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DIFFUSION AND UTILIZATION OF MAGNETIC RESONANCE IMAGING IN ASIA

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Abstract

Objectives: An assessment of the current status of magnetic resonance imaging (MRI) was undertaken to provide input for future government decisions on the introduction of new technologies in Asia. The objective of the study is to describe and explain the diffusion pattern of this costly technology in several Asian settings.
Methods: Data on the diffusion pattern of MRI for different Asian countries (the Republic of Korea, Malaysia, Indonesia, the Philippines and Thailand) and regions (the cities of Shanghai and Hong Kong in China and the state of Tamil Nadu in India) were obtained from national representatives of professional bodies by using standardized questionnaires for the year 1997–98. In addition, utilization data were collected at the hospital level in three countries before and after the economic crisis in the region. For four countries plus Hong Kong, background information on the legal framework for "big ticket" technologies was collected.
Results: Since the introduction of the first MRI in the region in 1987, the number of MRIs has gradually increased both in public and private facilities in Asia. In 1998 the average number of MRI machines installed varied from less than 0.5 machine per million population to more than 5 machines per million population. The maintenance and operating costs, and not the absence of regulation, account for the low number of MRIs in the Philippines and Malaysia. Overall, installed MRIs have low magnetic field strength, vary with respect to brand and type, and are mostly in the private sector and in the urban areas of the region. The diffusion pattern of MRIs in countries of the Asian region appears to follow two types of patterns of diffusion: one set of countries seems to be composed of mostly early adopters and another set of countries appears to be composed mostly of late adopters.
Conclusions: Total number of MRIs per population in this region, though quite small compared to most OECD countries, reflects a higher share of the country's healthresource devoted to expensive high-technology devices. It is difficult to state the appropriate number of MRIs for each country; however, the study shows that there are observable problems in terms of efficiency, equity, and quality of MRI services. The research team proposes a few key recommendations to counteract these problems. Purchasing and regulatory bodies must be empowered with skill and knowledge of health technology assessment. Likewise, the fundamental problems resulting from inefficient and unfair health financing should not be overlooked, so that there is more equitable use of the technology.

Keywords: Magnetic resonance imaging, Health technology assessment, Diffusion, Economic impact, Developing countries

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Since its introduction in the early 1980s, magnetic resonance imaging (MRI) has become a familiar part of medical apparatus available for the diagnosis of different conditions. Its rapid diffusion has been documented in several countries, mostly developed. By 1993, there were more than 4,000 units worldwide (16). In the United States alone, over 2,700 were in use by 1997 (13). Similar information is less available for developing countries.

There are several routes for the diffusion of technology in developing countries (3). In the public sector, a common route is through "tied aid," where purchase of equipment is conditional on sourcing from the donor country. In the private sector, one major route is through investments by individuals or groups of individuals who believe there is a market for such equipment and have the capital to invest. In many cases, these individuals are wealthy doctors who bring in equipment, which they themselves use.

In both public and private sectors, a marketing strategy commonly employed is a rent-free "loan" of new equipment. The cost of the equipment is bundled into prices of reagents set in an exclusivity contract between the health facility and the supplier. If the full cost of the equipment cannot be bundled into the cost of supplies and consumables, an option-to-buy clause after a prespecified rent-free loan period is specified in the contract. This loan period is usually long enough to create dependence of the health facility on the loaned equipment. Thus, an optional action becomes, more often than not, mandatory to avoid disruption of set routines. A final route of technology acquisition in developing countries is through universities and research institutes, which collaborate with their counterparts in the developed world and get equipment as part of their share in the research grants.

In many of the developing countries, technology can enter "generally without control or supervision by any agency of the receiving government" (3). Lack of regulation gives rise to several areas of concern about the quality of care provided, as discussed below.

Once the market for equipment has been established, a stream of upgrades can follow. Hospitals are judged on their technological superiority by clients who believe that the more sophisticated the equipment, the better the care (17). Thus, a "me too" phenomenon is spawned. Hospitals, despite their close proximity with each other and potential ease of referral, will insist on in-house availability of equipment. Smaller or lower capitalized hospitals will attempt to purchase equipment, albeit of a lower model and cost. Discards from hospitals in developed countries that have upgraded are purchased by hospitals in developing countries on a second-hand basis. Depending on how old these models are, some models may run into maintenance problems because the manufacturer may have discontinued production of spare parts.

