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Probabilistic model to analyze patient accessibility to medical facilities using geographic information systems

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Abstract

In this study, we developed a probabilistic model to analyze patient accessibility to hospitals by using a geographic information system (GIS). In the consideration of patient accessibility, we do not have correct patient addresses because of the laws related to protection of a patient's personal information. Thus, we use a representational place in the city or the ZIP code of the area. However, this may lead to a decline in the accuracy of the analysis. In this study, we used a 500-m mesh map and obtained the population gender and age group data from the national census data, in order to estimate the patient accessibility to medical facilities in small areas. We calculated the probability that a patient lives in each mesh on the basis of the population gender and five-year age group data. We selected the appropriate mesh on the basis of this probability and investigated the time distance from the estimated mesh to each hospital by using a GIS. As a result, we calculated the time distance and its distribution by using the proposed method from limited available information. Further, we found that in the target cities, the average time distance to hospital calculated using the proposed method was longer than that calculated by using a previous method; the percentage of patients who took more time than the city average to reach a hospital by using the proposed method. This method is very useful when planning the geographical resource allocation of medical services.

Keywords: geographic information systems; grid mesh; revealed accessibility; health policy

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1. Introduction

In recent years, geographic information systems (GISs) have been used for investigating patient accessibility to medical facilities[1–3]. A GIS makes it easy to calculate the time distance from a patient's home to a medical facility by analyzing road-based travel routes. Usually, when we analyze patient accessibility on a large scale, we use the correct addresses of medical facilities; however, the correct patient addresses are not available because of the laws related to the protection of the patients' personal identifiable information. Therefore, we often use a patient's ZIP code or city code. In past studies, researchers used a representational place or area, such as a government office, as the patient's address in order to simulate the patient's accessibility to a medical facility[4]. This could lead to a decline in the accuracy of the analysis, particularly in a large city. Sanuki reported that the error of the road distance to facilities increases by the use of a representational place in a municipality area compared with a grid mesh[5]. A grid mesh is often utilized in works related to GISs to verify the spatial characteristics of small areas[6].

There are many studies that analyze spatial accessibility between people and medical facilities. Joseph classified such studies into two types: "revealed accessibility" and "potential accessibility"[7]. The latter is widely used by policy makers to estimate how healthcare policies affect potential accessibility. However, the utilization of revealed accessibility seems to be limited because of the difficulty of data preparation[8]. An epoch-making method is required to extract patient accessibility precisely from such limited information.

In this study, we used a 500-m mesh map, which is the smallest area for which we could obtain population, gender, and age group data from the national census data in order to estimate a patient's accessibility to medical facilities in small areas. The purpose of this study is to develop a probabilistic model to analyze patient accessibility to medical facilities.

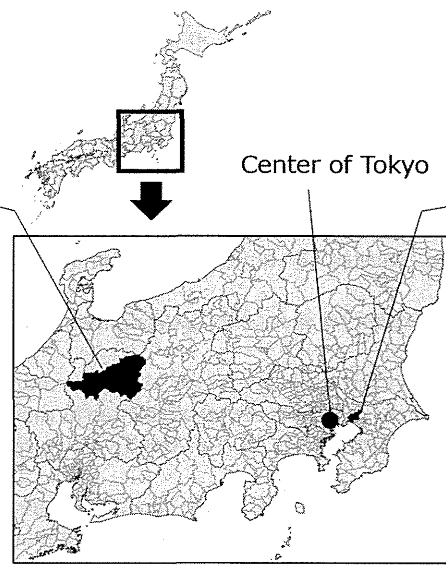
2. Materials and Methods

2.1. Materials

As a precondition of the simulation, we set the target field as two popular cities in Japan (Fig. 1). The first one, Funabashi, is a major urban city in Japan and a classic commuter town that belongs to the Tokyo Metropolitan Area. It has a population of about 610,000, an area of 85.6 km^2, and many medical facilities. The other is Takayama, the largest city in Japan. It has an area of 2177.6 km^2 but a population of only about 93,000. Takayama located in the countryside, as 92% of its area is surrounded by forests. In other words, Takayama is a provincial town and its people have only a few medical facilities to select from.

We targeted only the meshes in which people live. The number of target meshes in Funabashi was 386 and that in Takayama was 831.

In this study, we used the hospitalization data from a patient survey performed by the Ministry of Health, Labor, and Welfare of Japan. The target patients were discharged from each hospital during the month of September, 2011. The dataset provided data such as the patient's gender, five-year age group, city in which the patient lived, disease code, and hospital code. For our target facilities, we only considered hospitals, which have more than 19 beds as defined by law. The number of inpatient records in the 2011 survey was 1,009,943. From this set, we extracted the records of the inpatients that lived in the target cities. As a result, the number of records for Funabashi was 4,075 and that for Takayama was 860.



Takayama City

Population	92,747
Area	2177.6 km^2
Population Density	42.6 $persons/km^2$
Distance from central Tokyo	225.9 km
number of hospitals	4

Funabashi City

Population	609,040
Area	85.6 km^2
Population Density	7115 $persons/km^2$
Distance from central Tokyo	32.3 km
number of hospitals	21

Fig. 1 Locations of Funabashi City and Takayama City

2.2. Methods

This simulation consisted of the following two steps:

- Estimation of the approximate patient address locations
- Analysis of the time distance to hospitals from the patients' estimated addresses

2.2.1. Estimation of the approximate patient address locations

Fig. 2 shows a comparison of the concepts of a previous method and the proposed method. The previous study assumed that all patients lived in a representational place such as a government office. Thus, all of the patients going to the same hospital had the same time distance. In this study, we defined that each patient lived in one of the meshes in the target city based on the probability of population distribution. Thus, the time distance was different for each mesh.

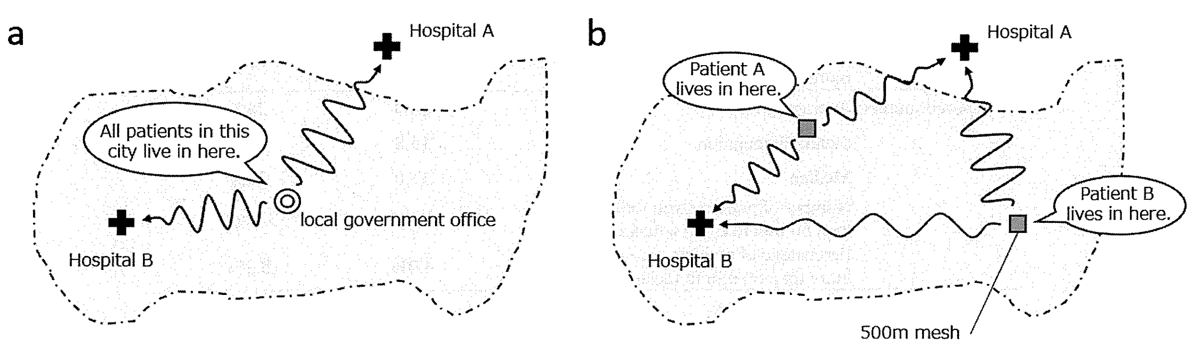


Fig. 2 Fundamental concept of (a) the previous method and (b) the proposed method

We obtained the population data for each gender and five-year age group from the 2010 national census data for each 500-m mesh. Note that when a mesh had an extremely low population, the population for that mesh was added to the population of an adjacent mesh. The population of the age-unknown people was distributed on this map for each gender and five-year age group.

Each record of the patient survey contained only the city in which the patient lived. Therefore, we estimated the mesh of each inpatient by the distribution of each gender and five-year age group in the population. First, we added up the populations of each gender and five-year age group of all the meshes in the city. Next, we calculated the probability that each mesh contained people of each gender and five-year age group. Finally, we selected a mesh based on this probability. This simulation was repeated 100 times in a random order for each inpatient.

2.2.2. Analysis of the time distance to hospital from patients' estimated addresses

We investigated the time distance from each mesh, containing the approximate geographical patient address, to the hospitals by using the GIS. The time distance was calculated as the transit time by car. We set 2 h as the limit of the analysis. We used ArcGIS Desktop Advanced ver. 10.2.2 and ArcGIS Network Analyst provided by ESRI Japan Co. Ltd. for the analysis.

Finally, we compared the time distance in the cases of Takayama and Funabashi. We investigated the average time distance, distribution of time distance, and percentage of inpatients who took more than 60 min to reach a hospital for the two considered methods.

