resulted in ICER estimations that ranged from A$127,000 to A$509,000 (± €80,000 to €320,000) per QALY gained.

Lung cancer is a major health problem worldwide [3], with tobacco smoking responsible for up to 85% of cases [4]. Although comprehensive investment in tobacco control is the most important long-term strategy for primary prevention, the full benefits of these interventions will not be realized for many years to come [5]. Lung cancer screening with LDCT has the potential to significantly reduce the lung cancer mortality burden, especially in countries with historically high smoking rates and effective tobacco control initiatives [6].

Lung screening of asymptomatic individuals using LDCT reduced the risk of lung cancer mortality in the U.S. National Lung Screening Trial (NLST) by the detection of cancerous pulmonary nodules when at an early, potentially curable stage [2]. Current- and ex-smokers (who quit within the past 15 years) aged 55-74 years, with a ≥30-pack-year smoking history and screened annually with LDCT over three years had a 20% (95% confidence interval [CI]: 6.8%–26.7%) lung cancer mortality benefit after six years of follow-up compared to those who received three annual chest x-rays [7]. The trial had a relatively favorable health economic evaluation, with an incremental cost effectiveness ratio (ICER) of US$81,000 per quality-adjusted life year (QALY) saved for LDCT screening [2].

Many organizations in high-income countries now recommend annual lung screening with LDCT using variations of the NLST eligibility criteria [8-13]. Outside the U.S., lung cancer screening has not been systematically introduced, in part because of uncertainty around cost-effectiveness and budget impact in different settings [12]. Health economic evaluations are dependent on the underlying assumptions required to translate trial results into a population-based setting, which are necessarily less reliable where evidence is lacking. Cost-effectiveness evaluations for the United Kingdom [14], Germany [15], Switzerland [16], New Zealand [17], Canada [18-20], and the United States [21] have since modelled the NLST strategy and/or outcomes within a population-wide setting, and have demonstrated similar variations in results to ours.

In our sensitivity analyses, the most cost-effective screening scenario was due to the inclusion of non-lung cancer deaths in the evaluation. The NLST reported a statistically significant, 6.7% (95% CI, 1.2-13.6) mortality benefit of LDCT screening on deaths from any cause (3.2% due to deaths other than lung cancer) [7]. Given the smoking history of those eligible for lung cancer screening, it is not surprising that LDCT imaging from the lower neck to the upper abdomen detects other smoking-related, clinically significant abnormalities (e.g., coronary artery calcification, chronic obstructive pulmonary disease) that when treated, has the potential to save additional lives [22].

However there is, as yet, no standard approach to the reporting and management of screen-detected incidental findings,
which are common, and the definition of clinical relevance is left to the discretion of the radiologists [23]. Although we modelled the potential mortality benefit of treating incidental findings, we were not able to account for the potential harms and costs of overtreatment, which are still largely unknown. To what extent the treatment of incidental findings is likely to impact resource allocation and costs within the health system, and more specifically, the need for access to health services beyond the scope of a lung screening program, is also uncertain. We modelled a nominal cost of A$2000 (€1260) per incidental finding, with an estimate of one incidental finding in 19% of participants (based on a Canadian study [22]), which resulted in a more favorable cost-effectiveness estimate than modelling lung cancer outcomes alone. However, in the Netherlands-Leuven screening trial (NELSON), clinically significant psychological distress was observed at two months post-screening among participants with an ‘indeterminate result’ requiring three months surveillance [24]. Thus, we modelled a hypothetical drop in utility for two months following a positive screen (i.e., 0 vs. 0.05; similar to sensitivity analyses in the NLST evaluation [2]) and the ICER estimate ($/QALY) more than doubled as a result. The difference between NELSON and NLST findings in terms of the psychological impact of positive results could potentially be due to differences in the nodule management protocol, differences in the tool used to assess distress, differences in the risk communication protocol, and/or differences in the degree of health literacy of trial participants. Local implementation trials that incorporate population-specific assessments of health literacy and effectiveness of risk communication strategies will identify ways to minimise unnecessary psychological distress in relation to screening, and maximise cost-effectiveness.

We found that varying the number of false-positives and the cost of follow-up had a greater impact on cost-effectiveness than varying the cost of lung cancer treatment itself, even after accounting for the increasing costs of newer therapies for advanced disease. The number and cost of false positive screens depends on the definition of a positive scan and the nodule management strategy employed. In the NLST, a positive screening result was defined as a non-calcified nodule with a longest diameter of ≥ 4 mm [7]. Studies of nodule management since the NLST have demonstrated that in a lung screening setting, the largest lung nodules are not necessarily the ones that are malignant [25]. Improved nodule management protocols such as the Brock (Pan Can) nodule malignancy risk calculator [25], which is an externally validated, predictive tool that incorporates a number of individualized patient and clinical factors [26-29], are likely to result in fewer false positives than that observed in the NLST. Indeed, the tool has been incorporated into the screening guidelines of the American College of Radiology (Lung-RADS [30]) and the British Thoracic Society [31]. However the optimal balance between positive predictive value and sensitivity for a screening population remains a topic of discussion [32].

“... Lung cancer screening is possibly a “teachable moment” for current smokers …”

Our evaluation did not incorporate the potential mortality benefits that an adjunct smoking cessation intervention would have for current smokers, which has been shown to significantly improve cost-effectiveness [17, 19, 21, 33]. Lung cancer screening is possibly a “teachable moment” for current smokers, with evidence that quit rates are higher among screening participants than in the general population [34, 35]. In terms of cost-effectiveness, the additional benefits of a smoking cessation program for people aged 55 years and over will be dependent on the number of current smokers who participate in screening as well as the survival benefits that might be gained in this group. In Australia, like other high-income countries, the prevalence of smoking is now relatively low (12.2% in 2016 [36]) and the proportion of ex-smokers among lung cancer cases is expected to grow. Importantly though, long-term current smokers are now disproportionately represented in low socioeconomic, marginalized, and/or minority groups that are traditionally hard to reach [4, 37]. Recruitment of these population sub-groups to lung cancer screening programs is likely to be a challenge, and should be a focus of implementation studies [37]. Continued investment in tobacco control outside the context of a screening program will also remain a priority for these groups.

Recently, the results of the final round of the largest European lung screening trial, the Netherlands-Leuven screening trial (NELSON) were announced [38]. Specifically, 7915 participants aged 50-74 years, who had smoked >15 cigarettes per day for more than 25 years or >10 cigarettes per day for more than 30 years, including those who quit within the past 10 years were randomized to LDCT screening or usual care [39]. After ten years of follow-up, there was a significant 26% (95% CI 9%-41%; p=0.003) lung cancer mortality benefit among men [38]. Cost-effectiveness evaluations that have modelled the NELSON trial eligibility criteria have had favorable outcomes [15, 16]. A cost-effectiveness evaluation directly based on data from the trial itself would potentially provide further momentum for lung screening protocol development and implementation in Europe. Our evaluation demonstrated that lung cancer screening with LDCT was unlikely to be cost-effective in Australia based on NLST outcomes. However, our analysis could be updated to reflect improvements in lung screening protocols since the NLST, including the use of risk prediction tools for defining eligibility criteria [40].

CONCLUSION

Ultimately, for countries like Australia with a lower indicative willingness-to-pay threshold than the U.S. and a relatively small
... Our evaluation demonstrated that lung cancer screening with LDCT was unlikely to be cost-effective in Australia based on NLST outcomes ...

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**INTRODUCTION**

Hip and knee total joint arthroplasty (TJA) are some of the most commonly performed surgical procedures throughout the world. Hip replacements have been performed in the UK since the 1960s and knee replacement since the 1970s. In 2017 alone, more than 91,000 hip and over 102,000 knee replacements were performed in the United Kingdom [1].

These operations have revolutionised the management of painful and often crippling osteoarthritis and remain highly cost-effective solutions from a societal perspective [2]. The demand for TJA continues to rise year-on-year and, with an ageing population the increasing economic burden of this surgery are not insignificant. Recent modelling has predicted an exponential growth of 66% in the numbers of TJA procedures over the next 20 years [3]. It is therefore more important than ever that surgeons perform highly successful, long-lasting joint replacements, ensuring that these replacements need to be performed only once during the patient’s life, so reducing the need for complex and expensive revision surgery [4].

The prostheses used for TJA, and the techniques to implant them, have continued to improve over the decades. However the need for even more improvements in outcomes is being driven by evidence from the U.K. National Joint Registry whose data show significant variability in outcomes between individual surgeons, hospitals and different prosthetic implants. Sixty years after the inception of TJA we continue in 2019 to strive for the ‘forgotten joint’, when a patient is actually unaware of ever having had a TJA. Current imaging and surgical technologies are focussed towards achieving this goal.

The first documented use of robot-assisted surgery occurred in 1985 when a robot was used in neurosurgical biopsy surgery [8]. It quickly became apparent that robotic technology allowed for greater precision when used...
for minimally invasive surgery such as laparoscopies. The first laparoscopic procedure involving a robotic system was carried out in 1987 and in 1990 the AESOP system became the first system system to be approved by the FDA. Ten years later, in 2000, the da Vinci Surgery System became the first FDA-approved robotic system for general laparoscopic surgery. Orthopaedic surgery was not far behind when in 1986 the Robodoc was developed for total hip arthroplasty, first used on humans in 1992, however with variable success. The Mako surgical corporation developed the Rio robot in 2004 and this was further developed with clinical trials beginning in 2006. Mako was acquired by Stryker Ltd in 2010 for $1.65 billion and the Mako/Stryker system remains the most commonly used robotic system for TJA, having been used in over 100,000 procedures to date. The system, technology and applications have been described in more than 50 peer-reviewed clinical publications, with in addition more than 350 scientific abstracts being presented at peer-reviewed scientific conferences.

The MAKO robotic arm assisted TJA relies on preoperative imaging to create a 3D reconstruction of the patient’s native knee anatomy. A patient-specific model is created from the scans using generic software. This is used to calculate a haptic window to plan bone resection, to allow the selection of implant size and its positioning for the desired bone coverage, and consequently, limb alignment. An interactive robotic-arm with visual, audio and tactile resistive feedback then guides bone resection within this predefined haptic window. Intraoperatively the surgeon is able to dynamically reference and assess the balance of the joint, the joint stability, the range of movement and limb alignment. In this way the surgeon now has the ability to perform on-table corrections and modifications in order to optimise the position of the implants and soft tissue balance of the knee and subsequently reduce mal-alignment, soft tissue imbalance and increase patient satisfaction and longevity of the knee, all in the quest for ‘the forgotten joint’.

IMAGING AND ROBOTIC KNEE REPLACEMENT

Advances in Computer Tomography (CT) scanning and the development of software to map the patient’s knee and plan surgery have revolutionised TJA. The combination of advanced imaging techniques with accurate and reproducible robotic systems, has thus provided surgeons with the ability to accurately pre-plan surgery. Pre-operatively we can decide on bone cut angles and depths, overall limb and implant alignment, and execute these decisions on our patients with an accuracy that was previously impossible. The patients are imaged pre-operatively with plain radiographs of the hip or knee and full length leg CT scans.

CT scanning has been a constantly evolving technology since its early clinical use in the 1970s. With the widespread introduction of spiral multislice scanners in the last 15-20 years and rapid advances in computer hardware, software and display technology, multiplanar and volume-rendered reconstructed data have been widely adopted in various clinical fields. Some of the first clinical applications of volume rendering were in skeletal imaging with CT reconstructed data being used to plan orthopaedic implants as far back the mid-1980s. Since then, CT has become an important part of the assessment of complex and custom-made prostheses as the technology allows for detailed assessment of anatomy, torsion and bone stock around various orthopaedic implants. CT has become important for...
surgens to visualise deformities and in designing custom knee implants [11].

MRI volume scanning has also been utilised in prosthetic planning and patient specific instrumentation (PSI) has been planned using both MRI- and CT-based protocols [12]. Both modalities show good correlation with mechanical total knee replacement (TKR) parameters. Additional studies will further assess the optimal modality and protocols.

We use CT to generate a 3D model in the MAKO system. In this, the patient is positioned supine and feet-first prior to volume acquisition through the hips, knees and ankles [Figure 3]. The scan can be acquired at any time within 8 weeks prior to the surgery. Radiation dose is on average approximately 4.5 mSv, but with the increasing development pace of CT systems and related technology, this is likely to decrease in the future.

The Stryker/MAKO system has a large database (Stryker Orthopaedic Modelling and Analytics, SOMA) containing over 15,000 prosthetic knee cases which can be used to check design against a number of demographic variables. Analysis of the designs using this database and fit-testing are key parts of the planning and design process.

In robotic TKR, the volume analysis provided by CT is used to generate a 3D model — this is key to the process as this is the foundation of the robotic procedure. The MAKO system uploads the CT data and uses it to generate a patient specific model for 3D printing. The in-house 3D printing technology allows for highly accurate modelling without the linear constraints of traditional manufacturing process.

Of course, the 3D model so generated must then be interpreted by the surgeon and used to plan the surgery.

RESULTS AND OUTCOMES

The marriage between modern imaging and technological surgical advances is new and evolving. Early results using imaging and surgical techniques to optimise patient outcomes are very encouraging. In 2102 a cadaver-based study reported results generated by surgeons who were highly experienced in conventional knee replacement surgery, and who then performed robotic knee replacement surgery. The results showed significantly better precision in the sagittal and coronal planes of the implant with the robotic implants and demonstrated improved accuracy in femoral rotational alignment compared to conventional methodology [13].

Many clinical studies are now being published which replicate these results, showing that robot-assisted TJA has clearly the ability to provide super-accurate implant positioning [14]. The radiological advances of robotic arm joint replacement surgery are now being shown to have clinical relevance, with recent studies reporting several advantages compared to traditional TJA. These advantages include lower postoperative pain and analgesic requirements, reduced time in hospital, and quicker functional recovery [15,16]. Time will tell whether the longer term benefits are also realised, but there is currently much excitement in the surgical community that these new techniques will continue to revolutionise TJA, so paving the way for future, more complex interactions between imaging and surgery for the benefit of our patients. These developments hold out the promise that we will soon be able to achieve on a regular basis the ultimate goal of the “forgotten joint”.

REFERENCES

Artificial Intelligence (AI) has had many false dawns in modern medicine. The radiology community has in the past been cautious, and sometimes dismissive, of AI, automation and decision support tools; however, increased workloads and pressures have brought a newfound alignment of aims. For the first time, we are seeing true collaborative research with harmonised goals.

Patients have begun to embrace Big Data research through the success of UK Biobank and recognise the possible benefits from sharing their data. However, public trust in the use of their personal data for others to benefit is essential, especially in light of recent high-profile misuses of personal information, and general misgivings about the possible use and abuse of big data by large US companies for profit above societal gain.

AI algorithms will help medical staff work to the full potential of their “license”. The historical models of test requesting, imaging and reporting will benefit from these algorithms to help test selection and interpretation.

Digital image acquisition and reporting, with improved standardisation will help automatic reporting of certain findings, such as early signs of chronic disease or possible abnormalities, including tumors. The role of the radiologist as being a key data scientist at the centre of making a diagnosis has grown – reporting is much more structured, and the skill is now in decision-making, not description or detection.

MRI
Quantitative MRI has successfully been used in clinical applications for prostate cancer and liver disease, obviating the need for cruder, riskier and costlier methods such as biopsy. These experiences are informative, in that they show the changing pace of innovation, and the scalability of AI in medicine.

The use of imaging, particularly multiparametric MRI (mMRI) in the diagnosis of prostate cancer, has been one of the most widely publicized adoptions of AI in medicine. Previously, the clinical workflow for prostate cancer was to perform a prostate-specific antigen test, a rectal exam followed by an ultrasound-guided biopsy. This, however, has been augmented subsequent to the adoption of imaging in this workflow. Imaging can now identify tumors better and clearer than biopsy, and it has been shown that triaging mMRI might allow 27% of patients to avoid primary biopsies. If this method is used to direct biopsies, it could be possible to detect an additional 18% of clinically significant cancers when compared to the standard pathway, leading to an improvement in patient care and potentially outcomes [1].

Liver disease assessment used to follow a similar paradigm. Clinical suspicion and raised liver enzymes on blood testing would lead to liver ultrasound, followed by liver biopsy. In the last decade, there has been increasing prevalence as well as interest in non-alcoholic fatty liver disease (NAFLD)/non-alcoholic steatohepatitis (NASH) [2]. Alongside this, there have been multiple developments in non-invasive imaging as a safe and scalable technology, needed to identify and stratify patients. Multiparametric MRI has been shown to be equivalent to biopsy in the assessment of disease as well as in predicting clinical outcomes [Figure 1], [3].
As cross-sectional scans are available, imaging allows the physician to see an increased sample. Quantitative analysis further provides the clinician with more information to support their diagnosis, without putting the patient at risk or in pain. This method is currently being tested in the clinical pathway in large European trials, to measure cost-effectiveness as well as the reduction in unnecessary biopsies, with the aim of echoing in the success of mMRI in prostate cancer.

Clearly, imaging techniques have to be validated in clinical trials against older methods, and much of this work has been done or is in progress for prostate and liver applications. The EU’s Innovative Medicines Initiative (IMI) and the USA's Foundation of the National Institutes of Health (FNIH) both lead large consortia with industry and regulators to validate these new methods prior to clinical adoption. True value is demonstrated by generating compelling data - that the imaging is more useful than previous biomarkers in making a diagnosis, in predicting clinical outcomes as well as making treatment decisions. These data usually come from predictive outcome studies or from randomized controlled trials with health economic analyses, rather than direct head-to-head biomarker comparison studies. After all, to be better than a current standard, a new test cannot agree with it perfectly as this demonstrates equivalence, not superiority. These are also the data needed by healthcare payers, especially in the USA, to justify reimbursement for a new technology or biomarker.

The next phase of adoption for new imaging methods is for non-radiologists to appreciate the value of their outputs. Medical imaging is insufficiently taught to medical students, in comparison with laboratory diagnostic disciplines such as histopathology, hematology and biochemistry. Modern medical education should reflect the increasing use of bedside and point-of-care ultrasound, and diagnostic cross-sectional imaging. The increasing use of MRI for evaluating chronic conditions, such as back-pain and musculoskeletal injuries, has opened the door to primary care and non-medical referral pathways. This in turn has led to the need to transform large descriptive radiology reports into decision tools that can be used to determine which treatment pathway to follow, or whether secondary care involvement is required. The decisions and pathways involve a range of healthcare workers, most of whom are not versed in the intricacies of MRI reporting, who are however able to act on clinical decisions outputted from the imaging tests, such as physiotherapy as opposed to surgery.