When imported technology is tied to sourcing from the donor country, problems may arise with maintenance and availability of spare parts (4), especially if there is no local distributor. Once funding assistance has been accepted, "white elephants" loom on the horizon. Another area of concern is the scarcity of qualified individuals to maintain the machine in good working condition, to operate the machine, and to interpret the results. The few qualified individuals present in health facilities are constantly being "pirated" by rival hospitals within or even outside the country.

The phenomenon of the physician-entrepreneur has been described elsewhere (17). Physicians become entrepreneurs when they purchase expensive equipment from which they expect a profitable return on investment. This places the physician in a potential conflict-of-interest position (1). On the one hand, the physician is expected to act on behalf of his patients and undertake diagnostic and treatment interventions based on medical indications. On the other hand, he is an entrepreneur who wishes to recoup his investment in a reasonably short period of time and may be tempted to take advantage of situations where indications are not explicitly stated, or are vague with considerable leeway.

Such concerns make it imperative to understand the extent and determinants of the system-wide diffusion and utilization of new medical technologies, which are believed to drive healthcare costs upward (14).

THE ASIAN MRI STUDY GROUP AND OBJECTIVES

In 1997 and 1998, some Asian countries witnessed a dramatic recession of their economies and the viability of some of their expensive investments in health were threatened. The onset of the economic crisis in Thailand was in July 1997, immediately followed by Indonesia and some months later by the Philippines. In the same period, members of the Asian Health Technology Assessment Network met twice in Bangkok, Thailand (December 1997 and March 1998) to discuss the details of their first collaborative project on the diffusion and utilization of healthcare technology and its impact on quality of care. The following countries were represented in this collaborative study: China (represented by Shanghai and Hong Kong), India (represented by the State of Tamil Nadu), Indonesia, Republic of Korea, Malaysia, the Philippines, and Thailand (Appendix 1).

MRI was selected as the technology to be evaluated because of its potential to illustrate some of the concerns previously mentioned. MRI is an important imaging modality for examinations of the brain, spine, head, and neck. It is a relatively new imaging method that uses a combination of magnetic fields and radio waves. Being a piece of imaging equipment, it was felt that there would most likely be central sources of data on the presence of MRIs in different hospitals because of licensing requirements and safety concerns.

Costs and technical performance of MRIs are likely to vary, depending on the type and strength of their magnets. Hence, it was thought that the presence of different technical specifications of magnets of MRIs might lead to different patterns of diffusion (i.e., because of lower costs of purchase and maintenance for type of magnet) and utilization (i.e., expectation of higher resolution and better images with magnets of higher strengths) that could be analyzed in the study.

The following objectives of the Asian MRI study group were agreed upon:

- To compare the diffusion of MRI in each country according to type of technology acquired, mode and time of acquisition, and host institution by location, ownership, type and size of institution, and teaching status;
- To determine variables in the economic, legal/regulatory, and healthcare sector environment that can potentially explain differences in the diffusion of MRI in each country;
- To describe utilization patterns of MRI in selected hospitals in each country; and
- From the different country experiences, to provide general recommendations to facilitate rational diffusion and utilization of MRI.

In October 1998 a final meeting was organized in Khonkaen, Thailand, where the individual countries presented their results. This article reports the final results of this collaborative initiative.

METHODS

Data Collection

All countries participated in the diffusion phase of the study, and depending on the availability of institutional resources, also in the utilization phase of the study. Most recent data, preferably 1997–98, were collected at the national level for the diffusion study and at the hospital level for the utilization study. For pragmatic reasons, in the two largest study

countries, India and China, data collection was limited to the regional level. For India, data came from the State of Tamil Nadu, while China limited its data collection to Shanghai and Hong Kong. A standardized questionnaire was developed for the survey and distributed among the participating members of the project. Data were entered centrally using MS Excel™, and descriptive statistics were generated.

Data Sources

National Level Data Including MRI Diffusion Data. To give a general picture of the member countries in the study, main demographic, epidemiologic, socio-economic, and financial features at country level were collected from the different sites (e.g., total population, life expectancy at birth, proportion of urban versus rural population, literacy rate, poverty threshold, etc.). Most of the data from the national level came from existing documents from different national ministries and regulatory bodies, supplemented with key informant interviews and small, purposeful surveys. Missing country or province data were completed using the World Development Indicators/World Bank database (19).

Key variables collected on the adoption and diffusion of MRI in the different study sites were the total number of MRIs installed, year of first MRI installed, brand names, MRI strength, type of MRI, location, and ownership. Key informant interviews were carried out to determine the influence of regulatory and nonregulatory factors on the decision of a health facility to acquire an MRI.

