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Selection and concentration of obstetric facilities in Japan: Longitudinal study based on national census data

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Abstract

Aim: A shortage of obstetricians with increased workload is a social problem in Japan. In response, the government and professional bodies have accelerated the 'selection and concentration' of obstetric facilities. The aim of this study was to evaluate the recent trend of selection and concentration.

Methods: We used data on the number of deliveries and of obstetricians in each hospital and clinic in Japan, according to the Static Survey of Medical Institutions in 2005, 2008 and 2011. To evaluate the inter-facility equality of distribution of the number of deliveries, number of obstetricians and number of deliveries per obstetrician, Gini coefficients were calculated.

Results: The number of obstetric hospitals decreased by 20% and the number of deliveries per hospital increased by 26% between 2005 and 2011. Hospital obstetricians increased by 16% and the average number of obstetricians per hospital increased by 19% between 2008 and 2011. Gini coefficient of deliveries has significantly decreased. In contrast, Gini coefficient of deliveries per obstetrician has significantly increased. The degree of increase in obstetricians and of decrease in deliveries per obstetrician was largest at the hospitals with the highest proportion of cesarean sections. The proportion of obstetric hospitals with the optimal volume of deliveries and obstetricians, as defined by Japan Society of Obstetrics and Gynecology, was 4% in 2008, and it had doubled to 8.1% 3 years later.

Conclusion: The selection and concentration of obstetric facilities is progressing rapidly and effectively in Japan.

Key words: health policy, health resource, Japan, obstetric delivery, workload.

Introduction

A shortage of obstetricians and subsequent demand–supply mismatch of obstetric care has recently emerged as a social and medical problem in Japan.[1–3] For the past 30 years, the number of obstetricians and gynecologists (OB-GYNs) has decreased by 5% while the total number of physicians has increased by 116%.[4] Of even greater concern is that the number of new medical graduates who chose OB-GYN has been steadily decreasing.[4] The number of obstetric facilities is also decreasing: between 1993 and 2008 the number of obstetric hospitals dropped by 37% and the number of clinics by 42%.[5] The national and prefectural

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governments have implemented various policies and invested substantial amounts of money to increase the number of OB-GYNs.[6–10] As a short-term trend, the number of OB-GYNs has slightly increased: between 2006 and 2012 it rose by 8%.[11,12]

Japan Society of Obstetrics and Gynecology and Japan Association of Obstetricians and Gynecologists have noted that heavy workloads and long duty hours are the reasons for the shortage of OB-GYNs.[13,14] They have advocated expanding the scale of each delivery hospital and having obstetricians work in shifts.[13] The Society claims that ≥500 deliveries per year and six or eight obstetricians per 500 deliveries is the optimal volume of an obstetric hospital and has set the goal that most hospitals attain these optimal volumes by 2030.[15]

The Japanese government also recommends accelerating the selection and concentration of delivery hospitals,[16] and has earmarked funds to do so.[17,18] For example, in 2007 alone, the government subsidized 1251.7 million yen ($US12.5 m) to selected delivery hospitals to support their finances.[6] Selection and concentration of hospitals and subsequent upsizing of selected hospitals are certainly a rational option for making the best use of finite human resources. It is unknown, however, if these policies are effective and if the selection and concentration of delivery hospitals is progressing in reality.

The aim of this study was to investigate the recent trend in the selection and concentration status of deliveries and obstetricians among delivery facilities in Japan, based on national census data. We also analyzed a change in the inter-facility equality of distribution of delivery volume and obstetrician volume, which is potentially accompanied by selection and concentration. Based on the results, we discuss the effectiveness of current selection and concentration policies and the proposals of professional bodies.

Methods

Data used in this study were from the Static Survey of Medical Institutions (hospitals and clinics) in 2005, 2008 and 2011, provided with permission to use for research by Ministry of Health, Labour and Welfare. The Static Survey of Medical Institutions is conducted by the Ministry every 3 years. All clinics and hospitals in Japan are obliged by national law to report their activities and resources in the Survey. In Japan, a hospital is defined as a medical facility with ≥20 beds, and a clinic as one with <20 beds. The 2011 Survey did not cover all the facilities in Fukushima and some of the facilities in Miyagi prefecture because of the Great East Japan Earthquake.

Data on the number of deliveries and of obstetricians in each hospital or clinic were used. The number of vaginal and cesarean deliveries in September of each year was used. The number of obstetricians in the data was expressed as the number of full-time equivalent doctors, and the number was that on 1 October of the year. Data on the number of obstetricians in 2008 and 2011 were used because there was no obstetrician data in 2005 dataset. In order to estimate the capture rate of the Survey, that is, the rate of captured deliveries in the Survey among all the deliveries, the data were compared with the number of births in September of the year in the Vital Statistics conducted by the government based on Family Registration Law, which enumerates all births and deaths in Japan.[19]

As basic statistics, the following was calculated for all obstetric clinics and for all obstetric hospitals: total number of obstetric facilities, total number of deliveries, average number of deliveries per facility, total number of obstetricians, average number of obstetricians per facility, and the average number of deliveries per obstetrician. Facilities with one or more obstetricians were regarded as obstetric facilities in this study. In each year, the number of obstetric facilities that either stopped or started providing delivery services was calculated.

For evaluating the inter-facility equality of distribution of the number of deliveries, Gini coefficient was calculated. In the calculation, all of the obstetric facilities were ranked by number of deliveries, and the cumulative proportion of deliveries and that of individual obstetric facilities were plotted onto the plane of coordinates. The plotted line is the Lorenz curve, and the Gini coefficient is the area between the Lorenz curve and the 45° diagonal line, divided by the area of the whole triangle under the 45° line. The Gini coefficient ranges from 0 (complete equality) to 1 (complete inequality), according to the variation in deliveries. A similar procedure was conducted for the number of obstetricians and the number of deliveries per obstetrician. Significance test was conducted to examine the difference in Gini coefficient between 2 different years. This was done by calculating the bootstrapped standard errors for the Gini coefficient.[20]

To ascertain how the inequality is created, we classified all hospitals into equal-size tertiles (low, medium and high) according to the proportion of cesarean sections among all deliveries (CS rate) at each hospital in each year. We assumed, although indications for CS are sometimes relative rather than absolute,[21,22] that hospitals with a higher CS rate tended to be hospitals to which larger numbers of high-risk deliveries/pregnancies were referred. In the Static Survey of Medical Institutions used in this study, for example, the average CS rate of advanced treatment hospitals (*tokutei-kinou-byouin*), community center hospitals (*chiiki-iryou-shien-byouin*) and others in 2011 was 39.9%, 29.3% and 21.6%, respectively. The average number of deliveries, obstetricians, and deliveries per obstetrician in each tertile of hospitals was calculated, and the differences in these values between 2 years were compared.

