Tele-nuclear medicine

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This article presents a description of tele-nuclear medicine and, after outlining its history, a wide, representative range of its applications. Tele-nuclear medicine has benefited greatly from technological progress, which for several decades has provided greater data transfer rates and storage capacity at steadily decreasing cost. Differences in the practice of nuclear medicine between developed and developing countries arise mainly from disparities in their available infrastructure, funding and education levels of personnel involved. Consequently there are different emphases in their tele-nuclear medicine, which are elaborated. It is concluded that tele-nuclear medicine is important for all countries, but the emphasis on its application may differ between developed and developing nations, with an emphasis on distance learning in the latter.

Introduction

Applications of tele-nuclear medicine are steadily increasing in all parts of the world, though often for different reasons in developed and developing countries. These differences are described below. Tele-nuclear medicine uses information and communication technology (ICT) to transmit information about nuclear medicine between two or more locations. This information most often includes scintigraphic images, but also their reports, patient and research data and associated educational material. Nuclear medicine can investigate many different pathologies. Therefore a wide range of medical specialists use nuclear medicine studies, but particularly cardiologists, oncologists, neuropsychiatrists, nephro-urologists, orthopaedic surgeons and rheumatologists. Satisfactory but limited tele-nuclear medicine is possible using transmissions along copper telephone wires, as is often the situation in non-urban regions of developing countries. But modern sophisticated nuclear medicine, such as positron emission tomography/computer tomography (PET/CT) and single-photon emission tomography/CT (SPECT/CT), can produce large data sets, requiring rapid transmission and wide bandwidths for effective tele-nuclear medicine. Such ICT links are commonly found in developed countries and also within and between large cities of some developing countries. But these nations' tele-nuclear medicine most often transmits simple nuclear medicine images and data sets, which do not require sophisticated transmission facilities.

Tele-nuclear medicine has often been slow to be applied, in contrast to tele-radiology and tele-pathology, whose advantages were appreciated early in the history of tele-medicine. For example, in Norway, a wealthy developed country and pioneer in the field of tele-medicine, tele-nuclear medicine was only introduced and available about two decades after the first use of tele-medicine. Norway has a large area and many sparsely populated rural regions. It has this in common with developed nations such as the United States of America (USA), Australia and Canada, and also with very many developing countries, which now appreciate the benefits of all types of tele-medicine. Tele-medicine was mainly pioneered in developed countries and later its equipment and experience were used in developing nations. However, late and slow introduction of extensive tele-nuclear medicine has generally been the situation in all countries. Fortunately applications of tele-medicine and tele-nuclear medicine are now steadily increasing everywhere.

Emergency nuclear medicine can clearly benefit from tele-nuclear medicine, as can nuclear medicine associated distance learning and those clinical disciplines mentioned above. Because of the growing importance and application of all types of tele-nuclear medicine, and because little has been written about it, it merits an appraisal.

Relevant history and current trends

Modern tele-medicine probably began in about 1935, when the Italian International Radio Medical Centre used radio communications to provide free medical assistance to ships at sea without any doctor on board. An early form of Italian tele-nuclear medicine existed in 1986.[1] Tele-nuclear medicine allows consultations with specialists located away from the nuclear medicine facilities and patients. This can result in better management, savings in health care costs and fewer inappropriate studies. These benefits can arise from both fixed-link tele-nuclear medicine and internet connections. Also, tele-nuclear medicine may reduce travel costs for patients and practitioners and can aid provision of a nuclear medicine service where or when a nuclear medicine specialist is unavailable. There are considerable advantages in using distance-learning techniques for appropriate nuclear medicine (and other) education. High-speed fibre-optic and radio ICT links, available in many locations, can also facilitate rapid data transfer for studies in some parts of certain developing countries for cardiology and various dynamic nuclear medicine investigations, or SPECT/CT with large data sets, for example.