The falling prices of cross-sectional imaging (£400, or approximately €460, for an abdominal MRI in London, New York or Tokyo, including reporting fees) make it more scalable and accessible for chronic disease patients. Ten years ago, MRI was reserved for neurological conditions and suspected spinal cord compression, and medical emergency for oncology patients. The number of indications has grown exponentially, and the sophistication of questions posed for MR providers has
increased. Additionally, clinical pathways are now emerging which can simplify the role and scope of complex imaging, such as MRI in liver disease [Figure 2, 3] and assessment of suspected Transient Ischemic Attacks (TIAs).

In both cases, front door and primary care physicians are requesting and acting on rapidly reported anatomical and tissue characterisation data to guide their treatment decisions. Some examples include:
- Inflamed liver in AIH
- Inflamed brain in TIA
- Inflamed heart in myocarditis

THE IMPORTANCE OF PATIENTS

For AI in medical imaging to truly grow and impact on patient care, the main barrier is well-curated and complete data from patients with their consent. Deep learning techniques applied to patient groups can identify hallmarks and patterns that can be used to diagnose and stratify patients. There are regulatory paths forward to commercialize the algorithms, and the FDA in particular favours digital health solutions. However, this can lead to a tension – why would patients consent for companies to access their medical records, if the consequence is higher-costing healthcare, albeit with some greater insight? This tension can be resolved with true partnership between patients, doctors and healthcare innovators, wherein patients are aware of their importance in agreeing to donate parts of their health records for use in big data collection and algorithmic generation; doctors are happy to declare the limits of their expertise and identify areas where AI can be helpful; and AI scientists are willing to listen and address the specific questions posed to them. Some argue that, for the ‘greater good’, one can circumvent patient consent for data and aggregate anonymized images for deep learning. This has two flaws.

First, anonymized data can never be linked to clinical outcomes, so algorithms generated from them can never be tested as being predictive, which is what clinicians and patients, as well as healthcare providers, are really interested in.

Second, at a time when the importance of sensitive personal data ownership and stewardship has been eroded, it is important to emphasise the importance of consent and trust, especially in applied healthcare research. Even if a lawyer advises that one can act without consent, it is always preferable to act with consent. This also nudges AI healthcare researchers into engaging directly with patients in truly collaborative, and thus more meaningful, applied research to address real clinical problems. Genetic information is now readily being communicated to patients by central providers, such as Illumina and 23&Me. This has resulted in a shift in the patient-doctor relationship, with more accessible information in the patient's hands - a true innovation in the information age.

ENGAGING POLICY-MAKERS

In the UK, there has been a huge political shift towards digital radiology and smart diagnostics. This is driven by increasing patient demand, without a matched increased growth in workforce or resources. Put simply, there are not enough radiologists and pathologists to meet rising demand, so the appeal of AI, improvements to workflow and automation is very clear. More recently, the appointment of a Health Secretary with good understanding of technology and innovation, and the adoption of a Life Sciences Strategy to build the UK economy, have stimulated investment and focus in this area, with GE Healthcare in particular supporting a digital transformation in how radiology is done and perceived by the healthcare community. A National Consortium for Intelligent Medical Imaging (NCIMI) has been formed, with collaborators in 11 different National Health Service (NHS) hospitals, to build and test smart imaging tools. Commissioning groups in the UK, and healthcare payers more widely, have shown willing in adopting cost-saving technologies - especially if they are developed to address patient-centric problems. I am thus optimistic about clinical adoption if the development of AI in medicine is done in a trustworthy and transparent fashion.

Adoption will be further driven by newer therapies in an era of precision medicine. As more and more treatments are available, it is clear that better phenotyping and genotyping of disease may influence treatment choices, and patient outcomes from those choices. Thus, the ability to use AI is cost-saving not just in diagnosis, but more so in determining which patient(s) should benefit from newer, often costlier, therapies. For example, we know that imaging guides the decision of what type of cardiac intervention to utilise in coronary artery disease, and also in the management of aortic aneurysms. In the future, choice of immunotherapy for liver cancer and prostate cancer may depend more on imaging parameters of disease than histology. The UK government, Perspectum Diagnostics and GE Healthcare have made substantial investments in the delivery of a pipeline of AI tools for standardised imaging for the NHS, to be delivered within 3 years.

In summary, this is a great time for the AI community, healthcare and patients to work together for the common good, developing innovative solutions from big data to improve the diagnostic yield of modern radiology, for all our benefit.

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Obesity is a major public health issue in the Western world; in the U.S. more than two-thirds of adults are considered overweight or obese. Non-alcoholic fatty liver disease is common in obese patients. The condition can progress to cirrhosis and is associated with a higher risk of liver cancer. Bariatric surgical procedures such as gastric bypass or sleeve gastrectomy have proven to be effective weight loss interventions in patients with obesity. However, not much is known about the relationship between overall weight loss achieved by these treatments and decreases in liver fat content. Liver fat is difficult to measure noninvasively, and biopsy’s invasiveness makes it unfeasible for monitoring changes in the liver over time.

The new study assessed liver fat before and after bariatric surgery through The promising noninvasive imaging option known as quantitative chemical shift-encoded MRI (CSE-MRI). The technique produces a measure of liver fat known as a proton density fat fraction (PDFF).

“CSE-MRI allows us to represent the measurement of liver fat as a percentage,” said study coauthor B. Dustin Pooler, M.D., adjunct assistant professor at the University of Wisconsin School of Medicine and Public Health in Madison, Wis, USA. “Each patient can get an assessment of fat throughout the liver that is easy for them to understand. The numbers also allowed us to perform comparisons with liver fat measurements from surgical and biopsy specimens.”

Dr. Pooler and colleagues studied CSE-MRI in 50 obese patients who underwent bariatric surgery for weight loss. The patients went on a low-calorie diet before the surgery, an approach that has been shown to increase the safety and efficacy of the surgery.

The researchers performed CSE-MRI twice before surgery and then multiple times in the year following the procedure. They also compared liver fat changes as determined by PDFF with changes in body mass index (BMI), weight and waist circumference.

By six to 10 months following surgery, mean PDFF in the study group decreased from 18 percent to about 5 percent—normal range is 5 percent or less—and mean BMI decreased from 45 to 34.5. The mean estimated time to PDFF normalization was approximately five months. The initial PDFF was the only strong predictor of both liver fat loss and time to normalization.

“The results showed a rapid early phase of improvements in liver fat, followed by a phase of continued improvements at a slower pace,” Dr. Pooler said. “The changes began with the initiation of the low-calorie diet and occurred in advance of the overall improvements in BMI among the patients.”

The results suggest several potential roles for CSE-MRI in the management of obese patients with fatty livers. PDFF measurements could help in the selection of patients for bariatric surgery because of the strong correlation between liver fat reductions and pre-treatment liver fat content. In addition, since decreases in liver fat content were only weakly correlated with starting weight and overall weight loss, monitoring liver fat with MRI following bariatric surgery, independent of monitoring weight loss.
loss, would be useful. The greatest potential benefit could be for patients with fatty livers regardless of their starting weight or weight loss.

“There is this assumption that when you lose weight you also reduce liver fat, but the relationship was very hard to measure prior to having a good tool like MRI,” Dr. Pooler said. “This study shows that the MRI technique is very clinically feasible for monitoring liver fat over time.”

Dr. Pooler said the CSE-MRI technique could have applications beyond monitoring the effects of bariatric surgery.

“We looked at bariatric surgery patients in our study, but there’s no reason this clinical tool can’t be used to monitor all sorts of weight loss patients,” he said. “We want patients and physicians to know that this is an option for them. We’ve done the validation and the next step is to make people more aware of this option.”

REFERENCE

Book Review
PET-CT-MRI based Cardiovascular Imaging, 1st Edition
By A Alavi, A Salavati, P Høiland-Carlsen & MC Moghbel Pub. by Elsevier (2019) € 69

To be published shortly, PET-CT-MRI based Cardiovascular Imaging, will include articles on:

Evolving role of PET in detecting and characterizing atherosclerosis; Applications of modern CT techniques in assessing cardiovascular disorders; Applications of conventional MRI techniques in assessing cardiovascular disorders; PET/CT Assessment of ischemic heart disease; PET/CT evaluation of cardiac sarcoidosis; PET/MRI in cardiovascular imaging; Evolving role of PET in detecting and characterizing cardiovascular disorders; PET/CT evaluation of infectious diseases of the heart; State of PET-based gating in cardiac imaging; Potential role of PET in assessing cardiac arrhythmias; PET-based cardiovascular imaging tracers; and more!
The University Hospital of Brussels (UZB) combines not only the treatment of patients in routine clinical care but also R&D activities aimed at developing, evaluating and implementing the latest leading-edge technologies.

The MRI department in particular has recently been applying a new software package, SyMRI, which enables quantitative MRI examinations to be carried out with short acquisition times of typically six minutes. The pediatric neuroradiology section has been using the new software in the diagnosis and follow-up of certain pediatric neurological cases, especially neonates.

We wanted to find out more about UZB’s MRI department in general and their experience of SyMRI in pediatric radiology in particular so we spoke to Prof. Hubert Raeymaekers, Head of MRI, Dr. Tim Vanderhasselt, pediatric neuroradiologist and Maarten Naeyaert, Ph.D. student in MRI physics.

Q Let’s start with some background to UZB and the MRI department

In Belgium, the Universitair Ziekenhuis Brussel is one of a total of seven teaching hospitals attached to a university or medical school. We are affiliated with the Vrije Universiteit Brussel (VUB) which is the Dutch language university in Brussels. Located in the north west part of the city, we have approximately 750 beds and receive patients principally from the western suburbs and the surrounding areas. As an integral part of the hospital we have a specialised Children’s Hospital, so all our hospital departments also have a pediatric unit. For example, in our radiology department, headed by Prof. J. De Mey, we have a section devoted to pediatrics.

In the MRI section of the radiology department, we actually have four MRI systems: one is a 1.5T Ingenia from Philips, and then there are three 3 Tesla systems, namely a 3.0T Skyra from Siemens, a 3.0T Discovery system from GE and a 3.0T Ingenia from Philips. We know that such a mixture of different vendors of systems for the same modality is relatively unusual, but this was a deliberate policy choice taken to conform to the role of the UZB as a teaching hospital, and so to be able to provide resident radiologists who are carrying out their specialization here at UZB with as broad an experience of different MRI systems as possible. Such a set-up with MRIs from different vendors can sometimes pose logistic problems but can also be extremely interesting from a scientific point of view in enabling the comparison of the various systems.

Q And what about the SyMRI software that you have recently installed?

SyMRI is a software package developed and marketed by the Swedish company SyntheticMR. We were attracted to it since it provides an efficient way of integrating quantitative MRI into the clinical work flow. The principle of the system is based on the absolute quantification of the physical parameters of the patient that govern the MRI image signal intensity, namely R1 and R2 relaxation, and proton density. From these values it is possible to differentiate tissue and synthetically recreate contrast-weighted images that are independent
of scanner settings. One additional advantage is that the SyMRI method provides maps that are independent of the magnetic resonance scanner and hence provides the same result on all major platforms.

As for the practical implementation of the system in UZB it was clear that the only efficient way to do this was to have it installed at the level of the PACS system rather than at the level of the acquisition console on each individual MRI machine. Apart from this configuration being suitable for our park of multi-vendor MRI machines, having the SyMRI system in the PACS is more convenient for the radiologists for whom it is often time-consuming to physically go to each MRI machine to decide which contrasts are needed. This is even more important in UZB, since our MRI scanners are located in different parts of the hospital so it’s more efficient that SyMRI post-processing is carried out on the PACS. Thus, the use of the PACS plugin means that the SyMRI post-processing is closely integrated with the radiologist’s workflow.

**Q** And in what particular applications are you using the software?

The technique of SyMRI is being applied elsewhere to many adult pathologies, mainly in the brain but also in different areas such as the spine and the knee but here at UZB we are focussed on pediatric/neonatal neuroradiology applications principally because we already have experience in this field and we feel that the technology has a lot of potential in the area.

In UZB our standard protocol for babies born extremely preterm is to carry out an MRI examination at the term-equivalent age. Despite significant progress in therapeutic management over the last decades, these children are still at risk of developing cognitive and motor deficits later in life, such as cerebral palsy, cognitive impairment and autism spectrum disorders. High quality MRI can help identify children at high risk and so guide early intervention therapies and parent counseling, especially for children with major motor deficits. However, there is still some work to do in terms of predicting issues such as mild cognitive impairment or autism spectrum disorders. This is where we believe quantitative data could make the difference.

**Retrospective selection of contrast.**

We find SyMRI to be extremely useful in cases where according to the initial clinical indications we have already specified the acquisitions but then in retrospect we realize that it would have been good to have a different contrast. Sometimes e.g. in meningitis we need a FLAIR image which is not a routine contrast. Using SyMRI we can select that FLAIR contrast at the post-processing stage without having to recall the patient.

In longitudinal studies of course we are familiar with the patients’ characteristics so we can already select the optimal contrasts. We use a mixture of SyMRI and routine MRI; the choice between whichever of these approaches we use depends on the clinical indications. For example for the MRI examinations of premature babies at term who are under sedation we will routinely use SyMRI, principally because of the reduced scan time which is a big advantage when dealing with such patients. In other cases, for example if we know that a 3D T1 weighted image or 3D T2w images could be useful, we will go for that directly using standard MRI Protocols since 3D T1 or 3D T2 are not (yet) available on SyMRI.

**Quantitation of brain volume**

However we use SyMRI not just for the image contrast aspect, but also for the possibility of quantification, for example in the determination of the brain volume. This...
is a particularly useful parameter in the term-equivalent scan which, as we mentioned, serves as a reference point. Quantitative pediatric brain volume determinations are available in research environments but not in routine clinical use. Up till now clinically we have had to rely on indirect indications, for example by measurement of dilated ventricles. Now in a routine clinical setting we can have direct quantitative segmentation of the brain.

Validation

We have looked at the correlation of segmentation data of the brain that are generated by SyMRI with measurements of brain volume that are currently only available via research tools. So in fact what we are doing is validating the SyMRI method in the estimation of the brain volume in pediatric and neonate cases against values generated by standard methods. We think this is a good example of what the role of an academic teaching hospital like UZB should be in addition to routine clinical examinations using standard methodology.

We started this work about two years ago. In the beginning we noted that when applied to pediatric as opposed to adult brains, the SyMRI algorithm was not optimal, for example in the differentiation of CSF.

Through an efficient and successful collaboration, Synthetic MR managed to correct and upgrade the SyMRI software. This modified software is what we are now using regularly in our validation studies.

“...the correlation with the standard methods was very good, a finding that is all the more striking since the SyMRI results are obtained in a six-minute acquisition...”

Our study, involving 80 neonatal patients, shows excellent correlation of the automatic segmentation with that obtained in standard methods, a finding that is all the more striking since the SyMRI results are obtained in 6 minutes (acquisition, reconstruction and post-processing), compared to approximately 20 minutes for the standard methods. Such short examination times are especially advantageous since we are dealing with very young patients. The results of our study will be presented at this year’s ISMRM meeting. Given the encouraging results of our validation study, we are very keen to continue with this work, to eventually look at how brain volume measurements correlate with clinical outcomes in the development of such pediatric cases, of which we see some 200 per year.

It should be noted that these studies are carried out with the currently available software from SyMRI, based on 2D-acquisitions. Currently most neuroradiologists are used to work with 3D-acquisitions in the clinic, enabling thinner slices and better spatial resolution. A new version of the software, which will shortly be made available by Synthetic MR to us, will enable 3D-acquisition and we will initiate a new validation study of this. Again, we consider this work as part and parcel of our role as a teaching hospital.

We look forward to working with the 3D software since we anticipate that it will provide several advantages such as enabling the neuroradiologist to obtain not only quantitative volumetric data but also to use the reconstructed images for visual diagnosis.

The advantage of having such quantitative data is that the scoring of brain conditions can be much more objective.

In neonatal imaging, we use the Kidokoro brain abnormality score, which is calculated from a range of individual parameters and provides a comprehensive characterization not just of brain development but also of regional and global brain injury. The ease of use and value of scoring systems could be greatly enhanced through use of quantitative data. Yet another advantage of hard quantitative data is that comparison of datasets between collaborating hospitals will be greatly facilitated.

And so how do you see the future?

We hope that it is clear from our conversation so far that we are strong believers in the potential of quantitative MRI and in the way SyMRI enables it. We may even think of future MRI exams resulting in a report similar to a comprehensive blood test today: a procedure that generates a list of objective, quantitative parameters, biomarkers, to be evaluated against appropriate reference standards.

In this brave new world, the neuroradiologist will be freed up from routine to be able to consider the interpretation and significance of the data, for the greater good of the patient.
Vacuum-assisted procedures have revolutionised the diagnosis and therapy of both benign and malignant breast pathologies and can be used under sonographic, mammographic, and magnetic resonance imaging guidance.

A proportion of patients being assessed for breast abnormalities require tissue sampling for histological analysis. This ensures accurate nonoperative diagnosis avoiding unnecessary surgery for benign conditions. Neoadjuvant, systemic treatment and axillary surgery can also be pre-determined in malignant disease.

Breast tissue sampling techniques have evolved considerably over the last 20 years. Fine needle aspiration was introduced in the 1930s by Martin and Ellis and its use became more prominent from the 1980s [1]. However, this technique aspirates only a small volume of cells and has low accuracy in impalpable lesions.

Core needle biopsy (CNB) introduced in the 1990s provides a larger volume of tissue albeit retrieving only one sample at a time [1]. In malignant lesions, CNB provides additional information on individual tumour biology including tumour type, histological grade, in situ status, lymphovascular invasion and hormonal receptor and Her-2 status. It is the favoured diagnostic tool for sampling of a sonographically visible breast lesion giving a diagnostic concordance with subsequent surgical excision of around 91% or higher [2]. Most centres in the United Kingdom use a spring-loaded single use disposable biopsy gun and 2 or 3 cores of tissue are obtained to ensure representative sampling.

Despite the higher sensitivity rates of CNB, breast pathologies with inherent heterogeneity may be inadequately sampled by CNB leading to histological underestimation. Vacuum assisted breast biopsy (VABB) was developed in 1993 by Fred Burbank and colleagues to overcome some of the limitations of CNB. His technique utilised vacuum technology combined with larger bore needles which allowed retrieval of increased sample weights of breast tissue. A 14g CNB removes approximately 18mg of tissue per core compared with 84mg per core for 11g VAB, 121mg per core for 9g VAB and approximately 363mg for 7g VAB [3]. Therefore, 12 passes of a 7g VAB would recover approximately 4g of tissue which is the equivalent of a small surgical biopsy. (Figures 1 and 2).

