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# Medical Imaging Trends and Implementation: Issues and Challenges for Developing Countries

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Abstract. To meet the increasing demand for radiological services over the past few years there has been a growing trend toward introducing medical imaging across hospitals worldwide. Medical imaging technologies consist of a number of components including PACS (Picture Archiving Communication Systems), RIS (Radiology Information Systems) and HIS (Hospital Information Systems) which are typically linked and interfaced through a computer network. In this paper, we present an overview of global trends in the deployment of medical imaging and highlight some of the key issues and challenges which are faced by developing countries in its implementation.

# 1. Introduction

The potential benefits arising from the introduction of medical imaging in developing countries are numerous. Several studies have argued that medical imaging is a viable solution to some of the on-going problems and healthcare challenges experienced by these countries. For example, many studies have found that the use of medical imaging can increase efficiency in accessing, viewing and sharing patient radiographic images and diagnostic reports. There has also been an increase in the use of teleradiology and teleconsulting activities. These services have the potential to address problems associated with shortages of medical specialists and the lack of access to adequate healthcare infrastructure and services.<sup>3</sup> Further, the use of medical imaging has been found to be useful in containing disease outbreaks within hospitals. For instance, in the case of the severe acute respiratory syndrome (SARS) outbreak, the technology enabled the radiographic images of SARS patients to be readily available to clinicians which facilitated clinical consultations between the hospital's clinicians and radiologists, and allowed consultations to be conducted via telephone.<sup>66</sup> In addition, the use of medical imaging helped to reduce the unnecessary movement of staff and materials from the radiology department which helped to minimize the spread of the SARS virus.<sup>41</sup> In recent years, a number of studies have highlighted the need to have adequate access and proper use of medical imaging to perform clinical diagnosis and to confirm whether patients contracted H1N1 virus (see for example<sup>1</sup>). The World Health Organization (WHO) officially confirmed on June 11, 2009 that the H1N1 influenza outbreak, which started in early 2009, had reached global pandemic levels<sup>67</sup>. <sup>57</sup> recommend the utilization of teleradiology to help to minimize the risks of influenza outbreaks among healthcare professionals. From the patient's standpoint, the use of



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medical imaging can improve patient care because the systems can assist healthcare professionals to provide more personalized and effective medical care and treatment, quick and effective disease screening programs, and can encourage them to practice more evidence-based decision making.<sup>62</sup> This eventually leads to better quality healthcare services and delivery to patients.

However, it is also widely acknowledged in the literature that hospital-wide implementation of medical imaging is challenging and risky, particularly when there are financial and manpower constraints. Whilst substantial investment has been made to computerize hospital information systems globally, in practice, there are still many unsuccessful implementation projects.<sup>41</sup> In one case study situated in the Limpopo Province in South Africa, a lack of understanding about the complexity of the project and the health culture were identified among the factors that contributed to the failure of the project that cost nearly £14million.<sup>41</sup> Nevertheless several developing nations have actively deployed the technology in their community hospitals.<sup>23,24,26</sup>

In this paper, we examine the growing trends in medical imaging deployment worldwide. Medical imaging is defined as an information system application that consists of a number of technological components particularly imaging modalities, PACS (Picture Archiving Communication System), RIS (Radiology Information System) and HIS (Hospital Information System) which are linked and interfaced through a computer network. In hospital radiology service, RIS facilitates patient radiology examination scheduling, assists in tracking patient data and information, and permits online radiology diagnostic reporting, whilst HIS supports hospital administrative tasks such as patient registration, discharge and billing. PACS on the other hand is a system that specializes in the acquisition, storage, processing, and distribution of radiographic image data.<sup>31,32,54</sup> Patient radiographic images are obtained via the use of imaging modality. Examples of imaging modalities include CT scanners, ultrasound, MRI (Magnetic Resonance Imaging), General X-Ray etc. Medical imaging also offers the potential to be further reconfigured to support teleradiology activities, through which the benefits of the application can be extended to other organizations. This paper in particular aims to highlight key issues and what lessons can be learned from the current trends in medical imaging implementation in the context of developing countries.

