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COUNTRY REPORT

Imaging in the Lion City: Singapore Radiology Country Report

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Abstract

Singapore is a small tropical island city-state with limited natural resources that has achieved remarkable healthcare outcomes through effective long-term planning and judicious investment in human resources and technology. A full-range of medical imaging services is available in the country, with integrated care delivered to patients through a network of both government and private hospitals. Training in diagnostic radiology, interventional radiology, nuclear medicine and diagnostic radiography continue to evolve in Singapore, with an aim to further increase the range of subspecialty medical imaging services available and address projected challenges for the healthcare system in the future, such as an aging population. Continued government investment in technology and biomedical imaging is expected to further expand the scope and depth of medical imaging services in the future.

Introduction

SINGAPORE is a tropical island city-state situated between West Malaysia and Indonesia, just one degree north of the equator (Figures 1a, 1b). The name “Singapore” derives from the Sanskrit words “singa” (lion) and “pura” (city), which also explains why it is often called the “Lion City”. Initially founded as a British trading colony in 1819, Singapore became part of the Malaysian Federation in 1963 before attaining independence in 1965. This small nation of about 700 square kilometres has a population of about 5.5 million comprising mainly Chinese (74%), Malay (13%) and Indian (9%) ethnic groups (1).

Notwithstanding its small size, Singapore is currently amongst the world’s most prosperous countries, with a per capita gross domestic product of around 56,000 USD (2). Singapore has one of the world’s busiest ports, and is now a key global business and financial hub with one of the most business friendly and competitive economies in the world (3).

The Singapore healthcare system is recognized to be world class, delivering universal healthcare coverage for citizens at a cost of about 4% of GDP, though this is expected to increase with an aging population (4). Maternal mortality ratios (2/100,000 live and still births) and infant mortality rates (1.8/1000 live births) are very low. The life expectancy at birth in Singapore is also amongst the longest in the world, averaging about 82.8 years (80.5 years for males and 84.9 years for females) (5).

The radiology workforce

As of 31 Dec 2014, Singapore had a total of 11,733 registered medical practitioners. Of these, 4,485 medical practitioners were on the register of specialists, including 286 diagnostic radiologists (206 in the public sector and 80 in the private sector) and 23 nuclear medicine physicians (13 in the public sector and 10 in the private sector) (6) (Table 1). Diagnostic radiology and nuclear medicine are recognized as separate

Figure 1a. Southeast Asia Map.

