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REVIEW

The 21st Century Echocardiography Laboratory in Australia and New Zealand: Rapid Evolution of Training and Workforce, Practice and Technology

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Echocardiography is a common and increasingly used noninvasive imaging tool in medicine. In this paper, we imagine the echocardiography laboratory of the future and consider the challenges we face currently, and may face in the future, and how these might be overcome; challenges such as training enough sonographers to meet the increasing demands of the ageing population living with chronic cardiovascular disease and the need for surveillance in other clinical scenarios. We consider the changing qualification framework and the requirements for accreditation and registration in Australia and New Zealand and the potential for migrant sonographers to meet some of the increasing demand. Advanced scopes of practice are likely to be a feature of the future workforce and we consider some of the ways these may evolve. Lastly, we consider how the evolving clinical landscape and technology may change the way echocardiography is delivered.

Keywords Echocardiography • Sonographers • Registration • Advanced practice • Training

Introduction

Echocardiography is one of the most commonly used non-invasive tests in both cardiology and non-cardiology patients. In 2017, an Australian Federal government review of Medicare-rebated cardiac services revealed approximately 900,000 echocardiographic procedures (excluding stress echo) are reimbursed annually, at a cost of over $180 million per year [1]. In addition, echocardiography is growing at approximately 8.8% per year and, because of widely divergent population numbers, an 18.8-fold geographical difference has been reported between areas with the lowest number of echos per population and those with the highest [2].

In New Zealand, the majority of echocardiography is provided by the public health system: approximately 80,000 echos are performed per annum and although differences in population provision have been observed, this is not as wide as reported in Australia [3]. Interestingly, the difference in echo provision in NZ has been linked to the available capacity of sonographers, which is also lower than other similar international health systems, such as Canada and the United Kingdom [4].

Although echocardiography is primarily a diagnostic test, it is increasingly being used to monitor patients and to identify asymptomatic, yet potentially detrimental, changes earlier in the course of disease. For example, one area where growth is likely in the setting of chemotherapy, is where monitoring for early detection of cardiotoxicity is mandatory [5]. Echo is the main tool used to detect these early changes and both the New Zealand and Australian Federal agencies (Medsafe and Therapeutic Goods Administration, respectively) mandate 3-monthly echocardiograms for some agents. This is but one example, but it represents increased

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demand outside of cardiology and historical use expectations.

In addition to increase in clinical demand, our population is ageing and survival from cardiovascular disease is improving [6,7]. As a result, the number of older patients, with existing cardiovascular disease (CVD), requiring echocardiography is growing also.

It is clear that echocardiography is likely to continue to grow both in scope and technical application. In this review, we focus on some key factors that may impact on the future of echocardiography provision in Australia and New Zealand. Firstly, we focus on the training models and the impact upon sonographer numbers and, subsequently, provision of echocardiography across both countries. Secondly, we look at the process for registration and accreditation of sonographers in each country leading to a consideration of advanced practice for cardiac sonographers. Lastly, we consider the impact of technological advances on the delivery of echocardiography.

Training Sonographers

The numbers of accredited cardiac sonographers is steadily increasing in both Australia and New Zealand. For example, in Australia, there were 839 accredited cardiac sonographers in 2012, and 1,035 in 2016 (taken from the Australian Sonographers Accreditation Registry, downloaded 16/04/2018, www.asar.com.au). Demand seems unlikely to decrease and, indeed, is likely to increase, potentially creating challenges for training institutions and organisations to meet the demand.

The current training models require students to gain employment prior to enrolment in postgraduate programs. Historically, the Diploma of Medical Ultrasonography (DMU), offered through the Australasian Society for Ultrasound in Medicine (ASUM), was the only and most widely accepted program for training. This 2-year graduate entry course relied on a self-paced learning structure that included case-based assignments, practical examination and a log book (which documented a minimum of 2,000 echocardiograms performed by the trainee) submission. In Australia this course is no longer accredited by the Australian Sonographers Accreditation Registry (ASAR) and is being phased out in New Zealand. ASUM did offer a Graduate Diploma of Medical Ultrasonography (GDMU) aligned with level 8 of Australian Qualification Framework and on par with other Graduate Diplomas offered by universities within Australia, but this has also recently been discontinued.

University courses, such as the Graduate Diploma in Cardiac Ultrasound such as offered by the Queensland University of Technology (QUT) or Western Sydney University, have become the most common qualification pathways to becoming an accredited cardiac sonographer. Both these courses require the candidate to have completed an undergraduate degree in a relevant science or allied health field. Also, the student is required to be employed as a cardiac sonographer for at least 3 days per week for the course duration of 2 years. In New Zealand, there has been variable take-up of these university courses due to access and financial constraints, and many student sonographers have relied on the ASUM course for their qualification.