This paper is structured as follows. Firstly, it reviews the global trends in medical imaging deployment. Secondly, it discusses key issues related to the implementation of the technology in the context of developing countries. Finally, the paper concludes with a discussion of key challenges and lessons learned for developing countries based on the analysis of current trends in deploying the technology.

## 2. Global Trends in Medical Imaging Implementation

It is suggested that the demand for radiology services will continue to rise (see for example <sup>45,59,60</sup>). Studies have attributed the ever-increasing demand for radiology services to factors such as the global increase in illnesses, the increase in world population (including aging citizens), the rise in urbanization and worldwide healthcare programs and reforms. <sup>46,47,58,63</sup> With regard to illnesses, the increased number of patients with respiratory problems, cancer, cardiovascular and other form of lifestyle diseases for example has been frequently mentioned to contribute to the increased demand for radiology services.<sup>2,14,17</sup> In order to cater for this growing demand it is



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becoming increasingly common for healthcare organizations, especially in developed countries, to outsource some types of radiology services to foreign countries. Also, recent studies have reported that there has been an increase of radiology resource utilization particularly the use of advanced imaging services.<sup>17,41</sup> An increase in medical imaging implementation across hospitals worldwide has also been noted in the literature. The following presents the review of the deployment trend related to each of technological components of medical imaging.

### 2.1. Imaging Modalities

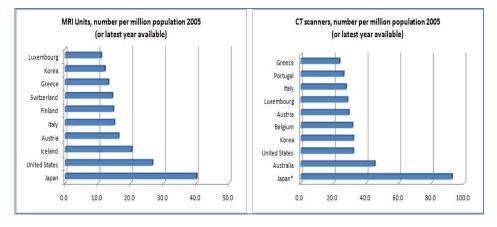
According to the <sup>22</sup>, in the year 2010, the market demand for medical imaging equipment in the United States will exceed US\$16 billion, with an expected 6.8 percent annual growth from 2005. The report anticipates that CT scanners will lead the market growth. A recent report published by Global Industry Analysts, Inc. mentioned that at present the United States, Japan and Europe have the highest CT scanner installations.<sup>65</sup> It was also reported that there has been a growing penetration of CT scanners among the developing countries, in which Asia Pacific particularly was reported to have the highest single-slice CT scanners<sup>65</sup>.<sup>10,11</sup> reported a growing trend in deploying new and advanced imaging modalities in Asia. Multi-slice CT for example was noted in the report (2010) as becoming widespread in India. Another report by Electronics.ca Research Network (2008) states that Europe represents the largest market for 3D imaging applications and this market segment will be driven further by the continuous development of MRI, CT and Ultrasound.

In 2007, the <sup>49</sup> published a report on the availability of advanced modalities such as CT and MRI across OECD countries for the year 2005. In the report, Japan was ranked as having the highest number of CT and MRI units per capita, followed by Australia for CT units and the United States for MRI units. Turkey, Hungary and Mexico were ranked the lowest. It was suggested that factors such as national income and total health spending could play a role in influencing the diffusion of these technologies. Figure 1, excerpted from the <sup>49</sup> report, shows the top ten countries for CT and MRI units per capita. To date, based on OECD Health Data 2010, it was further reported that between 2000 and 2008, there were more than doubled on average for MRI units per capita for OECD countries, in this case from 6 MRI units per million populations in 2000 to 13 in 2008.<sup>18</sup> Japan, the United States, Italy and Greece were mentioned to have a greater number of MRI units per capita in comparison to other OECD countries. The number of CT scanners also increased from 19 per million populations in 2000 to 24 in 2008.<sup>18</sup>



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\*In Japan, data for CT scanners relate to 2002 rather than 2005, because the 2005 data is more limited in terms of coverage of institutions and type of CT scanners.