In its 'Grand design for improving obstetric health system 2010 version 1.21,' the Japan Society of Obstetrics and Gynecology proposed the volume of a obstetric hospital be ≥500 deliveries per year and obstetrician-delivery ratio be ≥6 (necessary level), or ≥8 (sufficient level) per 500 deliveries in order to standardize the working hours and workload of obstetricians.[15] Based on the optimal volumes, the numbers and proportions of obstetric hospitals with ≥500 deliveries in which the obstetrician : delivery ratio was ≥6/500 (necessary volume) were calculated. The number and proportion of obstetric hospitals with ≥500 deliveries in which the obstetrician : delivery ratio was ≥8/500 or more (sufficient volume) were also calculated. Then the change of the proportion of the hospitals with the necessary or sufficient volume between 2008 and 2011 was obtained.

Statistical analysis

Statistical analysis was done using SPSS version 21 (IBM-SPSS Japan, Tokyo), except for calculation of Gini coefficients and significance test for their differences; these were done with STATA (version 12, College Station, TX, USA). The Ethics Committee, Graduate School of Medicine and Faculty of Medicine, University of Tokyo assessed and gave permission for this study (assessment number 10128).

Results

Based on the birth data in Vital Statistics, the capture rate of delivery in the Static Survey of Medical Institutions was estimated to be 91.8% in 2005, 93.8% in 2008, and 92.3% in 2011.

Basic statistics of obstetric hospitals are listed in Table 1. The number of obstetric hospitals in Japan decreased by 15% between 2005 and 2008 and by 7% between 2008 and 2011. The number of deliveries was almost unchanged between 2005 and 2011, thus the number of deliveries per hospital increased by 26%, indicating the progression of concentration of deliveries at fewer hospitals. The number of hospital obstetricians increased by 16% and the average number of obstetricians per hospital increased by 19% between 2008 and 2011, indicating the growing concentration of obstetricians. The number of deliveries per obstetrician decreased by 16% over the three-year period. Basic statistics of obstetric clinics are shown in Table S1. In clinics, the concentration of deliveries likewise increased, but that of obstetricians was unchanged.

The distribution of deliveries, obstetricians, and deliveries per obstetrician among obstetric hospitals is shown in Table 2. The Gini coefficient of delivery decreased between 2005 and 2011. This indicates that the number of deliveries at each hospital is becoming increasingly balanced. The Gini coefficient of obstetricians increased among hospitals from 2008 to 2011, suggesting that the distribution of obstetricians among

Table 1 Statistics for obstetric hospital in Japan

		Year		
		2005	2008	2011
Obstetric hospitals	Total	1 321	1 126	1 051
Deliveries	Estimated annual total†	514 216	532 328	511 810
	Total in September	44 865	46 404	45 052
	Average per hospital	34.0	41.2	42.9
	SD	28.7	33.2	32.9
Obstetricians	Total		4 910	5 689
	Average per hospital		4.7	5.6
	SD		3.7	4.6
Deliveries per obstetrician			9.5	7.9

†Based on the study data and birth data in Vital Statistics.[19]

hospitals is increasingly skewed, although the trend was not statistically significant. Gini coefficient of deliveries per obstetrician increased among hospitals between 2008 and 2011, indicating a widening disparity of the delivery volume per obstetrician among hospitals. The results for clinics are shown in Table S2. A similar trend was found in clinics.

The average number of deliveries, obstetricians and deliveries per obstetrician according to CS tertile (low, medium and high CS rate) is shown in Table 3. Between 2008 and 2011 the number of deliveries increased most in the low CS tertile, while the number of obstetricians increased most rapidly in the high CS tertile. As a result, the most pronounced decrease in the number of deliveries per obstetrician was found in the high CS group.

The number and proportion of hospitals that ceased or started delivery service is shown in Table 4. In both 2005–2008 and 2008–2011, the number of hospitals that ended delivery service exceeded the number of those that began offering this service. The gap, however, narrowed in 2008–2011 compared with 2005–2008 due to the decrease in the number of hospitals that stopped performing deliveries. The results for clinics are shown in Table S3. A similar trend was observed in clinics.

Table 2 Gini coefficients for obstetric hospitals

	2005	2008	2011	P1	P2
Delivery	0.425	0.402	0.395	**0.01**	0.536
Obstetrician		0.375	0.389		0.27
Deliveries per obstetrician		0.330	0.357		**0.022**

Gini coefficient ranges between 0 (complete equality) and 1 (complete inequality). P1, *P*-value for 2005–2011 difference; P2, *P*-value for 2008–2011 difference.

Table 5 lists the number and proportion of hospitals with optimal delivery and obstetrician volumes set by the Japan Society of Obstetrics and Gynecology. The proportion of obstetric hospitals with ≥500 annual deliveries slightly increased between 2008 and 2011. The proportion of the hospitals that had both ≥500 and obstetrician-delivery ratio ≥6/500 was only 4% in 2008, but doubled to 8.1% by 2011. Similarly, the proportion of the hospitals with ≥500 deliveries and ≥8/500 obstetrician-delivery ratio doubled over the 3-year period from 2.0% to 4.2%.

Discussion

The concentration of deliveries and of obstetricians has progressed rapidly. The distribution of obstetrician volume among hospitals has become unequal and the disparity of delivery volume per obstetrician has increased. The growing disparity, however, might be attributable to the increasing concentration of obstetricians at secondary and tertiary referral hospitals that have a larger proportion of high-risk deliveries. The work environment of hospital obstetricians overall is likely to be improving. The number of hospitals with the optimal volume of deliveries and obstetricians has increased rapidly. These trends accord with governmental policies and plans of professional bodies.

The national government is putting forth concrete policies that facilitate selection and concentration of obstetric hospitals. For example, a preferential fee schedule of social health insurance has been given to hospitals that have a neonatal intensive care unit (NICU), that accept patients with obstetric emergency, or that perform high-risk deliveries.[18] Subsidies are provided to general perinatal medical centers and community perinatal medical centers, both of which

Table 3 Change in delivery and obstetrician statistics over time

	CS tertile†	Average ± SD			2011–2005	2011–2008
		2005	2008	2011	Difference %	Difference %
Deliveries	Low	31.7 ± 32.0	37.9 ± 36.0	40.7 ± 37.3	28.4	7.4
	Medium	40.4 ± 29.6	47.7 ± 32.7	48.6 ± 32.0	20.4	1.9
	High	29.9 ± 22.7	39.4 ± 28.5	40.2 ± 28.6	34.1	1.9
Obstetricians	Low		3.4 ± 2.3	3.9 ± 2.8		16.8
	Medium		4.6 ± 3.0	5.4 ± 3.6		16.2
	High		6.1 ± 4.9	7.5 ± 6.0		21.6
Deliveries per obstetrician	Low		11.2 ± 7.2	10.8 ± 7.9		−3.6
	Medium		11.1 ± 5.9	10.2 ± 5.9		−8.2
	High		7.5 ± 4.6	6.8 ± 5.0		−10.3

†All hospitals were classified to equal-size tertiles in each year according to the CS rate at each hospital. Data given as counts for September. CS, cesarean section.

