ADIA australian diagnostic imaging association — Australian Diagnostic Imaging Association **Feature**

The Future of Medical Imaging

Medical imaging is consistently held to be one of the most important advances in the history of medicine[1], and has become an integral part of the diagnosis and treatment of patients around the globe. The New England Journal of Medicine identified imaging as one of the top 11 medical developments of the past 1000 years;[2] in 2010 the Fellows and Members of the Royal College of Physicians of Edinburgh ranked imaging third in the *Top 20 Most Important Medical Developments of the Last 50 Years.*[3] In Australia, the importance of medical imaging is demonstrated by the 3 million medical imaging services performed nationwide on non-admitted patients in public hospitals in 2012-13 alone [4], writes *Dr Chris Wriedt.*

In 2013, more than 600,000 Magnetic Resonance Imaging (MRI) examinations were performed in Australia, up over 50 per cent in 6 years;[5] there were over 2.5 million Computed Tomography (CT) examinations performed in 2013, up almost 50 per cent over the same period.[6] Ultrasonography examinations are equally as commonplace. While this level of growth is not always viewed favourably, it does demonstrate the high level of access to medical imaging that all Australians enjoy and can be regarded as a shift in the purpose of medicine from merely treating illness to employing methods that facilitate early intervention. Medical imaging has become the principal tool in early diagnosis - a process that saves lives and eases the strain on the Australian healthcare system.

It is becoming increasingly clear that the non-invasive methods which are used to see inside the human body have revolutionised medicine. Indeed, medical imaging techniques such as the MRI, CT, nuclear medicine, ultrasonography and diagnostic radiology are being utilised as diagnostic tools that not only assist radiologists in identifying the location and nature of diseases at the early stages but also play an integral role in identifying pathological abnormalities that determine treatment.

Given the importance of medical imaging in medicine, we take a look at some of the most important advances over the last 40 years and some of the new developments which provide an insight into the future of medical imaging.

Important Inventions in Medical Imaging

Computed Tomography

CT imaging (also referred to as CAT scanning) was invented in 1971 by Godfrey Hounsfield and Allan Cormack.[7] The technology uses x-rays to create cross sectional 'slices' of the body, which are then processed through a computer to provide a detailed image of the specific location of the scan. These images provide greater detail of internal organs, bones, soft tissue and blood vessels than traditional x-rays.

Today it is used widely throughout the world for scanning anything from heart disease to Alzheimer's. It has also been developed as an alternative to uncomfortable and painful procedures such as the colonoscopy.

Magnetic Resonance Imaging

The MRI was developed during the 1970's and its creation is attributed to a number of individuals including Raymond Damadian, Paul Lauterbur and Peter Mansfield. [8] An MRI works by the combining a strong magnetic field with radio waves resulting in the emission of energy signals which are processed and generated into a 3D image.

While it is one of the more expensive modes of medical imaging available, it does provide uniquely detailed scans and is considered to be more appropriate than a CT scan for patients who suffer from spinal cord injuries or brain tumours. An additional benefit of an MRI is that, unlike most imaging modalities, it involves no ionising radiation.

Positron Emission Tomography

Positron Emission Tomography (PET) scans are a form of nuclear medicine, a mode of medical imaging that involves the injection of radioactive substances in the diagnosis and treatment of various diseases. This modality differs from other forms of medical imaging because it records radiation emitting from within the human body rather than from an external source. The concept of emission and transmission tomography began with David E. Kohl, Luke Chapman and Roy Edwards in the late 1950's and was further developed by Michel Ter-Pogossian and Michael E Phelps.

In standard PET scans a radioactive tracer is introduced into the body and emits gamma rays or positrons that are processed through a sophisticated computer to produce a 3D image. While access to this procedure has previously been limited due to the prohibitive cost, it has become an integral part of cancer diagnosis and treatment monitoring.

The Future of Medical Imaging

There are many exciting, new imaging techniques that are continually being developed throughout the industry, and while it is often the case that new technologies take decades to perfect, the following developments provide an insight into the future of medical imaging.