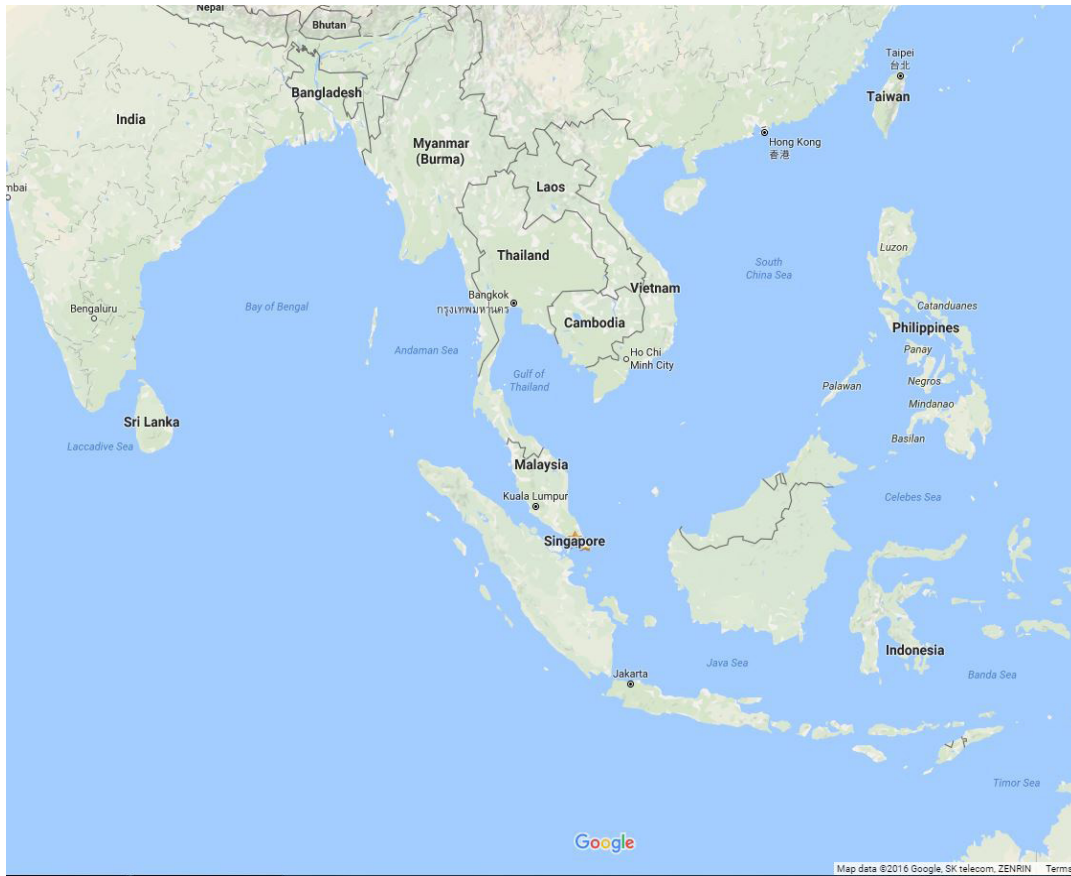
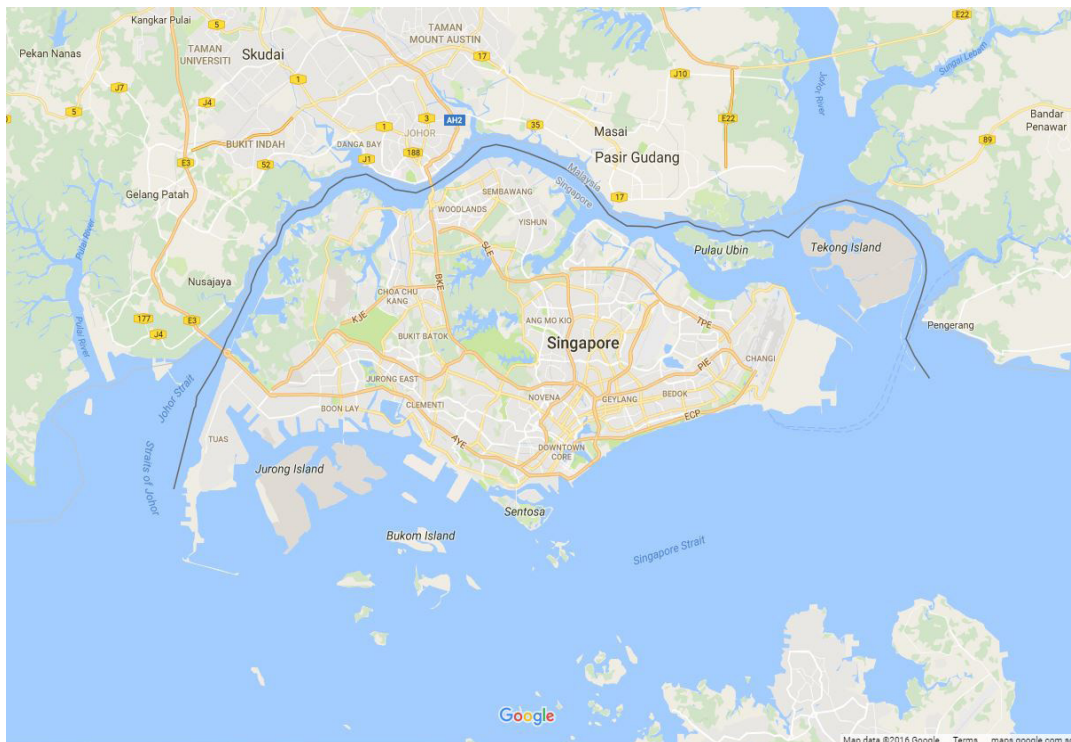


Figure 1b. Singapore Map.



medical specialties in Singapore. The diagnostic radiologist-to-population ratio of 1:19124 is lower compared to the United States, where a ratio of 1:11466 was reported in 2014 (7). To address Singapore's comparatively lower radiologist-to-population ratio, recent efforts have been made in the country to increase medical imaging specialist numbers, resulting in an increase of about 35% compared to 2010, and an approximately 30% increase in medical practitioner numbers within the same time frame.