Table 4 Hospitals that ceased or started to deliver

	2005 → 2008		2008 → 2011	
	n	%	*n*	%
Cease	240	18.2	116	10.3
Start	45	4.0	41	3.9

Table 5 Optimal delivery and obstetrician volume hospitals†

	2008 ($n = 1126$)		2011 ($n = 1051$)	
	n	%	*n*	%
Annual deliveries ≥500	408	36.2	403	38.3
and obstetrician-delivery ratio ≥6/500	45	4.0	85	8.1
and obstetrician-delivery ratio ≥8/500	23	2.0	44	4.2

†Defined by the Japan Society of Obstetrics and Gynecology as ≥500 deliveries per year and ≥6 or 8 obstetricians per 500 deliveries per hospital.

are designated by prefecture government.[17] Another subsidy has been earmarked to construct a network system among obstetric facilities within a prefecture.[17] These policies have potentially advanced the concentration of deliveries at some selected, large-scale hospitals. High-volume labor units, compared with low-volume ones, have been found to have had fewer neonatal mortalities and morbidities.[23–26] This suggests that the selection and concentration policies not only lightened the workload of hospital obstetricians, but also improved the safety of delivery.[27] In contrast, selection and concentration can cause closure of low-volume obstetric facilities and subsequent worsening of patient access to obstetric service. In the present study the number of facilities ceasing to deliver exceeded that of facilities starting to deliver. The national government therefore subsidizes small obstetric facilities in rural and remote areas.[17] At a time of rapid growth of selection and concentration, it seems important to balance centralization of resources with equal access. Policies should focus on providing access to women residing in remote or rural areas, while making the most of the advantages of high-volume labor units.

Effective placement of obstetricians seems to be progressing. The worsening of equality indicators for obstetrician and obstetrician workload shown in this study does not necessarily mean a worsening of their distribution and workload. The inequality seems to have evolved in a way that has concentrated obstetricians most rapidly at tertiary referral hospitals, meaning that obstetricians are increasingly distributed among the facilities that are in greatest need of their services. Appropriate distribution of obstetricians should be consistently pursued with the cooperation of the national and local governments, professional bodies, and, above all, medical schools, which traditionally have the largest physician-placement function in Japan.

The proportion of hospitals with optimal delivery and obstetrician volume defined by the Japan Society of Obstetrics and Gynecology has doubled for the past 3 years. Although the progression was rapid, the proportion was still low (8.1% or 4.2%). Political support from the national and prefectural governments and initiative by professional bodies should be continued, and the optimal volume needs to be revised by the Society based on the reality. Also the shrinking number of deliveries per obstetrician at tertiary referral hospitals might make it difficult for obstetricians to maintain their clinical skills. It is thus necessary for obstetricians, particularly young obstetricians in training, to rotate through hospitals of different levels in order to assist with an adequate number of deliveries, including high-risk ones.

In interpreting the results, the following needs to be accounted for. Deliveries range from low to high risk. High-risk deliveries, sometimes threatening fetal, neonatal and maternal lives, add to the workload of obstetricians; low-risk deliveries may be safely performed by midwives without requiring the presence of an obstetrician. Thus, the workload of each obstetrician depends on the presence or absence of complications. The 'number of deliveries per obstetrician' in this study thus may not necessarily reflect the real workload of an obstetrician. The trend of workload and workload disparity focused on in this study, however, would be less influenced by this problem. Some of the gaps in Gini coefficients were statistically insignificant, possibility because of the short observation period (3 years). To confirm the gaps, a longer-term study is needed.

Conclusion

Selection and concentration of deliveries and of obstetricians is progressing rapidly and effectively in Japanese hospitals. Continuous support from the national and local governments, professional bodies, and medical schools is recommended to maintain this trend.

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Disclosure

The authors declare no potential conflicts of interest.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Table S1 Basic statistics of obstetric clinics in Japan.
Table S2 Gini coefficients of delivery, obstetrician and deliveries per obstetrician among obstetric clinics.
Table S3 Clinics that ceased or started to deliver.

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RESEARCH ARTICLE

Geographic Distribution of Radiologists and Utilization of Teleradiology in Japan: A Longitudinal Analysis Based on National Census Data

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Abstract

Background

Japan has the most CT and MRI scanners per unit population in the world, and as these technologies spread, their geographic distribution is becoming equalized. In contrast, the number of radiologists per unit population in Japan is the lowest among OECD countries and their geographic distribution is unknown. Likewise, little is known about the use of teleradiology, which can compensate for the uneven distribution of radiologists.

Methods

Based on the Survey of Physicians, Dentists and Pharmacists and the Static Survey of Medical Institutions by the Ministry of Health, Labour and Welfare, a dataset of radiologists and CT and MRI utilizations in each of Japan's 1811 municipalities was created. The inter-municipality equity of the number of radiologists was evaluated using Gini coefficient. Logistic regression analysis, based on Static Survey data, was performed to evaluate the association between hospital location and teleradiology use.

Results

Between 2006 and 2012 the number of radiologists increased by 21.7%, but the Gini coefficient remained unchanged. The number of radiologists per 1,000 CT (MRI) utilizations decreased by 17.9% (1.0%); the number was highest in metropolis and lowest in town/village and the disparity has widened from 1.9 to 2.2 (1.6 to 2.0) times. The number of hospitals and clinics using teleradiology has increased (by 69.6% and 18.1%, respectively). Hospitals located in towns/villages (odds ratio 1.61; 95% confidence interval 1.26–2.07) were more likely to use teleradiology than those in metropolises.

Conclusions

Contrary to the CT and MRI distributions, radiologist distribution has not been evened out by the increase in their number; in other words, the distribution of radiologists was not affected by market-derived spatial competition force. As a consequence, the gap of the radiologist shortage between urban and rural areas is increasing. Teleradiology, which is one way to ameliorate this gap, should be encouraged.

Introduction

Japan has the most computed tomography (CT) and magnetic resonance imaging (MRI) scanners per unit population in the world [1]. In a previous study, we reported the geographic distribution of these diagnostic modalities across Japan [2]. We showed that the more abundant a modality, the more equal its distribution, and any increase in the modality makes its distribution even more equal. This suggests that the geographic distribution of the diagnostic imaging technology in Japan confirms the spatial competition hypothesis [2]. The spatial competition hypothesis is an economic model in which service suppliers are affected by the maximization of profit and an increase in the supplier density will increase competition for profit in urban areas, which leads suppliers to rural areas to improve the equity of physician distribution [3,4].