Hospital Utilization Level Data

For the hospital level of data collection, convenience sampling was based on access to patient records in a hospital (preferably public and Ministry of Health). One hundred consecutive patient charts were sampled in two time periods: approximately 3 months before and 3 months after the onset of economic recession. The remaining data were gathered by key informant interviews of the administrators of the hospital and by focus group discussion with physicians using MRI facilities. Key variables collected were number of patients, including background information of the patients who underwent MRI scan, sites of organ scan, specialty of the prescriber of the MRI, and mode of payment of each patient receiving MRI.

RESULTS

General Description of the Study Countries

General country information is found in Table 1. Except for Hong Kong, we report the national numbers and features of all the member countries in the project. The study countries represented almost 44% of the global population in 1998 (19). Most of the study countries have a predominantly rural population. The top three study sites with the highest ratio of health spending to gross domestic product (GDP) are Hong Kong, Republic of Korea, and Thailand (more than 5%). Furthermore, the public health component of total health expenditure varies from around 22% in India to 56% in Malaysia (19).

Diffusion Pattern

As an indicator of medical technology in the region, the number of computed tomography (CT) scans per million population shows wide variation (e.g., 179 CT scans per million population for the Republic of Korea compared with 0.3 CT scan per million population in Indonesia) (Table 2).

MRI Availability. The number of MRI per million population shows quite similar patterns to those of the number of CT scans in the study countries (Table 2). The same countries anchor the high (Korea) and low (Indonesia) ends of distribution for both MRIs

Table 1. General Country Information, 1998

	China	India	Indonesia	Korea	Malaysia	Philippines	Thailand	Hong Kong
Population, total (million)	1,238.6	979.7	203.7	46.4	22.2	75.2	61.2	6.7
Urban population (% of total)	31.1	27.8	38.8	80.4	55.9	56.8	21.0	100.0
GDP per capita (current US $)	774	439	462	6,908	3,268	866	1,819	24,889
GDP per capita, PPP (current international dollars)	3,105	2,077	2,651	13,478	8,137	3,555	5,456	20,763
Official exchange rate (LCU per US $)	8.3	41.3	10013.6	1401.4	3.9	40.9	41.4	7.7
Health expenditure, total (% of GDP)	4.55[a]	NA	1.33	5.58[a]	2.37	3.70	6.18	5.02[b]
Health expenditure, public (% of GDP)	1.97[a]	NA	0.63	2.54[a]	1.33	1.67	1.65	2.25[b]
Health expenditure per capita (current US $)	33.27[a]	NA	6.14	578.28[a]	77.51	32.01	112.47	1,134.40[b]

Source: [19]
[a] 1997.
[b] 0995.

Table 2. Number, Number per Million, and Year of First Installed MRI in the Asian Region

Country	Number of CT scans per million	Total number of MRI by 1998	Number of MRIs per million	Year of first MRI installment	Average number of MRIs adopted per year
Shanghai (China)	67	12	0.92	1987	1.0
Tamil Nadu (India)	NA	10	0.18	N.A.	N.A.
Indonesia	0.3	9	0.13	1990	1.1
Republic of Korea	179	245	5.4	1988	24.5
Malaysia	3.3	26	0.8	1990	3.3
Philippines	1.1	11	0.16	1989	1.2
Thailand	3.8	28	0.47	1988	2.8
Hong Kong (China)	2.1	12	1.81	1992	2.0

and CT scans. Roughly the region can be categorized into three groups according to MRI availability: a) the Republic of Korea with more than five machines per million population; b) Hong Kong, Shanghai, and Malaysia with approximately 1–2 machines per million population; and c) Thailand, Tamil Nadu, Indonesia, and the Philippines with less than 0.5 machine per million population.

Adoption Rate. In general the study sites adopted their first MRI during the period from 1987–90. In terms of average adoption rate, the Republic of Korea has the highest rate with 24.5 MRIs per year, followed by Malaysia (3.2 MRIs per year), Thailand (2.8 MRIs per year) and Hong Kong (2.0 MRIs per year). The remaining study countries introduced less than 2 MRIs on average per year.

Figure 1 gives a more detailed pattern of the adoption of MRI in the region. The horizontal axis plots the year of adoption—starting from 1987 when the first MRI was installed in the region—while the vertical axis denotes the total MRIs installed per million population at the different study sites. The steeper curve for the Republic of Korea starting in 1988 characterizes it as an early adopter, with a persistent increase until 1998. The remaining study sites have an almost straight or concave curve, characterized as predominantly consisting of early adopters of MRI but resulting only in a small increase of MRIs per million population.