#### Figure 1: Top Ten OECD Countries for MRI and CT Units Deployment

Research suggests that a country's wealth and health expenditure can influence the rate of diffusion of expensive medical technologies, particularly in radiology. <sup>50</sup> statistically tested five categories of variables, namely purchasing power, patient needs, physician demand, government regulation and payment methods on the data of thirty OECD countries to examine the factors that influence the diffusion rate of CT and MRI. The study found that purchasing power, which is represented by a nation's total annual health expenditure and economic incentives to hospitals, can influence the diffusion rate for CT and MRI. The research findings of <sup>50</sup> confirmed many similar views about why there has been a huge disparity between developed and developing or non-rich countries with regard to deploying advanced imaging modalities. See also for example a study conducted by <sup>34</sup> which found a low diffusion rate of MRI in several Asian countries (China, India, Indonesia, Republic of Korea, Malaysia, Philippines, Thailand and Hong Kong).

Further, there is a notable trend in the increasing frequency of use of advanced modalities. In the United States, from 1992 to 2001, there was an increased utilization of MRI and interventional radiology, but a relatively unchanged level of use of radiography.<sup>5</sup> Another study by <sup>39</sup> that examined in-patient radiology utilization trends from 1984 to 1993 in one tertiary hospital in the United States reported a significant increase in the use of CT and MRI, and a decrease in conventional imaging studies (plain films and fluoroscopy). A follow-up study conducted by  $^{43}$ , using a similar method to examine in-patient radiology utilization from 1993 and 2002, also reported a similar trend. According to <sup>61</sup>, in the UK, from April 1997 to March 1998, there were about 41.5 million medical and dental x-ray examinations conducted annually. Among NHS hospitals, the study found that the highest increment in frequency came from CT, interventional radiology and mammography examinations. For the period from 1997 to 2002, there was a constantly increasing demand for CT, MRI and non-obstetric ultrasound procedures and a relatively slight demand growth for ultrasound, radiographs, fluoroscopy, nuclear medicine and obstetric ultrasound among English NHS hospitals.<sup>27</sup>



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#### 2.2. PACS

PACS has been widely implemented across hospitals all over the world. Global Data for example reported the total sales of the technology in 2008 accounted for 67% of the European radiology market.<sup>48</sup> According to the UK NHS (National Health Service), under the NPfIT (National Programme for IT) initiatives, as of 2007, there were about England 127 trusts in with PACS (http://www.connectingforhealth.nhs.uk/newsroom/news-stories/pacs-rollout). By early 2008, the UK Department of Health announced that the NHS had completed the installation of PACS across all UK hospital trusts under the NPfIT initiative.<sup>48</sup> In the United States, some analysts were optimistic that 90% of the health care facilities in the country would be equipped with PACS by 2010.<sup>37</sup> In the Asia Pacific region, Japan has been a leading player in PACS technological developments. Hence, it is not surprising that several studies mentioned the rapid growth of PACS installations in Japanese hospitals since the 1980s.<sup>35,36,56</sup> As of 2002, it was reported that 1468 PACS units had been installed across Japanese hospitals.<sup>36</sup> The same study also mentions the increasing diffusion of PACS among hospitals in Korea and Hong Kong, although in the context of Hong Kong public hospitals, <sup>9</sup> state that the utilization of PACS usually does not extend outside the radiology department. The growing diffusion of PACS is also reported in Taiwan<sup>8</sup> and China<sup>25</sup>. <sup>11</sup> estimated PACS accounted for 43% of the radiology informatics market in China in 2008.