In contrast the relationship between the number and the geographic distribution of radiologists is unknown. Despite the large number of imaging devices, the number of radiologists per unit population in Japan is the lowest among OECD countries [5], and is less than half of the number in the United States [6]. Fewer radiologists are working with many more imaging devices in Japan than in other countries. In order to make the best use of limited human resources, it is necessary to reduce the gap between the geographic distribution of radiologists and that of imaging devices. In Japan the number of major imaging devices such as CT, MRI and positron-emission tomography (PET) is rapidly increasing, and their distribution is becoming evenly spread among municipalities [2]. The number of radiologists must be better matched to the distribution of these devices.

In reality, however, human resources such as physicians do not necessarily follow the spatial competition hypothesis [7–9]. It is possible that there is a substantial and widening gap between the distribution of imaging devices and that of radiologists despite the lack of scientific evidence showing it [10]. As a practical solution, teleradiology has been used since the 1990s [11]. Several trials have connected urban and rural hospitals and supported the rural hospitals' use of teleradiology [11–13]. However there is scanty evidence of the nationwide status of teleradiology utilization in Japan.

In this study, based on national census data, we investigate the number and geographic distribution of radiologists in Japan and examine whether the number-distribution relationship is consistent with the spatial competition hypothesis. We also show the trend in the gap between the distribution of radiologists and of imaging devices. We then illustrate the current status and recent trend of teleradiology use among Japanese medical institutions. Based on the results, we predict a problem in radiology service provision and suggest a desirable policy option.

Materials and Methods

Radiologist data

Unpublicized individual data of the Survey of Physicians, Dentists and Pharmacists conducted in 2006, 2008, 2010 and 2012 were used. Permission to use the data for research was obtained from the Ministry of Health, Labour and Welfare. All licensed physicians in Japan are obligated to register in the Survey. Among registered physicians, only those whose main specialty was radiology were recognized as radiologists in this study.

The total number of physicians and that of radiologists in each municipality were calculated from the Survey. Because many municipalities were merged between 2006 and 2012, the municipality border in 2012 was applied to 2006, 2008 and 2010, and the number of municipalities was fixed in all years at 1811. According to the device data, municipalities affected by the Great East Japan Earthquake were deleted.

Device data

Details of device data have been reported in a previous study [2]. Unpublicized individual data of the Static Survey of Medical Institutions in 2005, 2008 and 2011, which was conducted by the Ministry of Health, Labour and Welfare and covered all the hospitals and clinics in Japan, were used to create the dataset on the number of utilizations of CT and MRI scanners in each municipality. In the same manner, the dataset on the number of medical institutions using teleradiology in each municipality in each year was created. The 2011 survey did not cover all of the facilities in Fukushima and some of the facilities in the Miyagi prefecture because of the Great East Japan Earthquake. For this reason, data in these areas was deleted. The municipality border in each year was incorporated into that of 2012 as was radiologist data.

Municipality data

The municipality population in 2012 was extracted from the Statistical Observations of Shi Ku, Machi, Mura 2013, published by the Statistics Bureau, Ministry of Internal Affairs and Communications[14]. The radiologist data and device data were connected to this municipality-based population data through the municipality code.

Classification of municipality

The means of classifying municipalities was reported previously [2]. Japan has three levels of government: national, prefectural and municipal. A municipality consists of three types of community: city, town and village. In this study, municipalities were classified as "metropolis," "city" and "town/village." "Metropolis" includes all of the wards (*ku*) of the ordinance-designated cities (*seirei-shitei-toshi*) and 23 special wards of Tokyo (n = 171). "City" includes the other cities (*shi*) (n = 756). "Town/village" includes towns (*cho*) and villages (*son*) (n = 884). The number of metropolises and cities is slightly different from those in our previous study [2], because the link between different year datasets was done through postcodes in the previous study but through municipality codes in this study.

Statistical analysis

The number of radiologists per 100,000 population in each municipality category (metropolis, city and town/village) was calculated using the data of the total number of radiologists and the total population in the category of municipalities. The number of radiologists per 1,000 CT in each category in each year was then calculated. Because years of radiologist data (2006, 2008, 2010 and 2012) do not agree with years of device data (2005, 2008 and 2011), 2006 radiologist data was applied to 2005 device data, and 2012 radiologist data was applied to 2011 device data. In a similar way, the number of radiologists per 1,000 MRI utilizations in each category in each year was calculated. The proportion of hospitals (or clinics) using teleradiology among all hospitals (or clinics) was also calculated.

To evaluate the inter-municipality equity of the number of devices per unit population, the Gini coefficient was calculated [2]. The Gini coefficient is used extensively in health-related literature to evaluate the inter-community equity of resources [7,15–21]. In the calculation of the Gini coefficient, all 1811 municipalities were ranked by the number of radiologists per 100,000 population. Each municipality was plotted onto the plane of coordinates with its x-axis being the cumulative proportion of the population and the y-axis being the cumulative proportion of radiologists. The plotted line is the Lorenz curve; the Gini coefficient is the area between the Lorenz curve and the 45-degree line, which is divided by the triangle under the 45-degree line. The Gini coefficient ranges from 0 (complete equity) to 1 (complete inequity), according to the variation in the number of radiologists per 100,000 population among the municipalities. A significance test was conducted to examine the difference in the Gini coefficient between years. This was accomplished by calculating the bootstrapped standard errors for the Gini coefficient.

Multivariate logistic regression analysis, based on the 2011 Survey data, was conducted to examine the characteristics of hospitals or clinics that use teleradiology. Data on all the individual hospitals (n = 8,632) and clinics (n = 101,083) was included in the analysis. The outcome variable was whether teleradiology was used. Explanatory variables in the multivariate regression model were location of the institution (metropolis, city or town/village), its ownership (private or public), whether or not it has a diagnostic device (CT, MRI or PET), the number of radiologists, and the number of inpatient beds. The odds ratio and its 95% confidence interval (95% CI) of each explanatory variable adjusted for other variables were calculated.

Spearman's rank correlation coefficient was calculated to evaluate the strength of correlation between total population in each municipality and the number of radiologists per 100,000 population in each municipality. Similarly, the correlation coefficient was calculated between total population and the number of radiologists per 1,000 CT utilizations, and that between total population and the number of radiologists per 1,000 MRI utilizations in each municipality.

All but one of these statistical analyses were conducted using SPSS version 21 (IBM-SPSS Japan, Tokyo); the calculation of the Gini coefficients and the significance test for their differences were conducted with STATA software (version 12, College Station, TX, USA). All the maps shown in the Results were created using ArcGIS version 10.1 (ESRI Japan Inc.).