A recent comprehensive review of nuclear medicine trends in developing countries by the International Atomic Energy Agency (IAEA)[2] emphasised increasing mortality and morbidity in developing nations from chronic and non-communicable diseases. Thus nuclear medicine's role in disease management there has increased, especially for neoplastic and cardiological conditions, although its application has been slower than desired. The two main reasons for this are the costs of modern, sophisticated equipment in countries with severely limited healthcare budgets and, equally importantly, insufficient education and training in nuclear medicine. The latter can be improved greatly by using tele-nuclear medicine, as examples given below indicate. Initiatives, mainly from the IAEA, assist in supplying appropriate nuclear medicine equipment to developing nations. Such aid has included over 50 dual-head SPECT cameras since 2004 and about 130 ongoing technical cooperation programmes, especially for developing countries.

Nuclear medicine practice differs between developed and developing countries, mainly because of insufficient funds and training in developing countries. In addition, there are different levels of infrastructure and prevalence for causes of morbidity. Regrettably some nuclear medicine departments in developing countries are inactive several days each month, typically because of unavailability of ^{99}Mo/^{99m}Tc generators, especially in Africa and Latin America, which have the lowest departmental efficiencies overall.[2] These drawbacks, especially inadequate training, 'hamper the growth of nuclear medicine practice in the developing world' and reduce 'the ability of nuclear medicine facilities to respond to the needs of referring clinicians'.[2]

Technology

Web-based information can aid most tele-nuclear medicine applications – for example, virtual picture archiving and communication systems, which can include nuclear medicine and other image data – and are particularly useful in remote rural areas. Mobile telephone use in Africa is now widespread. Many current African mobile telephone users have never had, nor are likely ever to have, fixed land lines, because of this explosive increase in inexpensive mobile telephone availability. Health care using mobile ICT devices (mHealth) is well established and steadily growing in developed countries, especially for home care surveillance. mHealth is also now increasingly used in developing nations. In 2011, the first published report on mobile phone tele-dermatology, from Egypt, used a 5 megapixel camera.[3] Many more mHealth trials are underway. Although mHealth has limits for transmitting high-resolution images comprising large data sets, it is highly suitable for other tele-nuclear medicine, such as reports delivered from a distant site and transmission of many types of static image. Image compression with acceptable degradation increases tele-nuclear medicine's effectiveness when using links with limited bandwidth. Many successful mHealth applications in developing countries use the short message service, ensuring compliance for those medicated for HIV or multidrug-resistant tuberculosis infections, for example. Cochrane reviews have also shown that such reminders[4] are equally effective to ensure attendance of (nuclear medicine and other) medical appointments.

Over the last few decades there has been a steady increase in electronic computing capacity, accompanied by decreasing costs, often expressed in terms of Moore's Law. One of the consequences is that more powerful tele-nuclear medicine equipment is becoming less expensive and thus more readily available, even in developing countries. This applies to PET/CT and especially SPECT/CT, which has been described by the IAEA[5] as 'a brilliant diagnostic tool in medical imaging, where anatomical details may delineate functional and metabolic information'. Images from the two different types of scans (SPECT and CT) are fused. SPECT can recognise specific tissues or tumours, which may be difficult to locate accurately with relation to other anatomical structures such as bones, usually readily identifiable by CT. This is especially useful where tissue location is very variable. One well-known application is to locate parathyroids, which may be distant from their usual site in the thyroid gland. Tele-nuclear medicine is most appropriate in supplying expert opinion, thus aiding interpretation of such sophisticated images.