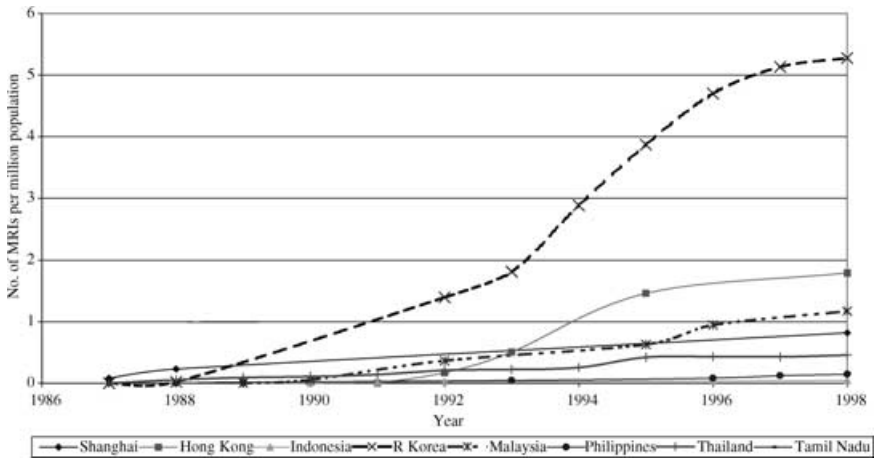

Figure 1. MRI diffusion pattern for study countries from 1986 until 1998 (per million population).

Table 3. MRI Ownership Characteristics in the Asian Region

Country (number of MRIs in 1998)	Public/private ownership ratio	Hospital/free-standing ratio	Capital/rural ratio	University/ others	Tertiary care/others
Shanghai, China (12)	100/0	100	NA	13/67	83/17
Tamil Nadu, India (10)	0/100	90	40/60	20/80	100/0
Indonesia (9)	33/67	89	66/33	22/78	NA
Republic of Korea (245)	0/100	95	40/60	30/70	29/71
Malaysia (26)	31/69	100	100/0	8/92	100/0
Philippines (11)	0/100	91	60/40	27/73	100/0
Thailand (28)	68/32	68	68/32	29/71	NA
Hong Kong, China (12)	50/50	100	NA	17/83	NA

Ownership and Location. All of Shanghai's MRIs are owned by the government, whereas Thailand has 68% and Hong Kong has 50% in the public sector. In the remaining countries, all (Philippines and Korea) or a majority (Indonesia and Malaysia) of MRIs are owned privately. Many of them are located in non–university-affiliated tertiary care hospitals. Thailand has the unique phenomenon of hosting a third of their MRIs in freestanding locations (Table 3).

Technical Characteristics. On average, about half of the MRI units installed (approximately 50%) in the selected countries have a low magnetic field strength (MFS). On both extremes are Tamil Nadu and Hong Kong: 90% of the MRIs installed in Tamil Nadu have a low MFS, while Hong Kong has MRIs with either middle or high MFS. The majority of the MRIs in Indonesia, Malaysia, Thailand, Republic of Korea, and the Philippines are superconducting electromagnet MRIs (Table 4).

Brand. No single brand is dominating the market or has a monopoly in the region. On average, almost 50% of the market share is possessed by Siemens and General Electric (Table 4).

Purchase Costs. For Thailand, acquisition costs range from US $1 million to $2.1 million with poor to good perceived viability. For the Republic of Korea, purchasing costs by lease vary from $200,000 to $270,000. Purchase cost in the Philippines is $1 million to $2 million, of which maintenance costs are approximately $25,000.

Regulatory Framework

Description of the regulatory framework is based on the experience of Thailand, Malaysia, Republic of Korea, Hong Kong, and the Philippines (Table 5). Based on expert opinion, some form of legal framework for the acquisition of big-ticket technologies is absent or is only applicable to the public sector in these countries. For example, no formal procedure like a certificate of need mechanism is required by a governmental body. Instead, a justification of need has to be delivered by the Ministry of Public Health in the case of Thailand or by the Hospital Authority Board in Hong Kong. For the Philippines, it is not even necessary to produce documentary evidence of the effectiveness and safety of the technology before purchasing. A description of the technical specifications suffices as a basis for making a purchase decision, particularly in hospitals in the private sector.

In all five study sites, there is a regulatory body (e.g., Ministry of Health, Hospital Chief or Hospital Authority Board) that approves the purchase of the technology. Brands are chosen through open or public bidding. In all the study sites, decisions on which brand to buy are made by physicians (Republic of Korea) or tender or a bidding board (Malaysia, the Philippines, Thailand, and Hong Kong). According to experts in all the countries, there is no financial incentive (e.g., tax-free importation) to purchase an MRI.