3. Result

We present the descriptive statistics of the obtained results in Table 1. In the case of the proposed method, the average time distance to a hospital is longer than that calculated using the previous method for both Takayama and Funabashi. In particular, for Takayama City, the average time distance of the proposed method is more than twice as long as that of the previous method. In addition, the proposed method shows that the standard deviation of the time distance is greater than that of the previous method for both cities.

Table 1. Descriptive statistics of the obtained results

		Takayama City	Funabashi City
Number of records		76,488	398,855
Previous method	Average (min)	7.8	24.1
	Standard deviation	9.0	15.6
	Median	6.2	22.1
	Number of patients who took more than 60 min to reach a hospital	390	11,655
	Percentage of patients who took more than 60 min to reach a hospital	0.5%	2.9%
Proposed method	Average (min)	16.9	28.8
	Standard deviation	15.8	18.0
	Median	11.0	23.7
	Number of patients who took more than 60 min to reach a hospital	3,082	32,766
	Percentage of patients who took more than 60 min to reach a hospital	4.0%	8.2%

The percentage of inpatients who took more than 60 min to reach a hospital was unevenly distributed between the two methods. In Takayama City, the percentage of such patients in the case of the previous method was only 0.5%; however, in the case of the proposed method, it was 4.0%. Similarly, for Funabashi City, in the case of the previous method, the percentage of inpatients who took more than 60 min to reach a hospital was 2.9% and that in the case of the proposed method was 8.2%. According to the past survey, the percentage of inpatients who took more than 60 min to reach a hospital in Chiba Prefecture, containing Funabashi City, was 10.2%[9]. This is close to the result obtained using the proposed method.

Figs. 3 and 4 show the lines from the meshes to the hospitals in the proposed method. The points denote the meshes and the squares represent the hospitals. Both maps are of the same scale. According to Fig. 3, the number of lines is not large because there are few hospitals around Takayama City. In contrast, there are many hospitals around Funabashi City. People living in Funabashi City selected a hospital from a large number of hospitals.

