RADIOLOGY IN SINGAPORE

WHERE INNOVATION MEETS MEDICINE

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Photo by SingHealth Diagnostic Radiology Residency Programme

Technological advancements are relentless in the modern era and few medical specialties have embraced innovations quite like radiology. From the emergence of MRI to early ventures towards artificial intelligence (AI), continual disruptive evolution renders the specialty abstruse to patients and professional contemporaries alike. To understand the essence amid such vicissitudes, we will have to connect the dots of recent key advances along the journey towards the cutting edge. This article will focus on the ongoing transformation of clinical practice in radiology, the growth of interventional radiology and nuclear medicine, as well as opportunities in digital informatics.

Transformation of clinical practice

Since the first X-ray department began in the new Singapore General Hospital (SGH) within the historic Bowyer Block in 1926, radiology has grown tremendously in scope and clinical impact.[1] Within a century, that nascent single modality general practice has metamorphosed into today's multi-modality subspecialty-based practice in all hospitals in Singapore.

The radiology departments today provide a wide variety of imaging techniques such as radiography, CT, MRI, ultrasound and nuclear medicine imaging under one roof. Local data from 2015 revealed 106 units of CT scanners and 78 units of MRI scanners in Singapore, translating to 19.4 and 14.3 units per million population, respectively. The ratios are mid-range when compared to developed nations in the Asia-Pacific, Europe and North America, which ranges from 7.4 to 97.3 CT units and 5.6 to 43.1 MRI units per million population.[2] The modalities may work in union too; for example, fusion of real time ultrasound with CT for hepatic interventions or combining anatomical information from CT or MRI with functional analysis in positron emission tomography (PET) CT/MRI. 3D printing has also recently created much excitement in the field due to technical breakthroughs and decreasing cost. The models generated from radiology images are used to optimise pre-operative planning across many disciplines, such as orthopaedics and vascular surgery.

Most radiology centres in Singapore now provide subspecialised services, employing consultant radiologists specialising in specific interest domains such as cardiothoracic, abdominal, neurology, head and neck, musculoskeletal, breast, emergency, vascular, intervention and nuclear medicine. The conventional imagery of a solo radiologist enclosed in the dark reading room churning out endless radiology reports in front of a blue screen has become irrelevant and superseded by progressive radiologist clinician teams. Globally, radiology has pivoted towards a value-driven ethos, departing from the traditional volume-based model. In 2013, the American College of Radiology published their influential strategic blueprint, *Imaging 3.0*, setting the stage for the next phase of radiology targeting optimal imaging care.[3] This initiative comprises active radiology involvement in managing imaging appropriateness, clinical decision support, safety, quality and providing patient-centric care. The goal is to acquire the right, personalised and best imaging for each individual.

These paradigm shifts in mindset have brought forth changes to the daily practice of a typical radiologist. A typical workday begins with a clinical radiology round where radiologists and other clinicians from various disciplines get the opportunity to work together by reviewing images and pertinent clinical information to optimise patient management. Strides are being made in enhancing the effectiveness of the radiology report, trending towards standardised structured reporting. Scoring systems such as BI-RADS (Breast Imaging-Reporting and Data Systems) and LI-RADS (Liver Imaging-Reporting and Data Systems) are now in practical application, using consistent terminology to reduce imaging interpretation variability and errors, enhancing communication with fellow clinicians and facilitating quality assurance and research. Many centres have concurrently introduced new-wave integrated multimedia reports, enabling educated patients of today to better understand their own radiology report findings.

Growth of interventional radiology

Interventional radiology is a specialty well positioned to lead radiology towards value-centric goals, extending our roles beyond diagnostics. It involves utilising minimally invasive image-guided procedures to diagnose and treat diseases in every organ system. By using the least invasive techniques available, risk to patients is minimised and health outcomes are improved. These procedures have less risk, pain and recovery time in comparison to open surgery.

The story of interventional radiology in Singapore began as early as 1959 when Dr Chow Khuen Wai introduced the Seldinger technique of vascular catheterisation after returning from advanced training in the UK.[4] Today, every radiology department within local academic centres and most major private imaging practices provide dedicated interventional radiology services around the clock. For example, the largest interventional radiology service within SGH developed into a full-fledged clinical department in 2017. Armed with eight interventional radiology suites and 17 interventional radiologists, it performs more than 10,000 procedures per year.