Ethics Statement

The Ethics Committee of the Graduate School of Medicine and Faculty of Medicine at the University of Tokyo have both assessed and given permission for this study (Assessment Number 10493). The Ethics Committee for Epidemiological Research at Hiroshima University agreed to this permission and approved this study (assessment number 838).

Results

Transition of the number of all physicians and that of radiologists is shown in Fig 1. Between 2006 and 2012, the number of physicians increased by 9.3% from 273,686 to 299,155. In the same period, the number of radiologists increased by 21.7% from 4,836 to 5,883, which exceeded the increased rate in the number of all physicians.

Transition of the number of radiologists per 100,000 population classified by municipality type is shown in Fig 2. The number of radiologists per 100,000 population was highest in metropolis and lowest in town/village. The gap of the value between metropolis and town/village was 3.1 times in 2006. Between 2006 and 2012, the value in metropolis increased by 28.4%, while that in town/village increased by 2.6%. Thus, the gap between metropolis and town/village increased by 3.9 times.

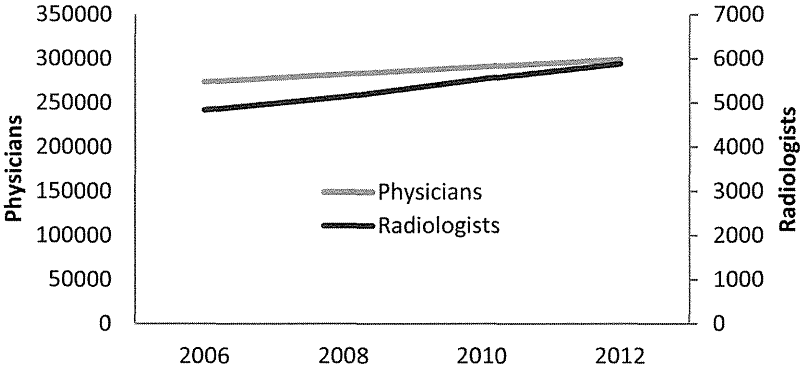

Fig 1. Number of physicians and radiologists in Japan.

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The Gini coefficient, an indicator of inter-municipality equity, of the number of radiologists is shown in Table 1. Lorenz curves are shown as supporting information in S1 Fig In spite of the rapid increase in the number of radiologists nationwide, Gini coefficient has remained almost unchanged between 2006 and 2012. As shown in Fig 3, this is in contrast to the transition of Gini coefficient of CT, MRI and PET, which significantly decreased in the similar period [2].

The number of radiologists per 1,000 CT or MRI utilizations is shown in Fig 4. The number of radiologists per 1,000 CT utilizations has decreased by 17.7% for the six years, and that per 1,000 MRI utilizations has decreased by 1.0%. This suggests that the workload of radiologists increased in terms of CT.

The number of radiologists per 1,000 utilizations of CT, classified by municipality type, is shown in Fig 5. The value was highest in metropolis and lowest in town/village. The value in metropolis has decreased by 18.3%, while that in town/village has decreased by 29.9%. The gap in the value between metropolis and town/village has widened from 1.9 to 2.2 times.

The number of radiologists per 1,000 utilizations of MRI, classified by municipality type, is shown in Fig 6. This value, too, was highest in metropolis and lowest in town/village. The value in metropolis has increased by 3.3%, while that in town/village has decreased by 17.5%. The gap in the value between metropolis and town/village has widened from 1.6 to 2.0 times.

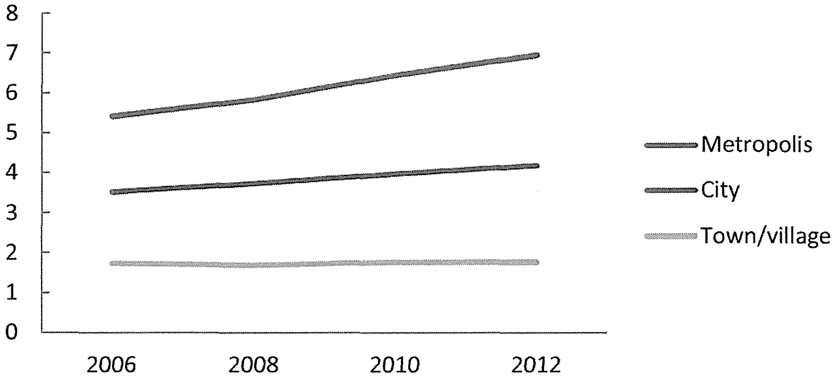

Fig 2. Number of radiologists per 100,000 population, classified by municipality type. "Metropolis" includes all the wards (*ku*) of the ordinance-designated cities (*seirei-shitei-toshi*), as well as 23 special wards of Tokyo (n = 171). "City" includes the other cities (*shi*) (n = 756); "town/village" includes towns (*cho*) and villages (*son*) (n = 884).

doi:10.1371/journal.pone.0139723.g002

Table 1. Gini coefficient of the number of radiologists among municipalities.

	2006	2008	2010	2012
Gini	0.61912	0.61769	0.61961	0.61791
P for difference from 2006 value		0.754	0.927	0.83

doi:10.1371/journal.pone.0139723.t001

A color map of the number of radiologists per 100,000 population in each municipality is shown in Fig 7B. For comparison, maps of population and population density are shown in Fig 7A. Radiologists were concentrated in areas with larger population or greater population density. Maps of the number of radiologists per 1,000 CT utilizations (Fig 7C) and that per 1,000 MRI utilizations (Fig 7D) are also shown. These values appear to be higher in areas with larger population or greater population density.

The Spearman's rank correlation coefficient among municipalities between total population and the number radiologists per 100,000 population was 0.663 (n = 1811, $p<0.01$), that between total population and the number radiologists per 1,000 CT utilizations was 0.621 (n = 1520, $p<0.01$), that between total population and the number of radiologists per 1,000 MRI utilizations was 0.477 (n = 1174, $p<0.01$) (data not shown in tables or figures). These numbers indicate that radiologists are concentrated in municipalities with larger populations.

The number of hospitals and clinics that use teleradiology is shown in Fig 8. The value has increased both for hospitals (increase rate 69.6%) and clinics (18.1%). The proportion of hospitals and clinics using telemedicine is shown in Fig 9. The proportion has increased rapidly (by 78.7%) among hospitals, but it has not substantially increased among clinics (only by 9.1%).

Results of multivariate analysis are shown in Table 2 (hospital) and Table 3 (clinic). Hospitals located in a town/village or city, public hospitals, hospitals with CT/MRI/PET and hospitals with more beds were more likely to use teleradiology than were their counterparts. In contrast the location of clinics was not associated with teleradiology utilization.