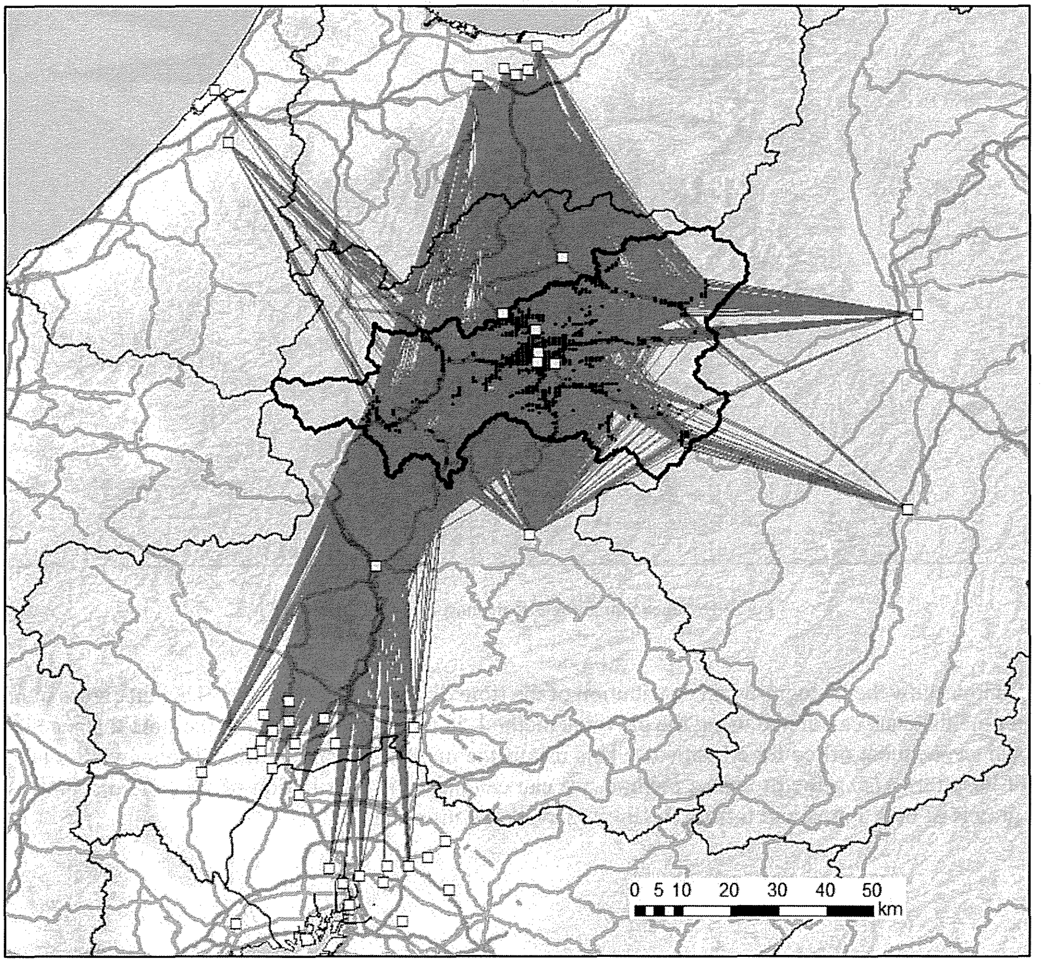


Fig. 3 The lines from the meshes to the hospitals for Takayama City

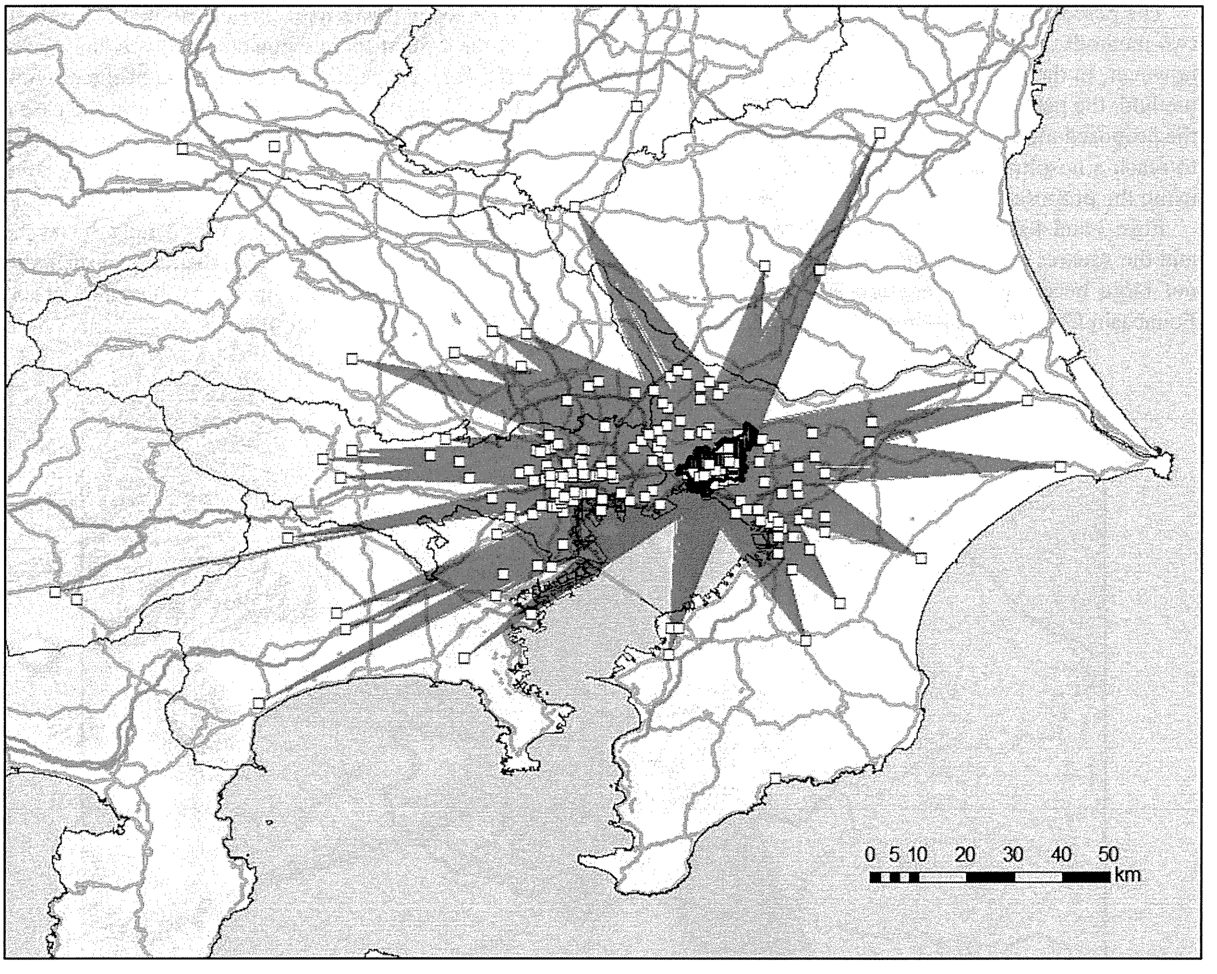


Fig. 4 The lines from meshes to the hospitals for Funabashi City

Figs. 5 and 6 show the histogram and distribution of the time distance for both cities. The left figure in both figures shows the time distance calculated using the previous method. In the previous method, the time distance is calculated from a local government office for all patients. This means the number of unique time distance values is equal to the number of hospitals. Using the proposed method, we can calculate the distribution of the time distance as shown in the right graphs of both Fig. 5 and 6 from the limited available information.

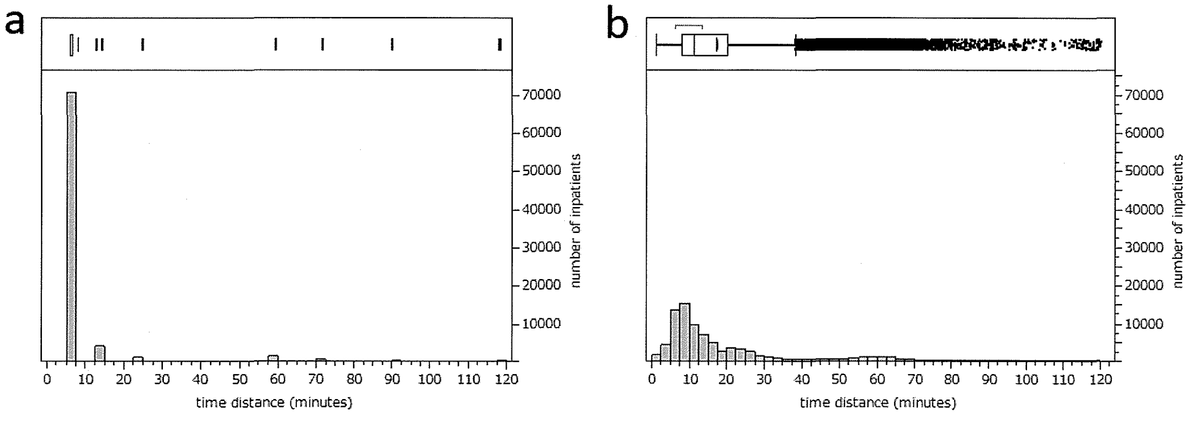


Fig. 5 Comparison of the histogram of the time distance in Takayama City obtained using (a) the previous method and (b) the proposed method

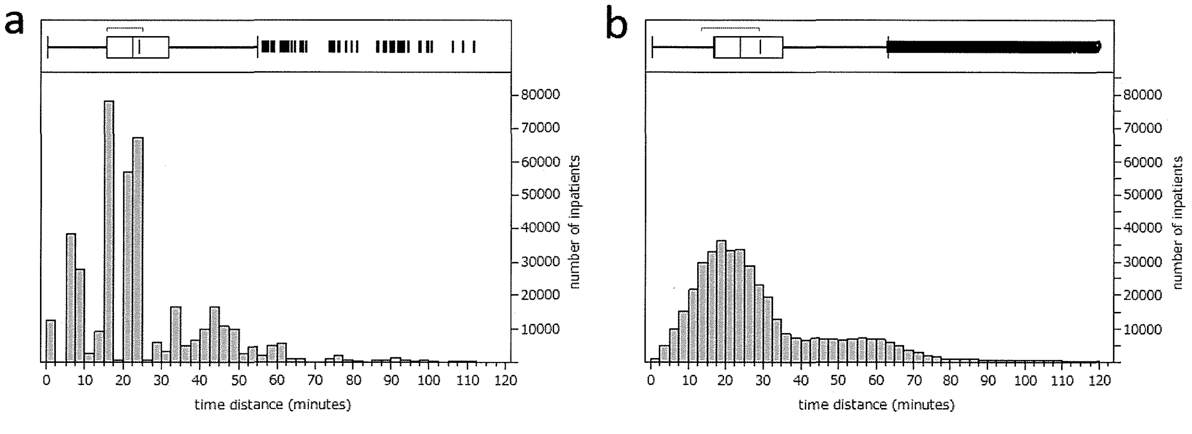


Fig. 6 Comparison of the histogram of the time distance in Funabashi City obtained using (a) the previous method and (b) the proposed method

Fig. 7 shows a comparison of the time distance between the previous and proposed methods. Both the vertical axis and the horizontal axis indicate the time distance in minutes. When we compared the distribution of the time distance between both cities, we found that this value for Takayama was wider than that for Funabashi.

The correlation coefficient between two methods of Funabashi City has a high value of 0.80. However, for Takayama City, it has a value of 0.48. For example, at a hospital in Takayama City, the time distance based on the previous method was 59.4 min; however, the minimum time distance calculated using the proposed method was 13.6 min and the maximum was 117.1 min.

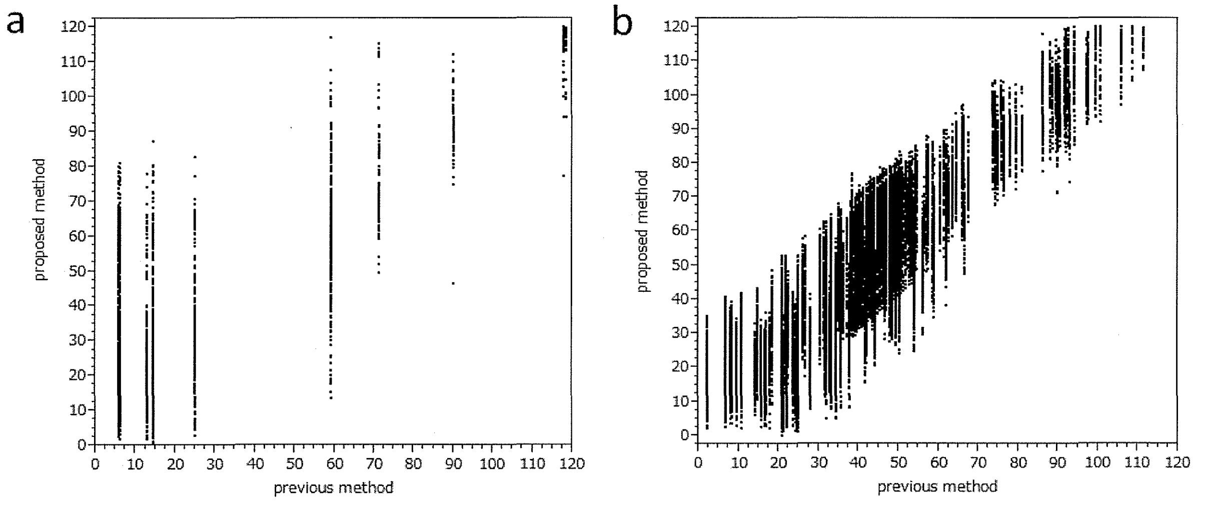


Fig. 7 Comparison of time distance between the previous method and the proposed method for (a) Takayama City and (b) Funabashi City

4. Discussion

In this study, we developed a probabilistic model to analyze the patient accessibility to medical facilities from each mesh by using a GIS. The proposed method estimates the approximate geographical address of the patient using a 500-m mesh, in contrast to the previous method that defines all patients as living in a government office of the city. By using this method, we can estimate the distribution of the time distance for analyzing a patient's accessibility to a medical facility, even from limited information.