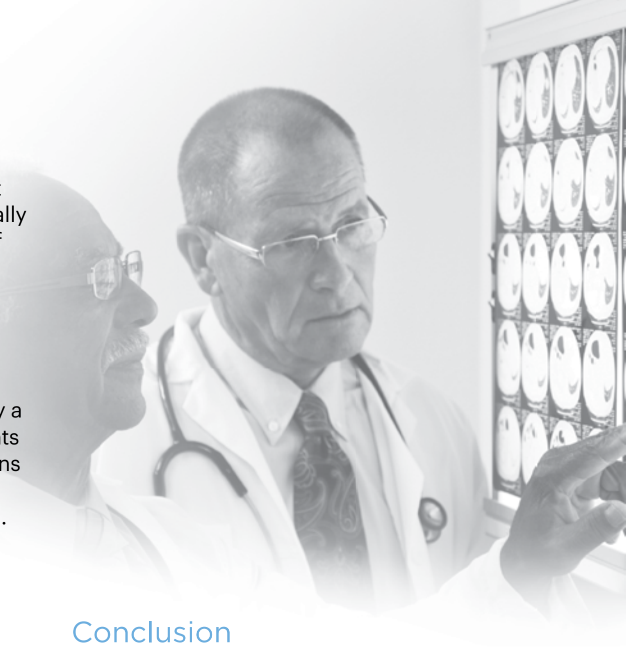
Phase-Contrast and Proton CT

Although the concept of phase-contrast imaging is not new, it has largely been confined to techniques that visualise cellular structures in live cells. The technique has not been transferred to x-ray phase-contrast imaging due a lack of compatibility with conventional x-rays tubes. However, the development of more advanced nanofabrication of gratings has resulted in techniques that are compatible with standard sources. This has removed a significant barrier to the use of phase-contrast imaging in the clinical sphere.

Unlike standard x-ray systems, which measure the attenuation of a beam through a biological sample in order to determine its structure, phase-contrast CT (PC-CT) focuses on variations in density which change the phase of the wavefront of an x-ray beam. These changes are then converted into an image.

As an alternative to x-rays, protons are being applied to existing imaging technologies, such as CT to create the proton CT scanner (pCT).[9] In 2010 Northern Illinois University, Loma Linda University (California) and the University of California collaborated to create a prototype pCT scanner and work is currently underway to create a pCT scanner that can produce 3D images in minutes.[10] PCT uses protons to document the location, direction and energy loss from a proton beam as it passes through the human body. This technique can be used to produce a 3D image of the body that assists in the diagnosis and treatment of a range of diseases.

Both PC-CT and pCT offer a number of benefits for patients, but perhaps the most notable is the active focus on developing CT technologies that use low dose radiation. PC-CT and pCT provide more detailed, better →



→ quality images and they are also designed with a view to ensuring low dose radiation examinations. In the case of pCT, for example, protons are able to target the object of the examination, safely bypassing healthy tissue which would normally be exposed to radiation.[11] These advancements make CT safer for the hundreds of thousands of Australians who rely diagnostic imaging each year.

Chemical Exchange Saturation Transfer

An MRI commonly relies on a radiologist's ability to 'measure the interaction of bulk water protons in the body with the external magnetic and electromagnetic fields,'[12] In order to adequately interpret images. However, this process can be hampered by a number of factors which ultimately leads to higher concentrations of contrast agents being used in order to obtain reliable images. In order to address the safety concerns associated with the use of higher concentrations of contrast agents, an alternative approach called chemical exchange saturation transfer (CEST) has been developed. The CEST contrast approach involves the selected saturation of molecules which can be detected through the water signal with enhanced sensitivity on an MRI.

CEST has also been combined with glucose (referred to as glucoCEST) as a radiation-free alternative to the PET scan which is used to detect tumours. This process labels glucose magnetically with radio waves so it can be detected with a standard MRI, producing images that can aid in the detection of tumours. This approach, once it has been refined, will have a profound impact on vulnerable patients, such as children and women during pregnancy, who cannot access PET scans because of the dangers associated with radiation exposure. Vital PET scans will now be performed without safety concerns, allowing radiologists to accurately diagnose and treat those patients who need it most.