Discussion

The results of this study show that a rapid increase in the number of radiologists nationwide has not improved the equity in their geographic distribution. This is quite contrary to the distribution of CT, MRI and PET, which have become more equitable with the increase in their number [2]. In other words, the distribution of radiologists has not followed the spatial competition model derived from market forces, which the distributions of diagnostic devices have

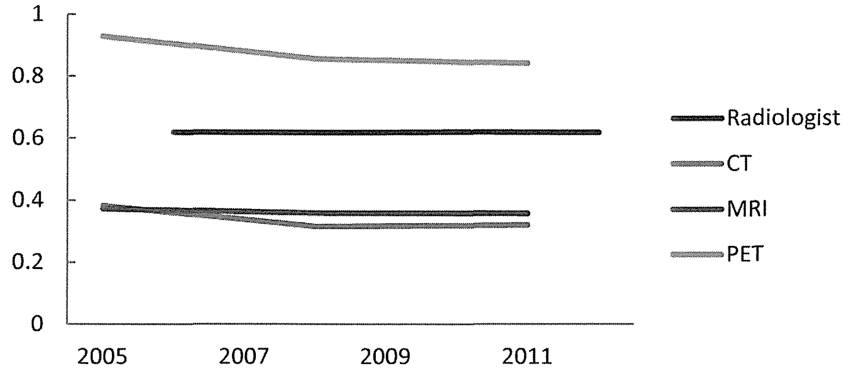

Fig 3. Gini coefficient of the number of radiologists and diagnostic device utilizations. Gini coefficients of diagnostic devices were excerpted from a previous study [2].

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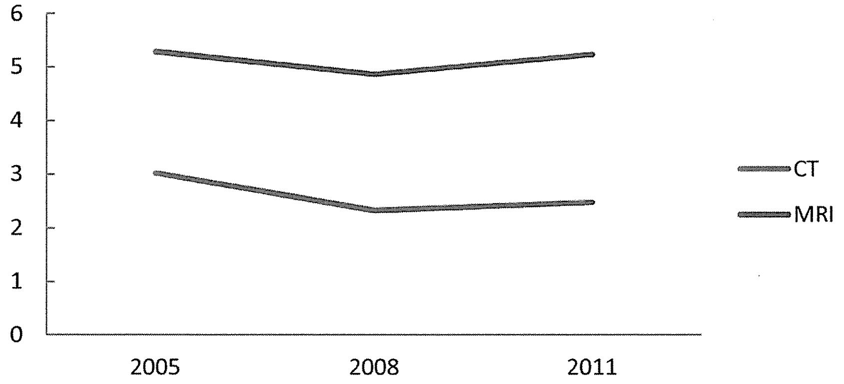

Fig 4. Number of radiologists per 1,000 CT and MRI utilizations.

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followed. The increase in the number of utilizations of diagnostic devices has outpaced the increase in the number of radiologists, which suggests an increasing workload for each radiologist. This is particularly true in rural areas, and the urban-rural gap of the workload seems to have widened. The use of teleradiology, which compensates for the disparity in the number of urban and rural-based radiologists, has increased, particularly among hospitals. Rural hospitals were more likely to use teleradiology than their urban counterparts.

Despite Japan's much lower reimbursement for imaging than other developed countries, the density of CT and MRI in Japan is the world's highest. This is partly because the cost of these imaging devices is substantially lower in Japan than in other countries due to the competition among the large domestic manufacturers [22]. The gap has created a severe shortage of radiologists. The proportion of CT and MRI images read by radiologists was only 40% in Japan, while almost all the images were reported by radiologists in 13 of the 14 reported European countries [5]. This means the quality of imaging diagnosis in Japan is not well-controlled.

The numbers of radiologists per 1,000 utilizations of CT and MRI (Figs 4–6) have slightly increased between 2008 and 2011, though they had rapidly decreased between 2006 and 2008. In the 2008 revision of medical service fees by the government, more than 80% of CT and MRI images needed to be interpreted in a day by full-time radiologists of the institution; this became a new requirement for making an insurance claim of interpretation fee for these images. This change has potentially slowed the increased rate of CT and MRI utilizations since 2008, which led to the upward trend between 2008 and 2011 in the Figs.

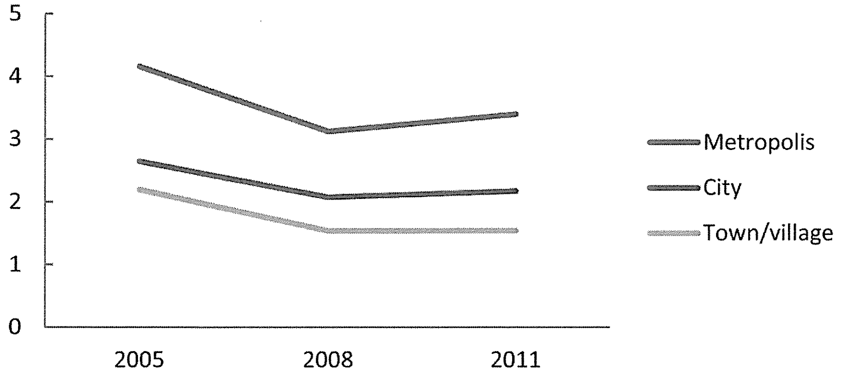

Fig 5. Number of radiologists per 1,000 CT utilizations, classified by municipality type.

doi:10.1371/journal.pone.0139723.g005

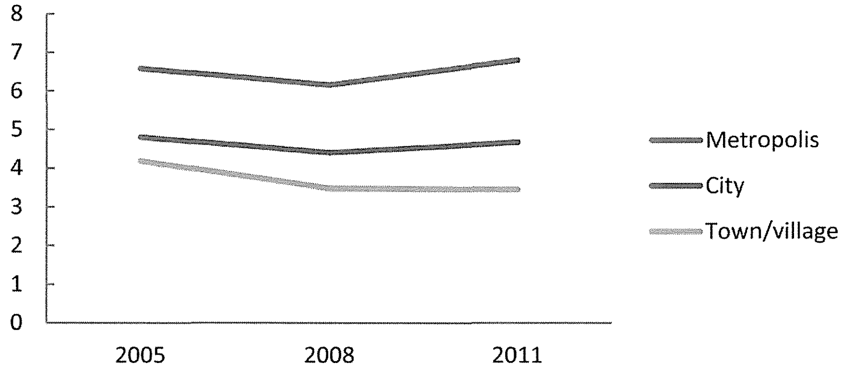

Fig 6. Number of radiologists per 1,000 MRI utilizations, classified by municipality type.

doi:10.1371/journal.pone.0139723.g006

The real increase in the workload of radiologists would be even larger than what we found in this study. Not only has the use of CT, MRI and PET increased, so have the number of images produced each time these devices are used. This situation would exacerbate the shortage of radiologists [5], which is contrary to the situation in other countries like the United States [23]. In such a shortage, the lopsided distribution of radiologists toward urban areas is unlikely to improve because of the dire need for radiologists even in urban areas. In addition, physicians generally have a strong preference for urban areas and are reluctant to work in rural areas even when offered a financial incentive [24]. These factors would help to explain why spatial competition force did not influence the distribution of radiologists. The discrepancy between the reality and the hypothesis has been observed not only among radiologists, but also among physicians in general [7–9,25,26].