In other developing countries such as in the South East Asia region, it has been suggested that PACS has a slow diffusion rate. <sup>23</sup> attributed the slow growth in this region to factors such as high cost, under-developed health care facilities and a lack of ability to deliver the high-technology infrastructure required. Nevertheless, due to the proactive role of the government and increasing demand in the medical tourism sector such as in the case of Malaysia, Thailand and the Philippines, Frost & Sullivan anticipated a positive growth for the South East Asia market in 2009. As for third world countries, the status of PACS diffusion is unknown. However, there have been several on-going projects that capitalize on the innovative features of PACS to provide healthcare radiology assistance under e-health and telehealth initiatives to help various third world countries, including some from Africa.<sup>21,44</sup>

#### 2.3. RIS/HIS Integration

A large-scale PACS installation will include RIS and HIS applications. Whilst PACS enables the efficient storage, processing, management and retrieval of image data, RIS on the other hand, permits online diagnostic reporting, patient scheduling, tracking of patient images and billing. For PACS and RIS to effectively support radiology in a hospital, important data such as patient registration, admission and discharge needs to be obtained from the HIS database. Some technical details pertaining to PACS/RIS/HIS integration can be read from <sup>31</sup> and <sup>6</sup>. A study that surveyed more than 275 sites that had implemented PACS reported that over 75% of the sites had an interface with RIS, and about 48% had an interface with HIS.<sup>51</sup> According to <sup>7</sup>, the growth of the RIS market is largely pushed by the expansion of the filmless work environment. RIS was argued to have low usage in a film-based radiology work practice.<sup>7</sup> Initiatives such as Integrating the Health Care Enterprise (IHE) taskforce that is responsible for establishing common integration standards such as DICOM and HL7



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have facilitated the complex integration and interface between these major components of medical imaging.  $^{6,28}$ 

# 3. Key Issues for Developing Countries

Learning from the existing trend, there are three key issues which can be drawn in implementing medical imaging technologies.

First, the increasing deployment of advanced imaging modalities such as CT and MRI will continue to drive greater demand for PACS installations. It is widely acknowledged in the literature that the use of advanced imaging modalities will lead to a higher volume of radiology images that need to be stored, processed and retrieved. PACS has been developed specifically to deal with the storage, access, distribution and retrieval of images. This dependency suggests that there will be an increasing number of healthcare organizations, particularly hospitals, which will consider moving from film-based to filmless work environments.

Secondly, despite the fact that acquiring medical imaging requires substantial resources, the technology has been increasingly deployed in developing and third-world countries. <sup>26</sup> argue that there is a trend amongst the governments of these countries to expand public radiology service infrastructures and access, including the acquisition of advanced imaging modalities and applications. Due to these government initiatives,<sup>23,24</sup> have positively anticipated the growing demand for medical imaging, particularly in the case of South East Asia and the Eastern Europe regions. Malaysia is an example of such a nation where the government via the role of Ministry of Health is responsible in making strategic decisions to deploy the technology into the public healthcare organizations.

Finally, the global rise in healthcare consumerism and medical tourism will spur medical imaging and teleradiology adoptions worldwide. In the United States for example, the increased demand for radiology service has spurred rise in outsourcing of radiology services to India as well as Australia.<sup>55</sup> At present, Nighthawk Radiology Services (<u>http://www.nighthawkrad.net/</u>) has capitalized teleradiology to create business opportunities and to take advantage of the increasing demand for radiology services<sup>68</sup>. <sup>16</sup> argued that the main push to adopt teleradiology is to acquire the ability to tap into healthcare expertises in another institution. Medical imaging in particular can be extended to support teleradiology and teleconsultation activities. The American College of Radiology (<u>http://www.acr.org/</u>) defined the goals of teleradiology as follows:

- Providing consultative and interpretative radiological services in areas of need
- Making radiological consultations available in facilities without onsite radiological support
- Providing timely availability of radiological images and radiological image interpretation in emergent and non-emergent clinical care areas
- Facilitating radiological interpretations in on-call situations
- Providing subspecialty radiological support as needed
- Enhancing educational opportunities for practicing radiologists
- Promoting efficiency and quality improvement
- Sending interpreted images to referring providers
- Supporting telemedicine



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• Providing direct supervision of off-site medical imaging

As for medical tourism, we anticipate a positive growth of the industry will encourage more deployment of medical imaging particularly among private healthcare institutions in the developing countries. It was noted that Malaysia, Singapore, and Thailand are the potential countries in Asia for medical tourism.<sup>4,15,29</sup> Frost & Sullivan projected more hospitals in Asia Pacific that are interested to take part in this industry will make an attempt to upgrade their medical imaging systems to meet patients' high expectations.<sup>64</sup>