Radio-Pharmaceutical Tracers

Medical Imaging is often used to detect tumours in the human body. Due to the high levels of glucose that tumours need, a form of glucose known as FDG is commonly used as a tracer in PET-CT to detect several varieties of tumours. However, there are a number of tumours (traditionally slow growth tumours), that do not use high amounts of glucose, leaving many patients unable to obtain that crucial early diagnosis or accurately track the progression of their illness. In order to overcome this disadvantage, a variety of PET tracers have been developed in order to specifically target the abnormal functions of particular tumours.

Prostate cancer is an excellent example. Prostate cancer is the most frequently diagnosed cancer in men, claiming over 3,000 lives in Australia each year. The early detection of prostate cancer is essential to a positive prognosis, but it is notoriously difficult to diagnose by traditional imaging methods. In order to overcome this obstacle a new tracer called *prostate specific antigen membrane* (PSMA) has been developed. PSMA is designed to target a protein on the membrane of prostate cancer cells which enables a PET-CT to detect the affected cells. The use of the PSMA for PET-CT has shown a great deal of promise, with increased accuracy in the detection of prostate cancer and surrounding areas such as the bones and lymph nodes. For the first time, men will be able to access reliable medical imaging for prostate cancer. These scans will not only assist in the early diagnosis of prostate cancer but will also mean that patients with suspected or confirmed prostate cancer will no longer have to undergo futile surgeries that can have serious consequences. PSMA enables men to take an active role in monitoring the onset of prostate cancer and gives clinicians a powerful tool with which to prevent and manage this illness.

PSMA is just one example of the benefits of targeted PET tracers, with others being developed for a variety of conditions such as musculoskeletal disease and head and neck cancers.

Conclusion

These advances demonstrate the growing importance of medical imaging in the patient journey. The medical profession is developing and using these technologies in order to ensure the best possible outcomes for patients. This can be done by providing access to medical imaging that: a) moves away from invasive procedures in favour of efficient, non-invasive services; b) focuses on the creation of better quality images to enhance the precision of diagnosis and treatment; and c) reduces radiation doses and utilises radiation-free methods to achieve reliable, high quality imaging results.

It is also important to remember that, while these new advances are significant, there is always a critical human element involved. The radiologist, and the critical role that they play in the patient journey, is essential. It is this marriage of man and machine that is saving lives every year and ensuring the best possible outcomes for patients who rely on medical imaging in the diagnosis and treatment of a myriad of conditions. In order to maintain an efficient, quality-driven health system it is essential to ensure Australians continue to have appropriate access to medical imaging and that our healthcare system supports the integral role of the radiologist in providing patients with the best possible clinical care. ⊕

References

1. See Richard Conroy, 'On the Horizon: Three Imaging Technologies Head Toward the Clinic', Radiology Business, 2015?; See also the Dartmouth-Stanford survey of medical innovations, which identified CT and MRI as the most valuable medical innovations in the last 30 years.

2. Editorial, 'Looking back on the Millennium in Medicine' (2000), New England Journal of Medicine, Vol. 342, 42-49.

3. Royal College of Physicians in Edinburgh, 'Top 20 most important medical developments of the last 20 years' <https://www.rcpe.ac.uk/sites/default/files/documents/pressreleases/rcpe-top20-list.pdf>.

4. Australian government, 'Australian hospital statistics 2012-13', <http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=60129547000>.

5. Organization for Economic Cooperation and Development, OECD Health Statistics 2014, June 2014.

6. Ibid.

7. Hounsfield and Cormack were awarded the Nobel Prize in Physiology or Medicine in 1979 for the development of computer assisted tomography.

8. Lauterbur and Mansfield were awarded the Nobel Prize in Physiology or Medicine in 2003 for the use of magnetic field gradients to determine spatial localisation, the process used in today's MRI machines.

9. See G. Coutrakon et al 'Design and Construction of the 1st Proton CT Scanner', 2013, accessed 20 March 2015 < www.niu.edu/nicadd/research/medical/CTScanner2012.pdf>.

10. Northern Illinois University, the Fermi National Accelerator Laboratory and the Argonne National Laboratory.

11. Peter Gwynne, 'Next-generation scans: Seeing into the future' Nature 502, S96–S97 (31 October 2013).

12. Conroy, above n1.