The number of radiologists has and will continue to increase, along with a projected increase in the number of physicians [27]. Also the number of imaging devices will increase because the elderly population and the accompanying medical demand are likewise projected to grow [28]. Considering the number-distribution relationship of radiologists obtained in this study and that of imaging devices in the previous study [2], we can predict that the gap in distribution between radiologists and imaging devices will continue to widen, as radiologists remain concentrated in urban areas while devices continue to diffuse to rural areas. There are many full-time urban radiologists in Japan that regularly work in rural hospitals on a part-time basis. Traditionally, they have filled the urban-rural gap. Recently, however, the rapid increase in their workload makes it increasingly difficult to continue their part-time job. In such a situation, there are three ways to keep this gap from widening: 1) equalize the distribution of radiologists; 2) either stop equalizing device distribution or stop increasing the number of devices; and 3) facilitate the use of teleradiology. In reality, the most feasible option is the third one. A high-speed line that enables transmission of high volume image data is now widely available. In addition, medical records are being shared among hospitals to a greater extent than ever. Thus teleradiology is now a practical way of improving quality of medical care, particularly in areas where there is a shortage of radiologists. As a result, the number of medical institutions using teleradiology is expanding in Japan as in other developed countries [29–31]. This trend should be maintained. However, caution should be taken with the subsequent prevalence of commercial-based teleradiology services whose quality might not meet the required standard.

A policy intervention such as giving financial incentives would be needed to incentivize the appropriate use of teleradiology. The government's 2014 revision of medical service fees tightened the condition to make an insurance claim of interpretation fee for CT and MRI images

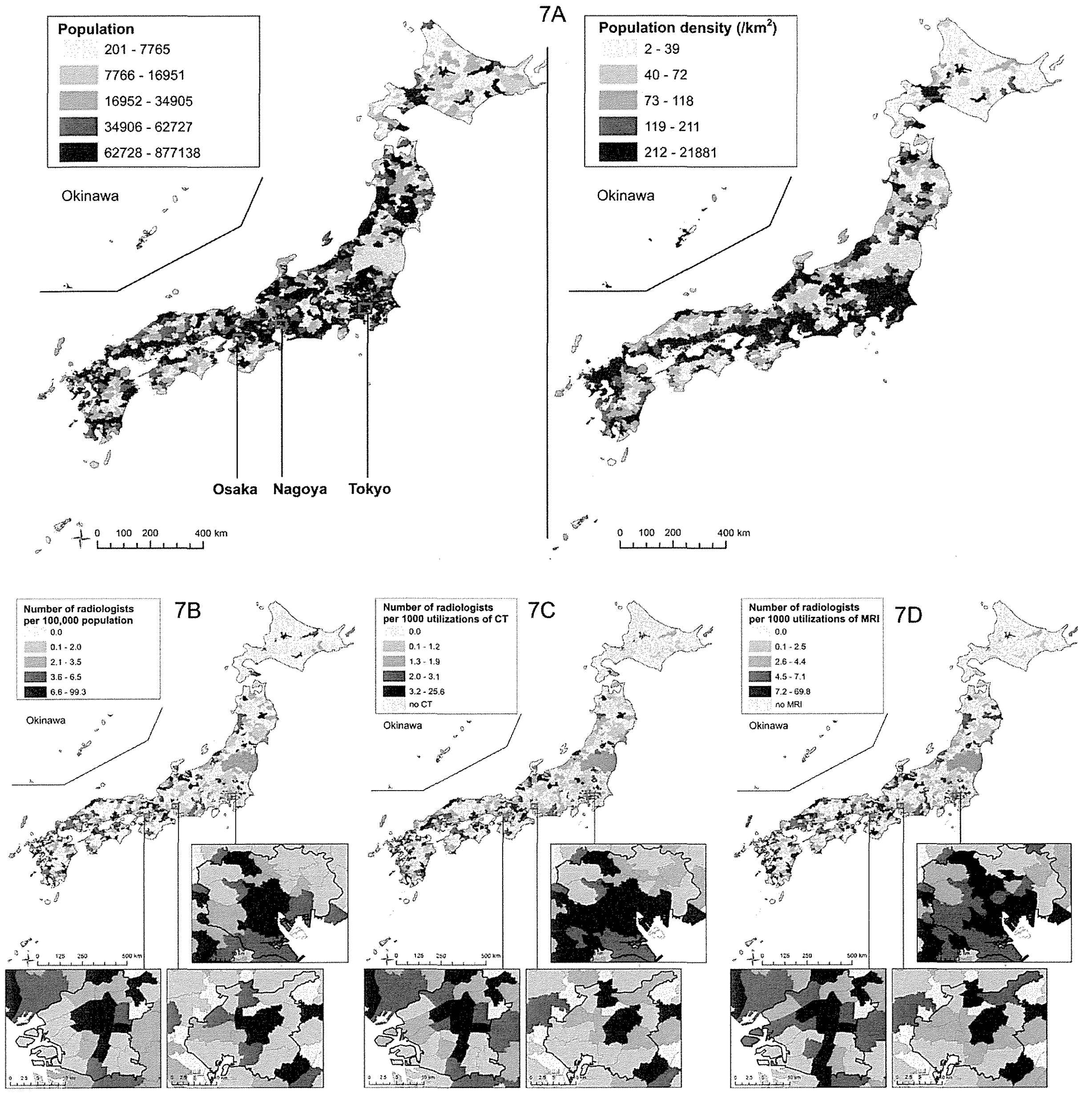

Fig 7. Population, population density (7A), number of radiologists per 100,000 population (7B), number of radiologists per 1,000 CT utilizations (7C), and number of radiologists per 1,000 MRI utilizations (7D) in each municipality in 2011. Quintile points of all values were used as cut-offs for color change.

doi:10.1371/journal.pone.0139723.g007

[32]. Contrary to the original policy intention to improve the quality of radiology services, this change has the potential to interrupt the current upward trend of teleradiology use, particularly in rural areas, which have to depend on teleradiology to provide radiology services.