The average time needed to travel to hospital is longer than that obtained using the previous method for both Takayama and Funabashi. In the proposed method, the percentage of inpatients who took more than 60 min to reach a hospital was approximately equal to the results of a past survey. This fact suggests our proposed method can reflect the reality of time distance. In addition, policy makers need to identify patients with lower accessibility than others in order to plan the resource allocation of medical services more effectively. We believe the propose method will be very useful when resolving policy planning issues.

In this study, we tentatively targeted two cities; however, this method could be applied in other areas. In addition, if we can use other factors in each city such as city size, number of hospitals, population density, and distance between local government offices and population centroid, we can include those potential factors affecting patients' accessibility in order to improve the proposed method. Furthermore, this model uses the probability that each mesh contains people of each gender and five-year age group when we estimate a patient's address. However, there are many other potential models. For example, the Huff model is often used to evaluate a hospital's attraction from a place by its size (number of beds) and distance (or time distance) [10]. By combining these models with our model, we will improve the accuracy of the estimate.

This study has the following limitations. First, patient survey in Japan is based on stratified sampling, not a complete survey. When calculating time distance, we did not consider time period, season, or means of transportation other than cars. Second, when estimating a patient's address, we used only population gender and age; however, the probability of selecting a hospital is not always the same for the entire city, even for patients of the same gender and age. In the areas around a hospital, the probability that a patient will select that hospital may be higher than the city average.

5. Conclusion

In this study, we developed a probabilistic model to analyze a patient's accessibility to hospitals by using a GIS and 500-m mesh. Using this method, we can calculate the distribution of the time distance and hence the patient's accessibility to medical facilities. This method is very useful when planning the geographical resource allocation of medical services. In future, we plan to target all cities of Japan and investigate the factors affecting patient accessibility.

Acknowledgements

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ORIGINAL ARTICLE

Career pathways of board-certified surgeons in Japan

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Abstract

Purpose To investigate the career pathways of board-certified surgeons' and the factors associated with them maintaining their certification in Japan.

Methods We analyzed data from the surveys of physicians, dentists and pharmacists. A multivariate logistic regression model was used to investigate whether factors such as gender, year of registration, place of work, and subspecialty board certification were associated with maintaining board certification.

Results Most Japanese surgeons attain board certification within 5–10 years of initial medical registration. After adjusting for possible confounding factors, the odds of maintaining board certification were significantly lower for women, those who were beyond 20 years post-registration, those who worked in hospitals other than academic hospitals or clinics, and those who had board certification in surgery only. Of the total board-certified surgeons analyzed, 93.2 % continued to work in hospitals and 2.8 % moved to clinics within 2 years. Of those who moved from hospitals to clinics, half continued to practice surgery, while nearly 40 % changed their specialty to internal medicine.

Conclusion It is necessary to establish a special training system for mature surgeons who move from surgery to general practice later in their careers. As the number of female surgeon increases, a support system is also required to secure the future supply of surgeons.

Keywords Board certification · Surgeon career pathway · Japan

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Introduction

Providing a high quality medical service is the common goal for all medical professions. To achieve this, a reliable training system and board certification are used as a quality assurance system. In Japan, specialty board certification for medical doctors is provided by an independent academic society. The standardization of the training program and the quality of board certification have drawn public attention amid growing concern about an aging population and the shortage and maldistribution of doctors. Thus, the Ministry of Health, Labour, and Welfare (MHLW) in Japan established a panel on medical specialties to review and redesign the board certification system. Its final report [1] recommended establishing an independent organization to

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accredit each training program and certify specialists. The new training program under this system is scheduled to start in 2017.

Previous studies have shown that doctors often change their specialty [2, 3], especially early in their career [4, 5]. In Japan, a proportion of surgeons who have left hospitals to work in clinics, no longer practice surgery [6, 7]. However, little is documented about when surgeons receive or resign their board certification, in what type of practice they engage after they leave hospitals, and what factors are associated with maintaining their certification. This is partly because the board certification process was operated by individual academic societies and the data were stored separately. The National Clinical Database initiative was started to collect clinical data including surgical procedures related to the board certification system [8], but this information has not yet been used to analyze surgeons' career pathways.

The infrastructure to analyze the career pathways of board-certified surgeons has recently been established. MHLW conducts a survey of physicians, dentists, and pharmacists every 2 years. This survey is based on the Medical Practitioners' Act, and physicians must report their work status at the end of the survey year. Since 2010, the survey has collected data on board certification status in 55 areas of specialty. We conducted the present study to investigate the career pathways of Japanese board-certified surgeons and analyze the factors associated with maintaining surgery certification. In particular, we sought to investigate at what point a surgeon acquires and later resigns surgery board certification, what factors are associated with them maintaining board certification, and what type of practice change prompts surgeons to move from hospitals to clinics.

Materials and methods

Setting

In Japan, doctors acquire an MD degree after completing a 6-year course in medical school. Thereafter, they undertake a 2-year postgraduate clinical training program. Those who seek board certification in surgery then need to be trained in a designated facility for at least another 4 years, which can include 2 years of postgraduate clinical training in a certain condition. Once they pass the written examination and have performed the minimum number of surgical procedures required, they are eligible to take a final oral examination, 5 years from when their surgical training started. Board certification needs to be renewed every 5 years thereafter. Board certification in surgery is a prerequisite for further certification in surgical subspecialties such as gastroenterological, thoracic, cardiovascular, and pediatric surgery. According to data from the 2012 survey of physicians, dentists and pharmacists, 303,268 doctors responded to the survey, including those who were not practicing at the time. Of those working in medical facilities, 16,083 (5.6 %) reported general surgery as their area of practice [9].

Data analysis

After being granted permission from the MHLW to use data from the physicians' subset of the survey of physicians, dentists and pharmacists for our research, we created a cohort data set from the 2010 and 2012 surveys. In each survey, gender, years since initial medical registration, place of work (academic hospital, local or independent hospital or clinic, and others), area of practice and board certification status were investigated for board-certified surgeons. The status changes of those surgeons who held board certification in either one of the survey years were analyzed by the year of medical registration. Four levels were defined:

1. "No report to certification", for those who did not participate in the survey in 2010 and whose board certification status was therefore unknown, but who had surgery board certification in 2012;
2. "No certification to certification", for those who were not certified in surgery in 2010 but who were certified in 2012.
3. "Certification to no certification", for those who were certified in 2010 but not in 2012;
4. "Certification to no report"; those who were certified in 2010 but did not participate in the survey in 2012, and whose board certification status was therefore unknown.

The net change in each registration cohort was calculated.

To investigate the factors associated with maintaining board certification in surgery, a logistic regression analysis was conducted for those doctors with board certification in surgery in 2010 and who completed the survey in both 2010 and 2012 ($n = 18\ 712$), by adjusting sex, years since initial medical registration (0–9, 10–19, 20–29, 30–39, 40–49, 50 years or more), type of facility (academic hospital, other hospital, clinic, or other), and status of board certification (surgery only; surgery and another area but excluding gastroenterological, general thoracic, cardiovascular, and pediatric surgery; or board certification in surgery and at least one of gastroenterological, thoracic, cardiovascular, and pediatric surgery).

To examine what happened to board-certified surgeons who left their hospitals (whether academic or other types), those who worked in hospitals in 2010 were followed up in 2012. The facility type by years since initial medical registration, and practice areas, were investigated. IBM SPSS