VABB utilises a console unit and disposable handpiece with needle size ranging from 7-12 gauge. Tissue collection is either automated or manually controlled by the operator using hand or foot switches. The handpiece utilises a double-lumen probe and the vacuum generated draws adjacent breast tissue in to the trough of the needle enabling the tissue to be excised by a rotating trocar. The tissue then passes into a tissue filter within a biopsy chamber ready for retrieval and histological assessment. The currently available systems are directional, allowing continuous 360 degree sampling of a lesion through a single needle puncture as a local anaesthetic procedure.

The increase in size of the tissue cores retrieved by VABB has significantly reduced sampling error and histological underestimation and in turn has reduced surgical upgrade rates of malignancy. The recent evolution in practical applications of vacuum procedures has ensured that VABB is integral to both diagnostic and therapeutic patient management pathways.

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VACUUM ASSISTED DEVICES IN THE DIAGNOSIS OF BREAST PATHOLOGY

The UK NHS Breast Screening Programme (NHBSBP) requires that a minimum of 90% of invasive cancers and 85% of non-invasive cancers should be diagnosed by a minimally invasive non operative biopsy rather than a diagnostic surgical procedure. Women undergoing diagnostic
surgery should be minimised to ≤ 3.5/1000 at the prevalent screening round and ≤ 1.6/1000 at their incident screen (NHS BSP guidelines). The exponential use of VABB in the UK NHSBSP has led to a marked increase in nonoperative diagnosis rates with a concomitant fall of diagnostic surgical biopsies. At our institution stereotactic/tomosynthesis guided VABBs, are performed as the first line procedure for all indeterminate USS occult lesions including microcalcifications, mammographic distortions or small lesions of less than 5mm.

VABB is regarded as a highly sensitive and specific biopsy method and numerous studies have shown superior results with VABB (11-8 gauge) compared with 14 gauge CNB [4, 5]. A systematic review by Fahrbach et al. demonstrated a higher frequency of technical failures with CNB than VABB (5.7 vs. 1.5%) and with non-diagnostic samples (2.1 vs. 0%). Of the non-diagnostic CNB samples, 23% were subsequently found to be malignant [6]. A systemic review by Huang et al. showed superior diagnostic performance by VABB compared to CNB in the diagnosis of DCIS [3].

The use of VABB as a first line procedure is supported by a recent study which demonstrated VABB to have higher sensitivity than 14g core biopsy [7]. Although 14g core biopsy is more cost effective, it is less sensitive as first line sampling for microcalcifications. There is also a trend for lower repeat biopsy rate, higher diagnostic accuracy and lower surgical upgrade with VABB [7].

Advances with VABB technology include the Brevera (Hologic) device which has a built-in specimen x-ray cabinet to streamline breast biopsy using real-time verification of calcifications [Figures 3 and 4]. This allows early confirmation of representative microcalcifications and hence potentially minimising the number of samples required. The aim is to reduce procedure time, patient discomfort and complications. Our initial results of sampling of 90 MCC clusters showed earlier confirmation of calcification retrieval during the biopsy procedure due to real-time imaging. However 18% of cancers would have been underdiagnosed if sampling was stopped as soon as calcification was confirmed to be present.

During 2016 – 2018 we performed 1900 first line stereotactic vacuum biopsies on screening patients and in the majority of cases a definitive diagnosis could be made using the tissue sample retrieved at this initial procedure. There are however a number of clinical scenarios where more tissue is required, including histology considered not to be representative of the targeted lesion (B1); lesions suspicious for malignancy (B4) and high risk lesions (B3) which are a heterogeneous group of pathology with uncertain malignant potential. More tissue is required to aid diagnosis in these situations in order to confidently exclude an associated malignancy or indeed to upgrade pathological classification of a lesion with suspicious radiological features. At our institution a larger volume of tissue is retrieved by performing a vacuum assisted excision (VAE). The majority of VAE are for B3 lesions, which may coexist with malignant disease and are found in approximately 7% of breast core biopsies. This group includes Flat Epithelial Atypia (FEA) (35%), Atypical Ductal Hyperplasia (ADH) (20%), papillary lesions (PL) (20%), Lobular Carcinoma in Situ (LCIS), and radial scars (RS)/complex sclerosing lesions [8]. Surgical excision has traditionally been required to obtain a definitive histological diagnosis and to exclude associated malignancy. These lesions have different upgrade rates on CNB to malignancy on surgical excision ranging from 8.9% for RS without atypia to 50.4% for ADH in a large series of 1,025 B3 core biopsies, which also illustrated lesions with associated atypical proliferation consistently having a much higher upgrade rate [9].

Though high risk lesions are usually excised surgically, the UK NHSBSP guidance recommends VAE. This should be performed with a larger bore needle with either 7 gauge or 8 gauge devices obtaining approximately 4 grams of tissue. This obviates the need for diagnostic surgical excision allowing either a definitive diagnosis of malignancy or the patient to be safely discharged to annual mammography.

VAE can be performed using either stereotactic, USS or MRI guidance depending on how the lesion is best visualised. USS guided vacuum sampling is a well-established and well tolerated alternative to open surgery for both diagnostic and therapeutic indications. It is a minimally invasive well tolerated procedure requiring a skin incision of less than 5mm, performed in an...
outpatient setting under local anaesthesia and taking between 15-60 minutes to completion. USS VAE is generally used for excision of large mass lesions requiring further histological assessment due to lesion size and associated risk of under sampling. For lesions seen only on MRI, MRI guided biopsies are performed. Published literature has shown the overall malignancy rate for MRI biopsies in high risk patients is around 21 -23 % [10, 11].

Not all lesions can be adequately diagnosed using VAE. In particular, papillary lesions with atypia diagnosed on needle biopsy have a malignant upgrade rate of up to 36% and require surgical excision to properly assess the entire lesion [12]. We performed a retrospective analysis of 125 papillary lesions which underwent vacuum excision over a 2-year period and found a malignant upgrade of 29.6%.

Multicentre trials are being conducted utilising VABB as a means of minimising the requirement for surgery. In the UK LORIS study, VABB is used to establish the diagnosis of low-grade DCIS and to randomise patients into surveillance or conventional surgical treatment. The PICASSO study aims to pilot the use of non operative vacuum excisions of small to moderate sized breast cancers in women who are unfit for surgery. A further example is the concept of performing extensive vacuum sampling for patients who have undergone neoadjuvant chemotherapy and who have demonstrated an apparent complete radiological response to treatment. This provides a more accurate assessment of the presence of residual disease than imaging alone and enables a more informed decision making process for surgical planning and treatment.

CONCLUSION

In conclusion, sampling and excision of lesions using VABB for both diagnostic and therapeutic indications has now become standard of care. In the UK we are already utilising this technique to avoid unnecessary surgery in asymptomatic women with incidental high risk lesions. However recent advances in technology and trials centred on evolving and extended applications of vacuum assisted breast tissue excision show further promise of a treatment revolution in the diagnosis and management of breast cancer.

REFERENCES

Pattern recognition software for CTEPH granted FDA Breakthrough Device Designation

Bayer has recently announced that the U.S. FDA has granted Breakthrough Device Designation to the artificial intelligence software for Chronic Thromboembolic Pulmonary Hypertension (CTEPH) pattern recognition, which Bayer is currently developing jointly with the pharmaceutical company MSD.

A rare form of pulmonary hypertension, CTEPH affects an estimated 8 to 40 people per million globally. CTEPH can be difficult to diagnose because its symptoms are similar to those of other lung diseases. Being a rare disease, physicians may not always recognize CTEPH due to several factors including a lack of clinical awareness and complex findings involving the heart, lung and pulmonary vessels. Computed tomography pulmonary angiography (CTPA) as well as a ventilation/perfusion scan (V/Q scan) are common diagnostic modalities to detect CTEPH.

CTEPH is a progressive type of pulmonary hypertension, in which it is believed that thromboembolic occlusion of pulmonary vessels gradually builds up and subsequently leads to an increased blood pressure in the pulmonary arteries, resulting in an overload of the right heart. CTEPH may evolve after prior episodes of acute pulmonary embolism (PE). The standard and potentially curative treatment for CTEPH is pulmonary thromboendarterectomy (PTE), a surgical procedure in which the blood vessels of the lungs are cleared of clot and scar material. However, a considerable number of patients with CTEPH (20%-40%) are not operable and in up to 35 percent of patients, the disease persists or reoccurs after PTE. As many as 1 out of every 25 people who had a PE (even if they were treated with at least 3 months of anticoagulants) could go on to develop CTEPH. Symptoms of CTEPH include shortness of breath, edema, fatigue, and chest pain and are therefore similar to other, more common diseases, resulting in an often delayed diagnosis of CTEPH.

Radiologists may have the first opportunity to identify CTEPH in patients; so it is vital that they recognize CTEPH indicators on CTPA images.

Development of the software will rely on the use of deep learning methodology to support radiologists by identifying signs of CTEPH in CTPA scans. The software processes image findings of cardiovascular, lung perfusion and pulmonary vessel analyses in combination with the patient’s history of pulmonary embolism. If the development is successful, the software could be deployed via Bayer’s Radimetrics, an informatics technology platform that connects contrast medium with injector and scan information to provide important insights.

“Bayer is looking forward to leveraging our expertise in Radiology to develop a software to support radiologists and treating physicians in the complex diagnostic decision making process of this rare disease,” said Prof. Dr. Olaf Weber, Head of Radiology Research & Development of Bayer AG’s Pharmaceuticals Division. “We hope that greater awareness of CTEPH in conjunction with a decision-support tool will eventually assist in diagnosing patients earlier and more reliably, thereby allowing earlier treatment.”

BAYER BERLIN, GERMANY
www.bayer.com
www.cteph-info.com

79 Patents granted to Carestream in 2018

Carestream Health was awarded a total of 79 new patents in 2018 for innovation in digital radiography, extremity CT imaging and other healthcare technology areas. Of these 79 patents, 42 were granted in the U.S. and 37 additional patents were granted in European and Asian countries.

The new patents earned by the company’s scientists and engineers include:

• New medical image capture technologies related to the development of computed tomography (CT) systems designed for extremity exams; and
• Continued technology advances that further enhance the image quality delivered by Carestream’s growing portfolio of radiology imaging systems and detectors.

“These valuable patents demonstrate our continued success in developing advanced diagnostic imaging technologies that serve healthcare providers around the world,” said Susan Parulski, Carestream’s Chief Patent Counsel. “Our employees are committed to delivering new products that can enhance image quality, deliver greater productivity and offer new capabilities to help improve the quality of patient care.”

Carestream’s product portfolio includes digital imaging systems for general radiology and specialty areas such as orthopaedics and pediatrics; digital laser imagers that output medical images to film and hospitals, clinics and physician practices.

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Please visit us at ECR hall X3 #304
AI algorithms, viewer and platform CE Mark certified

The image analysis platform developed by the Spanish-based company QUIBIM has received CE Mark certification as a class IIa Medical Device. Included in the approval is the company’s imaging biomarker analysis algorithms, the zero footprint DICOM viewer and medical imaging data which are hosted by the platform. A company spokesman said that “with this CE approval milestone, the products are now ready for commercial deployment in European hospitals and diagnostic imaging centres”.

The software, which includes not only quantitative image analysis but also structured reporting capabilities, can be seamlessly integrated into radiology workflows. The current certification includes 15 algorithms in the main areas on which QUIBIM is focused, namely • Oncology: ADC Diffusion, IVIM Diffusion, Semiquantitative Perfusion, Pharmacokinetics Modeling, T1 mapping, T2 mapping. • Neurology: White matter lesions detection, Brain atrophy modules. • Musculoskeletal: 3D /2D Trabecular Bone Microarchitecture • Liver: Liver fat and Iron quantification. • Lung: Lung Emphysema and densities.

Also included in the CE Mark certification was the company’s DataMiner, which is designed to provide advanced visual analytics of large databases of patients for population health management and scientific exploitation, as well as a DICOM web viewer that enables the user to visualize the images of a sequence, draw ROIs or apply filters.

Ángel Alberich Bayarri, CEO & Co-founder of QUIBIM said “We are so proud of getting the ISO 13485:2016 and CE certification by BSI, one of the most prestigious notified bodies. This allows QUIBIM to commercialize QUIBIM Precision as a Medical Device in the European market, which is a major milestone for our company” He added, “Since its inception, QUIBIM has carried out extensive research and validation for its products together with European, American, Indian, and South American partners, ranging from top academic and research hospitals & diagnostic centres to the leading pharmaceutical companies and CRO’s, sharing the results in publications in both national and international congresses. Now with the CE Mark approval, QUIBIM is excited to commercialize its efforts in Europe and other regions of the world where the CE Mark is accepted.”

Belén Fos Guarinos, QA and Regulatory Affairs Manager at QUIBIM, pointed out that “QUIBIM is a company committed to improving diagnosis, so quality is one of the aspects we pursue the most in our company, not only by certifying the quality of our product with the CE Mark but also at the organizational level. This is why we have established our Quality Management System certified by the ISO 13485:2016, a standard related to the quality management system applicable to medical devices”.

QUIBIM,
VALENCIA, SPAIN
www.quibim.com

MRI diagnostic software for evaluation of body composition receives FDA clearance

AMRA Medical has received FDA clearance for its AMRAProfiler software which is now available for use in a clinical setting in the US. AMRA Profiler is indicated for use as an MRI diagnostic device for non-invasive fat and muscle evaluation that enables the generation, display and review of MR-based body composition measurements. AMRA is the first in the world to transform MR-images from a 6-minute whole-body MRI scan into 3D-volumetric fat and muscle measurements, enabling outstanding accuracy and precision when assessing volume and distribution of fat and muscles, as well as metabolic status.

“We are delighted with the FDA’s decision. The challenges facing healthcare systems across the world are well-documented. Cost constraints, together with societal issues such as obesity and an aging population, are putting hospitals and private clinics under increasing pressure,” stated Eric Converse, CEO of AMRA. “AMRA Profiler helps address these challenges by providing physicians with the most detailed body composition assessment and imaging available, cost-effectively and with minimal intrusion to the patient. Ultimately this enables clinicians to make more informed treatment decisions about the whole body. This clearance is the next step in our journey of translating the benefits of AMRA into clinical practice and in ultimately contributing to the real world data and real world evidence that are playing an increasing role in health care decisions today.”

AMRA MEDICAL
LINKÖPING, SWEDEN
www.amramedical.com
GE Healthcare in collaboration to accelerate use of 3D printing in patient care

GE Healthcare and VA Puget Sound Health Care System have announced that they are collaborating in a partnership to accelerate the use of 3D imaging in healthcare. (VA Puget Sound has nine facilities in the Pacific Northwest of the USA and has the 5th largest research program within the USA national VA system). As part of their research agreement, GE Healthcare will provide software and work stations, and the VA will provide input on its use of the technology. The VA will use GE software designed specifically for the medical field – which is expected to reduce the time it takes to create 3D models from hours to minutes.

The use of 3D medical printing in healthcare is still very much in its infancy, and software designed exclusively for the medical community is limited. Such software designed to allow manual preparation of image data into 3D printable files can be labor intensive, requiring hours of work.

Using GE Healthcare’s advanced visualization tool, specifically designed for the medical community, VA radiologists will be able to produce models of normal and pathological anatomy using automation techniques that will speed up the pre-3D printing preparation work and the diagnostic process. This is expected to reduce the time it takes to create 3D models from hours to minutes.

3D printing is primarily used to manufacture orthopedic implants and guide surgical cutting. The number of peer-reviewed research publications on the potential impact in patient care has expanded exponentially.

GE HEALTHCARE
CHICAGO, IL, USA
www.gehealthcare.com

Leader of Philips Image-Guided Therapy division appointed member of Executive Committee

In an appointment reflecting the growth and importance of Philips Image-guided therapy division, the company has announced that as of 1st Jan, Bert van Meurs will become a new member of the Executive Committee, reporting to Philips CEO Frans van Houten.

Bert van Meurs currently leads Philips’ EUR 2+ billion Image-Guided Therapy businesses which offer integrated solutions comprising interventional imaging systems, smart catheters, planning and navigation software, and services with the aim to improve minimally invasive treatments. Driven by the benefits of such treatments for patients and care providers, including reduced patient trauma and shorter recovery times, the EUR 8+ billion market is showing high-single-digit growth and represents a key growth opportunity for Philips.

Frans van Houten, CEO of Royal Philips said, “To strengthen our leadership in this fast growing market, we have significantly invested in our R&D programs which resulted in the launch of the very successful Azurion next-generation image-guided therapy platform, and the acquisitions of Volcano, Spectranetics and most recently EPD Solutions, which enabled the expansion into smart devices such as diagnostic and therapeutic catheters.”

Bert van Meurs and has held various leadership positions in Philips, in research & development, clinical science, and marketing & sales in Europe and Asia.

PHILIPS HEALTHCARE,
AMSTERDAM, THE NETHERLANDS
www.philipshealthcare.com

CE Mark granted for MRI compatibility of focussed ultrasound for brain treatments

Siemens Healthineers and INSIGHTEC have announced the CE clearance of Exablate Neuro compatible with the Magnetom Skyra, Prisma and Prisma Fit MRI scanners from Siemens Healthineers. Exablate Neuro uses focused ultrasound for treatments deep within the brain with no surgical incisions. MR imaging provides a complete anatomical survey of the treatment area, patient-specific planning and real-time outcome monitoring throughout the treatment.

“INSIGHTEC and Siemens Healthineers are working in partnership to transform patient care,” said Dr. M Ferré, INSIGHTEC CEO. “This milestone is key to expanding patient access to incisionless brain surgery using focused ultrasound.” The CE mark includes approval for treatment of medication-refractory essential tremor, tremor-dominant Parkinson’s disease and neuropathic pain. FDA approval for the Exablate Neuro compatibility with MRI scanners from Siemens Healthineers to treat medication-refractory essential tremor has now been received.

SIEMENS HEALTHINEERS
ERLANGEN GERMANY,
INSIGHTEC
HAIFA, ISRAEL,
Biliary visualization software gets FDA approval

510(k) clearance from the U.S. Food and Drug Administration has been awarded to MRCP+, an advanced biliary visualization software developed by the UK company Perspectum Diagnostics.