The indications, frequency and variety of procedures performed in the interventional suite increase steadily year after year. Procedures are broadly divided into endovascular and non-vascular methods, but interventional radiologists in Singapore are slowly but surely moving into super subspecialisation based on systems. Neurointervention has, over the last decade, evolved into the first treatment of choice for hyperacute strokes and cerebral aneurysms, improving patient prognosis through intravascular thrombectomy and coil embolisation, respectively. Similarly, in appropriate patients, vascular intervention has enabled definitive treatment of aortic aneurysms and peripheral vascular disease through endovascular stenting and angioplasty. Percutaneous biopsies, radiofrequency ablations and radioembolisation of visceral neoplasms by abdominal intervention increased treatment permutations and improved quality of life in many oncologic patients. Vertebroplasties for spine fractures, ultrasound-guided articular injections and bone tumour cementoplasty under musculoskeletal intervention, as well as breast biopsy with wire localisation under breast intervention, also play integral roles in various clinical pathways.

The impact of interventional radiology in medicine today cannot be understated. For example, 24-hour emergency embolisation for management of pelvic trauma-related haemorrhage is now standard of care within all our major trauma centres. Interventional radiology residency has become one of the most competitive medical specialties in the US and is poised to remain so in the near future. While local residency programmes currently do not offer a dedicated interventional track at the moment, we have definitely noticed its increasing popularity among our graduating radiology senior residents as their eventual choice of specialisation.

Nuclear medicine, molecular imaging and theragnostics

Nuclear medicine, as a specialty, grew out of the Therapeutic Radiology Department and became an independent Department of Nuclear Medicine, SGH, in 1980. Over the years, nuclear medicine centres have also been set up in other public hospitals and private institutions to meet the increasing demand for nuclear medicine services.

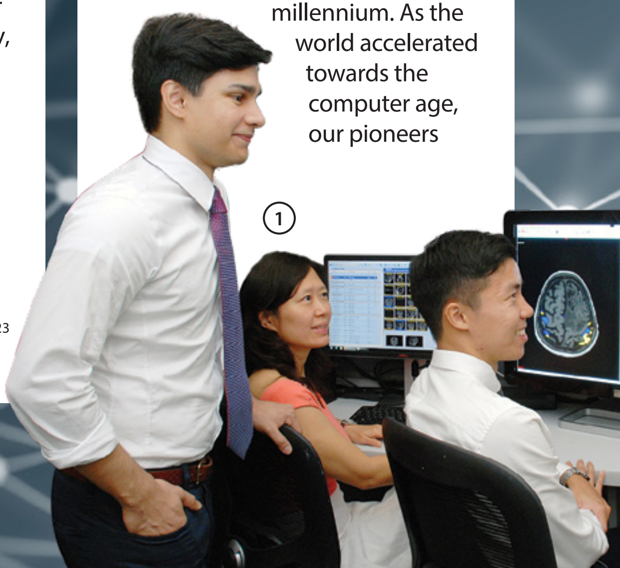
From the 1980s to 1990s, majority of the imaging work centred on Technetium-99m (Tc-99m) radiopharmaceuticals and radioiodine (I-131) therapy for thyroid conditions. The discovery of accumulation of 18F-fluorodeoxyglucose (^{18}F-FDG) in tumours revolutionised PET imaging in 1980. ^{18}F-FDG PET was soon established as a routine imaging tracer in neuroimaging and cancer diagnosis and management. Today, ^{18}F-FDG remains the workhorse of PET imaging, although there are newer, more specific radiotracers which have gained interest due to their clinical applications in neurology, neuro-oncology and oncology. For example, ^{18}F-fluoroethyl-L-tyrosine (^{18}F-FET) is a promising biomarker for response assessment in gliomas; ^{123}I-ioflupane and 18F-Flutemetamol are now used as diagnostic criteria biomarkers in dementia with Lewy bodies and amyloid.

