論 文

Radiological equipment and staffs distribution in Hokkaido, Japan

- Lorenz curve and Locational Gini Index analyses -

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[Purpose] The purpose of the present study was to analyze the geographic inequalities in radiological medicine in the Hokkaido area (Japan) by the Lorenz curve and the adjusted Locational Gini Index (Gini coefficient). [Methods and Materials] The data concerning the distribution of the radiological equipment (CT, MRI and irradiation units) and staff (physicians, radiologists and radiological technologists) related to the radiological medicine was obtained from official publications. Both the population-based analysis and the outpatient-based analysis were performed. [Results and Discussion] The population-based Gini coefficients for physicians and radiological technologists were almost equal, 0.130 and 0.112 respectively. But that for radiologist inequality was at 0.361, showing significant inequality. The population-based distribution of CT and MRI equipment was identical all over the Hokkaido area, whereas the distribution of irradiation equipment was disproportionate.

[key words] Locational Gini Index (Gini coefficient), Lorenz curve, Radiological medicine, Geographic inequalities

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1. Introduction

In Japan, image diagnosis equipment and irradiation equipment such as computed tomography (CT), magnetic resonance imaging (MRI) and Linac (Liner accelerator for irradiation) are widely used. In 1997 there were 14,204 CT units (118.4 per million population), 3165 MRI units (26.4 per million population) and 714 Linacs (6.0 per million population)[1]. CT units were often introduced in clinics with fewer than 19 beds, and even in outpatient offices. The average number of CT units per hospital is 0.73, but in clinics that average is only 0.028[2].

Hokkaido is the northernmost and the second-largest island in Japan. Its area (78.4 × 10^3 km^2) accounts for about 20% of Japan (377.8 × 10^3 km^2). The prefectural government of Hokkaido is located in Sapporo City, where 31% of the population and 35% of the hospitals are concentrated. Many people, except for those lived in urban and suburb, needs more time and money for consulting medical specialists in hospitals. Furthermore, the ratio of aged people in rural areas is higher than that in urban areas, so it can be inferred that the higher the ratio of aged people, the higher the ratio of patients who need medical treatment[3,4]. We assumed that disparities between image diagnosis and irradiation treatment between urban hospitals and rural clinics existed. The purpose of the present study was to analyze the regional characteristic and geographic distribution of the radiological equipment (CT, MRI and irradiation units) and the medical staffs (physicians, radiologists and radiological

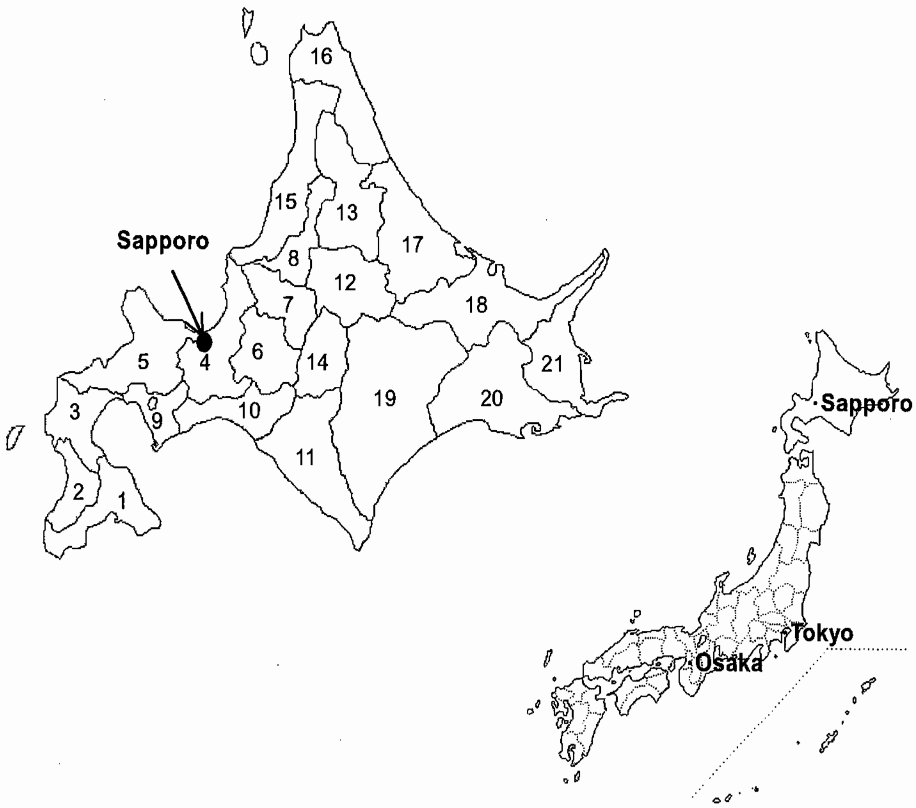

Figure 1 Secondary medical regions in Hokkaido

technologists) in Hokkaido, by using a Lorenz curve and Gini coefficient (adjusted Locational Gini indexes), which are more usually used to analyze income inequality, medical distribution and mortality analysis[5-11)]