# 4. Lessons Learned for Developing Countries

From the standpoint of developing countries, there is no doubt that medical imaging deployment can offer substantial benefits. However, it is important to understand the challenges of implementing the technology particularly in the context of a hospital-wide utilization. Some of the key challenges are as follows:

# • Require a substantial and ongoing investment

Overall, the implementation of technological components of medical imaging particularly digital imaging modalities and PACS/RIS is very expensive. It is widely acknowledged in the literature that limited financial resource is the main factor that can hamper the growth of medical imaging adoption in healthcare institutions of developing countries. The World Health Organization (WHO) for example has noted consistently how these factors among others can slow down the deployment and use of important medical technologies and devices that can save many lives. Obtaining a substantial and ongoing funding to purchase, install and maintain the technology is a major challenge for healthcare organizations of developing countries.

# • Require a good understanding on the complexities in implementing and managing the technology, as well as extending its application to support teleradiology activities

Many studies describe medical imaging implementation as risky, expensive and complicated. Its implementation success rate depends on many factors. Among them are: the commitment of key stakeholders and decision makers, the support from clinicians and radiologists, the high frequency of user training and technical support, and the ongoing support from suppliers and vendors.<sup>33,38,52,53</sup> A good understanding on the complexities and issues related to implementing the technology is very crucial in order to have a successful implementation plan for a hospital-wide medical imaging installation.

# • Providing good ICT (Information Communication and Technology) service support, and training to users

Technology users particularly radiologists, clinicians, radiographers and nurses require efficient good and reliable ICT technical support services to facilitate their day-to-day use of medical imaging applications particularly PACS



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and RIS. PACS and RIS can automate many aspects of traditional radiology activities. Providing good ICT service and frequent training to these users can help to increase the adoption rate and effective use of the technology in organization.