Table 1. Radiology workforce in Singapore compared to the general population.

| | 2010 | 2015 (As of 12/31/ 2014) | % change |
|--|----------|--------------------------------|----------|
| Total registered medical practitioners (specialists and general practitioners) | 9030 | 11733 | + 29.9% |
| Medical practitioner-to-population ratio | 1:562 | 1:466 | |
| Diagnostic radiologists | 211 | 286 | + 35.5 % |
| Diagnostic radiologist-to-population ratio | 1:24060 | 1:19124 | |
| Nuclear medicine (NM) physicians | 17 | 23 | + 35.3% |
| NM physician-to-population ratio | 1:298629 | 1:237813 | |
| Singapore population | 5076700 | 5469700 | + 7.7% |

Radiographers in Singapore were traditionally not listed on a national register. However, state registration for radiographers was initiated in April 2016, and all existing radiographers are expected to complete their registration by April 2017 (8,9). A survey by the Singapore Society of Radiographers in 2014 put the total number of radiographers in Singapore at around 1,300, as stated in an email communication with Sng Li Hoon on March 23, 2016.

Radiological services in Singapore include the full range of sub-specialty services, namely abdominal (both gastrointestinal and genitourinary), breast, cardiothoracic, musculoskeletal, neuroradiological and pediatric imaging, along with vascular and interventional radiology. Nuclear medicine and PET services are also offered, either from separate nuclear medicine departments or as part of hospital radiology services.

Training and qualifications

Diagnostic radiology, interventional radiology and nuclear medicine

Radiology training in Singapore recently transitioned from

a system modeled after Britain's to a residency training program following the system in the United States. In the past, radiology trainees had to undergo two years of postgraduate general medical or surgical training (including internship) before embarking on three years of basic specialist training in diagnostic radiology. Trainees were expected to successfully complete the examinations in clinical radiology offered by the Royal College of Radiologists in the United Kingdom before starting advanced specialist training which would last at least two additional years. When they had completed these periods of training, they were then eligible for specialist accreditation as diagnostic radiologists. Most radiologists subsequently had 6 to 12 months of overseas radiology fellowships (usually in North America or Europe), before establishing themselves as consultants in diagnostic radiology. Those with special interests in interventional radiology currently pursue a similar training path, with increased vascular and interventional radiology rotations, although this is expected to change in the coming years following the development of different training tracks for interventional radiologists in North America.

Since 2011, postgraduate training in diagnostic radiology has followed a residency program format accredited by the International Arm of the Accreditation Council of Graduate Medical Education (ACGME-I). This entails four years of residency audited by ACGME-I, followed by a fifth year of residency for more focused rotations or mini-fellowships. At the third to fourth year of training, radiology residents continue to take the Joint Final Examination for the Fellowship in Clinical Radiology (FRCR), conjoint with the Master of Medicine (Diagnostic Radiology), between the Royal College of Radiologists and the National University of Singapore. From 2017 on, residents will be expected to take an additional "exit examination" administered by the Specialists Accreditation Board before being considered as successfully completing the program (10). There are a total of three sponsoring institutions offering residency programs in diagnostic radiology, namely National University Health System, National Healthcare Group and Singapore Health Services (SingHealth). The practice of overseas fellowships for junior radiologists continues, though this is expected to be modified in the coming years with increasing subspecialty radiological training being offered in Singapore.

Nuclear medicine specialist training is offered as a two-year senior residency program. Trainees are only eligible to enter this program if they have completed the basic internal medicine residency program (or the previous "basic specialty training") and passed the relevant postgraduate internal medicine examinations (Membership for the Royal College of Physicians or American Board of Internal Medicine). Alternatively, trainees can have completed four years of diagnostic radiology residency and passed the FRCR examination. Those who come through the diagnostic radiology route will have dual accreditation in both nuclear medicine and diagnostic radiology when they complete their senior residency.