The company developed quantitative MRI and AI algorithms for Magnetic Resonance Cholangiopancreatography (MRCP) images to provide improved visualization of intra-hepatic ducts and to measure the widths of bile ducts, biliary tree volume and gallbladder volume. Combining image viewing, processing, and reporting tools, the metrics provided are designed to support physicians in the visualization, evaluation, monitoring, and reporting of hepatobiliary structures. This is especially relevant for serial evaluation of Primary Sclerosing Cholangitis (PSC) patients.

“I am excited by the FDA clearance of MRCP+. Non-invasive MRCP+ detection of both the numbers and diameters of strictures in patients with PSC has the potential to become a primary end point for therapeutic trials in PSC, a disease for which no effective treatments exist,” commented John M Vierling, Prof of Medicine and Surgery, Baylor College of Medicine, and former President of the American Association for the Study of Liver Diseases (AASLD).

The diagnosis of PSC is hindered by lack of effective biomarkers. Interpretation of conventional MRCPs itself is both qualitative and subject to relatively low inter-operator reliability. Perspectum worked with patients with biliary disease to design and validate the software, scanning over 140 patients. MRCP+ has shown diagnostic potential for PSC in a study released at the 2018 AASLD Meeting and is being evaluated for acute biliary imaging later this year.

Martine Walmsley, Chair of Trustees for PSC Support:

“The ability to diagnose and monitor the progression of PSC is needed to help develop new treatments, improve methods for cancer surveillance and allow the early management of symptoms and complications of PSC. To this end we welcome the clearance of MRCP+ which will provide additional information for clinicians and researchers, helping address unmet need for patients with PSC.”

MRCP+ is already cleared for clinical use in Europe, with CE-marking. It can process data from all 1.5T and 3T MR scanners from GE, Siemens and Philips that support 3D MRCP sequences, providing standardized quantitative metrics for the pancreateobiliary system. MRCP+ is safe, non-invasive, involves no contrast. A typical scan takes less than 15 minutes, and provides same day results.

Professor Sir Michael Brady, Chairman of Perspectum Diagnostics said, “Perspectum develops quantitative MRI for decision support in a range of diseases in the liver and related organs. MRCP+ is one of the first examples of AI in medical imaging being used to solve unmet needs in hepatobiliary medicine.”

PERSPECTUM DIAGNOSTICS LTD,
OXFORD, UK.
www.perspectum-diagnostics.com

English football club selects system to consolidate players’ medical images

Southampton Football Club has selected BridgeHead Software’s Independent Clinical Archive (ICA), HealthStore, to assist the long-term consolidation, protection and secure sharing of its players’ medical images. In turn this will support the club’s clinicians in assessing injuries, collaborating on player rehabilitation and developing education and injury prevention strategies. The need for fast and easy access to players’ data was driven by the club’s medical team who sought a solution that allowed them to work individually or as part of a multi-disciplinary team when examining and comparing medical images, such as ultrasounds and MRIs. HealthStore will provide a central repository for all players’ medical images enabling club medical staff and authorised hospital specialists to access and view that data, when and where they need to, securely, on any approved device.

Dr. Steve Baynes, Southampton Football Club’s first team doctor said: “Being able to access, view and collaborate with my medical colleagues, wherever they might be around the world, means that quicker diagnostic and treatment decisions can be made for our players and can reduce their time away from the pitch.”

“It’s also important for the medical team to have a full view of players’ information when carrying out pre-signing medicals or monitoring serious injuries over a period of time. BridgeHead’s HealthStore will allow us to easily compare scans showing progression or improvement and, ultimately, make rehabilitation recommendations that positively impact player recovery and performance.”

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ASHTEAD, SURREY, UK
www.bridgeheadsoftware.com
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Spotlight
Global Cardiovascular Health

Abstract submission: December - 14 February
Clinical Case submission: Mid January - 1 March
Late-Breaking Science submission: Mid March - 21 May
Early registration deadline: 31 May
Late registration deadline: 31 July

escardio.org/ESC2019
International study shows that large variation in radiation doses in CT are due to how scanners are used by medical staff rather than by patient characteristics or machine manufacturer or model

The findings of a recent study shows that large differences in radiation doses used for CT scans are mainly due to how the scanners are used by medical staff rather than differences in the patients scanned or the machines used. (Smith-Bindman R, et al. International variation in radiation dose for computed tomography examinations: prospective cohort study BMJ. 2019 Jan 2;364:k4931. doi: 10.1136/bmj.k4931)

Radiation doses for computed tomography (CT) vary substantially across patients, institutions, and countries. Ionizing radiation is a known carcinogen, and CT radiation is associated with increased cancer incidence so it is important to minimize exposure from medical imaging and reduce unnecessary variation by optimizing examination protocols. Evidence suggests that in many instances, CT doses can be reduced by 50% or more without reducing diagnostic accuracy. Setting more consistent dose standards should therefore be possible and will ensure that patients are not exposed to unnecessary radiation risks. However, differences in patient populations and inconsistencies in data collection and analysis have challenged both accurate quantification of dose variations. The recently published study was designed to determine if dose variability is driven primarily by patient characteristics (patient size, indications for imaging), institution type (eg, academic, private, trauma facility, or 24 h/day provider of CT), machine factors (eg, machine age, specific manufacturer and model, or use of updated software that permits dose reduction), or regional choices that affect dose optimization or image quality (or both).

To do this, the international research team analysed standardized dose data data from over 2.0 million CT examinations of adults who underwent CT between November 2015 and August 2017 in 151 institutions, across seven countries. They included scans of the abdomen, chest, combined chest and abdomen, and head from 1.7 million adults. The data were analyzed for a range of variables related to the patient (eg. sex and size), institution (eg. trauma centre, academic or private), and machine (eg. manufacturer and model).

The researchers found that most of these factors had only a small effect on dose variation across countries. For example, after adjusting for patient characteristics, there was still a fourfold range in mean effective dose for abdominal scans and a 17-fold range in proportion of high dose scans (4-69%). Similar variation persisted for chest scans, and combined chest and abdomen scans.

Adjusting for institution and machine factors also had little effect on dose variation. However, adjusting for technical factors (how scanners were used by medical staff) substantially reduced or eliminated nearly all the dose variation across countries.

The researchers conclude that the variation in doses used for CT scanning of patients is primarily driven by how CT scanners are used, rather than to underlying differences in the patients scanned or the machines used. The study was an observational study, and as such, can’t establish cause, in addition, as the researchers point out, the study inevitably had some limitations that may have influenced the results.

Nevertheless, they say these findings suggest that optimising doses to a consistent standard should be possible. The researchers also call for more education and international collaboration to set benchmarks for optimum target doses.

Smith-Bindnam R et al. paper doi: 10.1136/bmj.k4931.
Many patients with radicular pain due to nerve root compression or low back pain related to degeneration of the facet joint respond favorably to imaging-guided spinal therapeutic injections with steroids. Lumbar transforaminal epidural and lumbar facet joint steroid injections can be performed reliably, safely, and quickly with either a fluoroscopy-guided or CT-guided technique.

However it is unknown what is the difference in the level of radiation dose to which both patients and the clinicians are exposed, depending on the imaging modality used to guide the injection. Neither has it been specifically studied whether fluoroscopy-guided injections yield more favorable clinical patient outcomes than CT-guided lumbar spinal therapeutic injections or vice versa.

A group of clinicians from Zurich, Switzerland set out to compare the procedure-related radiation exposure for patients and interventionalists during fluoroscopy-guided and CT-guided lumbar spinal injections and also the clinical outcomes of the patients in a study involving more than 5000 patients. For the patients, the effective dose for fluoroscopy-guided procedures was calculated in mSv from the dose-area product (in Gy/cm²) displayed on the control panel of the fluoroscopy system; the effective dose in mSv for CT-guided injections was calculated from the dose-length product (in mGy.cm) provided by the protocol of the CT scanner.

For the interventionalists, exposure was measured by two dosimeters, one fixed outside the lead gown at the level of the left breast; the second dosimeter was worn on the dominant hand like a wristwatch.

Clinical outcomes were assessed using a Patient Global Impression of Change (PGIC) scale tool at 1 day, 1 week, and 1 month after the intervention.

The results of the study, have just been published (Dietrich TJ et al. Fluoroscopy-guided versus CT-guided Lumbar Steroid Injections: Comparison of Radiation Exposure and Outcomes. Radiology. 2019:181224. doi: 10.1148/radiol.2018181224.)

For lumbar transforaminal epidural injections, it was found that the patient radiation dose exposure was significantly (1.4 times) lower with fluoroscopy-guidance than with CT-guidance; for lumbar facet joint injections the patient exposure was also significantly (3.3 times) lower with fluoroscopy-guidance compared to CT-guidance.

Conversely, the radiation exposure to the body and wrist of the interventional physicians was significantly (between 3.7 times and 10 times) higher for fluoroscopy-guidance compared to CT-guided lumbar spine injections. These results can be explained as follows: Fluoroscopy-guided lumbar spine injections necessitate real-time manual guidance and manipulation of the needles; thus, the body, wrist, and hand of the interventionalist is exposed to scattered radiation due to the proximity of the primary x-ray beam. Conversely, CT-guided lumbar spine injections frequently allow steering and manipulation without simultaneous verification of the needle location by the X-ray beam. Another advantage of CT-guided spinal injections is that to minimize the radiation exposure the interventionalist can leave the CT room and go to the control room during image acquisition. Thus, the radiation exposure for the body and wrist of the interventionalist was significantly higher during fluoroscopy-guided than with CT-guided lumbar spinal injections.

There was no statistically significant difference in patients clinical outcomes between the guidance methods. doi: 10.1148/radiol.2018181224.
This article summarizes a recently published study which evaluated a new system of controlling the operation of procedures involved in chest CT examinations using two hand-held devices, a mobile tablet device and a remote control unit. By analyzing and quantifying the workflow of the radiographers using the new hand-held mobile systems, it was found that the radiographers spent significantly more time in proximity to the patient than with conventional CT workflows.

The potential of the new tablet- and remote control- based system looks highly promising for reassuring patients, increasing compliance, minimizing re-takes and generally improving the patient experience.

INTRODUCTION

Digitalization, together with the introduction of radiological information systems (RIS) and picture archiving and communication systems (PACS), is at the base of modern image interpretation and has enabled the establishment of linear workflow patterns in the carrying out of computed tomography (CT) examinations [1]. Technological advances in hardware (e.g. tube, detector, or gantry) and software components (e.g. reconstruction algorithms, dose-saving algorithms) have resulted in faster image acquisitions with higher resolution and at reduced radiation doses [2].

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However, despite these developments, the actual sequence of the procedures involved in CT examinations has stayed almost the same up till now: registration of the patient in the CT machine; positioning on the patient table; planning (localizer and range definition); contrast media injection; the actual CT examination; release (of the patient from the...
table); reconstruction of the CT data-set; archiving of the images in the PACS and documentation in the RIS. During all this, the actual contact the patient has with the medical staff is limited to the stages of initial positioning and the eventual release of the patient from the table in the examination room.

The majority of instrument settings and adjustments are controlled from a stationary operating console in a separate control room, where communication with the patient is limited to microphones and speakers. This separation between patients and medical staff severely hampers efforts to ensure patient compliance, especially in uncooperative patients. Patients who are injured, critically ill or demented, as well as pediatric cases are especially vulnerable and may require direct re-assurance, assistance and surveillance during the entire examination, even during the phase of radiation exposure [3].

MOBILE DEVICES

Mobile devices are of course already well-established in the consumer market and are also being increasingly used for home medical applications [4]. With their performance continuously improving in terms of computing power and battery capacity, mobile devices have recently been evaluated in various implementations in radiology departments, e.g. for patient briefing [5], diagnostic procedures [6], clinical knowledge assistance [7], case database management [8] or augmented reality in interventional procedures [9].

Recently, a new CT system (Somatom go.Up, Siemens Healthineers) incorporating a complete user interface application on a portable tablet computer has been introduced. The new system uses a wireless remote control for triggering the radiation and for patient table positioning. The mobile graphic user interface on the tablet is simple, intuitive and guides the radiographer through the whole examination in a 7-click procedure. Patient registration, planning, examination, and reconstruction can be carried out on the tablet system, while positioning and release of the patient is performed with the remote control device.

The integration of these devices into the daily clinical routine means that a redesign of the whole examination workflow now seems possible, with the aim of bringing the radiographer into closer contact with the patient.

CURRENT STUDY

In our study [10], we set out to evaluate whether the time spent by the radiographer with the patient — considered as a surrogate for patient contact and interaction — could be increased in chest CT examinations through the use of the mobile-based workflow as opposed to the conventional stationary console workflow. To facilitate the radiographers’ freedom of movement in the examination room and to minimise their exposure to scattered radiation, we constructed a prototype radiation protection cabin with 3 mm lead equivalent walls in the radiation shadow beneath the gantry [Figure 1]. According to the protocol, 98 chest CTs were randomized to examination either by the mobile-based workflow in the test group (n = 47) or by conventional workflow in the reference group (n = 51). The study design is shown in Figure 2.

WORKFLOW SURVEILLANCE

The workflow was recorded by three cameras (see icons in Figure 1). Video recordings were started when the
The patient was brought in from the waiting room and were stopped as soon as the archiving and documentation of the examination were finished. Dedicated software for person recognition and motion tracking was used to analyze the videos. Visualization of the movement of personnel was obtained using relative target density heat-maps, in which warm colors indicate a relatively high presence of persons in that area (hot areas, red) whereas cold colors indicate a low presence of persons (cold areas, blue) [11]. Virtual areas within the cameras’ imaging areas were defined for quantitative evaluation as shown in Figure 3. Moving objects in those areas were automatically registered whenever a threshold was reached and mean counts per patient (cpp) were calculated for each area.

To support the validity of the video recordings, the duration of all workflow tasks was also simultaneously recorded manually by an observer who was located in the observer area in the control room [Figure 3].

RESULTS:
The randomisation of the patients ensured that overall the patients’ characteristics were similar in both groups.

Heat-maps:
Heat-maps of the radiographers’ movements provide a comprehensive overview of the radiographers’ location throughout the examination sequence [Figure 3]. Hot areas decreased in the control room, especially in front of the console and across the floor area. A remaining hot area is located in front of the RIS-monitor, (integration of the RIS system with the mobile device is not yet available). The relatively constant hot area in front of the surveillance monitor in the control room can be explained by the presence of the stationary observer. In the test group it was found that in the examination room, the focal hot spot beneath the top of the patient table and the front cover of the gantry in the reference group grew to a large hot area spread out over the entire left side. Also in this group it was found that a new area of high relative target density occurred in the radiation protection cabin.

Area counts:
Area counts are a quantitative measure of the number of times a moving person is detected in specified areas and are shown in Figure 4a. They are normalized by patient number. There was a substantial decrease of counts per patient in all areas of the control room for the mobile workflow. The highest reduction was observed in the console- (−62%) and in the floor-area (−55%). Reduction in the RIS-area was less (−30%). Overall area counts per patient were increased in the examination room, especially in the radiation protection cabin (+151%), on the left side of the patient table (+20%) and in the door-area (+21%).

Counts from the observer-area were discarded in order to simulate a normal clinical routine situation, i.e. without an observer. The area counts per patient in the examination room, (i.e. where the patient is), are almost doubled using the mobile-based workflow (48% of all cpp) compared to...
the conventional reference system (25%). However, in our study more than a quarter of all counts per patient (26%) are still due to an interaction with stationary systems (console 17%, RIS 9%).

**Time measurements**

The median duration of the exams, excluding contrast media injection, was slightly lower in the test group (10:36 min, range 05:48–20:35 min) compared to the reference group (10:50 min, range 05:03–29:57 min). This difference was not statistically significant (p = 0.29, Figure 5). Neither was there any statistical significance in the time spent by operators in all phases of the sequence (0.17 ≤ p ≤ 0.89). Median time spent by the radiographer in the same room as the patient increased from 3:06 min (28%) in the case of conventional routine (positioning and patient release sequences) to 6:01 min (57%) for the mobile -based system (p < 0.05) because the registration, planning, and examination sequences could be carried out in the examination/patient room.

**DISCUSSION**

Several studies have been published in which the effect on patient throughput in CT of various techniques such as intelligent scheduling or multiple radiographer workflows have been evaluated[12, 13]. However, to our knowledge, no approach has yet been presented in which the whole conventional workflow sequence has been completely re-designed. Lin et al. were able to show that the time physicians or medical personnel spend with patients is a determinant of patient satisfaction [14]. Although we didn’t directly assess patient satisfaction, our conclusion from this study is that the increased proximity of the radiographers to the patients is beneficial for patients’ compliance during the examination, especially with critical cases such as excited or confused patients. It is also well known that children’s compliance often depends on their parents being in the examination room [15]. The in-room radiation protection cabin described in this study could be used for such cases and minimizes the time of separation between pediatric patient and the parent and enables voice and visual contact to be maintained without any danger of radiation exposure. The radiographers’ increased freedom of movement and the in-room solution of a radiation protection area described in this study also opens up additional approaches to further improve the cost-effectiveness of CT, even if these were not yet evaluated in our study.

“... the time the radiographers spent in the same room as the patient ...was almost doubled when the examination was carried out with the help of mobile devices...”

Future software versions of the mobile application are likely to increase its functionality, so that in more developed form, mobile devices could completely replace the stationary console. If the RIS was also accessible via the mobile device, completely new design concepts of room organization would be possible. Changes in architectural lay-out could then eliminate the entire control room in favor of a radiation protection area in the examination/patient room. Other procedures that could benefit from the implementation of mobile-based control system are interventional procedures such as image guidance as described by Hirata et al. [16]. Indeed interventional suites in general would benefit from this approach and would require no additional equipment other than the tablet and the mobile remote control.

**CONCLUSION**

In our study of chest CT, the time the radiographers spent in the same room as the patient — which we consider as a surrogate for patient contact and quality in patient care — was almost doubled when the examination was carried out with the help of mobile devices. The radiographers’ freedom of movement increased and their interaction with the scanner was transferred from the control room into the patient/examination room without having any effect on the total time needed for the examination.

**REFERENCES:**

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Computed tomography (CT) scanners are ubiquitous in healthcare as they are reliably fast, non-invasive and accurate in helping to detect a wide range of diseases and conditions for patients. In years past, healthcare organizations only considered the technology’s quantitative specifications; today, the CT scanner is only part of what they are purchasing. Increasingly, healthcare providers also want integrated solutions, workflow advancements and quality improvements that can be leveraged across the organization and beyond the clinical domain to derive economic benefit.