The clinical placement requirements of these training courses create an enormous challenge and are a significant limitation towards increasing the number of fully accredited cardiac sonographers in Australia and New Zealand. This model places a high demand on already busy clinical practices to train students and is also demanding on the student to complete studies whilst also performing their required job.

In addition, the universities are expensive. and although some employers are willing to bear this cost as the need for trained sonographers is so great, not all are. For New Zealand trainee sonographers, there is no local course available and the added burden of travelling to Australia for block courses is a significant hurdle for many employers.

Future Training Models

The main constraint to the existing models for training sonographers is that it is based on an apprenticeship model that requires the trainee to obtain a position that will support their studies and provide the on-the-job aspects of their training. This traditional apprenticeship model has significant other costs associated with it, including the provision of a paid senior cardiac sonographer to teach and supervise the student which results in a reduction in overall productivity of the supervising sonographer during the training period; and there are human resource complications that may arise in the event of poor progression.

The Echocardiography/Cardiac Physiology program introduced 3 years ago at Central Queensland University (CQU) partially addresses some of these issues. This is a 4-year combined undergraduate bachelor/postgraduate diploma program that requires no prior experience and the graduates are trained in all aspects of clinical physiology, including electrocardiography, Holter testing, exercise stress testing and catheterisation laboratory procedures, electrophysiology as well as echocardiography. This program has been approved by ASAR and is currently available at metropolitan campuses in Perth, Brisbane and Sydney and current students (approximately 100) are a mix of school leavers and mature age students who have met strict minimum requirements for undergraduate entry. The program incorporates significant time in small group scanning skills classes in the CQU state-of-the-art simulation labs. Students must pass rigorous practical skills exams prior to clinical placement. These exams assess the ability of the student to complete a specified ultrasound study on a normal volunteer within a set timeframe. The program builds the skill of history-taking and image evaluation so that the students can assess patients and evaluate their findings in a safe and effective manner. Students are also given access to the unique Sydney simulation centre for hands-on training to support theoretical content surrounding cardiac rhythm management.

With such a short supply of trained cardiac sonographers, this new CQU model of training may be a potential game-changer in the industry. One of the main barriers to this concept of training might be finding sufficient clinical placements for the students, but this may be balanced by the minimisation of the training burden on industry that currently exists. Students placed with industry partners would possess a basic skill set, combined with underlying theory, upon which industry can build skills to suit their workplace. Interestingly, the undergraduate clinical physiology component of this degree is very similar to the historical model previously offered in New Zealand and overseas, although echocardiography remained a separate post-graduate qualification. In the USA and Canada, sonographers complete an associate degree, which is at undergraduate level and is specifically focussed on echocardiography.

The failure to address sonographer shortages and the challenges associated with sonographer training will exacerbate the uneven distribution of services across both countries.

Practice Model

In Australasia, echocardiograms are predominantly performed by dedicated cardiac sonographers. The competency of sonographers is based on an American model where sonographers undergo the formal educational standards and are properly accredited with an appropriate body. Sonographers are expected to have technical competency in the ability to operate the ultrasound equipment and obtain good quality two-dimensional imaging, M-mode and Doppler for diagnostic interpretation. Lastly, sonographers are required to maintain skills and knowledge through continued work in the field and continued education [8]. This is done through acquiring points with continued professional development (CPD) programs. There are several available within Australia and New Zealand.

Registration Versus Accreditation

In New Zealand, sonographers are registered health professionals and registered alongside radiographers and radiation therapists under the Health Practitioners Competency Assurance Act (HPCAA) and via the Medical Radiation Technologists Board (MRTB). The MRTB reviews and accredits qualifying courses and maintains a registry of registered practitioners. The MRTB also stipulates ongoing continuing education requirements and provides Annual Practicing Certificates (APCs) and has the power to ''strike off'' registered sonographers for unprofessional behaviour or incompetence. And lastly, and importantly, the title of ''registered sonographer'' is protected in order to protect the public from unqualified individuals offering this service.

In Australia, although radiographer and radiation therapists are registered in a similar way as New Zealand through the Medical Radiation Practitioners Board Australia (MRPBA) and mandated through the Australian Health Practitioners Registration Agency (AHPRA), unlike New Zealand, sonographers were not included in this practice board when it was established. Instead, sonographers are accredited, but not registered, through the ASAR.