Diagnostic radiographers

Training in diagnostic radiography is also undergoing

transition in Singapore. Previously, diagnostic radiographers in Singapore were required to have a minimum diploma qualification from the Nanyang Polytechnic through a three-year diploma in diagnostic radiography. After attaining the diploma, it was possible for diagnostic radiographers to subsequently pursue degree-conversion programs in selected overseas universities, either as a one-year distance-learning program with the London South Bank University or a one-year full time program jointly offered by the Singapore Institute of Technology and Trinity College Dublin (11,12). It was also possible to practice in Singapore with degrees in diagnostic radiography pursued at overseas universities.

From 2016 on, the Singapore Institute of Technology, the fifth autonomous university in Singapore, will progressively take over the training of diagnostic radiographers. Initial enrollment in this new four-year direct honors degree course began in September 2016.

In terms of postgraduate studies and subspecialization, the only postgraduate course for diagnostic radiographers currently offered in Singapore is the Advanced Diploma in Ultrasonography offered by Nanyang Polytechnic. For more advanced postgraduate subspecialty studies in other imaging modalities, such as CT, MRI, interventional radiology and breast imaging, diagnostic radiographers in Singapore generally further their training at overseas universities, mainly in Australia and the United Kingdom.

Radiological equipment in Singapore

As of 2015, there are a total of 26 hospitals and specialty centers in Singapore. These include 16 public hospitals and specialty centres (with a bed capacity ranging from 185 to 2010 beds) and 10 private hospitals (capacity range from 20 to 345 beds).

Singapore's public sector hospitals and centers are administered as private companies wholly owned by the government, each receiving annual government subvention or subsidy for the provision of subsidized medical services. The eight major public hospitals are comprised of six acute general hospitals, one women's and children's hospital, and one psychiatric hospital. In 2012, the average length of stay in public acute care hospitals was about 5.8 days, with an average occupancy rate of about 85% (13).

To support the wide range of medical and surgical services available across the country, the full range of radiological and imaging equipment is available. The quantity of imaging equipment in Singapore is given in Table 2.

As of 2015, Singapore has about 19.4 CT scanners and 14.3 MRI scanners per million persons. These ratios are mid-range when compared to selected countries in the Asia-Pacific region, Europe and North America, where figures range from 7.4 to 97.3 CT scanners per million population and 5.6 to 43.1 MR scanners per million population (14) (Table 3).

Equipment serviceability and maintenance are at high levels in Singapore, given the small size of the city state, well-established transport networks, and national oversight of equipment licensing via the National Environment Agency.

Table 2. Quantity of radiological imaging equipment in Singapore.

| Equipment Type | Total number of licenses* | Machine-to-population ratio** | Units per million population |
|--|---------------------------|-------------------------------|------------------------------|
| X-ray / radiography units | 1739 | 1:3145 | 318.0 |
| Mammography units | 197 | 1:27765 | 36.0 |
| Fluoroscopy units | 71 | 1:77038 | 13.0 |
| Angiography units (interventional radiology) | 67 | 1:81637 | 12.2 |
| CT scanners | 106 | 1:51600 | 19.4 |
| PET-CT scanners | 28 | 1:195346 | 5.1 |
| MRI scanners | 78 | 1:70124 | 14.3 |
| SPECT scanners | 9 | 1:607744 | 1.6 |
| DEXA scanners | 64 | 1:85464 | 11.7 |

* Data obtained from the National Environment Agency, Singapore (which licenses the use of irradiating equipment for imaging), May 2016.