Clinical tele-nuclear medicine

Medical emergencies require speedy reporting and tele-nuclear medicine can provide this for emergency nuclear medicine studies, as necessary. It is appreciated, however, that CT and ultrasound comprise most emergency imaging. Emergency nuclear medicine studies include ventilation-perfusion pulmonary scans for suspected pulmonary embolism, especially in young women of reproductive age or pregnant. This minimises radiation exposure of breast and foetus and requires no iodinated contrast media in pregnancy. Patients who are diabetic, in renal failure, or sensitive to contrast media also benefit from this nuclear medicine study, which can also diagnose comorbidity, such as chronic obstructive pulmonary disease, left heart failure, or pneumonia.[6] Similarly, with equivocal ultrasound investigations, a radionuclide testicular study can obviate unnecessary exploratory surgery. To avoid needless hospitalisation, and a premature discharge of misdiagnosed patients wrongly suspected of having the acute coronary syndrome, a resting myocardial perfusion study can provide more effective triage and it is an appropriate procedure for developing countries.[7] Other nuclear medicine studies can offer efficient solutions to emergency situations, thus reducing the need for more expensive and complex procedures. They investigate chest pain in low-risk patients, acute cholecystitis, gastrointestinal bleeding and radiographically occult fractures.[8] A less frequent emergency is a blocked cerebrospinal fluid shunt in a paediatric patient, for which nuclear medicine provides increased sensitivity.[9] If local reporting is impossible or impractical for emergency nuclear medicine, tele-nuclear medicine can usually provide an acceptable substitute.

Tele-nuclear medicine also provides valuable support in many non-urgent situations.

Cardiology database access may allow improved management. An IAEA study[10] established that approximately 80% of cardiovascular deaths occur in developing nations and suggested that regional training centres could reduce such morbidity by disseminating instruction, allowing increased utilisation of nuclear cardiology. As shown below, tele-nuclear medicine can greatly increase such training centres' effectiveness. Incidence of diabetes mellitus, and hence silent myocardial ischemia, is increasing in developing countries. For its management nuclear medicine studies have been shown to be more accurate than stress echocardiography.[11] These studies' interpretation may also benefit by accessing distant specialists using tele-nuclear medicine.

Tele-nuclear medicine links have many other applications useful for developing countries, such as database access. Relevant medical databases include one for the francophone Indian Ocean island nations (Dr Joseph Mourouvin 2011, personal communication, September) and another in China.[12] Both have been associated with emergencies related to infectious disease outbreaks (in the case of the former, with a bubonic plague outbreak in Madagascar) and the rapid resulting action averted an epidemic. When magnetic resonance imaging (MRI) and CT availability are limited, as is often the case in developing countries, there are situations where tele-nuclear medicine can be very useful in the absence of hybrid imaging, such as in skeletal studies with suspicion of multifocal lesions or poor symptomatic localisation where there is a need for a second opinion.[13] Thyroid problems, frequently investigated with nuclear medicine, commonly occur in developing countries where they unfortunately often present very late. An Indian project aimed at managing thyroid cancer established a most successful tele-medicine network between a specialist hospital and secondary hospitals, which was able to 'disseminate knowledge, educate doctors and paramedical staff, improve and develop their consultation and surgical skills'. This network also provided similar benefits for rheumatology patients.[14]

Tele-education

Nuclear medicine tele-education uses tele-nuclear medicine links. For many years one longstanding bidirectional tele-nuclear medicine link connected a South African medical faculty (University of Stellenbosch) with the Windhoek National Hospital, Namibia and later the University of Namibia's School of Medicine, allowing distance reporting, remote processing and expert second opinions, all partially overcoming problems of relative isolation for nuclear medicine practice in Namibia. However, this link is no longer operational (Prof. Annare Ellmann 2013, personal communication, November 17). A similar tele-nuclear medicine link has been used between the University of Cape Town and the University Hospital in Lusaka, Zambia. The IAEA has provided appropriate ICT equipment for both these nominally clinical links. However, both links also had an important tele-nuclear medicine education function (both formal and informal), clearly demonstrating the power of clinical tele-nuclear medicine links to permit tele-education, when not occupied with clinical nuclear medicine.