In this new world of radiology department economics, CT is a key enabler in addressing some of healthcare’s most pressing challenges from a clinical, operational and business standpoint. Providers understand the importance of putting quality initiatives in place to ensure they are on a plan for continuous improvement. They want to know how they can consistently maximize their CT capabilities or improve the CT scanner experience for patients and staff while controlling costs across the organization. Most importantly, they want to ensure that they can maintain efficiency in the face of healthcare market consolidation and an outcomes-based environment.

**Diagnostic Confidence of CT Provides Tangible Results**

With imaging volumes growing exponentially, technologists need to be able to scan more patients and radiologists need to read more cases in less time.

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This puts tremendous pressure on radiology departments to overcome imaging obstacles to not only improve diagnostic confidence on the first scan but also streamline workflows to improve patient care and staff efficiency. Intuitive technology advances from the CT scanner to the console to the reading room are helping to improve the patient experience and every step of the radiology workflow. More and more providers need superb image quality, fast results and consistency from scan to scan with solutions that keep the technologist close to the patient.

From a diagnostic confidence standpoint, Spectral-detector CT is redefining the standard of care for...
patients. One of the key benefits of Philips IQon Spectral CT technology is that it applies spectral technology 100% of the time, which gives radiologists the ability to find lesions that aren’t visible with ordinary scans – lesions they may not have even been looking for that may be significant in determining a patient’s diagnosis. There are tremendous benefits for both patients and healthcare organizations in eliminating the guess-work in image reading with Spectral CT. At the same time, it is a major workflow advancement, leading to fast procedures and an enhanced patient experience that may achieve a cost savings for hospitals as well.

**BENEFITS OF CT IN THE REAL WORLD**

Working with CARTI Cancer Center, we have seen first-hand how Spectral CT can provide not only diagnostic confidence for clinicians but also operational improvement and cost savings. Approximately 14 percent [1] of the general U.S. population suffer from chronic kidney disease (CKD) and these patients cannot tolerate typical contrast doses in imaging as this would increase their chance of getting contrast-induced nephropathy (CIN). At CARTI Cancer Center, these CKD patients were typically scanned with non-contrast CT and followed up with scans on other modalities such as MRI and ultrasound for further confirmation or diagnostic information. However, this sometimes increased the time-to-diagnosis and cost of follow-up scans for the center.

To address this, CARTI utilized IQon Spectral CT which allowed radiologists to make a confident diagnosis fast using low-contrast imaging and provided more insights than conventional CT at a low radiation dose. The low monoE results of IQon Spectral CT allowed for improved visualization of the vascular structures on this delayed CT.

By using IQon Spectral CT, CARTI was able to reduce the time-to-diagnosis and the need for additional follow-up scans, resulting in a savings of $453 per follow-up scan on a patient population that would not have been eligible to receive contrast [2].

Another instance of the overall benefit to diagnostic confidence and value of IQon Spectral CT is evident in a study by the University Hospitals in Cleveland related to incidental findings, a prevalent issue in imaging. In fact, incidental findings are so commonly encountered on abdomen CT scans (approximately 15-20 percent) that the American College of Radiology has issued guidance that recommends follow up imaging exams on different modalities depending upon the size and nature of the incidental finding to enhance diagnostic confidence.

To remedy the issue of incidental findings, University Hospitals started using Philips IQon Elite Spectral CT scanner which provides multiple layers of spectral results in every exam and retrospectively. This provided benefits even in patients who would not have been pre-selected for a dual-energy protocol. The site observed that the retrospective availability of IQon Spectral CT’s rich spectral results resulted in a 30 percent reduction in follow up exams, which in turn could result in savings for the hospital of approximately $55K per year [3].

**OPERATIONAL RELIABILITY OF CT BRINGS PREDICTABILITY**

Operationally, radiology department administrators are focused on ensuring the reliability or uptime of imaging equipment. If a piece of imaging equipment such as a conventional CT scanner is not working there is a tremendous negative ripple effect throughout the department and into patient satisfaction and care. Radiology administrators need a solution that will fit seamlessly within their operation from throughput to image quality to uptime.

With proactive monitoring via remote services, radiology administrators are able to solve problems before they impact daily operations.

Actionable insights are also crucial to radiology administrators to ensure reliability, quality and continuous improvement in the imaging department. For example, radiation exposure for patients and staff is a key concern in any imaging operation. With radiation exposure management software such as Philips DoseWise Portal, radiology departments can collect, measure, analyze and report on radiation exposure data automatically. This makes a radiology administrator’s job easier and enables them to more readily make sure patient and staff safety and quality initiatives in their
department are on track and meeting standards. With imaging solutions that are integrated and data-driven, hospitals or healthcare providers are in a better position to achieve short- and long-term improvement gains. Meaningful operational analytics solutions, such as Philips PerformanceBridge can help radiology departments gather all the data and metrics around and beyond their practice to improve workflow, reduce manual processes, and achieve gains in many areas to run their practice more efficiently.

REDUCED LONG-TERM EXPENSE OF CT OFFERS VALUE AND FLEXIBILITY

With the shift to value-based care, radiology departments often operate more like a business within a hospital, with efficiency-driven KPIs and metrics that they are measured against. From a business standpoint, hospitals or health providers must remain competitive and profitable to survive with increasing consolidation in the market. This creates greater focus on increasing patient volumes and referrals to bring in revenue while, at the same time, lowering operating costs to save it. It also means there's many dimensions to "cost" and "value" in imaging that differ per hospital but can include: acquisition, integration, personnel, maintenance and replacement costs. There's also hidden costs when providers consider both short- and long-term value.

Clearly, each hospital or healthcare provider has to create their own measure and critical dimensions of what cost and value mean to them. Many providers are still trying to determine, "What does the value measure mean?" around the key areas of access, satisfaction and efficiency. There is still some uncertainty on how value-based care will be operationalized or reimbursed.

However, there are some imaging costs that are fairly consistent across healthcare organizations and straightforward. Take CT tube life for example. What if hospitals no longer had to worry about tube cost in their operating budget? The potential savings can be as high as $400,000 for not having to replace the tubes of a CT scanner over a ten-year useful life of a CT system [4]. With Philips Incisive CT, hospitals can keep control of operational costs such as tube life that can then be reinvested into patient care. Incisive CT also offers upgradeable systems technology so that hospitals can purchase what they need now with an easy path to add up-to-date features as their clinical needs evolve. This enables hospitals to stay clinically advanced while maximizing their imaging investment with a right-sized solution.

Today's healthcare environment is full of surprises that include everything from financial obstacles to staff shortages to government mandates. There will always be new challenges or issues to overcome but imaging will always play a critical role in healthcare's future. The balancing act of assessing cost versus value will continue to be a factor in purchasing decisions of imaging technology in the context of value-based care. Ultimately, imaging is about providing accurate information to facilitate more confident decision-making that guides enhanced patient care and confident diagnostics in the future. Providers can maximize the value of their imaging equipment overall and CT in particular, by determining how imaging solutions and partners can best support them with actionable, intelligent insight at every step from acquisition through results and across all fronts - clinical, operational and financial - for continuous improvement.

REFERENCES AND DISCLAIMERS:
[2] Results from case studies are not predictive of results in other cases. Results in other cases may vary.
[4] Actual operating costs for customers vary significantly because many variables exist (such as CT make and model, hospital/imaging center size, case mix, system usage). The potential savings identified estimates the avoidance of purchasing replacement tubes over a ten-year useful life of a CT system, based on an average selling price of $140,000 per replacement tube and estimated tube life of three years. There can be no guarantee that all customers will achieve this result.
The Maastricht University Medical Center (MUMC+) is renowned for its high level of patient care and has a reputation for being equipped with the most up-to-date technology. Since July 2013, the Department of Radiology and Nuclear Medicine at MUMC+ has been using a Radimetrics software system for radiation dose management of their CT scanners. Based on this experience, the department is currently in the process of extending the use of the dose management system to all other x-ray modalities and also to nuclear medicine imaging.

We wanted to find out more about the MUMC+ in general and their experience with the Radimetrics system in particular, so we talked to Dr. Cécile Jeukens, Medical Physicist in the Department of Radiology and Nuclear Medicine.

Let’s start with a bit of background information on MUMC+

As you said in your introduction as an academic center we have a high reputation based on our recognized expertise, which means that patients are referred to us from the whole southern region of The Netherlands as far as the city of Eindhoven (Maastricht is located in the south east part of the Netherlands). For some specialities we even receive patients from other parts of the country. In addition we occasionally receive patients from the neighboring parts of Germany and Belgium. There are 700 beds in our hospital and we care for more than 26000 in-patients annually and also carry out a total of approximately 21 000 individual treatments on an out-patient basis, including multiple treatments on the same patient. We also provide radiological support for primary care/GPs in the immediate surrounding areas of Maastricht/Heuvelland.

Let’s turn to the Radimetrics system. Since when have you had the system?

The system was installed in July 2013 when we hooked up all three of our CT-scanners to it. Back then, and even more so still now, our department already had a commitment to research and development on CT and contrast agent injection protocols, so the acquisition of the dose management system fitted well with our overall R & D strategy. Since 2013 we have built up a significant experience in the field. During this period we have enjoyed a close collaboration with Bayer Healthcare, who developed the Radimetrics system, as well as with Siemens Healthineers.

Now, what about the radiology and nuclear medicine department?

As you might expect of a University hospital, we have the whole gamut of imaging modalities, including CT-scanners, MRI scanners, Interventional Angiosuites, Radiography units, Mammography Units, Mobile radiography systems, Mobile C-arms, PET-CT, SPECT-CT, PET-MRI, DXA.

For reasons of operational efficiency all the machines in any one modality are sourced from the same vendor but over all the modalities, all the major vendors are represented: Philips, Siemens, GE, Canon, Hologic, Shimadzu, Ziehm and Oldelft, which is an old Dutch company, now a part of Canon.

The patient scorecard enables a review of the patient history with cumulative dose exposure across modalities.
As for the actual installation of the software itself, that went very smoothly, although we did find that one of the scanners was not transmitting the dose data correctly. Once discovered, this problem was quickly resolved. Another issue that we did encounter early on when using the system was that our three CT-scanners had to have different names for what were actually the same or very similar protocols. Also within one scanner, protocol names had slight changes. Even minor changes such as changing a lower-case letter into an upper-case letter or the insertion of a space in the protocol name meant that for the Radimetrics system these were totally different protocols, so we ended up with many individual protocols.

In addition, the Radimetrics system showed us that there were several protocols that had only been used a very few times, and so were basically obsolete. The result of all these points was that we put a lot of effort into the very useful exercise of tidying up all our protocol names as well as adjusting and making the technical settings of the protocols more uniform.

The system in routine practice
The way we chose to use the system in practice means that only a limited number of radiographers are actively involved in the direct use of the Radimetrics system. Thus, we arrange that one of our radiographers spends four hours each week on ‘Radimetrics’. During this period she will typically review the studies carried out over the past week/month to identify those which were the highest in dose; these studies are then be discussed in more detail with the team radiologist. In this way, inconsistencies in protocols between scanners can be identified and corrected.

Another interesting finding that came out of the use of the Radimetrics system to regularly review studies was the discovery that our “obese” protocols were being used in an inconsistent manner. We had been unaware of this inconsistency until then but once we identified the issue, we formulated a much clearer indication for the use of the obese protocols.

In cooperation with our radiation protection officer, who is now also a frequent direct user of Radimetrics, dashboards were made to monitor the dose of several standard head, thorax, abdominal protocols and to check compliance with the national Diagnostic Reference Levels (DRLs) on a regular basis.

It was observed that, as could be expected, our three CT-scanners actually performed differently in terms of the radiation dose used, in the sense that the high-end scanner outperformed the next best scanner and the medium end scanner.

Besides checking DRLs with the system, the Radimetrics software is also employed as a database to gain insight into the usage of CT-scanners in terms of typical dose-length-product per protocol for each of the protocols selected. This information is used to carry out risk analysis of imaging procedures (which is in fact required by Dutch law) based on actual usage instead of estimates from literature. Dose estimates are also needed to quantitate and justify the use of radiation to which study subjects may be exposed in any research proposals that are submitted to our local medical ethics committee. To obtain reliable dose estimates for such purposes we use the CT-dose data from the Radimetrics system.

Research Projects
As I said before, we are actively involved in several development programs so, in addition to the use of the Radimetrics system for our routine clinical work, we also carry out several research projects with it.

- For example in CT angiography, we wanted to establish local diagnostic reference levels. We knew that the dose-related parameter CT Dose Index (CTDI) depends strongly on the size of the patient — for slim patients a lower radiation dose can be used whereas for more bulky patients a higher radiation dose is necessary to obtain a diagnostic image of acceptable quality. For this reason a fixed DRL is not adequate to identify and monitor dose outliers in CT angio applications. To solve this we developed and introduced a size-dependent local DRL.

In general I believe that dose monitoring software opens up opportunities to establish methods based on the patient’s individual characteristics. . .
Bench marking of the CT protocols and comparison dose parameters of CT examinations now becomes possible on a large, even international, scale. In this context, we have participated in the multicenter, multinational CT Dose Benchmarking project headed by Prof R Smith-Bindman of UCSF, in California in the United States. All the participants in this project had Radimetrics software, so sharing and comparison of data was easy. Thus, in the study, data from our Radiometrics database were shared with the other participants. As feedback we obtained audit reports and participated in collaborative conference calls to optimize the protocols. The results of this study have recently been published (Smith-Bindman R, et al. International variation in radiation dose for computed tomography examinations: prospective cohort study. BMJ. 2019 Jan 2;364:k4931). The significant conclusion of the study was that “CT protocols and radiation doses vary greatly across countries and are primarily attributable to local choices regarding technical parameters, rather than patient, institution, or machine characteristics. These findings suggest that the optimization of doses to a consistent standard should be possible”. Such findings encourage us to pay continuous attention to the issue of dose optimization and lead to more awareness of the issue by all concerned.

In another project, this time concerning pregnant women, we used the Monte Carlo dose calculation module incorporated in the Radimetrics software to study how much radiation dose could be reduced in such cases — not just for the woman but also for the foetus — by optimizing the scan range during CT scans for suspected pulmonary embolism. The results of this study have just been published (Hendriks BMF et al. Computed Tomography Pulmonary Angiography during Pregnancy: Radiation Dose of Commonly Used Protocols and the Effect of Scan Length Optimization. Korean J Radiol. 2019 Feb;20(2):313-322). The study showed large variations in the CTPA radiation dose between several CT scanners and scan protocols. By evaluating the effect of an optimized scan length, it was found that the scan range could be reduced by 30 -33%. In this way, the patient could be spared about 25% of the usual radiation dose and the foetus could be spared approximately 80% of the dose that would otherwise have been used before optimization, while still maintaining diagnostic confidence. These results are being used to encourage and instruct the CT technicians and to make them again aware of the importance of avoiding scan ranges that are longer than strictly needed.

Our belief in the value of the system can be seen from the fact that recently we have purchased additional monitoring software so that we can connect not just to our CTs but to all X-ray modalities as well as to nuclear medicine imaging systems. In addition we intend to make use of the module in the Radimetrics system which monitors the parameters involved in the administration of contrast media and the associated contrast injectors. We plan to use this also for the monitoring of MRI contrast media.

Different aspects of the system are appreciated by different members of our team, but one feature in particular that I personally find very useful is the fact that the database can be accessed in so many different ways, Thus the database can be interrogated by looking up a specific examination type, or a particular series within an examination, or an individual patient, or by making dashboards that are updated automatically. The fact that email-alerts can be send, makes it a versatile program that can be used not just by technicians physicists and radiation protection officers but also by medical physicists such as myself. This strength is however also partly a weakness, since the very many possibilities can make it difficult for new or infrequent users to find their way around the program. It would be nice to have a slimmed-down version, which would hopefully make the program more accessible and easy to use for inexperienced users.

As for the future, my personal desire is to see more technicians and physicians becoming much more closely involved and interested in the radiation doses used so routinely in daily routine. Such involvement can only increase awareness of the subject on the part of all the personnel, which is a vital step in the optimal use of imaging modalities which rely on ionizing radiation.

I hope that from the above you have already got a feel for the use we make of the system and our impression of it. In short, I think that it is extremely useful to have a database of accumulated CT dose-related data together with an easy method of accessing the data so as to be able to analyze and learn from the valuable information contained in the database.
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Systematic evaluation of the effect of radiation dose reduction on diagnostic performance in young patients with suspected acute diverticulitis

By Dr. S.S. Walter, Dr. M. Maurer, Dr. C. Storz, Dr. J. Weis, Dr. R Archid, Dr. F. Bamberg, Dr. J. H. Kim, Dr. K. Nikolaou & Dr. A. E. Othman

INTRODUCTION
Diverticular disease, which can be caused by low-fiber nutrition and sedentary lifestyle, is defined as mucosal protrusion through muscle gaps of the digestive tract [1-3]. Acute inflammation of such protrusions — acute diverticulitis — is the third most common gastrointestinal cause for hospitalization and the second most common cause for surgery in Western countries, with a prevalence of 5-45% depending on the patient's age [2, 4-7]. The typically sudden onset of abdominal pain can vary from unspecific to being localized in the lower left quadrant of the abdomen [8-10].

Thus, patients with suspected acute diverticulitis routinely undergo computed tomography (CT), because of its high sensitivity and specificity [2, 10-13]. With this approach, severity and complications (e.g. abscess or fistula) can be diagnosed early, differential diagnoses ruled out and clinicians can adjust their therapeutic treatment accordingly (conservative vs. surgical) [2, 9, 14].

However, as recently described, this has led to a marked increase in the number of abdominal CT scans that are carried out for the investigation of acute abdominal pain [9, 11]. This is particularly relevant for the increasing number of young adults with suspected and often recurring acute diverticulitis who are primarily treated conservatively but undergo multiple CT scans [2, 7]. Hence, it is desirable to implement low-dose CT protocols, according to the ALARA principle (as low as reasonably achievable), to reduce radiation dose for patients by as much as possible [9, 11].

We hypothesized that even a significant reduction of radiation dose exposure in young patients with suspected acute diverticulitis wouldn't substantially affect diagnostic confidence and diagnostic accuracy.