Table 1 Characteristics of the study subjects

	2010 survey		2012 survey	
Number, (%)	19562	100.0	20214	100.0
Male, (%)	18697	95.6	19146	94.7
Place of work, (%)				
Academic hospital	3960	20.2	4301	21.3
Other hospital	11670	59.7	12355	61.1
Clinic and others	3932	20.1	3558	17.6
Main area of practice, (%)				
Surgery	8345	42.7	8196	40.5
Gastroenterological surgery	3134	16.0	3521	17.4
Cardiovascular surgery	1735	8.9	1881	9.3
General thoracic surgery	1078	5.5	1193	5.9
Breast surgery	859	4.4	1,044	5.2
Pediatric surgery	381	1.9	473	2.3
Other surgical area	368	1.9	372	1.8
Internal medicine	1429	7.3	1366	6.8
Gastroenterology	641	3.3	563	2.8
Other internal medicine	234	1.2	208	1.0
Other	870	4.4	940	4.7
Unknown	488	2.5	457	2.3
Area of board-certified specialty, (%)				
General surgery	19562	100.0	20214	100.0
Gastroenterological surgery	5241	26.8	5524	27.3
Gastroenterology	2938	15.0	2953	14.6
Gastroenterological endoscopy	2263	11.6	2277	11.3
Cardiovascular surgery	1386	7.1	1527	7.6
General thoracic surgery	1032	5.3	1201	5.9
Coloproctology	1024	5.2	1067	5.3
Breast surgery	792	4.0	897	4.4
Emergency medicine	614	3.1	663	3.3
Cardiology	555	2.8	568	2.8
Hepatology	446	2.3	573	2.8
Pediatric surgery	434	2.2	486	2.4
Bronchoscopy	405	2.1	432	2.1
Anesthesiology	197	1.0	153	0.8
Dialysis	184	0.9	178	0.9
Ultrasonography	168	0.9	157	0.8
Respiratory diseases	139	0.7	187	0.9
Clinical oncology	119	0.6	112	0.6
Years since initial medical registration, mean, SD				
Total	22.5	11.2	22.6	10.9
Sex				
Male	23.0	11.1	23.1	10.9
Female	13.1	6.6	13.4	6.4
Place of work				
Academic hospital	16.5	8.0	17.8	8.1
Other hospital	22.0	10.0	22.5	10.0
Clinic and others	30.3	12.7	27.2	13.3
Board certification				
Surgery only	20.3	12.5	20.3	12.2
Surgery + other 1[a]	24.5	11.3	24.6	10.6
Surgery + other 2[b]	23.9	9.1	23.9	9.2

Table 1 continued

[a] Board certification in surgery and other fields, excluding gastroenterological, general thoracic, cardiovascular, and pediatric surgery

[b] Board certification in surgery and at least one of gastroenterological, general thoracic, cardiovascular, and pediatric surgery

Statistics Ver. 21.0J. (IBM Japan, Ltd., Tokyo, Japan) was used for statistical analyses. $P < 0.05$ was considered significant. The Ethics Committee, Graduate School of Medicine and Faculty of Medicine, The University of Tokyo, assessed this study and gave permission for it to be carried out.

Results

Characteristics of study participants

The vast majority (95 %) of board-certified surgeons were men. Overall, 40 % of the surgeons reported "general surgery" as their main area of practice, another 40 % reported "other surgical subspecialties", and 10 % reported "internal medicine and its related areas". About 25 % reported additional board certification in gastroenterological surgery; 15 %, in gastroenterology; and 10 % each in gastroenterological endoscopy and cardiovascular surgery (Table 1).

Career pathways of board-certified surgeons

The timing of initial reporting of board certification in surgery was skewed to the surgeons' early career, within 5–10 years of initial medical registration, with numbers gradually declining over time. The net change fell to negative around 20 years post-registration (Fig. 1). Of the board-certified surgeons working in hospitals in 2010, 6.8 % had left these hospitals 2 years later. Notably, more than 10 % of the surgeons in the youngest age group (0–9 years since initial medical registration) and in the much older group (35 or more years post-registration) had left their hospitals, and the number of those who did not complete the survey surpassed the number of those who moved elsewhere in the age groups of 0–14 years and 40 years or more since initial registration (Fig. 2). Of those who moved from hospitals to clinics and other facilities, the number who continued to practice surgery and its related fields fell by half. Almost half, 49.2 %, chose internal medicine and its related areas as their main area of practice, with 35.4 % choosing internal medicine and 13.8 % choosing an internal medicine-related area of practice (Fig. 3).

Factors associated with maintaining general surgery board certification

The annual surgery board maintenance rate for those who were certified in 2010 and who completed the survey in both 2010 and 2012 was estimated to be 92.3 % (the square root of 15 951/18 712). After adjusting for possible confounding factors, the odds for maintaining board certification in surgery were significantly lower in women, those who were 20 years or more post-registration, those who worked in hospitals other than academic hospitals or in clinics, and those who had no additional certification on top of the surgery board; than in men, those who were less than 10 years post-registration, those working in academic hospitals, and those with subspecialty certification, respectively (Table 2).

Discussion

Career pathways of board-certified surgeons

Based on the findings of our study, the career pathways of board-certified surgeons in Japan seem to follow a certain pattern. Those who intend to obtain board certification in surgery generally receive it earlier in their careers, within 5–10 years post-registration. After 20 years, they tend to give up renewing their certification in surgery, without any definite retirement age. Most of those who stopped working in hospitals gave up their surgical career and changed their practice to internal medicine or a related area.

As shortage of surgeons has become a major concern in the medical workforce, studies of surgeons' career paths is now important. Previous studies identified the negative attitude of medical students towards surgery, because of the time and effort required to obtain board certification [10]. Thus, revision of the subspecialty certification requirements and standardization of the certification process without sacrificing quality, are key issues in the current reform of the Japanese board certification system.

The smooth transition from one surgical career to another is important. Board-certified surgeons working in hospitals give up their surgical career if they move to work in clinics. That many of them change their main area of practice to internal medicine or its related areas is one of the key features of Japanese surgical careers. Surgeons who change their area of practice can work for longer than those who retire instead. This naturally increases the net labor supply of doctors. It should be noted that in Japan, general practice/family practice has not been widely accepted as an

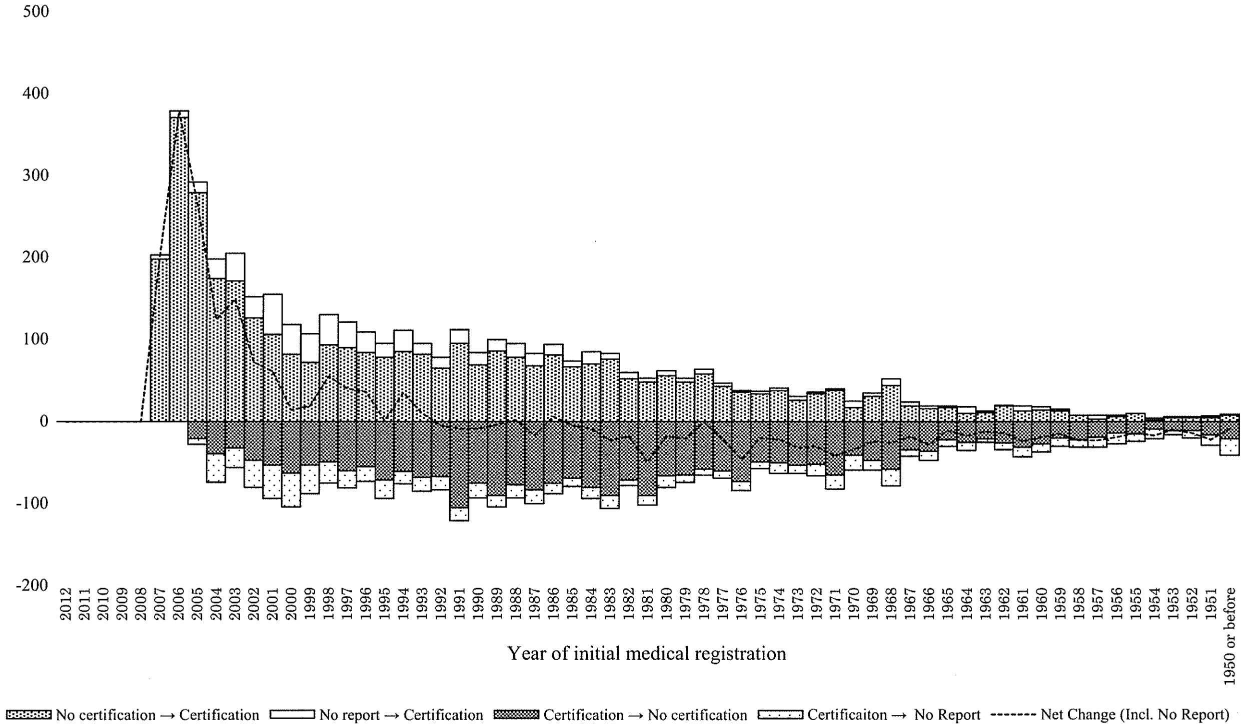

Fig. 1 Changes in surgery board certification status between 2010 and 2012 by the year of initial medical registration. The inflow of board-certified surgeons peaked in the early years from initial medical registration, and gradually declined thereafter. The net change fell to minus at around 20 years after initial medical registration, but no retirement age was defined