The ASAR maintain a public list of accredited sonographers and performs similar roles as a registration body would, such as reviewing and approving training courses and overseeing CPD. The ASAR, from a government perspective, is largely a mechanism to ensure that Medicare reimbursements are only paid to practices that use qualified sonographers. From a sonographer's perspective, it helps to ensure professional and appropriately qualified sonographers provide the majority of ultrasound imaging in Australia. As such, the ASAR serves as a quasi-registration board. But an important distinction is that it is not mandatory for sonographers to be accredited to practice. For example, if a sonographer works in a public hospital environment that does not charge a Medicare fee then the sonographer is not required to be registered with ASAR. The public hospital however, may or may not demand accreditation with ASAR as an essential requirement in its job description to maintain a professional standard.

AHPRA came into effect in 2010 and is governed by the Health Practitioner Regulation National Law. This is enforced in each state and territory and regulated by nationally consistent legislation. AHPRA supports 15 boards that are responsible for regulating the health professions, its primary role is to protect the public by setting standards and policies that all registered practitioners must meet, if these standards are not met or are breached, the health practitioner can have restrictions placed on their registration or even be ''struck off'' the register. Importantly, the ASAR have no ability to ''strike off'' sonographers even in the event of criminal activity.

Sonographers are not currently governed by AHPRA, however this may be reviewed in the future. ASUM, in conjunction with the Australasian Sonographers Association (ASA), has been lobbying the government to create a registration board for sonographers but to date this remains unresolved.

In both Australia and New Zealand, many cardiac sonographers work as cardiac physiologists/scientists as well as performing echocardiography. Neither country has a formal pathway, through AHPRA or the HPCCA, to register cardiac physiologists/scientists. In New Zealand, a voluntary registration board, the Clinical Physiologists Registration Board, has been established but it holds no legislative power. Furthermore, it is unclear whether clinical physiologists performing echocardiography are legally doing so. As it stands, the HPCAA does not protect the activity of performing ultrasound, but it does protect the title of sonographer. And although this may seem pedantic, there are financial implications, given that the Multi-Employer Collective Agreement (MECA) in New Zealand and some state employment collectives in Australia pay more for registered sonographers. For example, in New Zealand, cardiac sonographers paid under the Sonographer MECA receive a significantly higher salary than their cardiac physiology colleagues and in

NSW, sonographers who are registered as radiographers with AHPRA also enjoy higher pay rates.

Sonographer registration is an important step for the profession as it recognises training and skills and also helps to maintain a highly professional workforce and also evens out pay differences. The differences between Australia and New Zealand, two closely linked countries, does impact upon sonographer movement between the two and it also has important implications for employment of migrant sonographers.

Migrant Sonographers

One of the potential solutions to the workforce shortage of sonographers is employing migrant sonographers. Anecdotally, there is no shortage of cardiac sonographers wanting to work in Australia and New Zealand, but sonographer training, at post-graduate level, is amongst the highest in the world. Of most concern for the accreditation process is that local sonography programs are at a higher educational level than in many similar countries making direct comparison difficult. Even though training models in both the United Kingdom (UK) and North America are different to those in Australasia, each has a robust registration pathway, which is similar to New Zealand, but arguably more rigorous than in Australia. There is a pathway and documented processes for migrants to become accredited in Australia and registered in New Zealand and these are managed through the MRPBA and MRTB in each country, respectively. In both cases, applicants need to demonstrate that their training in their home country is of a similar standard and that they have met similar minimum requirements in the number of scans performed. In addition, there are minimum English language standards that need to be met, especially when their qualification and/or training was not conducted in English. In some cases, a clinical competency exam is undertaken. This system appears to work well, but it is expensive, and each year there are sonographers who apply who are not granted the right to practice.

The ability for sonographers to move easily between countries of similar health systems should be easy and seamless; improving this could assist with workforce shortages.

Advanced Practice

Advanced practitioners are increasingly common amongst other health professionals. For example, nurse practitioners, who have undergone additional higher-level training, now perform tasks that traditionally were the domain of doctors only. Advanced practice is defined as health practitioners undertaking tasks that fall outside their usual or traditional scope of practice and models are being developed for sonographers to assist with framing advanced practitioner roles [9,10].

For cardiac sonographers, this could include tasks such as inserting an intravenous access line, administering a contrast agent, or reporting the scans they perform. The first two areas are governed at a local level: individual hospitals, states and countries are responsible for regulating who can undertake these activities and the required training. Sonographer reporting is probably the most controversial area of advance practice for sonographers but potentially brings the most added value to services and the profession.