** Population of 5,469,700 as of 2015.

Table 3. Comparison of CT and MRI scanner density per million population.

| Country | CT scanners per million population | MRI scanners per million population |
|-------------|------------------------------------|-------------------------------------|
| Australia | 38.7* | 5.9* |
| Canada | 13.9* | 8.0* |
| Japan | 97.3** | 43.1** |
| Korea | 37.1* | 19.0* |
| New Zealand | 14.6* | 9.7* |
| Singapore | 19.4 | 14.3 |
| U.K. | 7.4** | 5.6** |
| U.S.A. | 34.3*** | 25.9*** |

* Data as of 2009 ** Data as of 2008 *** Data as of 2007

Data obtained from Health United States 2011 report by the National Center for Health Statistics, USA. Available from <http://www.cdc.gov/nchs/data/hsr/2011/123.pdf>

Local medical economy and radiology services

Singapore is known to have a strong healthcare infrastructure. The Joint Commission International has accredited 11 hospitals and three medical centres in Singapore, attesting to the high standard of medical care available (18). Effective long-term planning and judicious investment in technology and human development have resulted in enviable healthcare outcomes and universal healthcare coverage for Singaporeans. However, healthcare expenditure is expected to increase in the coming years in response to Singapore's aging population (15). Singapore is a leading medical tourism hub in Southeast Asia, with medical receipts ranging from 777 million SGD to 1.11 billion SGD between 2009 and 2013. However, there is strong competition for such medical tourism from other countries in the region (16).

The public healthcare system in Singapore is being restructured towards an integrated care model, currently divided into six regional health systems ("clusters"), each anchored by a regional hospital working together with a variety of primary, intermediate and long-term care facilities. These healthcare clusters are Alexandra Health (anchored by Khoo Teck Puat Hospital in the North), Eastern Health Alliance (anchored by Changi General Hospital in the East), Jurong Health (anchored by Ng Teng Fong General Hospital in the west), National Healthcare Group (anchored by Tan Tock Seng Hospital in the central region), National University Health System (anchored by National University Hospital), and SingHealth (anchored by Singapore General Hospital). An Agency for Integrated Care (AIC) was also set up to facilitate patient transition between healthcare settings at the national level.

All public sector radiology departments utilize Picture Archiving and Communication Systems (PACS) to digitally review and store radiological images, supported by Radiological Information Systems (RIS). Singapore is a highly connected city-state; healthcare providers in public hospitals are able to view and share medical images and records from other public hospitals via the National Electronic Health Record. Some healthcare clusters have also established teleradiology initiatives, both international (e.g. with Indonesia, Hanoi and India) and local (17).

Besides the contribution of radiology in clinical services, there are also numerous opportunities for medical imaging to expand along with the growth of Singapore's medical technology and innovation industries. In 2011, Singapore's medical technology sector contributed about 4.3 billion SGD in output, compared with 1.5 billion SGD in 2000. Many global medical technology companies carry out research and development in Singapore, attracted by dedicated infrastructure, including the Medtech Hub, Biopolis and Tuas Biomedical Park, all of which provide an ecosystem for companies to partner with public sector clinician-researchers and hospitals. Singapore is currently home to over 30 medical technology companies that have established commercial-scale plants producing medical devices for both regional and global markets. There is strong commitment from the Singapore government to grow the medical technology industry, with 3.7 billion SGD invested in biomedical sciences research from

2011 to 2015, a 12% increase from the previous five years (18).

The Singapore Bioimaging Consortium (SBIC), one of ten research institutes of the Biomedical Research Council under Singapore's Agency for Science, Technology and Research (A*STAR) is of particular relevance to radiology and medical imaging. SBIC has a multidisciplinary team of scientists, engineers and clinicians investigating human diseases of major public health interest using molecular physiology and advanced bioimaging tools. This consortium has expertise in chemical and biological probes, optical imaging, multimodal magnetic resonance imaging and spectroscopy, nano SPECT, micro PET and image processing (19).

Investment policies, regulation and risk of investment

To maintain a strong position in the global economy and remain an attractive investment destination, Singapore has established its reputation for integrity, quality, reliability, productivity, rule of law and enforcement of intellectual property (IP) rights. It was rated as the best place in Asia for IP rights protection in the IMD World Competitiveness Report of 2011 and the World Economic Forum's Global Competitiveness Report 2011-2012 (20). In 2015, Singapore's economy was ranked #1 in the World Bank's ease of doing business rankings (21).