Many people, located at different receiving sites, can benefit simultaneously from one tele-education teaching session, whether it comprises lectures, demonstrations, case presentations or self-administered computer-controlled instruction. The IAEA has recently invested much effort and funding in providing distance-learning web-based training for nuclear medicine[15] in basic topics and also for some advanced studies, especially for nuclear medicine technologists. The basic training programme (particularly relevant to developing countries) uses 14 modules and the advanced studies 6 modules, covering complex equipment such as PET/CT and PET/MRI. English and Spanish versions are currently available and used in 24 mostly developing nations. Turkish translations are underway, for Turkey currently has over 200 nuclear medicine departments, with little formal training in nuclear medicine technology. In Australia, completion of appropriate modules allows licensing of some nuclear medicine scientists. The development of all these programmes has received many contributions, but the Universities of Sydney and Cape Town were major providers of teaching material. Both obtained much support and coordination aid from the IAEA. Its Human Health Division recently indicated that its nuclear medicine training programme aims (1) to improve basic knowledge, necessary for effective practice of the discipline, with emphasis on practical skills and (2) to establish assessed common basic standards of training.[16] Currently, about 450 students participate and over 370 students have completed sections of the various courses. An extensive system of cost-free web-based educational nuclear medicine seminars (webinars) has also recently been described by the IAEA.[15] The United States Society of Nuclear Medicine and Molecular Imaging also provides such webinars, live workshops and lectures.[17] Other informal tele-nuclear medicine activities are underway in Africa, serving both clinical and educational needs.

Adequate medical physics expertise and facilities are essential components of the effective and safe practice of nuclear medicine. Inadequacies in medical physics often serve as an obstacle to achieving the full potential of nuclear medicine in developing countries. Tele-nuclear medicine can often aid medical physicists in ensuring effective limits on radiation exposure. A report from a developing country stated that, after ^{131}I treatment in one location, the general public and patients' families (children in particular) received an excessive radiation dose equivalent to or greater than the annual dose limit; in addition, some of the patients were overdosed.[18] This arose directly from inadequate medical physics monitoring. It was remedied by further training, which tele-nuclear medicine using distance-learning techniques can effectively provide. Similarly, the IAEA has found that inadequate quality control and faulty radioactivity measurements in nuclear medicine laboratories of some developing countries resulted in inconsistent and unsafe conditions. Regional training centres and dissemination of appropriate tele-education from the IAEA can resolve this situation.[19] Another application of nuclear medicine's tele-education is teaching effective management of radiation release accidents (and also 'dirty' bomb detonations), such management often being the responsibility of nuclear medicine departments and their medical physicists. Relevant advice for treating patients and protecting personnel and the environment can be provided rapidly. These links can also be used effectively in such circumstances to assist with control of resources and patient transport decisions.[20] Tele-education, although very useful, is not always a simple, direct and universal substitute for other learning methods, as one report from a Brazilian project on early sentinel lymph node diagnosis shows.[21] Although participants completed the tele-nuclear medicine course, insufficient preparation and consequent lack of motivation of the physician trainees resulted in unsatisfactory results. It was deduced that appropriate preparation was lacking in this application of non-traditional learning methods and that the pro-active participation of a tele-nuclear medicine course coordinator is essential. This sentinel lymph node project was a notable exception in tele-nuclear medicine education. Other such education programmes usually prove most successful and effective, with clear cost benefits. It is not always understood that the 'optimization of current resources is more important than obtaining additional equipment and resources'.[22]

As illustrated, tele-nuclear medicine education is seen to be very effective overall and in high demand in developing nations. This successful aspect of tele-nuclear medicine complements all its other applications outlined above. Hence the discipline's achievements and potential deserve to be expounded more widely.

Conclusion

In all parts of the world, tele-nuclear medicine is playing an increasing role in the improved practice of nuclear medicine, by allowing access to expertise that is unavailable otherwise. An important part of this is the educational power of tele-nuclear medicine, which is particularly cost-effective, especially for developing countries where adequate numbers of experts and levels of training often lack for financial reasons. Tele-nuclear medicine has two principal, proven advantages. The first is the rapid and efficient transmission of data sets of all degrees of complexity, without significant loss of resolution, thus aiding provision of a nuclear medicine service with any degree of distance between the participating nuclear medicine physician and the location of camera and patient. The second is that tele-nuclear medicine can allow cost-effective distance learning at all levels.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

N.S. (Stanford University) and S.W. (Medical Research Council and University of Cape Town) jointly decided upon the type of material to be researched for this review and agreed what each would study. Then each researched his assigned field, contributed a comparable amount of text and took part in the final editing.

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