Conduct and Reporting of Scans

In the UK, sonographers do report their own scans and they have a higher level of registration (sonographer consultant) for sonographers. This was accepted on the basis of significant shortage of senior imaging doctors and it allows the doctors to focus on higher level tasks.

International guidelines suggest a complete echocardiogram report should include assessment of all cardiac chambers, valves and the great vessels from multiple windows; and include Doppler assessment of flow through valves and across atrial and ventricular septa [11]. A typical echo report incorporates patient demographics, echocardiographic findings, and a short summary or conclusion. Usually, the demographics and echocardiographic findings (including appropriate measurements and written description of cardiac chambers and valves) are completed by the sonographer. Then the final conclusion is completed by the reporting cardiologist, who has final responsibility for the findings.

Cardiac sonographers in both Australia and New Zealand usually provide a preliminary report of their findings which is then reviewed by a cardiologist, who will sign it off. In some hospitals, due to backlogs and the time constraints of cardiologists, it is common practice to make ''preliminary'' echo reports available to referring clinicians prior to cardiologist review. Inevitably, clinical management decisions are made as a result of preliminary echocardiogram reports, but as these reports carry a proviso indicating a cardiologist has not reviewed the report or the images, the responsibility for these decisions lies with treating doctor.

In Europe, the echocardiographic practitioners (who may be a sonographer or physician) take responsibility for the entire echo, eliminating the need for review of images and interpretation from a second individual. They have two levels of training: a basic level, where they are able to independently perform and report transthoracic echocardiograms and should have exposure to both transoesophageal and stress echocardiography but are not required to perform these tests by themselves; and an advanced level where the practitioner is able to independently perform and interpret transoesophageal and stress echocardiograms [12].

This poses the question, would this be suitable practice for Australia or New Zealand to adopt? Currently, any cardiology trainee, who has completed advanced training in cardiology through the Royal Australasian College of Physicians should have Level 1 basic skills in echocardiography, and they can report (and bill for) echocardiograms. There is no requirement for sub-specialty cardiac imaging training. Based on overseas experience, it is likely that senior sonographers, with many years of experience would be capable of reporting echocardiograms at a comparable level. Level 1

competency includes performing and interpreting 300 transthoracic echocardiograms, observing and interpreting 50 transoesophageal echocardiograms and observing and interpreting 25 stress echocardiograms [13].

If appropriately trained sonographers were able to work at advanced practitioner level, independently reporting transthoracic echos for example, could this alleviate the backlog of reports waiting to be finalised by busy cardiologists? This would also eliminate some of the risk associated with clinical decisions being made from preliminary reports. Creating an advanced practitioner pathway for cardiac sonographers would also help to retain senior sonographers in the workforce.

Advanced practice is not only an issue for sonographers. In Australia and New Zealand, qualified cardiologists are considered to have sufficient experience in their advanced training program to enable them to supervise and report transthoracic echocardiograms (Level 1) and those with experience in stress and transoesophageal echocardiograms require a higher level of experience (Level 2). This is similar to the USA, except that there is an additional layer, Level 3 training, that allows echocardiologists to supervise laboratories and train other physicians or advanced trainees [14]. Importantly, Level 3 requires additional sub-specialty training and is not possible within a typical 3-year cardiology training program. Despite some strong lobbying this has not been introduced in the Australasian setting. Furthermore, the USA echocardiologists have additional examinations which are retaken after 10 years.

Another important area is the accreditation of echo laboratories, which is growing overseas. Although this may look like a ''tick the box'' exercise, there is evidence that accredited labs performed better overall, and, importantly, their echos were more clinically useful [15]. Anecdotally, there are wide variations in Australasian echo labs in terms of the training of the cardiologists with lab oversight and the conduct of examinations. But there are challenges with service delivery in both countries where populations of need are geographically distant and widely spread. A rigorous, one-size-fits-all approach, no matter how well intentioned, may not work in our setting. In Australia, it is possible that the Federal government may intervene if the ever-growing rebates for echocardiography are not reined in.

Imagining the Echo Lab of the Future

The way we perform echocardiography has changed significantly in the last few decades and will continue to evolve further. For example, the number and complexity of measurements has increased markedly; much of the measurement and analysis can be performed off-line and we are increasingly incorporating new technologies, such as three-dimensional (3D) and speckle tracking, into our clinical guidelines. The last 30 years has seen rapid development of echo applications and increasingly complex assessments, but will this continue? Will our echo examinations become even more complex? And what technology is on the horizon? It is certainly likely that the current technological advances will not abate, and may even increase. Not only will the imaging performed be differently but how that data is managed will also be impacted greatly.