Table 4. MRI Characteristics in the Asian Region

Country (number of MRIs in 1998)	Magnetic strength Low/mid/high	Magnetic type Sup/Res/Per[a]	Brand								
			Siemens	GE	Elscint	Hitachi	Philips	Toshiba	Shimadzu	Picker	Others
Shanghai, China (12)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu, India (10)	90/0/10	NA	20	30	0	10	30	10	0	0	0
Indonesia (9)	87.5/12.5/0	38/13/49	0	14	0	29	0	29	14	0	14
Republic of Korea (245)	13/54/33	87/3/10	28	24	1	10	9	8	10	5	5
Malaysia (26)	27/61/12	27/0/73	9	2	0	8	3	4	0	0	0
Philippines (11)	54/36/10	NA	27	46	27	0	0	0	0	0	0
Thailand (28)	57/0/43	88/0/12	3	33	6	16	3	10	26	3	0
Hong Kong, China (12)	0/25/75	100/0/0	42	33	0	0	25	0	0	0	0

[a] Sup = superconductive; Res = resistive; Per = permanent.

Table 5. Overview of Regulatory Framework in Republic of Korea, Malaysia, Philippines, Thailand, and Hong Kong

Description of legal/regulatory mechanisms	Republic of Korea	Malaysia	Philippines	Thailand	Hong Kong (China)
Big ticket acquisition propose	No	User & Planning division, Ministry of Health (MOH)	Head of radiology department	Hospital/university/ Ministry of Public Health (MOPH)/ Private	Hospital authority (HA)
Certificate of need	No	Justification required	Justification of need	No	Justification of need
"Need" decided by:	Each hospital	MOH	Hospital chief	NA	HA
Evidence of effectiveness before purchase	No	Health technology assessment (HTA)	No	Yes	Yes
Body to decide technology is effective	No	HTA	Radiologists and clinicians	MOPH	HA
Evidence of safety before purchase	Yes	HTA	No	Yes	Yes
Body to decide technology is safe	Korean Food and Drug Administration (FDA)	HTA	None	MOPH	Expert committee
Evidence of cost-effectiveness before purchase	No	Yes	No	No	Yes
Body to decide technology is cost-effective	No	HTA	None	None	HA
Financial incentives to purchase	No	No	No	No	No
Financial discentives to purchase	No	No	Maintenance and operating costs	Capital and maintenance cost	No
Body to approve purchase	No	MOH	Hospital chief	NA	HA Board
Criteria for brand chosen	No	Open tender	Public bidding	Open tender	Open tender
Body to decide which brand	No	Tender board, MOH	Bidding committee	Tender board	Central tender board
Body to decide on location	No	MOH	Hospital chief	MOPH	HA
Registration agency	No	Atomic Energy Licensing board	Radiation Health Service, Department of Health	MOPH	No
Registration requirement	No–radiologists	All above	NA	Voluntarily	NA
On site inspection	No	Yes	NA	Randomly	No

NA = not applicable.

Based on the survey, the considerable maintenance and operating costs tend to be a restraining factor for the adoption of MRI. In some of the countries, specifications or upgradability, rather than price or length and type of service of the technology, are important decision features during the purchase process.

Finally, comparing the distribution of MRIs with regard to ownership (Table 3), there is a tendency of countries with a rather weak regulatory framework to have predominantly private MRIs .

Utilisation Pattern

Only three study countries succeeded in collecting pre- and postcrisis utilization data (Thailand, Korea, and the Philippines) for about 100 patients. Only data on MRI from private hospitals are included. An overview of the utilization pattern is given in Table 6.

Patient Characteristics. In the three study countries, there is almost the same proportion of male to female patients receiving MRI. The mean age of the patients ranges from late 30s to late 40s. Outpatients make up the majority of patients receiving MRI in Thailand and the Philippines, but this is not true in Korea, where two-thirds of the patients who receive MRI are hospitalized.