The growth in theragnostics has been exponential in the past decade with the advent of personalised medicine and therapy. Some of these newer therapies include ^{90}Y selective internal radiation therapy (SIRT) for hepatic malignancies, peptide receptor radionuclide therapy (PRRT) for neuroendocrine cancers and prostate specific membrane antigen radioligand therapy (PSMA RLT) for metastatic castrate resistant prostate cancers. In ^{90}Y SIRT treatment of hepatomas, super-selective intra-arterial targeting improves tumoricidal radiation doses delivered to the tumour within a minimally invasive procedure, significantly improving patient outcomes. SGH is also one of the pioneers in introducing PRRT and PSMA RLT in South East Asia, attracting up to 40 referrals annually from neighbouring countries, as well as China and Taiwan for PRRT alone.

Given the unique position of nuclear medicine straddling expertise between imaging and medical therapeutics, its main local specialist training programme is now a senior residency programme under the Joint Committee on Specialist Training, accepting trainees from both internal medicine and diagnostic radiology residency tracks. The specialty also has training pathways for dual accreditation in nuclear medicine and radiology, equipping residents with essential skills required for the exciting future in functional imaging and targeted molecular therapy.

Digital informatics

A major inflection point for radiology was the introduction of picture archiving and communication system (PACS) before the turn of the millennium. As the world accelerated towards the computer age, our pioneers



readily embraced new technology, transiting images away from printed form onto digital screens. The impact was exponential. Rapid scrolling of multiple images in digital form enabled more complex cross-sectional imaging to be obtained and optimised with innumerable post-processing techniques. Easy access to prior imaging data improved reporting standards and efficiency. Most significantly, the ability to review high-quality images anywhere in the wards and consultation rooms on demand contributed to ubiquitous application of medical imaging in clinical workflows today.

Fast forward to the 21st century, rapid progress in AI and machine learning (ML) research arising from advances in computing infrastructure and deep learning techniques, such as convoluted neural networks, promises a Fourth Industrial Revolution. It is no surprise that radiology is one of the first medical specialties to take the leap of faith by incorporating AI into our practice.

AI is the branch of computer science devoted to creating systems to perform tasks that ordinarily require human intelligence. ML is the subfield of AI in which algorithms are trained to perform tasks by learning patterns from data rather than by explicit programming. Image recognition within scans is of particular interest in research, translating to clinical applications such as automated fracture and bone age classification from radiographs, pulmonary nodule detection on CT and cartilage defect detection on MRI. Furthermore, AI applications are not confined to automated image detection – these algorithms are starting to extend into other operational domains such as decreasing scan acquisition times, automated clinical decision support and scan triaging.[5]

As true clinical applications of AI applications have continued to grow beyond the computer laboratory over the last few years, facile fears of machines replacing human radiologists have shifted towards a more sanguine view of AI-augmented radiology practice. The lamentable regret from the introduction of PACS is the unwanted effect of radiologists retreating deeper into the dark room, losing invaluable rapport with other clinical colleagues and patients. In an ironic twist, thought leaders now believe that as AI/ML algorithms are trained to perform repetitive mundane diagnostic tasks, radiologists will finally be able to concentrate on adding value, improving inter-human communications and managing patients beyond mere diagnostics. There is concurrently potential for radiology to venture further into precision medicine, with many researchers reporting early results of combining avant-garde techniques in radiogenomics and AI.

In Singapore, efforts towards developing our radiology AI capabilities are rapidly picking up pace. The Radiology Artificial Intelligence Machine Learning Imaging Informatics committee under the Singapore Radiological Society was formally formed in 2017 to facilitate development of this domain within Singapore. It has been working closely with different radiology departments, as well as domain experts, such as the Agency for Science, Technology and Research, to explore novel methods harnessing this exciting technology clinically. The College of Radiologists, Singapore, and the local radiology residency programmes have also made progressive steps to insert informatics and data science into the standard training curriculum, preparing the future generation of radiologists for our next iteration.

Change is the only constant

Radiology is a specialty that continues to improve patient care by challenging established mindsets, inventing new diagnostic and therapeutic techniques, and assimilating the latest advancements in digital technology. As a medical discipline that is neither considered new nor old, she has chosen to advert mid-life crisis though relentless reinvention. Although her face is ever-changing, her immutable spirit of innovation will always remain the pillar of strength, the northern star and the guiding light. Like the city we live in, work in progress is always status quo since we know no other way. ◆

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Legend

1. Modern collaborative approach to add value into medical imaging

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