STUDY DESIGN
In this retrospective study 54 consecutive patients of ≤ 40 years of age (mean age 35.2 ± 5.3 years, 77.8% male) with suspected acute diverticulitis were included. All patients underwent clinically indicated abdominal CT exams with intravenous and rectal contrast over the period 2006-2010. Exclusion criteria were impaired image quality (e.g. motion artifacts) or insufficient contrast administration (intravenously or rectally). Abdominal CT imaging was acquired on a dual-source CT-system (Siemens Somatom Definition DS; 2x64). Using a low-dose simulation technique described elsewhere [15-17], and which is based on sinogram synthesis and quantum noise modelling, datasets were computed at 25% (Dose25), 50% (Dose50) and 75% (Dose75) of the original radiation dose (Dose100) [Figure 1].

All datasets were randomized and evaluated individually by two blinded radiologists for overall image quality, sharpness, noise and artefacts using a 5-point Likert scale (5 = best possible outcome for the assessed category; 1 = worst).

To assess the presence of acute diverticulitis or establish a differential diagnosis, three radiologists evaluated each dataset, that is the original and the low-dose reconstructions, individually in a blinded and randomized fashion. If an acute diverticulitis was present, further information was then obtained namely: a). localization of diverticulitis; b). thickening of the intestinal wall with measurements on the most prominent location (pathological ≥ 4 mm) [18]; c). perifocal inflammation; d). diverticulitis related abscess, e). contained or extraluminal gas; f). presence of a fistula. Furthermore, the classification of diverticular disease (CDD) was applied [19].

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The diagnostic confidence of the presence or absence of acute diverticulitis in the evaluated datasets was...
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assessed using a 5-point Likert scale (5 = high confidence; 1 = no confidence). The original CT datasets were used as the reference standard for diagnostic accuracy. Thus, cases displaying the criteria listed above were defined as positive, while cases without these features or cases with a differential diagnosis, which could otherwise account for the symptoms, were defined as negative.

RESULTS
Of the 54 patients included in the study, 57.4% were diagnosed with acute diverticulitis, 22.2% with a pathology other than acute diverticulitis and 20.4% had no radiographic finding for their acute clinical symptoms. Concerning image quality parameters, it was seen that decreasing radiation dose step-by-step down to Dose25 resulted in a significant decrease of overall image quality, noise, artefacts and sharpness ($p<0.001$) [Figure 2]. However, the images acquired with radiation doses of at least 50% of the original dose were consistently rated as being sufficient ($\geq 3$). In contrast, Dose25 had insufficient ratings ($\leq 2$) for overall image quality in 22.2% of the evaluated datasets and, for sharpness in 14.8% of the datasets. In addition, image noise was rated as high for Dose25 with a median value of 2.

On the other hand there was no significant difference between Dose75 and Dose100 as far as diagnostic confidence was concerned, whereas diagnostic confidence was significantly decreased with further dose reduction ($Dose50$ and $Dose25$ ($p\geq0.09$)). Dose75 was rated as being as good as the original images for diagnostic accuracy with a sensitivity and specificity of 100% (95%-CI: 88.8 – 100; 85.2 – 100) as well as a positive (PPV) and negative (NPV) predictive value of 100%. With a specificity and PPV of 100%, Dose50 was equally rated to Dose75/100, but sensitivity and NPV decreased slightly to 96.8% (95%-CI: 83.3 – 99.9) and 95.8% (95%-CI: 77 – 99.4), respectively. Furthermore, for Dose25 sensitivity, specificity, PPV and NPV decreased to 93.6% (95%-CI: 78.6 – 99.2), 95.7% (95%-CI: 78.1 – 99.9), 96.7% (95%-CI: 81 – 99.5) and 91.7% (95%-CI: 74.2 – 97.7), respectively. Inter-reader agreement for pathology diagnosis resulted in a high sensitivity for all dose levels except for Dose25, while specificity was similarly high for all datasets. In addition, radiation dose of 50% and above had an almost perfect agreement for CDD classification, while Dose25 showed substantial agreement.

OUTCOME / SIGNIFICANCE
The findings of our retrospective study indicates that, despite a slight reduction of image quality, diagnostic confidence and accuracy in low-dose CT datasets, radiation dose may be reduced down to 50% of the original dose in patients of ≤ 40 years of age. However, further radiation dose reduction — down to 25% — is not feasible due to a substantial loss of the image quality and diagnostic confidence.
Up till now, CT acquisitions of the abdomen with low-dose protocols have been limited to only a few indications, e.g. the detection of urinary stones [20]. The study we carried out provides evidence that a radiation dose reduction in young patients with suspected acute diverticulitis is feasible without impairing diagnostic accuracy. Previously, a prospective study carried out in 2005 showed similar results when comparing sensitivity and specificity of contrast enhanced standard dose CT to unenhanced low-dose CT in 110 patients with suspected acute diverticulitis [13]. In that study the authors concluded that diagnostic performance was not significantly decreased in low-dose CT scans for acute diverticulitis [13]. However, it should be noted that unenhanced abdominal CT scans cannot fully deal with the severity of the complications of acute diverticulitis (e.g. small abscesses).

Our results are based on simulated CT image datasets, so further evaluation in a prospective setting with a larger clinical cohort is necessary.

CONCLUSION
Decreasing the original radiation dose exposure by 50% in abdominal CT for young adults with suspected acute diverticulitis is possible, while still yielding high image quality, diagnostic confidence and accuracy.

REFERENCES
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The value of the erect abdominal radiograph for the diagnosis of mechanical bowel obstruction and paralytic ileus in adults presenting with acute abdominal pain

By W Z M Geng, M Fuller, B Osborne & Dr. K Thoirs

Plain abdominal radiography (PAR) is often the initial diagnostic imaging tool for patients presenting with acute abdominal pain [1]. In the acute setting PAR may consist of supine and erect abdominal radiographs and an erect chest radiograph [2]. There is discord on the value of the erect abdominal radiograph (EAR) for diagnosing acute abdominal pathologies. The EAR procedure can be uncomfortable for patients in pain and it also increases the radiation dose to which they are exposed. This article summarises the results of a recent study on whether the EAR improved diagnostic accuracy for identifying mechanical bowel obstruction and/or paralytic ileus in adults presenting with acute abdominal pain.

**INTRODUCTION**

Bowel obstruction is one of the most common diagnoses in patients presenting with acute abdominal pain, accounting for 12.6–21.8% of emergency admissions [2,3,4]. Immediate life-saving surgical intervention is required in some cases so a rapid diagnosis is required for these bowel obstructions. It has been postulated that a separate EAR may not actually be necessary because most of its findings can also be identified on the supine abdominal radiograph (SAR) [5,6]. However, air–fluid levels are only seen on the EAR and are a significant radiological sign for diagnosing acute small bowel obstruction (SBO) [7]. It would thus be helpful for radiographers to know the precise value of the EAR, as it can be a difficult radiography procedure to carry out for both the radiographer and the patient, especially when the patient is in pain or disabled. The procedure also adds to the radiation dose to which the patient is exposed. However there have only been limited investigations into the true diagnostic value of the EAR, with most studies having been undertaken over two decades ago and without the use of a standardised reference standard [2,3,8-13].

We undertook this study to determine if the inclusion of EAR in plain abdominal radiography improves diagnostic accuracy in identifying mechanical bowel obstruction and/or paralytic ileus in adults presenting with acute abdominal pain.

**METHODS**

40 patient cases were retrospectively sampled. There were several inclusion criteria, namely: patients who were 18–65 years old; had presented to the emergency department (ED) with acute abdominal pain and clinical suspicion of mechanical bowel obstruction or paralytic ileus; had undergone SAR and EAR within 24 h of presentation to the ED and had undergone an abdominal computed tomography (CT) scan within 4 h after PAR.
Cases were excluded if the patient was institutionalised, had psychiatric or neurological disorders or had an equivocal CT result.

Two plain abdominal radiography protocols were compared. Protocol 1 (PAR 1) consisted of only SAR, whereas protocol 2 (PAR 2) consisted of SAR and EAR. Two radiology consultants and two ED consultants, all of whom were experienced in interpreting PAR in the acute setting, participated in the study. Each assessor independently assessed the two PAR protocols, with a minimum 6-week interval between starting PAR 2 and completing PAR 1. Clinical information from the request form for each case was included with the images.

Cases were presented to the assessors in a randomised order and they were instructed to indicate their diagnostic assessment on a visual analogue scale (VAS). This consisted of a 0–100 continuous scale which provided an indication of how sure each participant was of their assessment. The left and right ends of the scale were labelled with ‘definitely no obstruction/paralytic ileus’ and ‘definite obstruction/paralytic ileus’ respectively.

REFERENCE STANDARD
The radiology report for the CT scan from each case was used to categorise each case as ‘positive’ or ‘negative’ and served as the reference standard. The assessors were blinded to the CT results. CT has a reported sensitivity, specificity and accuracy of 90–94%, 93–100% and 94–95%, respectively, for the detection of mechanical bowel obstruction, and has the highest accuracy for the differential diagnosis of mechanical small bowel obstruction and post-operative paralytic ileus [14,15].

STATISTICAL ANALYSIS
Diagnostic accuracy was measured by calculating the area under the receiver operating characteristic curves (AUROC) for each participant for each testing session. Pair-wise comparisons (P < 0.05) were made between PAR protocols and assessors.

AGREEMENT TESTING
Ten duplicate cases for each PAR protocol were used to test for intra-rater agreement of each assessor’s diagnostic interpretations. Each assessor was given different duplicate cases randomly mixed into the case series. Intra-class correlation coefficients (ICC) were calculated using a two-way mixed-effects model based on a single measure and absolute agreement.

RESULTS
The 40 cases in the study included 17 females and 23 males (mean age 49.0 ± 9.42 years). Fifteen (38%) cases had bowel obstruction or paralytic ileus diagnosed by CT.

DIAGNOSTIC ACCURACY OF CONSULTANTS’ INTERPRETATIONS
Across all assessors, the AUROC ranged from 0.581 to 0.712 with an average of 0.632 for PAR 1 and from 0.565 to 0.673 with an average of 0.632 for PAR 2. There were no significant differences (P > 0.05) in AUROC between the two PAR protocols. Average sensitivity and specificity were 69.7% and 61.0% for PAR 1, respectively, and 80.0% and 53.4% for PAR 2 respectively. There was a wide variation in sensitivity and specificity values between assessors and between PAR protocols.

INTRA-RATER AGREEMENT
Moderate-to-excellent intra-rater agreement (ICC of 0.551–0.939) was achieved for PAR 1. Adding EAR to PAR 2 increased the intra-rater agreement of diagnostic interpretations for all assessors except one radiology consultant.

INTER-RATER AGREEMENT
Moderate-to-good agreement (ICC of 0.413–0.733) between the assessors was achieved for PAR 1, and good-to-excellent agreement was achieved for PAR 2.

DISCUSSION
Both PAR protocols demonstrated low-to-moderate diagnostic accuracy for identifying mechanical bowel obstruction and/or paralytic ileus in adults presenting with acute abdominal pain. We found no significant differences in the overall accuracy between the two protocols. This is consistent with other studies which have demonstrated limited value of the EAR [8,11,13]. We found no significant differences in overall diagnostic accuracy between the assessors. Intra-rater and inter-rater agreement increased when the EAR radiograph was added to the protocol. This improvement was most profound for inter-rater agreement between the two ED consultants, which more than doubled when the EAR radiograph was added. Factors behind this result may include both the doctor’s specialty or years of experience which was different from the radiologists. However, the wide confidence interval for some results indicates that the 10 duplicates cases used to test reliability may not have been enough to give a true indication of the parameter.

We asked the assessors to rate, on a continuous scale, the definite presence or absence of the conditions rather than to dichotomise their assessment into ‘positive’ or ‘negative’. This reflects radiologic practice, where descriptors such as ‘probable’, ‘unlikely’ or ‘apparent’ are commonly used. There were wide variations in the sensitivity and specificity values between the assessors. This variation was also demonstrated in previous studies reporting wide ranges of sensitivity (19–96.2%) and specificity (57–100%) for diagnosing SBO [4,16,17].

Our results do not strongly support the inclusion of EAR
in PAR, with the likelihood that additional confirmatory imaging such as CT is still required. This study builds on the existing limited body of evidence investigating the value of the EAR when bowel obstruction or paralytic ileus is suspected.

LIMITATIONS
The retrospective design and sampling methods are limitations of our study. Confidence intervals for many of our outcome measurements were wide, raising the possibility that the sample was not large enough to detect true significant differences. Alternative radiographs to the EAR, such as decubitus abdominal or erect chest radiographs, were not considered in this study. The departmental CT reporting process also did not control for intra-reader and inter-reader variability between different radiology consultants.

CONCLUSION
Both PAR protocols demonstrated low diagnostic accuracy for the identification of mechanical bowel obstruction and paralytic ileus in adults presenting with acute abdominal pain. Radiographers performing PAR in the investigation of mechanical bowel obstruction and paralytic ileus should be aware of the limited value of the erect radiograph, especially in situations where it is technically difficult to achieve, patient tolerance is low and the radiographs are to be viewed by an experienced consultant radiologist.

REFERENCES
The use of Ca-/Zn-DTPA for chelation of gadolinium in “Gadolinium Deposition Disease”

By Dr. RC Semelka & Dr. M Ramalho

Gadolinium deposition disease (GDD) has been proposed as the name for a newly described, not yet widely accepted, condition of gadolinium (Gd) toxicity. In this review, we summarize the results from our recently published investigation on the use of Ca-/Zn-DTPA chelation in 25 patients with presumed Gadolinium Deposition Disease (GDD) [1]. We also expand our discussion to include the strengths and weaknesses of our paper, our current thinking on the disease, and more comprehensive possible future treatments for GDD.

GDD FEATURES
The classic symptoms of the newly postulated but not yet confirmed condition of gadolinium deposition disease (GDD) have been described as including: brain fog; head pain; blurred vision and dry eyes; skin and skin substrate burning pain; boring bone and/or joint pain; sharp pins and needles pain (neuralgia); and glove and sock changes of skin discoloration, doughy or thickened skin, and pain [2-5]. The typical symptoms that patients experience include those also described in Nephrogenic Systemic Fibrosis (NSF) but are less severe, in particular, as regards changes of the distal arms/hands and distal legs/feet.

GADOLINIUM DEPOSITION DISEASE (GDD): WHAT’S IN A NAME?
We believe that one advantage of using a name that begins with Gadolinium to describe the condition is that there is no doubt about what the condition refers to. In contrast, for example, Nephrogenic Systemic Fibrosis (NSF), does not really convey a sense of what the disease is about. According to Dorland’s Medical Dictionary, a disease is defined as: “…a definite morbid process that has a characteristic train of symptoms…”, which applies to GDD. It appears that the persistent presence of Gd could be responsible for the long duration and drawn-out nature of the disease. The term “deposition” suggests a more embedded process than “retention” for example; Gd is embedded in skin and bone. Some observers have suggested the term “associated” but we feel that “associated” does not communicate appropriately the sense of Gd remaining in the body. Another alternative term that could be considered for inclusion in a description of the condition is the word “exposure”. However this may better describe an acute hypersensitivity reaction, which gives an aspect of transiency and not the concept of Gd remaining in the body.
Some patients have actually wanted to call the condition “poisoning”. However, this usually implies that everyone who receives a similar amount of a causative substance should get similarly sick, which is not the case in GDD.

**EPIDEMIOLOGY**

Many of the individuals afflicted by GDD are

1. women,
2. individuals of central to northern European ancestry, and
3. suffer from an autoimmune disease.

**HYPOTHETICAL DISEASE MECHANISM**

The original hypothesis behind our study of the effect of using a chelating agent to remove Gd in GDD sufferers was that this by itself would be sufficient to cure patients of their symptoms. The chelating agents we used were the calcium and zinc salts of diethylene triamine penta-acetic acid (DTPA) which is approved by the FDA for intravenous administration in the treatment of patients contaminated by heavy metals of the actinide family. Gadolinium is an element of the lanthanide series, which have similar ionic radii and shares a number of chemical characteristics with actinides.

Our published results [1], our continued clinical experience and worldwide observations suggest however that chelation alone may not be sufficient to cure many patients.

This has led us to theorize that the disease has two components: 1) the presence of Gd in the body, and 2) the host response to that presence.

Intravenous DTPA may be currently the best available chelating agent; however, if the host response is not addressed, many patients will not recover from the disease.

**HOST RESPONSE**

Our current thinking is that GDD involves many elements of the immune system, including acute humoral response (granulocytes, mast cells, B cells), subacute response (macrophages, T-cells) and chronic response (circulating fibrocytes). Hence it is similar to a combination of acute hypersensitivity reactions and NSF. The similarity to acute hypersensitivity reaction could explain why all GBCAs, regardless of structure, can cause GDD, whereas NSF is primarily associated with less stable linear agents. Managing the host response is part of our ongoing efforts, not reported in the chelation paper [1].

**CYTOKINES**

Our initial analysis of the variability of the response of patients to GBCA injection, which ranges from no response at all, (which we term Gadolinium storage condition, and covers the vast majority of subjects who have received GBCA), to patients suffering from GDD, was stimulated by an article published on a similarly variable response elaborated by ex vivo peripheral blood monocyte cells (PBMCs) from different individuals to the presence of Candida albicans. The reaction varied also from no response at all to a massive response, as shown by cytokine release [7]. This was also supported by studies performed by the research team of Wermuth and Jimenez [8] who showed a dramatic elevation of various profibrotic cytokines to the presence of all the GBCAs, with differences observed between the agents. Based on all this, our current opinion is that cytokine release may be central to the disease, and thus key to the underlying mechanisms of the disease.

Our rationale behind the therapeutic treatment of GDD individuals relies on the concept that Gd is the precipitating cause, with Gd deposition reflecting continuous ongoing exposure of Gd, from the continued slow release of Gd (from tissue reservoirs) into the vascular system. Thus if Gd released from GBCAs in vivo was the sole causative factor, then simple chelation should suffice. Therefore, our group investigated the off-label use of Ca-/Zn-DTPA for the treatment of symptomatic patients with presumed GDD.