Table 6. Utilization Pattern of Republic of Korea, Philippines, and Thailand

	Republic of Korea		Philippines		Thailand	
Utilization data	Before crisis	After crisis	Before crisis	After crisis	Before crisis	After crisis
Number of patients	96	94	100	100	100	100
Average waiting time (days)	3.5	3.5	NA	NA	0	0
Sex						
Female	45%	43%	45%	37%	52%	54.0%
Male	54%	56%	55%	63%	48%	46%
Mean age	42	45	37.6	37.7	49	47
Proportion of outpatients	29%	36%	100%	94%	61%	71%
Organ						
Brain	59%	48%	44%	38%	36%	34%
Head & neck	0	0	0%	0%	16%	10%
Spine	16%	19%	36%	39%	40%	45%
Muscular skeletal	8%	9%	7%	17%	1%	6%
Abdomen/pelvis	5%	6%	8%	4%	1%	0%
Cardiovascular	0	0	0%	0%	0%	1%
Others	0	0	0%	0%	5%	4%
Specialty						
Neurologist	42%	44%	NA	NA	33%	20%
Orthopedic surgeon	13.5%	20%	NA	NA	38%	40%
General Practitioner	4.5%	1%	NA	NA	3%	1%
Others	40%	35%	NA	NA	26%	39%
Payment method						
Out of pocket	100%	100%	NA	67%	71%	65%
Private insurance (in full)	0	0	NA	10%	0%	12%
Private insurance with copay	0	0	NA	1%	29%	13%
Public insurance (in full)	0	0	NA	0	0%	4%
Public insurance with copay	0	0	NA	0	0%	5%
Others	0	0	NA	0	0%	0%
Charity	0	0	NA	0	0%	0%

Area Imaged/Indication for Imaging. Utilization data from the three study sites show that in general, MRI is performed in accordance with proven clinical applications. Overall, brain and spine examinations account for approximately 70% of the workload in all study sites. For the Republic of Korea, over half of MRIs are for brain examination, while in Thailand the majority of the MRI examinations were used for the spine (Table 6).

Specialty of Referring Physicians. Only two countries had data on the referring physician. In Thailand most patients were referred by orthopedists for musculoskeletal/orthopedic diagnosis, while in the Republic of Korea the predominant group utilizing MRI were mostly radiologists for neurological diagnosis.

Fees and Mode of Payment by Patients. In the three countries, many patients pay out-of-pocket for MRI services. In Thailand and the Philippines there is a proportion of patients who get the services with some form of public or private insurance, with full or partial coverage. The impact of the economic crisis can be seen in the case of MRI services in Thailand. The proportion of patients paying out of pocket for MRI investigation decreased from 71% to 65%. The average charge of an MRI examination of the head in Thailand and the Republic of Korea is approximately US $191 and $357, respectively.[1] For comparison, the average charge for a CT scan of the head in Thailand and the Republic of Korea is only $122 and $120, respectively.

DISCUSSION

The Asian countries involved in the study display a wide spectrum of economic productivity as measured in terms of GDP per capita. This spectrum of GDP per capita is also reflected in the spectrum of the number of MRIs per million population, which varies tenfold from a high of 5 per million population in Korea to a low of less than 0.5 MRI in Indonesia and the Philippines. Not surprisingly, there is some concordance between GDP per capita and MRI per million population.

If we compare the current average number of MRIs per million population in Asia with other regions of the world, it can be concluded that it is quite modest. Using the average of 1.3 MRIs per million population in the countries involved in this study, the region as a whole would be ranked at the bottom of the Organization for Economic Cooperation and Development (OECD) list of MRIs (Figure 2). However, as previously stated, the average hides a considerable spread, and some Asian countries like Korea, an OECD member, can compare favorably with other OECD countries. Furthermore, taking into consideration the total health expenditure per capita, Figure 2 supports the findings by Lazaro and colleagues (10) that lower income economies devote a larger fraction of their health expenditure to expensive big ticket medical technologies compared with the same fraction in high-income countries. Because there is no "gold standard" for the appropriate number of MRIs per inhabitants, it is difficult to claim whether this number is too low or what the ideal number of MRIs in the region should be.

From the results, there appear to be two patterns of diffusion of big-ticket items such as MRIs. One set of countries seems to be composed of mostly early adopters, and another set of countries appears to be composed mostly of late adopters. There appears to be no concordance of the pattern of diffusion with either the presence of a regulatory framework or the absolute numbers of MRIs. It was initially hypothesized that a pattern of late adoption would be seen if there was a regulatory framework that required evidence of effectiveness before an MRI can be approved for purchase. For example, in Canada the MRI was first introduced as a research tool in 1982, and the first clinical use was in 1985. There was slow diffusion of MRI technology because of Canada's global budgeting system of the Canadian hospitals. There were little funds to buy new, expensive technology like the MRI, and a