Artificial Intelligence, Machine Learning and Automation

Computers are being used to streamline many tasks that previously fell to the sonographer or cardiologist. It is worth considering the difference between artificial intelligence (AI), which would see computers being able to carry out many tasks in a manner that is beyond simple automation, and includes a measure of ''smartness'' or decision making. Machine learning (ML) applies AI to data and allows the computer to learn from that data and is particularly suited for cardiac imaging [16]. Machine learning probably best describes the situation with current automation where the onboard computers are using databases of hundreds of images to ''learn'' how to perform tasks, such as how to trace cardiac chambers from ultrasound. We are already seeing a number of vendors offering automated measurements: significantly minimising the time needed to accurately quantify heart volumes, and stand-alone software that has been shown to be more reproducible than manual tracing for assessment of left ventricle (LV) volumes and left ventricular ejection fraction (LVEF) [17].

This is a rapidly expanding area, not just in medicine, and will have a significant impact on how we measure the echo images we acquire. Many vendors are working on a single heart beat, full volume acquisition where the entire heart will be imaged, and individual views and images created and measured afterwards. If realised, this would reduce the scan acquisition time significantly. It is likely that computers will carry out many tasks, especially routine measurements, currently the responsibility of sonographers. And whilst this could lead to a decrease in the workforce, there will still need to be expert oversight and interpretation. Similarly, we have recently seen some robotic scanners, but these still need an operator and given the non-standard nature of echo windows and views, and the need to manipulate respiration, robots are unlikely to take over entirely. There is no doubt, however, that artificial intelligence, machine learning and robotics will change the way we work.

Multimodality Imaging

As cardiac magnetic resonance imaging (CMR) has evolved, there was a tendency to compare it with echo, and typically echo came off as second best. Cardiac MRI had better resolution; CMR was more accurate; and CMR was more reproducible. But CMR has worse temporal resolution; is more expensive; is not widely available; is not as well tolerated by patients; and simply can't be done in some patients. I think we are beginning to understand that, rather than comparing CMR to echo, the real benefit lays in showing the added clinical value of CMR over echo. And this is true for cardiac computed tomography as well, which has the added negative factor of radiation exposure. Ultimately, we will not be

able to replace echo with these techniques, which have their own limitations and lack the portability of echo, but we will need to be aware of the advantages of each modality as access to imaging continues to grow.

Clinician Performed Ultrasound

Clinician-performed ultrasound examinations are fast becoming the normal standard of clinical care [18]. Intensivists and emergency physicians have led the use of protocol-driven point of care ultrasound (POCUS), but soon almost all clinicians will own a transducer capable of scanning almost any body part. POCUS has been likened to a stethoscope and, in fact, a term ''echoscopy'' has been suggested to differentiate this point of care ultrasound from referred ultrasound as we know it [19]. Many medical schools are including POCUS in their curriculum and within a decade or two, almost every medical graduate will be able to use, and likely own, a handheld transducer. And, given there are stand-alone transducers available for smartphone applications retailing under US$2,000, cost is no longer a barrier. The use of POCUS is already being extended to nurse practitioners and the expansion is unlikely to abate.

As the expert users of echocardiography, sonographers and cardiologists will need to position themselves carefully in this future clinician picture. Many simple cases will never make it to cardiology and those patients that are referred will be more complex. This is not substantially different to how referrals to cardiac surgery have diminished with percutaneous interventions. But, as the surgeons and interventionists have learned to work alongside one another, so should we. Sonographers have a potential role as mentors and teachers to new POCUS users. Sonographers can, and should, position themselves as the technological experts of echocardiography. Otherwise, they will become increasingly isolated: POCUS users will turn to other sources for support if sonographers shun them.

This ''creep'' of scopes of practice is both a threat and a challenge to the future echo labs. As other health providers take over some of the traditional echo lab practice, sonographers need to ensure the services they provide are relevant and timely. And sonographers should take advantage of this erosion of professional boundaries to extend their own practice.

Conclusion

Cardiac sonographers play a vital role in the provision of cardiac imaging within Australia and New Zealand and reliance on sonographers to provide this clinical service is unlikely to abate. Some workforce challenges need to be addressed, such as registration and the training model, in order to ensure an adequately trained, appropriately sized workforce is in place. The impact of technological change and the expansion of scopes of practice will need careful consideration. Echocardiography equipment will become more specialised and powerful, and simultaneously more simple (in the case of handheld transducers). The need for echocardiography is unlikely to diminish however, and is, in fact, likely to grow with increased applications in an ageing population living with chronic heart disease.

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