2. Methods

(1) Survey area and secondary medical region

All of Hokkaido was the survey area in this study. There are 212 primary medical regions and 21 secondary medical regions in Hokkaido prefecture. A primary medical region was decided based on an administrative region, including city, town and village. A secondary medical region was decided by considering the geographical conditions and social conditions such as daily life and transportation facilities. **Figure 1** shows the map of Hokkaido and its secondary medical regions. The analysis using the Lorenz curve was obtained for the 21 secondary medical regions in Hokkaido. The number of outpatient was counted for the hospitals and clinics located at each secondary medical regions.

(2) Survey items

The population, number of outpatients per day and number of physicians and technologists in each medical region were determined according to the annual report of health statistics in Hokkaido[3,4)]. **Table 1** summarizes the area, population and the number of outpatients per day for each secondary medical region. **Table 2** summarized the medical staff related with the radiologic medicine and the

Table 1 Area, population and out patients each medical region in Hokkaido

#	Medical regions	Area		Population		Out patients (per a day)	
		km^2	%	Persons	%	Persons	%
1	Minami Oshima	2,642.70	3.37	447,255	7.86	100,655	9.75
2	Minami Hiyama	1,643.34	2.10	37,982	0.67	7,851	0.76
3	Kita Hiyama-Oshima	2,253.06	2.87	46,501	0.82	11,888	1.15
4	Sapporo	3,539.65	4.51	2,154,646	37.85	285,167	27.63
5	Shiribeshi	4,305.31	5.49	274,893	4.83	66,088	6.40
6	Minami Sorachi	2,651.36	3.38	219,852	3.86	52,277	5.07
7	Naka Sorachi	1,882.06	2.40	134,365	2.36	33,637	3.26
8	Kita Sorachi	2,024.84	2.58	50,591	0.89	14,260	1.38
9	Nishi Iburi	1,346.05	1.72	226,097	3.97	46,155	4.47
10	Higashi Iburi	2,341.04	2.99	218,927	3.85	36,557	3.54
11	Hidaka	4,811.80	6.14	89,937	1.58	19,981	1.94
12	Kamikawa Cyubu	3,471.09	4.43	417,615	7.34	76,422	7.41
13	Kamikawa Hokubu	4,197.80	5.35	85,904	1.51	21,292	2.06
14	Furano	2,183.57	2.78	50,293	0.88	12,564	1.22
15	Rumoi	4,019.83	5.13	70,403	1.24	14,186	1.37
16	Soya	4,045.89	5.16	86,378	1.52	17,254	1.67
17	Hokumou	5,541.56	7.07	254,756	4.48	45,524	4.41
18	Enmon	5,148.73	6.57	91,790	1.61	20,020	1.94
19	Tokachi	10,830.99	13.81	357,126	6.27	76,649	7.43
20	Kushiro	5,997.17	7.65	287,643	5.05	52,497	5.09
21	Nemuro	3,540.11	4.51	89,367	1.57	21,019	2.04
	All over Hokkaido	78,417.95	100	5,692,321	100	1,031,943	100

radiologic equipment for diagnosis and irradiation. The number of CT, MRI and irradiation units was obtained from the basic health statistics of regional medicine in Japan[2]. We surveyed the number of radiologists. All data were obtained in 1996. In this study, the physician was defined as a clinician only, and the radiologist was defined as the specialist on image diagnosis, radiation oncology or nuclear medicine. In Japan, the term radiological technologist includes those who work with radiographs (X-ray technologists), CT, MRI, nuclear medicine, ultrasound and radiation therapy. The term X-ray technologist refers to those who work with radiographs and CT exclusively. In this study, the number of CT units included standard single slice CT for the head or for the whole body as well as spiral CT. Irradiation equipment was used to indicate Linac (linear accelerator), Co-60, Betatoron, Micorotoron or Brach-therapy equipment.