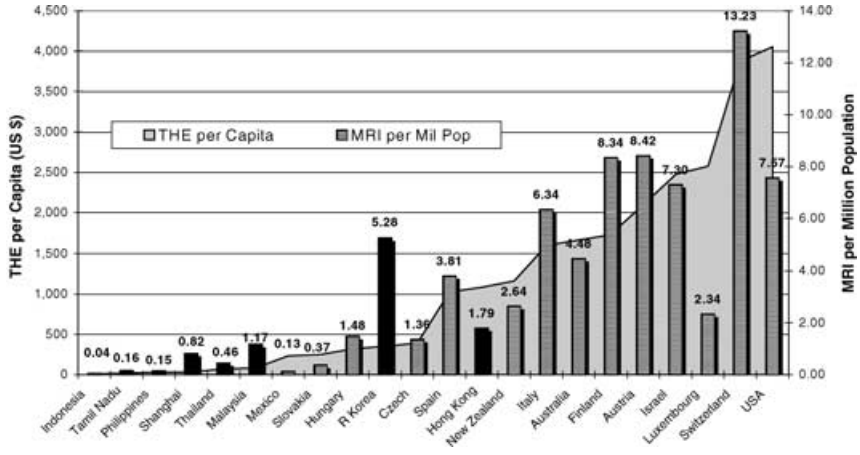

Figure 2. Number of MRIs per population and total health expenditure (US $) in study countries (black columns) and selected OECD countries (patterned column) in 1998. Total health expenditure per capita figures for Shanghai and Tamil Nadu are from the national average.

technology assessment report emphasized the lack of evidence of the diagnostic superiority of MRI (4).

On the other hand, in Japan, which most recently became first in terms of MRIs installed per million population, the main determinants of diffusion include the technical attributes, the market situation of the medical engineering industry, the reimbursement system, and Japan's sociocultural background. It was specifically mentioned that the introduction of MRI in Japan was not linked to formal assessments of effectiveness (9). Perhaps the Asian experience of rapid adoption and diffusion of MRI in primarily private and urban areas is facilitated not only by the lack of a regulatory framework that is implemented in the public as well as the private sector, but also by the sociocultural context. In particular, the so-called "me too" phenomenon coupled with the economic surplus in those early years could explain the rapid and widespread use of this technology. As mentioned earlier, competitiveness of hospitals is judged by their technological superiority by clients who believe that the more sophisticated the equipment, the better the care.

The relatively low number of MRIs per million population that have been installed in the Asian region—in comparison with the OECD numbers—is a quite remarkable finding of this study (except in the case of Korea). Before the onset of the financial crisis in 1997, when the Asian economies were booming, one would expect more MRIs to have been installed. Also, because of the absence of a regulatory framework in this region for big-ticket technologies like MRIs, there would be no barriers, other than economic, to investing in such technologies. Evidence from the early 1980s in the United States showed that certificate of need stringency had a strong negative impact on the adoption of the first MRIs in that country (18). Thus, it appears that the limited number of MRIs in the region is probably due to its high acquisition cost, and perhaps also to lack of technical know-how on the part of the investors and the availability of better investment potentials other than high-tech technologies.

Probably because of lower or even no acquisition costs either through second-hand purchases or through donations, many MRIs with low MFS are present in the region. However, this does not necessarily imply low-quality imaging. Literature shows that the relationship among the variables contributing to image quality is complex and extends far beyond MFS (2;11;12;15). In addition, there are no completed studies that can directly

demonstrate the superiority of higher MFS over low MFS. Preliminary results from two studies show no significant diagnostic difference between low (0.5 or 0.64 Tesla [T]) and high (1.5 T) MFS (11;12).

The utilization pattern of the study findings are in accordance with the existing evidence where diagnostic improvements resulting from MRI mainly involve the central nervous system, the spinal cord, and the neuromuscular system (16). However, because of the continuing heavy financial burden of maintenance and operation of an MRI, there is danger of shifting to examinations of organs where MRI still has some limited application. It was hypothesized that a change in utilization patterns might be demonstrated before and after the crisis, but this was not shown in the limited data available.

Looking at international experience on appropriate use of MRIs, there are similarities with the Asian experience. For example, in British Columbia, 69.4% of MRI services were for patients referred by neurologists. Only 4.5% were referred by general practitioners (13). Among in-patients in France, neurologic and neurosurgical indications accounted for two-thirds of MRI examinations (5). During the first years of its introduction in the United States, procedures involving the head and spine accounted for 77% (6).