**TREATMENT WITH CA-/ZN-DTPA CHELATION**

The best agent currently approved for patient use worldwide is Ca-/Zn-DTPA. In the USA this agent is FDA approved as a “decorporation” agent (similar to a chelator) for a variety of radioactive actinide metals, the best known of which is plutonium. A variety of investigators have looked, somewhat randomly, at a number of chelators, including EDTA and desferroxamine. What is often missing in these studies is that the fundamental criterion for the appropriateness of a chelator agent, namely that it should have high thermodynamic stability (also known as stability constant) with the element it is to chelate (Gd), and also kinetic stability. Determinations of the thermodynamic and kinetic stability were established for GBCAs at their initial inception. Thus it seems obvious and appropriate to use these same data for assessing chelating agents that could be used to capture the Gd in vivo. Table 1 shows the stability constants and

<table>
<thead>
<tr>
<th>Gd Chelate</th>
<th>Structure Type</th>
<th>Thermodynamic Stability</th>
<th>Kinetic Stability</th>
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<tbody>
<tr>
<td>DOTAren®</td>
<td>Macroyclic-ionic</td>
<td>25.6</td>
<td>19.3</td>
</tr>
<tr>
<td>Gadavist®</td>
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<td>21.8</td>
<td>14.7</td>
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<td>MultiHance®</td>
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<td>Magnavist®</td>
<td>Linear ionic</td>
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<td>17.7</td>
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<td>Linear non-ionic</td>
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structural characteristics of the main Gadolinium-based contrast agents (GBCAs). Note that DTPA has a higher stability constant for Gd than other chelating agents and also for other heavy metals. For example, DTPA binds Gd several magnitudes more tightly than EDTA (around 288,000 greater affinity) [9,10].

These data were behind our decision to use Ca-/Zn-DTPA to re-chelate Gd in patients with self-described GDD [1].

The basic regimen of the protocol we used was: Ca-DTPA day 1, Zn-DTPA day 2, in a fashion analogous to the protocols used for the "decoration" of radioactive metals. The process was repeated weekly or monthly, for a total of three chelation treatment time-points. The results of our study showed that Ca-Zn-DTPA increased the urine level of Gd, as measured in 24-hour samples. This increase was substantially higher for linear agents. Also, the increase was greater following Ca-DTPA on day 1 than with Zn-DTPA on day 2. One interesting finding was that even with macrocyclic agents, the urine level of Gd was increased, but by less than half the increase observed for all GBCAs collectively. Overall, there was a mean increase of Gd in urine of 30 fold in monthly regimen and by 12 -fold in the weekly regimen (p < 0.001) [1].

Following our experience of intravenous DTPA chelation in humans, Boyken et al. [11] described Ca-DTPA chelation of Gd in a rodent model with three infusions of Ca-DTPA or saline, once weekly. In their study, they observed that DTPA induced a 10-fold increase of urinary excreted Gd in rodents who had received linear GBCA (e.g. Gadopentetate; Magnevist) but not after a macrocyclic agent (Gadobutrol; Gadavist). In their study they distinguished spontaneous and Ca-DTPA-induced Gd excretion, subtracting the amount of Gd determined in the saline-infusion animals from that in the Ca-DTPA–infused animals and defining the remaining amount as mobilized Gd. The differences between this study and our results [1] could be attributed to differences in the timing of Gd deposition, which could vary from months to years after the latest GBCA exposure [1] and only seven weeks in the rat model [11], Thus comparison of spontaneous excretion before and after treatment may show different results. In addition, there was no rigorous control of the human study participants, so the possibility couldn’t be excluded that patients might have received previous unrecorded linear GBCA injections. Nevertheless we think that the key factor may reflect characteristics specific to GDD patients, such as the clavage of the bonds between the macrocyclic agents and Gd; that DTPA is acting as a leveraging agent of intact chelate out of tissues; or DTPA acting as a carrier molecule of the intact chelate, and of course possibly a combination of all three effects.

**CLINICAL RESPONSE TO CHELATION**

In our preliminary study, only mild to moderate improvement of symptoms was observed [1]. Our observation was that three chelation sessions might not be sufficient, and our ongoing current clinical experience and observation of worldwide reports seem to confirm this. Overall there was a mild improvement in most of the patients, with the symptom most consistently improved being brain fog, which is a symptom also described as a prominent feature in lead poisoning [12].

**LABORATORY FINDINGS OF SERUM BIOCHEMISTRY**

Three-chelation sessions spaced either one week or one month apart, as carried out in our study, did not give rise to abnormalities in blood chemistry, in particular in the serum levels of cations and metals, including zinc, magnesium and potassium. If sessions are spaced much more closely and at a higher total number, it is not unreasonable to anticipate that perturbations in blood levels of cations or metals may occur. Thus, close surveillance of serum chemistry is indicated if more aggressive chelation is performed.

**FLARE UP REACTION**

The flare-up (or flare) reaction is the most common adverse reaction to chelation therapy. In our study, we reported that this occurred in 44% of the patients [1]. We speculate that this reflects a host immune response to the remobilization of Gd in the vascular system, probably primarily through a cytokine response. So, effective re-chelation in a patient with true GDD may result in a flare, and our opinion is that development of flare may be the most specific clinical evidence for the presence of GDD. Flare, as we initially described it, is an intensification of already developed symptoms of GDD. In our more recent clinical experience, we have observed the development of new symptoms of GDD, or expansion of existing symptoms.

**SUMMARY**

Our published results using intravenous DTPA to remove Gd from humans, showed that the approach does increase Gd elimination from the body. However, it appears that although patients symptoms improve, they probably require more sessions than we carried out. Also, it seems that the management of the host response might be necessary in order to achieve optimal cure for many patients.

**REFERENCES:**

Demand for imaging continues to grow, fuelled by the development of new technologies and population health screening strategies. With imaging providing both diagnostic and therapeutic interventions the opportunities to influence the future of medicine are potentially limitless. However a factor likely to affect the future delivery of such current and new services is the ongoing challenge within the workforce. Capacity issues are affecting all professions involved in service delivery, radiologists, radiographers and nurses, although some countries are more affected than others.

This article explores how the UK has expanded its imaging capacity through the implementation of assistant roles to undertake some tasks previously undertaken by radiographers.

WHY ASSISTANTS?
At the turn of the century, the UK formally considered how radiographer roles could evolve to take on greater responsibilities within the imaging department, supported by expansion of the role of support staff. Following pilot projects in England this national strategy set out a plan to expand imaging capacity and provide a more challenging career for radiographers [1]. Initially scoped for breast screening and general x-ray (as well as radiotherapy) the principles were established regardless of setting.

Assistant Practitioner (AP) roles were to perform protocol-limited clinical tasks under the direction and supervision of a State-registered practitioner [1]. The new workforce was drawn from those in previous imaging support roles as well as new entrants to the speciality with individuals undertaking both academic and workplace training [2,3]. As the role has a limited scope they are based within a single modality or clinical area, e.g. breast, x-ray, MRI, undertaking image acquisition and support functions. In comparison to a radiographer, APs usually only work with non-complex adult patients, although they may assist a radiographer with examinations that are outside of their agreed scope.

WHAT MAKES THIS MODEL WORK?
This move to introduce assistants was underpinned by the move of the UK radiography profession to Bachelor’s degree entry in the 1990s to the associated growth of post-graduate education provision. This standardization at European qualifications framework (EQF) level 6 confirmed the expectations of a graduate radiographer [4]. This also helped the implementation of the role from a radiographic perspective, as they were delegating tasks that previously only a registrant radiographer could perform. The exact qualification the AP undertakes varies across the UK, but they are usually at EQF level 5, which also should enable individuals to continue their education and graduate as a radiographer.

The AP role was not introduced in isolation; the strategy also included the formal development of a four-tier structure including new role for radiographers at senior clinical and leadership levels. It was recognized that radiographers can improve their skills to act as gatekeepers [5] and undertake higher level clinical tasks including some procedural studies and reporting [6,7]. Although, like the assistant role, their scope is very narrow and limited. This whole system approach did ease the introduction of the AP, although opportunities at all levels have not been consistently implemented, which itself has caused some dissatisfaction [2,8].

THE IMPACT
With increasing workloads and expansion of health screening programmes there is an ongoing and urgent need to grow all imaging professions. As technology becomes more...
complex there are also facets of activity which lead themselves to straightforward and repetitive tasks, but which require high precision and good patient care skills. It has been these areas which have been the fertile ground for implementation of new roles. Although APs require supervision by a radiographer the expansion of the team has provided additional capacity and a new route into the radiography profession.

The most successful departments have been those which have embedded the four tiers, using the AP role to backfill radiographer duties and enabling them to take on new skills. The assistant was never a replacement for radiographers and in many departments the role has provided an opportunity for many to enter a professional arena undertaking studies which may not have been possible otherwise. As such, the post holders are often locally based and are committed to the region assisting in the retention of staff.

THE CHALLENGE

The developments have involved a collaboration between a range of governmental, educational and professional bodies, ensuring that the interests of the health service, employers, patients and radiographers have been considered. Key to the success of the role is national agreement on the scope of practice and expectations on how they can contribute to service delivery. Although there is national guidance issued by the radiographer professional body, there was always an expectation that the local implementation would respond to clinical needs. Although the role of radiographers in advanced practice, particularly reporting may remain controversial to some, the practice has been in place for over two decades. The same nervousness radiologists may feel towards radiographers has been replicated at the assistant level, both from the radiographer and assistant perspective. Previous research [2,8] confirms that there are many who embrace the assistant role and perceive themselves to be a valued team member, but role overlap with radiographers and scope creep has left many APs feeling exploited, particularly where departments are short staffed.

A premise of the national strategy was to provide a career escalation with assistants able to step onto the undergraduate radiography training courses, fulfilling their role aspirations. Although this remains an aspiration, it is a difficult process for many, exacerbated by funding and academic hurdles [2].

WOULD THE MODEL FIT IN EUROPE?

There is increasing standardization of the radiographer training across Europe with adoption of EQF level 6 qualifications by many countries [4]. This work is being championed by the European Federation of Radiographer Societies (EFRS), bringing together national professional bodies to work collaboratively on such issues. Some radiography programmes are still at EQF level 5, the same academic level of the API in the UK with a plethora of role titles and acceptance [9]. Indeed, the radiographer title is translated as ‘assistant’ in a number of countries which must lead to a disparity in professional recognition.

Probably the biggest challenge to adoption of the role internationally is the current limited opportunities for clinical radiographer career progression. Whilst UK radiographers have been afforded opportunities to develop their skills and have taken on clinical and leadership roles supported by EQS level 7 and 8 qualifications, this is not widespread elsewhere, despite the aspiration of many [10]. This disparity has led some to question whether the radiography profession is stagnating and the lack of clinical and educational advancement may result in a ‘dying profession’ [10].

Although some countries may not face a shortage of radiographers, indeed some have a surplus, others are experiencing acute and chronic workforce gaps [9] and supplementing the radiographer role with trained assistants under the direction of radiographers is an attractive proposition. However, this requires careful consideration to ensure that any proposals do not undermine the integrity of the radiography profession and in particular decrease the quality, and safety, of current services.

FUTURE DEVELOPMENTS

2019 sees a pilot of a European Diploma in Radiography [10], designed to provide a standardised assessment for the profession, but the diploma will currently not provide a transferable qualification. It may be in the future that international credentialing of the assistant, radiographer and advanced level skills may be possible, linked to professional qualification in own country. This would provide a more mobile and flexible workforce. With the continued growth of imaging there is a need to consider whether the current workforce model is appropriate and is the development of new, adjunct roles would provide greater opportunities to utilise radiographers at a higher skill level. The future is unclear, but the debate will continue...

REFERENCES

5. European Society of Radiology (ESR); American College of Radiology (ACR) (2016) European Society of Radiology (ESR) and American College of Radiology (ACR) report of the 2015 global summit on radiological quality and safety. Insights Imaging 7: 481–484.
Advances in clinical imaging portfolio to maximize productivity

At ECR 2019, FUJIFILM will be showing the latest advances in their clinical imaging portfolio and IT solutions which maximizing productivity and ensuring improved patient care. The principles underlying the company’s latest advances are three-fold; namely: value-based radiology to improve care quality, access and control costs; a patient-centric approach, via enhanced portfolio of products and technologies; augmented radiologists’ experience by means of artificial intelligence-powered enterprise imaging solutions.

The FCT Speedia and FCT Speedia HD systems underline the company’s commitment to the medical systems field, adding CT imaging to its comprehensive portfolio of well-known room and mobile digital solutions. The 64-slice Speedia HD system will be shown at the Fujifilm Booth, together with “Synapse One” an empowered multi-modality workstation that embeds the core modules of Synapse 3D, the flagship of FUJIFILM’s informatics portfolio. An advanced AI-based solution, FCT Pixel Shine, highlights the advantages of FCT images acquired at extremely low dose using AI-based deep learning.

AMULET Innovality is FUJIFILM’s flagship in the digital mammography field and features an innovative dual angle approach to tomosynthesis, with unsurpassed 50 micron pixel output, to meet breast screening and diagnostic mammography needs. The Bellus II digital mammography workstation is a new, comprehensive workstation for FFDM and DBT image management. With multi-modality support, advanced image visualization functions and processing, together with an embedded reporting utility, the system provides key features crucial for an efficient and stress-free mammography diagnosis workflow. The range of images that can be viewed on the Bellus II include 2D and DBT images resulting from a new iterative reconstruction (ISR), synthetic 2D-View (S-View) images and energy subtraction CEDM images.

In digital radiography the FDR Smart X is a new flexible and scalable room solution which provides solutions from simple floor-mounted to ceiling-suspended configurations with long view stitching functionality, and in combination with the FDR D-EVO II and FDR-ES digital panels, has been designed to increase the productivity of all imaging departments.

The FDR D-EVO GL is the world’s first 43.2 x 124.5 cm long size DR panel, which allows long view radiography with a single exposure ensuring consistent, easy patient positioning and repeatable image acquisition, so reducing exam discomfort. The system features the company’s proprietary ISS technology for single-shot exposures of the whole spine and limbs which can provide excellent image quality and dose reduction.

Building on FUJIFILM’s advanced image quality with Dynamic Visualization II (DVII), virtual grid processing and dose performance, the FDR Go PLUS provides sophisticated yet simple operation and redefines mobile imaging with improved mobility, workflow and image quality.

FDR nano is FUJIFILM’s ground breaking compact digital X-ray cart system for the critical moments. Extremely lightweight and compact, it utilizes FUJIFILM’s Innovative products, D-EVO II and image processing technologies Dynamic Visualization II (DVII) and Virtual Grid, to generate high quality images with low patient dose and to simplify everyday imaging operations.

FUJIFILM, DÜSSELDORF, GERMANY

Universal image sharing platform

RIS/PACS software developer PaxeraHealth will launch its image sharing platform PaxeraShare at the upcoming ECR 2019 meeting.

A modern approach to image sharing and data access, the PaxeraShare platform has been designed using the latest HTML5 technology that requires no software installation and enables recipients – whether they be physicians or patients – to instantly view the images and reports from anywhere, from any browser or smart device regardless of the operating system or file type.

In addition, healthcare providers have the ability to share images and reports directly with their patients through the CareRad app, which is available to them for free through App Store and Google Play.

According to the company, PaxeraShare is easily deployed on top of any existing PACS in a few hours with no IT customization required. The solution is designed to improve care management by allowing physicians to share images easily and securely through one click or create a temporary link for the study, eliminating the need to take burned CDs or DVDs to the hospital, reducing cost and readmissions, as well as enhancing clinical care.

PAXERA HEALTH
BOSTON, MA, USA.
https://paxerahealth.com/
Multi-patient solution with no compromise on efficiency and patient safety

The OptiVantage multi-use injector from Guerbet is now CE-marked. The injector is designed for injecting contrast agents used in X-ray (CT scan) medical examinations and includes the tried-and-tested OptiVantage syringe-based injector, a complete range of associated syringes and disposables (manyFill day set and secufill patient line), services and support systems (OptiProtect).

The OptiVantage multi-use system will initially be marketed in EMEA as of January 2019, then progressively in other regions of the world (Asia and Latin America). Existing OptiVantage customers may benefit from an upgrade to easily implement the new multi-use feature.

Guerbet Group Chief Commercial Officer, Diagnostic Imaging, David Hale declared: “We are delighted to be providing radiology professionals with this new multi-use injection solution, which answers market needs without compromising efficiency and patient safety.”

Launched in 2005, the OptiVantage injector is a medical device (Class: IIb, CE0123) intended for use by medical imaging and diagnostic health professionals, for injecting radiopaque contrast media and saline into a patient’s vascular system during CT examinations. The new version is adapted to multi-use markets and is available in pedestal and ceiling-mount versions.

The market targeted by OptiVantage multi-use represents over half of all CT procedures worldwide.

GUErBET VILLEPINTE, FRANCE.
www.guerbet.com

Wide-bore 1.8T MRI promises increased productivity

The newly introduced Vantage Orian 1.5T MRI system from Canon represents a new standard in the premium wide-bore 1.5T market with new technology designed to boost productivity, enhance patient comfort and deliver diagnostic clinical confidence.

The Vantage Orian offers a range of innovative hardware features that can help improve workflow and deliver clinical confidence. These include:

- All-new detachable, dockable table option enabling preparation outside the scan room, enhancing workflow and allowing medical staff to respond to patient requirements quickly and easily.
- Saturn Technology for high performance imaging capability, including a new slim gradient that delivers a gradient performance with a maximum amplitude of 45 mT/m, combined with a slew rate of 200 T/m/s that enhances high resolution and diffusion imaging for improved image quality.
- Adaptive noise cancellation PURERF Rx technology that reduces noise at the source, resulting in an increase in SNR by up to 38 percent and enhanced image quality.
- A re-designed digital gantry interface which displays important patient-related and coil information, allowing clinicians to ensure a proper and complete setup without leaving the patient’s side.

The Vantage Orian also offers a suite of software enhancements to help reduce scan time and increase productivity. New features include the Multiband SPEEDER, which enables clinicians to reduce DWI acquisition times, and the k-t SPEEDER (up to x8 accelerated), which allows high frame rate cardiac cine and perfusion imaging with free breathing – enabling clinicians to image a wide range of cardiac patients while reducing stress to the patient. The system also features EasyTech technology which enables clinicians to improve workflow with automatic slice alignment for neuro, spine and cardiac exams, and FSE Dixon, which allows clinicians to take four contrasts in just one scan to show uniform fat-suppression in difficult-to-shim areas.

The all-new system enhancements come in addition to the existing patient-friendly MRI features that Canon Medical offers, including the 71cm wide bore patient aperture and in-bore immersive virtual experience which encourages patients to relax and stay still, enabling clinicians to produce stable, high-quality imaging, as well as Pianissimo technology which significantly reduces the noise in and around the MRI environment and Pianissimo Zen quiet sequences which further reduce noise to just above ambient noise level, making exams even more comfortable and easier to complete.