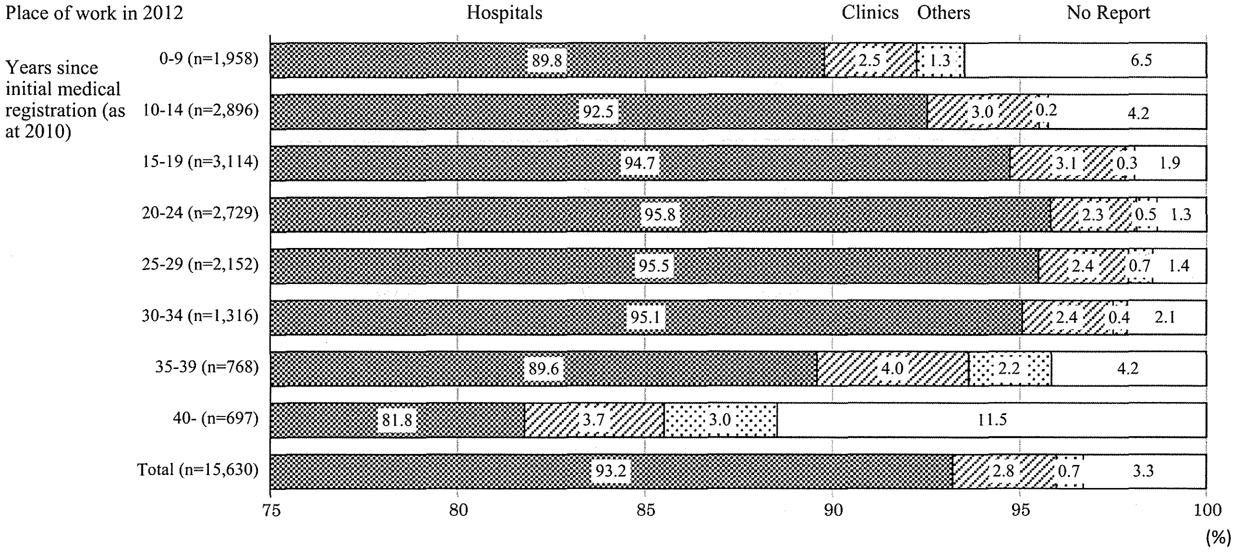

Fig. 2 Workplace distribution in 2012 for board-certified surgeons who worked in hospitals in 2010. In total, 93.2 % of surgeons continued to work in hospitals, but the ratio differed in age groups. Individuals in both the youngest and oldest age groups were more likely to move to other workplaces

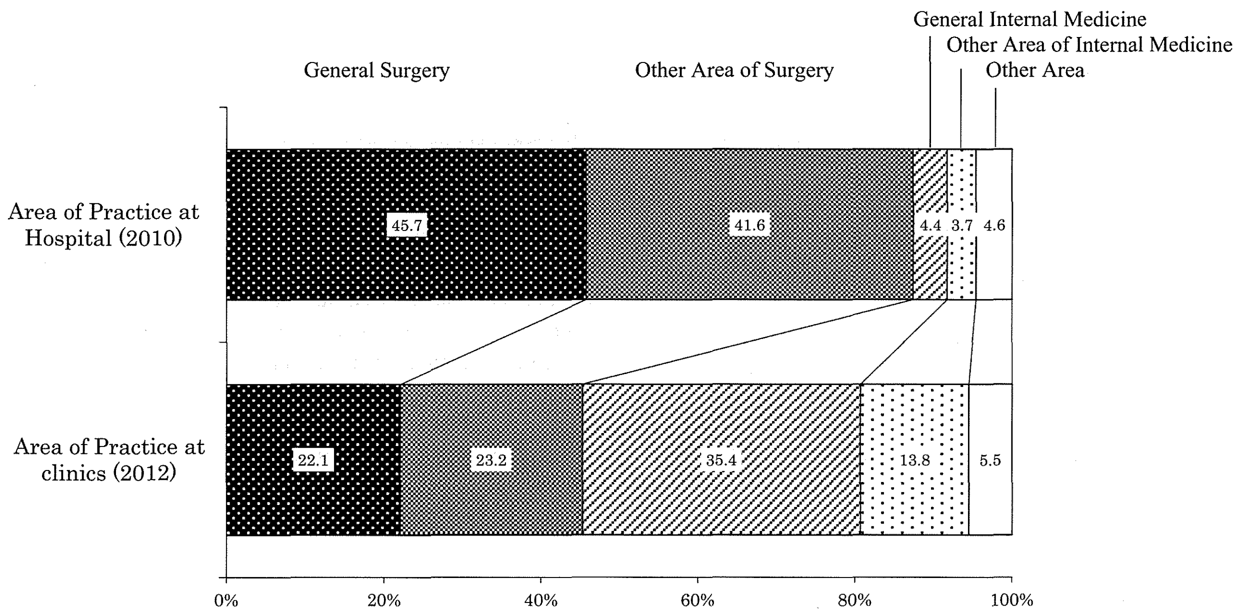

Fig. 3 Distribution of practice area of 2010 board-certified surgeons who moved from hospitals to clinics between 2010 and 2012 ($n = 435$). The proportion of surgery and surgery-related areas of practice fell sharply from 97.3 % (45.7 + 41.6 %) to 45.3 % (22.1 + 23.2 %) when they moved. Many changed their area of practice to internal medicine and its related fields

area of practice for physicians [11, 12]. Rather, physicians of general internal medicine based in clinics provide primary care in Japan. One of the key issues in revising the medical specialty board system is to establish a certification system for doctors providing primary care. There have been various discussions on what sort of training should be mandated and how to certify doctors who intend to work in general internal medicine. These discussions have focused mainly on establishing a training and certification system for young doctors. The present study shows that a significant number of surgeons give up their surgical career to enter general practice/family medicine at clinics. This

Table 2 Predictors of continuation of general surgery board certification status

	Number			Adjusted odds ratio	(95 % confidence interval)	P value
	Total ($n = 18712$)	Certified in 2012 ($n = 15951$)	Not certified in 2012 ($n = 2761$)			
Sex						
Male	17906	15,254	2652	1.00	(Reference)	
Female	806	697	109	0.80	(0.65–0.99)	0.043
Years since initial medical registration (2010 figure)						
0–9	1907	1715	192	1.00	(Reference)	
10–19	6520	5868	652	0.95	(0.79–1.13)	0.55
20–29	6073	5273	800	0.73	(0.61–0.87)	0.001
30–39	2791	2200	591	0.43	(0.36–0.52)	<0.001
40–49	1025	684	341	0.29	(0.23–0.36)	<0.001
≥50	396	211	185	0.21	(0.16–0.27)	<0.001
Place of work in 2010						
Academic hospital	3768	3441	327	1.00	(Reference)	
Other hospital	11345	9944	1401	0.84	(0.74–0.96)	0.009
Clinic and others	3599	2566	1033	0.40	(0.35–0.47)	<0.001
Board Certification as of 2010						
Surgery only	7552	6284	1268	1.00	(Reference)	
Surgery + other 1[a]	3440	2839	601	1.16	(1.03–1.30)	0.01
Surgery + other 2[b]	7720	6828	892	1.51	(1.37–1.67)	<0.001

[a] Board certification in surgery and other fields, excluding gastroenterological, general thoracic, cardiovascular, and pediatric surgery

[b] Board certification in surgery and at least one of gastroenterological, general thoracic, cardiovascular, and pediatric surgery

indicates that the re-training of these surgeons should be considered.

Female surgeons and board certification

An important finding of this study is that the odds ratio for maintaining board certification in surgery was significantly lower for women than for men, after adjusting for possible confounding factors. This has several implications. The proportion of female doctors is very low, despite increasing numbers of female medical students. This could lead to further shortages in the surgical workforce [13] as female doctors still tend to encounter difficulties with their surgical career development [14, 15]. The workforce participation rate drops for female doctors in their late 20 s and early 30 s [16].The retention rate is also lower for surgery than other specialties in Japan [17]. As the number of female doctors increases in the future, the career support for female surgeons will become more important to secure the surgical workforce.