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#### References

- Abella, H.A. (2009). X-rays and CT offer predictive power for swine flu diagnosis. *Diagnostic Imaging*. Retrieved from http://www.diagnosticimaging.com/digital-x-ray/content/article/113619/1425699.
- Adam, C.W.S. (2010). Enterprise Imaging Informatics: PACS in Radiology and Beyond. Retrieved from <u>http://binaryhealthcare.files.wordpress.com/2010/06/enterprise-imaging-informatics-pacs-in-radiology-and-beyond.pdf</u>.
- [3] Androuchko, V and Parlette, B. (2006). Low cost teleradiology for developing countries. In e-Health Networking, Applications and Services, 2006. HEALTHCOM 2006. 8th International Conference on 17-19 August 2006, New Delhi, India.
- [4] Arunanondchai, J. and Fink, C. (2007). *Trade in Health Services in the ASEAN Region*. World Bank Research Policy Paper No. 4147. World Bank.
- [5] Bhargavan, M and Sunshine, J.H. (2005). Workload of radiologists in the United States in 2002-2003 and trends since 1991-1992. *Radiology* 236(3), 920-31
- [6] Boochever, S.S. (2004). HIS/RIS/PACS Integration: Getting to the Gold Standard. Radiology Management, May/June 2004.
- [7] Cannavo, M.J. (2008). *Reinvigorating RIS*. Retrieved from <u>http://enterprise-imaging-radiology</u> management.advanceweb.com/Editorial
- [8] Chang, I. C., H.-G. Hwang, et al. (2006). Critical factors for adopting PACS in Taiwan: Views of radiology department directors. *Decision Support Systems* 42(2), 1042-1053.
- [9] Cheung, N.-T., Lam, A et al. (2005). Integrating images into the electronic patient record of the hospital authority of Hong Kong. *Computerized Medical Imaging and Graphics* **29**(2-3), 137-142.
- [10] Clearstate.com. (2008). South East Asia's X-ray market reached USD90million in 2007 with strong growth led by Thailand and Vietnam. Retrieved from <u>http://clearstate.com/2008/south-east-asias-x-ray-market-reached-usd90-million-in-2007-pdf/</u>
- [11] Clearstate.com. (2009). Penetration of Radiology Informatics in China: A nascent market with growing interest in workflow and imaging applications. Retrieved from <u>http://clearstate.com/2009/penetrationof-radiology-informatics-in-china-a-nascent-market-with-growing-interest-in-workflow-and-imagingapplications/</u>
- [12] Clearstate.com. (2010). India's diagnostic imaging market reached USD380million in 2008. Retrieved from <u>http://clearstate.com/2010/india%E2%80%99s-diagnostic-imaging-market-reached-usd380-million-in-2008/</u>
- [13] Computer Business Review. (2007). UK NHS digital x-rays rollout to be completed by 2008. Retrieved from http://www.cbronline.com/news/uk\_nhs\_digital\_x\_rays\_rollout\_to\_be\_completed\_by\_2008
- [14] Cury, R.C., Techasith, T., et al. (2011). Cardiovascular Disease and Stroke in Women: Role of Radiology. AJR 196, 265-273.
- [15] Davis, L and Erixon, F. (2008). The health of nations: Changing approaches to trade in health care. *Fraser Forum* 09(08), 28-31.
- [16] Dimmick, S.L. and Ignatova, K.D. (2006). The diffusion of a medical innovation: where teleradiology is and where it is going. *Journal of Telemedicine and Telecare* 12 (Suppl.2), S2, 51-58.
- [17] Dinan, M.A., Curtis, L.H., et al. (2010). Changes in the Use and Costs of Diagnostic Imaging Among Medicare Beneficiaries With Cancer, 1999-2006.
- [18] EAHP European Association of Hospital Pharmacists. (2010). EU Monitor, 42. Retrieved from <u>http://www.eahp.eu/News/EU-Monitor/OECD-Health-Data-2010-report-shows-growth-in-health-spending</u>.
- [19] Editor. (2008). The Diagnostic Radiology Exam of the Future: The Law of Unintended Consequences Meets the Law of Supply and Demand. AJR 190, 1147-1148.
- [20] Electronics.ca Research Network. (2008). Global 3D Medical Imaging Market to Reach \$3.9 billion by 2012. Retrieved from http://www.electronics.ca/presscenter/articles/970/1/Global-3D-Medical-Imaging-Market-to-Reach-39-billion-by-2012/Page1.html



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Accepted: March 16, 2011

- [21] Ferguson, E.W., Doarn, C.R., et al. (1995). Survey of Global Telemedicine. *Journal of Medical Systems* 19(1): 35-46.
- [22] Freedonia Group, Inc. (2007). U.S. Demand for Medical Imaging Products to Reach \$21.4 Billion in 2010. Retrieved

from http://www.redorbit.com/news/health/863550/us\_demand\_for\_medical\_imaging\_products\_to\_rea ch\_214\_billion/index.html