The countries in this collaborative initiative were part of the surging world economy in the early 1990s and, due to the increased wealth in the region and increased education of its populace, demand for health care grew and the private sector expanded to account for 40% to 81% of healthcare expenditures. Most of the expensive technology, like the MRI, now belongs to the urban and private sector (4). Access has been limited by geography and ability to pay, bringing issues of equity into focus. A detailed study in eight hospitals in Thailand shows that there is inequity in terms of MRI access among different payment groups. The rate of MRI utilization is much lower for those under the public assistance scheme compared with those paying out-of-pocket or those covered by the Civil Servant Medical Benefit Scheme (7).

To avoid cost escalations and inefficiencies in national health systems, it is recommended that legal frameworks and regulatory bodies be strengthened for the introduction of big-ticket technologies in both public and private sector. In particular, implementation of regulations in the private sector should be taken as a policy opportunity to improve the delivery of health care. For example, a certificate of need plus a technology assessment report could be required from those who plan to acquire such machines. For several of the countries in the study, there is no agency formally tasked to undertake health technology assessment. Expertise in this area needs to be built up, because some technology assessment reports from the developed countries cannot be imported in total for direct application to developing countries. Authorities need to be able to decide which parts of the technology assessment report can be generalized to their own setting and which ones will need adjustment or tailoring.

In addition, unequal access to such services, such as for rural populations and disadvantaged groups, could be improved through more equitable financing. The wide spectrum in the number of MRIs per million population only demonstrates variations among countries and at the most can be interpreted as a signal that there may be evidence of under-availability in some countries and even excess availability in others.

The conclusions of this collaborative study need to be interpreted with caution. First, due to the pragmatic approach of the collaborative initiative, it has to be emphasized that the study has a descriptive retrospective design that limited the ability to analyze the data in an ideal way. Second, some data, in particular on utilization, were incomplete and outdated by the time this study was published. Third, for pragmatic reasons we had to limit country experiences of India and China to regional data. Fourth, the study sites have different health systems and epidemiologic profiles that make the direct comparison of MRI diffusion and utilization problematic. This limits our ability to completely understand and analyze the

diffusion of MRIs in the region. We are well aware of the complex combination of economic, organizational, political, institutional, medical, social-demographic, and cognitive factors, and this varies in time. We believe, however, that the patterns shown in this study highlight a common area of concern: the need for incorporating health technology assessment tools in policy making in Asia.

Despite the limitations of the study, one can clearly say that the present healthcare systems in the countries studied, as exemplified in this one-time, limited case study on MRI diffusion and utilization, still deviate from the ideal as described by Hillman et al. (8) as early as 1985:

> In an optimal medical care system, new technologies and innovations would be adopted rapidly once their safety and efficacy are established and once favourable cost-effectiveness ratios are anticipated. The technologies would be purchased and sited in the most efficient and appropriate settings and would be available equally to everyone in need. Payment would reflect the actual costs of appropriate and efficient medical care at all time, regardless of which technologies are used and whether they are cost-saving or cost-increasing (9).

NOTE

[1]The costs associated with receiving an MRI examination vary widely depending on the complexity of the images required, physicians' charges for interpretation, and other variables.

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APPENDIX 1
List of Investigators in Alphabetical Order with Their Affiliation During the Study

SHANGHAI CITY, CHINA

Professor Jie Chen, Professor Hengjin Don, and Dr. Lu Jun, *Shanghai Medical University, Shanghai*

HONG KONG CITY, CHINA

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STATE OF TAMIL NADU, INDIA

Dr. K. R. John, *Christian Medical College, Vellore*

INDONESIA

Dr. Puruhito, *Airlangga University, Dr. Soetomo Hospital, Surabaya*;
Dr. Sukanto Sumodinoto and Dr. Wahyu Dwi Asutuiti, *Center for Health System Research and Development, Surabaya*

REPUBLIC OF KOREA

Dr. Chang-Yup Kim, *College of Medicine, Hallym University, Kangwon-do*;
Dr. Sun M. Kim, *Seoul National University, Seoul*; and
Dr. Young-sung Lee, *Chungbuk National University, Chungbuk*

MALAYSIA

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THE PHILIPPINES

Dr. José Acuin and Dr. Teresa Pascual, *De La Salle University, Dasmasrinas, Cavite*;
Dr. Anette Peralta, *Radiation Health Service, Department of Health, Manila*; and
Dr. Tessa Tan-Torres, *University of the Philippines, Manila*

THAILAND

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Mr. Raymond Hutubessy and Mr. Mana Vatakul, *WHO Collaborating Center on Health Economics, Chulalongkorn University, Bangkok*