The reason that clinics in cities were less likely to use teleradiology services than clinics in metropolis or towns/villages is unknown. It may be that clinics in metropolises have more financial power than those in cities and thus can be afford to use the services. Or it may be that

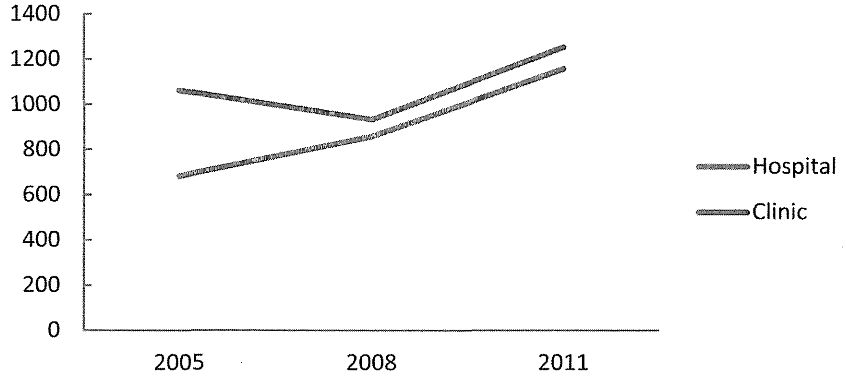

Fig 8. Number of institutions using teleradiology.

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metropolises have more specialised clinics that heavily use CT or MRI, such as comprehensive health check-up clinics and neurosurgery clinics, and thus need to use the services more than cities.

Limitations

Not all of the radiologists in this study are board-certified. All physicians whose self-reported specialty was radiology were recognized as radiologists in this study. Thus it is possible that our study subjects include trainees and senior radiologists that do not hold the board certificate of the Japan Radiological Society. In 2012, the number of radiologists in this study was 5883, which is substantially more than the 5108 registered board-certified radiologists in that year [33]. Also the radiologists in this study include not only diagnostic but also therapeutic radiologists, though the proportion of therapeutic radiologists among all radiologists is only 16.8% according to the survey of Japanese Board of Medical Specialties [34].

The urban-biased distribution of radiologists might be justified considering the functional difference between urban and rural hospitals. In general, urban hospitals serve as the specialized, technologically-advanced referral institutions compared with rural hospitals that mainly provide primary care. Therefore, urban hospitals need more radiologists than their rural counterparts.

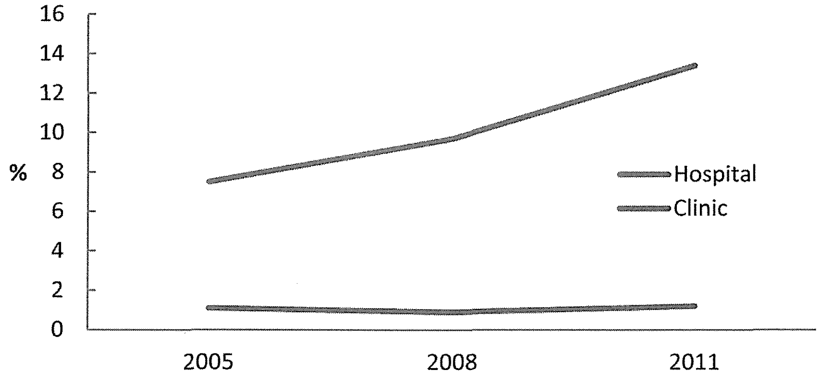

Fig 9. Proportion of institutions using teleradiology.

doi:10.1371/journal.pone.0139723.g009

Table 2. Hospital characteristics associated with using teleradiology (n = 8,632).

	Odds ratio	95% CI	P
Place			
Metropolis	1		
City	1.319	1.11–1.566	0.002
Town/village	1.612	1.257–2.068	<0.001
Ownership			
Private	1		
Public	1.916	1.635–2.246	<0.001
Diagnostic device			
without CT or MRI or PET	1		
with CT or MRI or PET	16.671	10.668–26.052	<0.001
Number of radiologists	1.007	0.983–1.033	0.561
Number of beds (per 100 beds)	1.071	1.024–1.121	0.003

CI: confidence interval

doi:10.1371/journal.pone.0139723.t002

Medical institutions using teleradiology in this study include institutions that both use and provide teleradiology services. Most of the institutions are presumed to be service users, but some large and urban hospitals can be providers. For this reason, the proportion of rural hospitals using teleradiology shown in the results may have been underestimated. In any case, however, most of the teleradiology services in Japan are provided by private companies that were not included in the dataset of this study, and thus the existence of service-provider hospitals would not influence the result.

Not all CT and MRI images were interpreted by radiologists. In Japan it is not unusual for neurologists and neurosurgeons to interpret CT and MRI images of the brain without consultation with radiologists. Thus increase in CT and MRI utilizations does not necessarily mean that the demand for radiologists has increased. Ideally all the images should be read by radiologists, and thus, the rate of increase in the production of images should be met by a corresponding increase in radiologists to interpret them; however, with so many images with such a few radiologists, this is unrealistic. A policy to regulate the number of the imaging devices in each secondary tier of medical care may be a reasonable option.

Table 3. Clinic characteristics associated with using teleradiology (n = 101,083).

	Odds ratio	95% CI	P
Place			
Metropolis	1		
City	0.764	0.672–0.87	<0.001
Town/village	0.908	0.733–1.125	0.376
Ownership			
Private	1		
Public	3.185	2.58–3.933	<0.001
Diagnostic device			
without CT or MRI or PET	1		
with CT or MRI or PET	18.777	16.721–21.086	<0.001

CI: confidence interval

doi:10.1371/journal.pone.0139723.t003

The geographic unit of analysis is municipality. Municipality is the smallest administrative unit and thus is ideal for this study, which aims at a precise analysis of geographic distribution. However, patients often cross municipality borders to seek medical services, and thus inter-municipality disparity of radiologists and radiology devices is not necessarily a problem. Rather, as reference data for redressing the resource maldistribution, the analysis based on the secondary tier of medical care, which is a complex of several municipalities within which most of the healthcare services are provided and managed, might be better, which should be conducted in the future.

Conclusions

The rapid increase in the number of radiologists has not equalized their geographic distribution in Japan; in other words, the number-distribution relationship has not followed the market-derived spatial competition force. The result was contrary to the amount-distribution relationship of diagnostic devices such CT and MRI reported previously [2]. The demand-supply balance of radiologists was more disrupted in rural than in urban areas, and the rural-urban gap continues to widen. Teleradiology, which is the only feasible way to close the gap, is spreading; therefore, a policy that supports the increasing use of teleradiology is needed.

Supporting Information

S1 Fig. Lorenz curves of the number of radiologists.
(TIF)

Author Contributions

Conceived and designed the experiments: MM S. Koike S. Kashima KA. Analyzed the data: MM S. Kashima. Wrote the paper: MM S. Koike S. Kashima KA.

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