- [23] Frost & Sullivan. (2006). Southeast Asian Picture Archiving and Communication Systems Market. Retrieved from <u>http://www.marketresearch.com/map/prod/1399386.html</u>
- [24] Frost & Sullivan. (2008). Growth Opportunities in the Medical Imaging Sector. Retrieved from <u>http://www.frost.com/prod/servlet/cpo/155480312</u>
- [25] Fu, H., Jin, Z., et al. (2003). Picture archiving and communication system in China: the development, problem, and integrating strategy with IHE. *International Congress Series* 1256, 915–923.
- [26] Garner, P., Kiani, A et al. (1997). Editorial: Diagnostics in developing countries. BMJ 315, 760-761.
- [27] Hart, D and Wall, B.F. (2004). UK population dose from medical X-ray examinations. *European Journal of Radiology* 50, 285-291. http://www.connectingforhealth.nhs.uk/newsroom/news-stories/pacs-rollout
- [28] Hood, M. N. and H. Scott. (2006). Introduction to Picture Archive and Communication Systems. *Journal of Radiology Nursing* 25(3), 69-74.
- [29] Horowitz, D.M. et al. (2007). Medical Tourism: Globalization of the Healthcare Marketplace. MedGenMed, 9(4), 33.
- [30] Hynes, D. M., G. Stevenson, et al. (1997). Towards filmless and distance radiology. *The Lancet* 350(9078), 657-660.
- [31] Huang, H. K., R. K. Taira, et al. (1993). Implementation of a large-scale picture archiving and communication system. *Computerized Medical Imaging and Graphics* **17**(1), 1-11.
- [32] Huang H. K.. (1999). Picture archiving and communication systems: principles and applications, Wiley, New York.
- [33] Huang, H. K. (2003). Some historical remarks on picture archiving and communication systems. *Computerized Medical Imaging and Graphics* 27(2-3), 93-99.
- [34] Hutubessy, R.C.W., Hanvoravongchai, P., and Edejer, T.T. (2002). Diffusion and Utilization of Magnetic Resonance Imaging in Asia. *International Journal of Technology Assessment in Health Care* 18(3), 690-704.
- [35] Inamura, K., J. Konishi, et al. (2001). Status of PACS and technology assessment in Japan. Computer Methods and Programs in Biomedicine 66(1), 5-15.
- [36] Inamura, K., K. Satoh, et al. (2003). Technology assessment of PACS in Osaka University Hospital. Computer Methods and Programs in Biomedicine 43(1-2), 85-91.
- [37] Jackman, M.W. (2004). A Digital Imaging Transformation in Radiology Departments. HCT Project Volume 2. Retrieved from <u>http://www.hctproject.com/documents.asp?grID=332&d\_ID=2776</u>
- [38] Kinnunen, J. and Pohjonen, H. (2001). PACS in Toolo Hospital. Computer Methods and Programs in Biomedicine 66(1), 31-35.
- [39] Khorasani, R., Goel, P.K., et al. (1998). Trends in the Use of Radiology with Inpatients: What Has Changed in a Decade. AJR 170, 859-861.
- [40] Lim, C.C.T., Goh, J.S.K., et al. (2003). CT and Picture Archiving and Communication Systems: Radiology Response to the SARS Outbreak [letter], *Radiology* 228, 901.
- [41] Littlejohns, P and Wyatt, J.C. (2003). Evaluating computerised health information systems: hard lessons still to be learnt. *BMJ* 326, 860-863.
- [41] Lysdahl, K.B and Hofmann, B.H. (2009). What causes increasing and unnecessary use of radiological investigations? A survey of radiologists' perceptions. *BMC Health Services Research* 9, 155.
- [42] Marketwatch (2007). PACS market growth set to continue. *CBR* **6**(6), 172-173.
- [43] Matin, A., Bates, D.W., et al. (2006). Inpatient Radiology Utilization: Trends over the Past Decade. AJR 186, 7-11.
- [44] Mbarika, V. (2004). TeleMedicine in Africa: A Possible Panacea for Sub-Saharan Africa's Medical Nightmare, *Communications of the ACM* **47**(7), 21-24.
- [45] McLoud, T.C.(2000). Education in radiology: challenges for the new millennium. AJR 174, 3-8.
- [46] Mettler, F.A. (1987). Diagnostic Radiology around the World. *Radiology* **175**, 577-579.
- [47] Mettler, F.A., Haygood, T.M., et al. (1990). Diagnostic Radiology: Usage and Trends in the United States, 1964-1980. *Radiology* 162, 263-266.
- [48] Next Generation Healthcare. (2011). *The future of private sector medical imaging*. Retrieved from <u>http://www.nghealthcareeurope.com/article/The-future-of-private-sector-medical-imaging/</u>.
- [49] OECD. (2007). Healthcare Resources and Utilisation. In Health at a Glance 2007: OECD Indicators. Retrieved from <u>http://www.oecd.org/health/healthataglance</u>