CANON MEDICAL SYSTEMS EUROPE
ZOETERMEER, THE NETHERLANDS
https://eu.medical.canon/
Ultraportable ultrasonic system

Sonoscanner, Europe’s leading manufacturer of portable and ultraportable diagnostic ultrasound systems has announced the launch of its new, fifth generation U-Lite device, a full featured, digital auto-optimizing system with 11 interchangeable transducers for every clinical application, anywhere.

The latest version of the U-Lite series has a unique, integrated digital manager for continuous optimization of pulse contours, image reconstruction, and feature enhancing signal processing. Able to handle all conventional clinical uses, the great potential of the U-Lite is its ability to easily create new uses for ultrasound. This has already been the case with super low noise and high frame rate presets and transducers that achieve submillimeter axial and lateral resolution and a standardized gray scale display while retaining penetration.

The optimal size of the U-Lite was developed to meet the specifications needed in the routine, daily practice of medicine. For example the system fits into the pocket of a white coat, has the biggest possible HD screen, and can be operated with one finger.

Dr. Bruno Richard, founder and Chief Medical Officer of Sonoscanner, said “the ultraportable, tablet sized U-Lite was designed from the beginning for real life medical use especially the demanding settings of academic and private practice radiology and nuclear imaging.”

Etienne Richard, Director of Operations at Sonoscanner added “The U-Lite is the most advanced tablet sized unit in the world. Our beta sites have already described the new platform as spectacular”

SONOSCANNER PARIS, FRANCE
www.sonoscanner.com

Advances in multimedia reporting

Vue Reporting is the latest generation of radiology reporting systems from Carestream and features the integration of multimedia content such as graphs, tables, images and hyperlinks. These elements add value to traditional reports while boosting productivity and collaboration among healthcare providers. Machine vision algorithms also enhance the reporting process and increase radiologists’ efficiency by providing tools that can help detect, measure and diagnose abnormalities. Multimedia reporting can facilitate collaboration among caregivers. Radiologists at the National Institutes of Health (NIH) Clinical Center (Bethesda, Md. USA) were early adopters of multimedia reporting. Tools for serial tumor measurement have reduced the time needed for NIH radiologists and oncologists to measure and compare tumor size and provide a higher level of standardization. Rapid access to clinically relevant information has boosted adoption of multimedia reporting, which now is used for 70 percent of CT reports and 50 percent of MR reports at the NIH Clinical Center.

The University of Virginia (UVA) Health System recently evaluated the use of hyperlinks in more than 500,000 reports during a two-year study. “The use of hyperlinks is prevalent in MR, PET-CT and CT studies. We believe interactive multimedia reporting technology represents an important advance in delivering clinically relevant information that can directly impact patient care,” said Dr. Cree Gaskin, Professor of Radiology UVA Health System in Charlottesville, VA.

Vue Reporting improves physician efficiency and patient experience. This Clinical Collaboration Platform module provides reading and reporting in a single workspace. It helps accelerate turnaround time with user-defined templates, structured reports and embedded voice recognition. Users may indicate key anatomical regions and findings with bookmarks and hyperlinks that clinicians and patients can easily navigate with the click of a mouse. Vue Reporting helps reduce costs and improve outcomes with one system that’s easy to deploy and train across multi-site, multi-vendor environments.

CARESTREAM ROCHESTER, NY, USA
www.carestream.com

New design of RF coils give total freedom in coil positioning

The AIR technology from GE uses an industry-first suite of RF coils which enable total freedom in coil positioning and handling during a MRI scan. The choice of coils includes a 30 channel anterior array (AA) coil; a 21 channel multi-purpose (MP) large coil and a 20 channel (MP) medium coil. These coils are available for GE’s 1.5T and 3T systems. The AA coils are designed to conform to the human body. Each coil is lightweight, flexible and just like a blanket, designed to closely wrap around patients for incredible image quality.

Used for examinations that were
including large field-of-view cover-
addresses several clinical needs, it makes it easier to scan the patient and the ultra-lightweight design makes it easier to scan the patient and all patient ages, sizes, and shapes. The coils offer greater flexibility in all axes to help conform to patients’ anatomies and fit all patient ages, sizes, and shapes. The large field-of-view coverage in abdominal imaging without repositioning the patient, and high-density coil when using compressed sensing and parallel imaging techniques.

Designed to provide automated slice prescriptions to help reduce previously redundant, manual steps, the AIRx tool from GE increases consistency and productivity. The tool is built on Edison, GE’s intelligence platform comprising of applications and smart devices which enable the integration and assimilation of data from disparate sources, the application of advanced analytics and AI to transform the data to support clinical, financial and operational decision-making.

AIRx is intended to produce images presented to radiologists that have lower inter-technologist and inter-technologists variability, to help lower the chances of a patient recall due to incorrect slice placement. Increased consistency is particularly important in longitudinal assessments for diseases such as Alzheimer’s and Multiple Sclerosis.

AIRx features a pre-trained neural network model that leverages deep learning algorithms and anatomy recognition to define the correct anatomical landmarks and automate the scanning process not just for routine but also challenging set-ups. The algorithm automatically aligns the scan prescription to anatomical references that are based on a database of over 36,000 images sourced from clinical studies and reference sites.

Working with AIR Technology coils, the AIR Touch system is an intelligent patient recognition software which helps optimize every scan. AIR Touch connects the coil to the system to automatically tell the scanner exactly where the patient is with just one touch thus dramatically simplifying the scan set up for the technologist, saving time during each scan. This new feature also optimizes key elements in the coil configuration automatically to get an excellent image for every patient while using the full power of each coil.

GE Healthcare’s ultra-premium MR system, SIGNA Premier now features an expanded suite of AIR Coils and new software. These include MUSE, diffusion weighted imaging for brain and abdomen; AIR Touch; Hyperband fMRI, a new technique that simultaneously excites and acquires multiple slices to reduce scan time for diffusion weighted imaging, diffusion tensor imaging in the brain, and fMRI with minimal loss in SNR; and Progres, a distortion correction application. The SIGNA Premier features a 70-centimeter bore, a 3.0T shortbore superconductive magnet, and the SuperG gradient coil—the most powerful gradient system GE has produced for a wide-bore, 3.0T system. SuperG is designed to provide the performance of a research class 60-centimeter MR system in a 70-centimeter bore.

“On the Premier system, we obtained good [image quality] for [cardiovascular MR] exams, particularly in difficult cases such as a large patient,” said Dr. Alexander Hirsch, cardiologist at Erasmus MC Rotterdam. “The AIR Coil is definitely much better than the previous coils we had. Additionally, the gradient performance of this 3T wide bore system provides shorter TE and TR resulting in less banding artifacts on 2D cine.”

Remote Scanning Assistance software makes workforce management more flexible

The Syngo Virtual Cockpit recently introduced by Siemens Healthineers enables medical staff to connect remotely to scanner workplaces thus assisting personnel at a different location, especially where more sophisticated examinations are required. The software can be used with Siemens’ CT and PET/CT scanners as well as with MRI and MRI PET systems. With the ability to deploy experienced technologists...
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**MEDICAL DOCTORS (respond below)**

1. What is your occupation? (check only one)
   - 50 ☐ Diagnostic Radiologist
   - 51 ☐ Other Physician (please specify)

1a. What is your radiology sub-speciality? (check only one)
   - 52 ☐ General Radiology
   - 53 ☐ Nuclear Radiology
   - 54 ☐ Pediatric Radiology
   - 55 ☐ Neurology
   - 56 ☐ Vascular & Interventional
   - 57 ☐ Other (please specify)

1b. I am a Head of my department ☐ Yes ☐ No
   Please continue with question #2 below

**NON-PHYSICIAN PROFESSIONALS (respond below)**

1c. What is your occupation? (check only one)
   - 60 ☐ Radiology Administrator
   - 61 ☐ Business Manager
   - 62 ☐ Business Consultant
   - 63 ☐ Chief Information Officer/IT Manager
   - 64 ☐ Chairman/Managing Director/Executive Director
   - 65 ☐ Chief Financial Officer/Other executive titles
   (Non-physician may qualify based on the criteria listed below)

**ALL RESPONDENTS reply to the questions below**

2. In what type of facility do you work? (check only one)
   - 20 ☐ Private Clinic
   - 21 ☐ Hospital (check number of beds):
     - a ☐ More than 500 beds
     - b ☐ 200-299 beds
     - c ☐ 400-499 beds
     - d ☐ 100-199 beds
     - e ☐ 300-399 beds
     - f ☐ 0-99 beds

3. With what technologies or disciplines do you work? (check all that apply)
   - 01 ☐ Diagnostic X-ray
   - 02 ☐ Nuclear Imaging
   - 03 ☐ Mammography
   - 04 ☐ CT
   - 05 ☐ Ultrasound
   - 06 ☐ MRI
   - 07 ☐ Cardiac Imaging
   - 08 ☐ PET
   - 09 ☐ CT
   - 10 ☐ PET/CT
   - 11 ☐ Bone Densitometry
   - 12 ☐ Ultrasound
   - 13 ☐ Cardiac Imaging

4. If you currently receive Diagnostic Imaging Europe, how many other people read your copy?
   - a ☐ 0
   - b ☐ 1
   - c ☐ 2
   - d ☐ 3
   - e ☐ 4
   - f ☐ 5
   - g ☐ 6 or more

5. Please describe your involvement in the decision to purchase medical imaging equipment/products for your department.
   (Check all that apply)
   - 33 ☐ Approve purchase of product
   - 35 ☐ Recommend purchase of product
   - 34 ☐ Specify type of product to purchase
   - 36 ☐ None of the above

**Signature:**  
**Date:**
across multiple locations healthcare providers can transform care delivery and achieve a higher level of standardization that leads to more accurate diagnoses.

Many healthcare markets suffer personnel shortages or bottlenecks for various reasons. Amongst others, not all hospital or practice locations will have the appropriate experts on hand for scanning patients with complex medical questions. Syngo Virtual Cockpit can help ease a tight HR situation and improve productivity at the facility.

For radiological examinations, experienced colleagues can “tune in” quickly and in real time via headsets, conference speakers, or chat or video functions. That means the experts can remain in their own location and provide guidance for the colleagues operating the scanner at the other locations, e.g. to adjust protocol parameters. Up to three scanners at different locations can be supported simultaneously in this way by one expert.

“We expect the use of Syngo Virtual Cockpit to have a significant impact because we will save costs by not sending dedicated experts from one site to the other. We will also be able to better utilize our scanner fleet. Our patients will also benefit, because they no longer have to go to a dedicated site in our network to get a special examination,” states Dr. Justus Roos, head of Radiology and Nuclear Medicine, Lucerne Cantonal Hospital (LUKS), Switzerland.

“Ensuring the best possible support from experts can help achieve a uniformly high image quality at all locations of the healthcare enterprise, which in turn enables more accurate and precise radiological diagnosis,” says Christian Zapf, head of the Syngo Business Line at Siemens Healthineers. “Syngo Virtual Cockpit can therefore help improve the productivity of medical institutions and provide access to healthcare for more patients who need complex examinations in particular.

The software solution is also suitable for training purposes, since having a trainer in the background can help operators learn how to perform complex examinations like cardiac MRIs in a practical situation. In other words, Syngo Virtual Cockpit can enable all technologists to benefit from the experience of the experts in the team.”

**Automated Ejection Fraction evaluation with mobile Point-of-Care ultrasound**

DiA Imaging Analysis (DiA), a provider of artificial intelligence (AI)-powered ultrasound analysis tools, has introduced its LVivo EF cardiac decision-support software which is now available for use with GE’s Vscan Extend handheld, pocket-sized ultrasound. The product is an outcome of collaboration between DiA and GE Healthcare that began last year. LVivo EF is the first AI-powered, ejection fraction automated app able to operate in the lowmemory and processing-power environments of mobile ultrasound. Ejection fraction (EF) evaluation is a key diagnostic criterion driving various treatment strategies in point-of-care (POC) settings—particularly in emergency medicine, intensive care and anesthesia. “As handheld, point-of-care ultrasound procedures expand across the industry, and AI plays a growing role in ultrasound analysis, working with GE Healthcare is the beginning of transforming point-of-care ultrasound to a more consistent and patient-centered process,” said DiA CEO and co-founder Hila Goldman-Aslan. “As the first automated EF software tool on a handheld ultrasound, we are confident that clinicians across emergency, primary care, ICU and other point-of-care settings will immediately recognize how LVivo EF empowers their real-time decision-making and enhances efficiency.”

Traditionally, most EF interpretation at POC is conducted through visual estimation, with clinician experience levels varying across POC settings. This means that achieving an accurate EF result in POC settings can be challenging. LVivo EF addresses this challenge by quickly and efficiently providing clinicians with left ventricle EF scoring and volume measurements via DiA’s advanced, proprietary AI technology and advanced pattern recognition algorithms that imitate the way the human eye identifies borders and motion.

“Offering the LVivo EF app underscores GE Healthcare’s continued commitment to supporting clinicians with improved productivity,” said Rob Walton, general manager of GE Healthcare Primary Care Ultrasound. “By collaborating with third-party developers and experienced Vscan Extend users, GE Healthcare has been able to offer apps that give users the option to customize their Vscan Extend according to their unique needs.”

**SIEMENS HEALTHINEERS**
**ERLANGEN, GERMANY**
[www.siemens](http://www.siemens)

**DIA IMAGING ANALYSIS LTD.**
**BE’ER SHEVA, ISRAEL**
[diaanalysis.com](http://diaanalysis.com)
Clinical excellence in image-guided therapy

Philips has announced the introduction of Azurion with FlexArm, to set a new standard for patient imaging and positioning flexibility for image-guided procedures.

During increasingly complex interventions, clinicians need to quickly and easily visualize critical anatomy and identify changes to the patient during the procedure. Azurion with FlexArm includes a set of innovations that makes it easier for the clinician to perform imaging across the whole patient in both 2D and 3D. As the clinician moves the system, the image beam automatically maintains alignment with the patient, allowing more consistent visualization and enabling them to keep their focus on the treatment.

"With FlexArm, Philips’ engineers have overcome near-impossible geometric and mechanical barriers to enable clinicians to achieve clinical excellence in image-guided therapy," said Barry T. Katzen, MD, Chief Medical Executive of the Miami Cardiac & Vascular Institute, Baptist Health South Florida (U.S.). "FlexArm enables us to dramatically optimize procedures around the patient; we can get the optimal view of what’s going on inside the patient without encumbering all of the clinicians that are working around the table. The result is an innovation that’s not only clinically important but also very simple and intuitive to use – a critical factor in the heat of a complex procedure."

The range and complexity of diseases that can be treated with minimally invasive procedures continues to expand. Correspondingly, the procedures themselves are also becoming more complex, requiring more physicians from different disciplines to be at the patient’s tableside, working together in a highly coordinated way. As a result, the clinical team is required to carry out increasingly challenging procedures in a highly constrained environment.

Azurion with FlexArm’s innovative design provides exceptional flexibility and intuitive control. Powered by a unique smart kinematic engine, the system moves on eight different axes, all controlled with its single ‘Axys’ controller. Simulation tests with clinicians have demonstrated the system’s potential to significantly reduce the repositioning of the patient, staff and equipment to improve access for minimally invasive procedures, including those that enter the body through the patient’s wrist (‘radial access’), and to reduce the risk of unintentional pulling of wires and tubes, as well as significant time savings. The system is ideally suited for Hybrid ORs that cater to multiple specialties in one room, such as a combination of surgical and endovascular procedures.

“Two years on from its launch, Azurion is now established as our leading platform for interventional procedures, favored by clinicians for its intuitive, seamless approach that enables them to focus on treating the patient, and by hospital administrators for its positive impact on productivity and efficiency,” said Ronald Tabaksblat, Business Leader Image Guided Therapy Systems, Philips. “FlexArm is the natural next step in our Azurion innovation journey, combining clinical and operational benefits to improve patient care and reduce costs, while opening up opportunities for new image-guided procedures as the field continues grow.”

Azurion with FlexArm is the latest innovation in Philips’ unique portfolio of systems, smart devices, software and services in image-guided therapy, which combine to provide healthcare providers with sophisticated, procedure-oriented solutions. As the range of diseases that can be treated with minimally invasive procedures continues to expand and the procedures themselves become more efficient, the patient’s treatment experience continues to improve. They experience less trauma, and as a result their stay in hospital can be dramatically reduced – often returning home after one night in hospital, and for some procedures even leaving the hospital on the same day.

PHILIPS HEALTHCARE
AMSTERDAM, THE NETHERLANDS
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Third generation non-invasive intracardiac blood flow visualization technology

Hitachi have introduced their latest level of intelligent Vector Flow Mapping (iVFM) systems, which provides unique information about the intraventricular vortex and its energetic efficiency, including kinetic energy loss, relative pressure or wall shear stress display and analysis.

CMUT diagnostic ultrasound solution for cardiologists that redefines the vision of cardiac ultrasound by providing exceptional clinical performance coupled with state-of-the-art features and analytics. Hitachi have a full range of innovative cardiovascular imaging systems, all of them designed to be a true one-system solution for adult, fetal, paediatric and congenital heart patients. With the introduction of the new iVFM system, Hitachi claims it is raising the bar not only in image quality but also in premium technologies, advancing cardiologists to the next level in CV ultrasound imaging.

HITACHI MEDICAL SYSTEMS EUROPE
ZUG, SWITZERLAND.
www.hitachi-medical-systems.eu

QA meters for X-ray systems

With the new Nomex Multimeter from PTW-Freiburg, it is even more easy to check all relevant QA parameters of various X-ray systems. The multimeters are now available individually for quality assurance of radiography, fluoroscopy, dental, CT and mammography units as well as for irradiation devices in image-guided radiotherapy (IGRT).

The Nomex Multimeters are part of the company's proven standard equipment, used by service and medical technicians as well as experts and medical physicists. The multimeters are used for acceptance testing and expert inspections, for constancy tests and as part of the service and maintenance work of X-ray equipment. No additional accessories and no additional display units are required for operation, except for a PC or a tablet. The meter only needs to be connected in a simple plug-and-play fashion to a mini USB port with no need for additional accessories.

QA accuracy for radiography/fluoroscopy units is between 40 and 150 kV ± 1.5 percent within the complete conventional measurement range and between 23 and 35 kV ± 2.5 percent in mammography. To measure additional, other radiological modalities, existing Multimeters can be easily upgraded for such applications if required. All types of X-ray equipment can be tested with the Nomex Multimeter all-in as a fully equipped variant. The Nomex Multimeters in the individual versions of RAD/FLU/MAM, RAD/FLU, DENT/DENT-PAN, MAM, CT and IGRT, each with or without mA option, are available as of February 2019.

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