Availability of Internet connections

As a technologically driven society, Singapore has a very high mobile phone penetration rate and high availability of Internet access. In 2014, the mobile penetration was 148%, indicating that there were almost 1.5 mobile phones for each person in the country (22). For Internet access, 88% of residential households in Singapore had access to the Internet in 2014, of which 87% had broadband access. Overall business usage of the Internet in 2014 was also high, at 87% (97% if only businesses with 10 or more employees were considered). In 2010, the Next Generation Nationwide Broadband Network (Next Gen NBN) was rolled out on the country's ultra-high speed optical fiber network, offering broadband speeds of up to 1 Gbps. This Next Gen NBN is part of the Intelligent Nation masterplan, which seeks to transform Singapore into a global city-state (23).

Disease profile, demographic and cultural factors

Since attaining independence in 1965, the disease profile of Singapore has mirrored its economic performance. In its transition from a developing to a developed country, the city-state now has a disease profile similar to developed western nations. The prevalence of lifestyle-related diseases has risen, with a significant prevalence of hypertension (23.5%), diabetes mellitus (11.3%), hypercholesterolemia (17.4%), obesity (10.8%) and daily smoking (14.3%) in the adult population in 2010. In 2014, the principal causes of death were cancer (29.4%), pneumonia (19%), ischaemic heart disease (16%) and cerebrovascular diseases (8.4%) (24).

Visiting Singapore and job opportunities

Singapore has an open economy, with potential job opportunities for expatriate radiologists and radiographers, as long as the relevant training qualifications and accreditation requirements are met. Foreign doctors are allowed to practice in Singapore, subject to successful registration of their medical and specialist qualifications with the Singapore Medical Council. For foreign diagnostic radiographers, their professional qualifications must be at least equivalent to those required for locally trained radiographers and be recognized by the Allied Health Professions Council (25). Diagnostic radiographers who do not meet these criteria will need to pass a Qualifying Examination conducted by the Nanyang Polytechnic in order to be eligible for employment in Singapore. An English Language Proficiency Test is also required if the foreign radiographic medium of instruction for the professional qualification was not in English (26).

Singapore was named Lonely Planet's Top Country to visit in 2015. Noted for its cultural diversity, food and shopping, Singapore is easily reached by air via Changi Airport, a major international gateway regularly voted as the world's best airport. Cruise ships also regularly dock in Singapore, and there are two land links between Singapore and Malaysia. Notwithstanding its cultural diversity, English is the main language used in Singapore, and is also the official language of instruction in schools.

Radiology education opportunities

Given the favorable conditions prevailing for high-quality medical care, economic prosperity, medical research and radiology education, many radiologists and radiographers in Singapore have been active in "giving back" to society. Local hospitals and teaching departments often host overseas radiologists and radiographers, ranging from short-term visits to year-long fellowships. Radiologists have participated in ongoing educational activities within Singapore's shores, and also contributed to regional and international meetings and conferences in diagnostic and interventional radiology, and in other domains of science and healthcare. In particular, the combined efforts of the College of Radiologists Singapore (27) and Singapore Radiological Society (28) have resulted in many opportunities to collaborate with societies and colleges in the region. For example, Singapore's radiologists often make up the invited faculty in regional scientific meetings, such as those hosted by the ASEAN Association of Radiology (AAR), Asian-Oceanian Society of Radiology (AOSR) (29), Asian-Oceanian Society of Head and Neck Radiology (AOSHNR) (30) and Asia Pacific Society of Cardiovascular and Interventional Radiology (APSCVIR) (31). Interventional radiologists frequently visit hospitals to proctor new, minimally invasive techniques, and both radiologists and radiographers have organized outreach teaching programs to emerging Asian nations in the region, in particular Myanmar and Cambodia (32). Since English is the working language, and Asia is within seven hours flying time from Singapore, there are many opportunities to collaborate with national and international organizations to improve healthcare for all.

Conclusion

Given its good infrastructure, sound policies and strategic planning, Singapore is well-positioned to be a global city of the future, and this includes being a forward-looking and friendly city in a region brimming with opportunities and possibilities. Notwithstanding limitations in size, Singapore has a lot to offer for global radiology in terms of health systems development, best practices, radiology education and imaging research.

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Conflict of interest

The authors report no conflict of interest.

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