Limitations

This study has several limitations. First, although the survey of physicians, dentists and pharmacists was designed as a census, there were non-respondents and the self-administered reporting system might affect the quality of the data. Second, as the survey only started to collect data on specialty board certification so recently, we could only analyze data from 2010 and 2012. The Japanese medical education system is in a state of transition since the introduction of mandatory initial clinical training in 2004, and sequential reform is under way. Therefore, current trends may not be applicable in the future. Third, renewing board certification requires a certain number of surgical procedures and if the applicant does not fulfill the minimum requirement, board re-certification is suspended. Surgeons can reactivate their certification when they fulfill the case requirements. As this study was unable to differentiate new from re-certifications, this may have affected the dynamics of board certification in surgery. Fourth, the study analyzed the current status but did not investigate the reason for transitions. We do not know why doctors change their career.

In spite of these limitations, this census data analysis of Japanese doctors provides a useful insight into board-certified surgeons and their career paths.

Conclusion

It is necessary to establish a special training system for mature surgeons who tend to move from surgery to general practice later in their careers, alongside that for younger surgeons. As the number of female surgeons increase, a support system for them is also required to ensure the future supply of surgeons in this country.

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Compliance with ethical standards

Conflict of interest Department of Health Management and Policy, Graduate School of Medicine, The University of Tokyo, where Soichi Koike is based, is an endowed department. It received funds from Nissay Information Technology Co., Ltd., Chugai Pharmaceutical Co., Ltd., Shionogi & Co., Ltd., Asahi Kasei Pharma Corporation, CRECON Research & Consulting Inc., and Otsuka Pharmaceutical Co., Ltd. The other co-authors have no conflicts of interest.

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RESEARCH Open Access

The effect of concentrating obstetrics services in fewer hospitals on patient access: a simulation

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Abstract

Background: In Japan, the number of obstetrics facilities has steadily decreased and the selection and concentration of obstetrics facilities is progressing rapidly. Obstetrics services should be concentrated in fewer hospitals to improve quality of care and reduce the workload of obstetricians. However, the impact of this intensification of services on access to obstetrics hospitals is not known. We undertook a simulation to examine how the intensification of obstetrics services would affect access to hospitals based on a variety of scenarios, and the implications for health policy.

Methods: The female population aged between 15 and 49 living within a 30-min drive of an obstetrics hospital was calculated using a Geographic Information System for three possible intensification scenarios: Scenario 1 retained facilities with a higher volume of deliveries without considering the geographic boundaries of Medical Service Areas (MSAs, zones of healthcare administration and management); Scenario 2 prioritized retaining at least one hospital in each MSA and then retained higher delivery volume institutions, while Scenario 3 retained facilities to maximize population coverage using location-allocation modeling. We also assessed the impact of concentrating services in academic hospitals and specialist perinatal medical centers (PMCs) alone.

Results: In 2011, 95.0 % of women aged 15–49 years lived within a 30-min drive of one of 1075 obstetrics hospitals. This would fall to 82.7 % if obstetrics services were intensified into academic hospitals and general and regional PMCs. If 55.0 % of institutions provided obstetrics services, the coverage would be 87.6 % in Scenario 1, whereas intensification based on access would achieve over 90.5 % coverage in Scenario 2 and 93.9 % in Scenario 3.

Conclusions: Intensification of obstetrics facilities impairs access, but a greater caseload and better staffing have the potential advantages of better clinical outcomes and reduced costs. It is essential to consult residents of hospital catchment areas when reorganizing clinical services; a simulation is a useful means of informing these important discussions.

Keywords: Japan, Health policy, Obstetrical delivery, Hospital merger, Facility access

Background

In healthcare the correct balance between quality, cost and access are difficult to achieve, and provision of clinical obstetrics services is no exception. Several studies have demonstrated the effects of closure on hospital cost [1] and the efficiency of the hospital market [2]. Other studies have examined the effect of hospital closure on neonatal and infant mortality [3, 4]. A study of maternal deaths occurring in Japan suggested that the intensification of obstetrics services to avoid single-obstetrician facilities reduces maternal mortality [5]. Even if closure of hospitals can achieve better quality of care as well as reducing the burden on obstetricians and midwives, public opinion is often firmly against hospital closures because of the impact on access to healthcare services. Reducing hospital services has political implications that may override technical considerations [6].

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Reorganization of maternity hospital supply is a highly sensitive topic and a matter for lively public debate [7, 8]. It is therefore important to be able to demonstrate improvements in outcome to balance against any perceived negative impact on access when services are reorganized. A simulation study of predicted outcomes after hospital closure conducted in the Netherlands found that the best strategy to avoid potential increases in intrapartum and first-week mortality was to close the ten smallest hospitals (approximately 10 % of the total number of hospitals), but to avoid closing adjacent small facilities [9]. Another study in Japan found a relationship between the time taken to drive to a specialist perinatal medical center and neonatal mortality rate, and concluded that neonatal mortality rate could be reduced by improving geographic accessibility to perinatal services [10].

In Japan, the number of obstetrics facilities has steadily decreased, and the selection and concentration of obstetrics facilities is progressing rapidly and effectively [11]. In 1996, there were 1720 hospitals and 52,976 deliveries, but these had fallen to 1126 hospitals and 47,626 deliveries by 2008 [12], representing a 3.5 % annual decline in the number of facilities and a 3.6 % increase in the rate of deliveries per hospital. This decline is considered to have occurred at least partly as a result of a shortage of obstetricians. As in many other more developed countries, obstetricians in Japan are reportedly demoralized by the fear of litigation and criminal negligence charges, and are leaving the profession [13]. An increasing proportion of female and younger obstetricians [14], who tend to put more emphasis on working fewer hours, life outside work and income [15], has also been identified as a factor contributing to the shortage of obstetricians. The disproportionate distribution of physicians in urban areas has been accelerating [16]. Consequently, preserving some hospitals in more rural areas does not necessarily mean that the hospital could function with sufficient staff.

Recently, the Medical Reform Committee of the Japan Society of Obstetrics and Gynecology published Grand Design 2015 (GD2015) entitled 'Renovation of the obstetrics and gynecology healthcare system in Japan' [17]. Although GD2015 did not set a target year, it recommended that services should be concentrated in regional flagship hospitals to reduce the burden on individual obstetricians and achieve sufficient numbers of full-time obstetricians in the core institution to populate a rotating shift system. It also recommended that local flagship obstetrics centers should be selected from existing secondary and tertiary public hospitals to provide a sustainable working environment for obstetricians.

The purpose of this study was to assess to what extent the negative effect on accessibility could be alleviated by different methods of service intensification. We defined optimal access to an obstetrics facility as the proportion of women of childbearing age (15–49 years) within a 30-min drive of a hospital providing obstetrics services. We considered intensification into academic hospitals and perinatal medical centers only, and three other scenarios: (1) consider only the number of deliveries (hospital volume) so as to maximize quality and minimize cost; (2) consider only maximizing accessibility; and (3) a combination of (1) and (2).

Methods

Setting

At the end of October 2011 there were 1896 municipalities forming 47 prefectures in Japan. The healthcare provision for several municipalities, divided into Medical Service Areas (MSAs) defined by Medical Service Law, is managed as a single unit of medical service provision for most diseases and conditions. Each prefecture regulates the number of hospital beds available in each MSA, overseeing the allocation of healthcare resources to provide services. In 2011, there were approximately 350 MSAs.

Medical services in Japan, including obstetrics services, are provided by hospitals or clinics. In Japan, medical facilities with 20 or more inpatient beds are defined as hospitals, and those with fewer than 20 as clinics. However, not all hospitals provide obstetrics services. We defined an obstetrics hospital as one that had an obstetrics department together with other support specialties. Among obstetrics hospitals, core facilities are selected and designated as perinatal medical centers (PMCs) by the government. There are two types of PMC. General PMCs have a maternal and fetal intensive care unit and accept round-the-clock emergency referrals of critically ill mothers and babies and high-risk pregnancies. Regional PMCs offer a higher level of specialist obstetric, neonatal and pediatric services [18]. In 2011, there were 8605 hospitals and 99,547 clinics in Japan; of these, 1075 hospitals and 46,386 clinics provided obstetrics services [19] and there were 100 general and 292 regional PMCs.

In Japan, cars may be driven by those aged 18 years or over, and lightweight motorcycles by those 16 years or older. Mean car ownership per household is 1.081 [20] and emergency transportation is provided free of charge.