Submitted: July 18, 2010

Accepted: March 16, 2011

- [50] Oh, E, Imanaka, Y, and Evans, E. (2005). Determinants of the diffusion of computed tomography and magnetic resonance imaging. *International Journal of Technology Assessment in Health Care* 21(1), 73-80.
- [51] Ondo, K. (2004). PACS Direct Experiences: Implementation, Selection, Benefits Realized. Journal of Digital Imaging 17(4), 249-252.
- [52] Pare, G. and M.-C. Trudel. (2006). Knowledge barriers to PACS adoption and implementation in hospitals. *International Journal of Medical Informatics, In Press, Corrected Proof, 1-12.*
- [53] Pilling, J. R. (2002). Lessons Learned from a Whole Hospital PACS Installation. *Clinical Radiology* **57**(9), 784-788.
- [54] Ratib, O., F. Terrier, et al. (1996). Evolution of PACS concepts in hospital environment. *RBM-News* 18(5), 112-121.
- [55] Reinus, W.R. (2007). American Radiology and Outsourcing. Radiology 242, 654-657.
- [56] Saranummi, N., Akisada, M., et al. (1992). User requirements and standards for PACS. 2nd Japan-Nordic PACS Symposium. *Comput Methods Programs Biomed* 37(4), 237-245.
- [57] Schafer, J.R.A., Agarwal, P and Kazerooni, E.A. (2010). Radiology Resource Utilization During an H1N1 Influenza Outbreak. *J Am Coll Radiology* **7**, 28-32.
- [58] Sikora, K. (2002). The impact of future technology on cancer care. Clin Med JRCPL 2, 560-8.
- [59] Smith-Bindman, R., Miglioretti, D.L., and Larson, E.B. (2008). Rising Use of Diagnostic Medical Imaging In a Large Integrated Health System. *Health Affairs* 27(6), 1491-1502.
- [60] Smith T.N. and Baird, M. (2007). Radiographers' role in radiological reporting: a model to support future demand. *Med J Aust* 186, 629-631.
- [61] Tanner, R.J., Wall, B.F., et al. (2000). Frequency of Medical and Dental X-Ray Examinations in the UK, 1997-98. Retrieved from <u>http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb\_C/1195733773072</u>
- [62] The European Science Foundation. (2007). Medical Imaging for Improved Patient Care. Science Policy Briefing. Retrieved from
- http://www.esf.org/fileadmin/links/EMRC/ESF\_POLICY28\_V09\_HD.pdf. [63] Thompson Reuters. (2010). *Fact File: Outpatient Trends*. Retrieved from http://thomsonreuters.com/content/healthcare/pdf/articles/539697.
- [64] TradingMarkets.com. (2011). Global Installed Base of Computed Tomography (CT) Scanners to Reach About 60 Thousand Units by 2015, According to New Report. Retrieved from <u>http://www.tradingmarkets.com/news/stock-alert/mdsy\_global-installed-base-of-computedtomography-ct-scanners-to-reach-about-60-thousand-units-by-2015--1433584.html.</u>
- [65] TradingMarkets.Com. (2010). Frost & Sullivan: APAC's Medical Imaging Market Is Looking Up. Retrieved from <u>http://www.tradingmarkets.com/news/stock-alert/frsu\_frost-amp-sullivan-apac-s-medical-imaging-</u>
- market-is-looking-up-1038904.html [66] Tsou, I.Y.Y., Goh, J.S.K., et al. (2003). Severe Acute Respiratory Syndrome: Management and
- Reconfiguration of a Radiology Department in an Infectious Disease Situation. Radiology 22, 21-26. [67] UN News Centre. (2009). World facing global A(H1N1) flu pandemic, announces UN health agency.
- Retrieved from http://www.un.org/apps/news/arty.asp?NewsID=31106&Cr=h1n1&Cr1.
- [68] Washington Times. (2008). Outsourcing Images. Retrieved from <u>http://www.washingtontimes.com/news/2008/mar/20/outsourcing-images/</u>