Data

We analyzed data from the most recently published Survey of Medical Institutions (Static Survey), undertaken in 2011. This survey is conducted by the Japanese government every 3 years, and covers all hospitals and clinics and is not limited to obstetrics facilities. Data are collected on clinical facilities and specific equipment available, staffing levels and services provided, but data concerning cost or outcome are not recorded. We obtained permission from the government to use individual hospital data for research purposes. Institutional data were current as of October 1, 2011 and the number of deliveries was recorded for the month of September 2011. Because of the effects of the Great East Japan earthquake, some of the affected areas were excluded from the survey and so were also excluded from our analysis. Population data were obtained from the 2010 National Census.

Data analysis

To analyze the characteristics of the study subjects, obstetrics hospitals were classified into general PMCs, regional PMCs and others. Three scenarios were used to simulate the intensification of obstetrics hospitals based on the number of deliveries per hospital and the individual characteristics of the MSAs: Scenario 1, to retain higher volume (number of deliveries) obstetrics hospitals until the target number of hospitals was reached without considering the MSAs; Scenario 2, to retain higher volume obstetrics hospitals until the target number of hospitals was reached but retaining at least one obstetrics hospital in each MSA; Scenario 3, to retain obstetrics hospitals to maximize the proportion of the female population aged 15–49 residing within a 30-min drive of the nearest facility (Table 1).

We selected three intensification targets for our simulations. Our selection was informed by the number of obstetrics facilities in 2011 (1075) and the number of PMCs and academic hospitals (405). We would have chosen targets of 1000, 800 and 600 hospitals to lie within this range, but revised these to take into account the proportion that did not submit data to the 2011 Medical Institution (Static) Survey because of the Great East Japan Earthquake. We therefore used adjusted targets of 985, 788 and 591. We reduced each target by 98.5 %, as in 2010—the year before the Earthquake—the number of hospital births in reported areas was 98.5 % of the national total [21].

In each scenario and for each target level of intensification, we calculated the number of deliveries, and the number of obstetricians and midwives reallocated to other institutions, and the national number of deliveries after intensification. Then, proportions of the female population aged 15–49 able to access the nearest obstetrics hospital within 30 min were calculated for each municipality, and the extent of the inter-municipality distribution difference was calculated using the Gini coefficient.

To assess any maldistribution caused by each scenario, the Gini coefficient was calculated to establish the level of inequity of the distribution of obstetrics facilities. The Gini coefficient is an index of unequal distribution widely used to assess inequity in incomes, but is now also used to examine healthcare resource distribution [22–26]. The index has a value between 0 and 1: when the distribution is totally unequal the value is 1, and exactly equal distribution is represented by a value of 0.

Analysis of variance was used to examine differences between group means. SPSS Statistics software (version 20.0J, SPSS IBM Japan Inc., Tokyo, Japan) was used for all statistical analyses except for the calculation of the Gini coefficient, for which Stata (release 12; StataCorp, College Station, TX, USA) was used. A P value <0.05 was considered statistically significant. The ethics committee of the Graduate School of Medicine and Faculty of Medicine, The University of Tokyo assessed and approved conduct of the study.

Geographic Information System analysis

Based on our three scenarios and the three target levels for facility intensification, a 1-km^2 grid was used to calculate the driving distance to the nearest obstetrics hospital using a Geographic Information System (GIS). Each square was classified as $\leq$30 min access, 30–60 min access or >60 min access. Then, the proportion of women aged 15–49 years resident in each 1-km^2 section was calculated by taking the mean pixel value within each 1-km^2 square and accumulated for each municipality, allowing us to make an assessment of the proportion of women

Table 1 Three scenarios for intensification of obstetrics hospitals adopted in this study

Intensification scenario	Factor(s) to be considered		
	Hospital volume (number of deliveries per hospital)	Borders of Medical Service Area (MSA)	Population coverage
Scenario 1: Retain facilities with higher volume of deliveries per hospital without considering the geographic boundaries of MSAs	Yes	No	No
Scenario 2: Priority was first given to retaining at least one hospital in each MSA and then higher volume of deliveries per hospital	Yes (secondary)	Yes (primary)	No
Scenario 3: Keep facilities to maximize population coverage without considering the number of deliveries per hospital or MSAs	No	No	Yes

of childbearing age living within 30 min of the nearest obstetrics facility. Each 1-km^2 mesh within a 30-min drive was colored brown, within a 30–60-min drive was red and further than a 60-min drive was orange. Non-residential areas and non-reported areas were colored gray. The color scheme was chosen with reference to the ColorBrewer system [27].

We used MarketPlanner GIS (version 3.3.3, PASCO, Tokyo, Japan) for geographic analyses except for the selection of obstetrics hospitals in Scenario 3. MarketPlanner GIS version 3.2.6 with road network data version 2013 was used to estimate access time. Its estimation is based on actual travel speed or predefined speed based on the classification of the road (10–80 km/h) according to the software's proprietary database.

In scenario 3, location-allocation analysis was undertaken to decide which hospitals should be retained using ArcGIS software (version 10.0, ESRI Japan, Tokyo, Japan). Location-allocation analysis is a tool in the ArcGIS Network Analyst extension that can determine the optimal locations for facilities to maximize coverage of the surrounding population [28] so that they can be allocated most efficiently [29].

Results

Status of obstetrics hospitals in Japan as of 2011

Of the 1075 study subject obstetrics hospitals, the 95 general PMCs and 279 regional PMCs had higher numbers of staff and deliveries than the 701 other hospitals. The regional and general PMCs also had a lower number of deliveries per obstetrician and a greater proportion of deliveries by cesarean section (Table 2). Distribution of hospital volume (number of delivery per hospitals per month) and staff level (obstetricians and midwives) of obstetrics hospitals were skewed to the right (Fig. 1). Graphical presentations of access status to current obstetrics hospitals (n = 1075, Fig. 2) and academic hospitals and PMCs (n = 405, Fig. 3) are shown. Of the 15–49 year-old female population, 95.0 % currently have access to an obstetrics hospital within a 30-min drive, with 82.7 % having access to an academic hospital or PMC.

Intensification of obstetrics hospitals and access to obstetrics hospitals

The effects of intensification on hospital volume and staff level were estimated at the target levels of 985, 788, 591 (representing a national estimate of 1000, 800 and 600 obstetrics hospitals). For each target level of intensification, the number of deliveries and staff levels of obstetricians and midwives per hospital were the same for each scenario after intensification, but the number of deliveries and the number of staff that would need to be absorbed by retained institutions were larger when intensification emphasized hospital volume (Table 3). With regard to population coverage and inequity among municipalities, if intensification occurred without considering the MSAs (Scenario 1), access would fall in an indirectly proportional relationship. However, when MSAs were taken into account, impaired access could be avoided until intensification to 591 obstetrics hospitals (55.0 % from the 2011 level, equivalent to a national estimate of 600). At this level of intensification, coverage was calculated to be 87.6 % for Scenario 1, compared with 90.5 % for Scenario 2 and 93.9 % for Scenario 3 (Fig. 4).

The Gini coefficient of 0.239 would rise to 0.473 when hospitals were intensified to PMCs and academic hospitals, indicating that the level of inequity would widen. Scenario 1 showed a directly proportional increase, but Scenarios 2 and 3 demonstrated a slower pace of increase in the Gini coefficient at intensification from the current level to academic hospitals and PMCs only, meaning that a greater extent of inequity can be avoided when MSAs and access are both taken into account (Fig. 5).

Table 2 Characteristics of institutions included in the study

	All hospitals providing obstetrics services (n = 1075)	Obstetrics hospital type			*P* value
		General perinatal medical centers (n = 95)	Regional perinatal medical centers (n = 279)	Other obstetrics hospitals (n = 701)	
Total hospital beds[a] (SD)	380.5 (252.2)	738.6 (276.9)	518.3 (212.8)	277.0 (183.4)	<0.001
Obstetricians, number (SD)	5.5 (4.6)	12.3 (6.9)	7.0 (4.7)	4.0 (2.7)	<0.001
Midwives, number (SD)	15.3 (11.8)	31.5 (15.4)	20.0 (12.0)	11.3 (7.9)	<0.001
Deliveries per month, number (SD)	44.1 (39.3)	75.7 (59.8)	50.5 (38.7)	37.3 (32.8)	<0.001
Cesarean sections per month, number (SD)	11.3 (11.0)	26.2 (18.2)	14.5 (10.8)	7.7 (6.4)	<0.001

Data are presented as the mean (standard deviation, SD)

[a] Total number of hospital beds including non-obstetrics beds