(3) Analyses by a Lorenz curve and Locational Gini Index

We performed both the population-based analysis and the outpatient-based analysis using Lorenz curve and Gini coefficient (Locational Gini index analyses)[5-11] by considering that there was a greater patient ratio in rural areas, where many elderly persons live, than in urban areas. In this study, we took use of the concept of Locational Gini Index that was introduced as a method to measure the industrial regional concentration[11]. A Lorenz curve can show the degree of uniformity of distribution of equipment and staff to regional

Table 2 Medical Staff and Radiological Equipments each medical region in Hokkaido

#	Medical regions	Physician		Radiologist		Radiological Technologist		CT		MRI		Irradiation	
			%		%		%		%		%		%
1	Minami Oshima	789	8.9	4	3.5	146	6.9	30	6.7	12	8.6	3	9.1
2	Minami Hiyama	32	0.4	0	0	9	0.4	5	1.1	0	0	0	0
3	Kita Hiyama-Oshima	52	0.6	0	0	12	0.6	4	0.9	0	0	0	0
4	Sapporo	4,807	54.2	70	61.4	993	46.8	181	40.5	53	37.9	16	48.5
5	Shiribeshi	288	3.2	0	0	88	4.1	21	4.7	4	2.9	0	0
6	Minami Sorachi	230	2.6	2	1.8	71	3.3	16	3.6	4	2.9	1	3.0
7	Naka Sorachi	174	2.0	0	0	52	2.5	12	2.7	7	5.0	1	3.0
8	Kita Sorachi	53	0.6	0	0	15	0.7	4	0.9	1	0.7	1	3.0
9	Nishi Iburi	306	3.5	3	2.6	90	4.2	14	3.1	6	4.3	1	3.0
10	Higashi Iburi	182	2.1	0	0	61	2.9	14	3.1	6	4.3	0	0
11	Hidaka	62	0.7	0	0	22	1.0	8	1.8	2	1.4	0	0
12	Kamikawa Cyubu	658	7.4	24	21.1	160	7.5	32	7.2	16	11.4	5	15.2
13	Kamikawa Hokubu	94	1.1	0	0	28	1.3	6	1.3	2	1.4	0	0
14	Furano	35	0.4	0	0	12	0.6	4	0.9	1	0.7	0	0
15	Rumoi	42	0.5	0	0	15	0.7	4	0.9	1	0.7	0	0
16	Soya	62	0.7	0	0	23	1.1	7	1.6	1	0.7	0	0
17	Hokumou	220	2.5	3	2.6	60	2.8	20	4.5	5	3.6	1	3.0
18	Enmon	98	1.1	0	0	24	1.1	7	1.6	1	0.7	0	0
19	Tokachi	322	3.6	6	5.3	117	5.5	30	6.7	9	6.4	1	3.0
20	Kushiro	317	3.6	2	1.8	111	5.2	23	5.1	9	6.4	3	9.1
21	Nemuro	41	0.5	0	0	14	0.7	5	1.1	0	0	0	0
	All over Hokkaido	8,864	100	114	100	2,123	100	100	100	140	100	33	100

population or number of outpatients. The curve would maintain a 45° diagonal if the percentage of equipment and staff to regional population and outpatients was equally distributed. The Locational Gini index, an area between the Lorenz curve and the 45° line divided by a triangular area, indicated the ratio of unequal distribution of equipment/staff.

We considered the distribution of equipment and staff among medical regions to be uniform if the Locational Gini index was small. The analysis proceeded as follows. First, the number of equipment and staff was arranged to correspond to the ascending of the total population and number of outpatients (population/outpatient). Second, we calculated the cumulative percentage of equipment/staff and population/outpatient. Third, we made a Lorenz curve by plotting the cumulative percentage of equipment and staff against that of population and outpatient. The Locational Gini Index was calculated using a trapezium approximation without doing smoothing of Lorenz curve because the item such as income distribution could not be described well by a smooth Lorenz curve. Furthermore, an adjusted Locational Gini Index was calculated by the equation as follows in order to correct the small-sample bias produced by the weight difference of the population or the outpatients[12].

$$G_n^{adj} = \frac{n}{n-1} G_n$$

Here,

G_n^{adj} : The adjusted Locational Gini Index by the number of sample n

n : The number of sample (the number of medical regions in this study is 21)

G_n: The Locational Gini Index by the number of sample n

3. Results

The Lorenz curves for the medical staff are shown in **Figure 2**. **Table 3** indicates the Locational Gini Index. Through the population-based and outpatient-based analysis of medical staff, it became clear that the distribution of

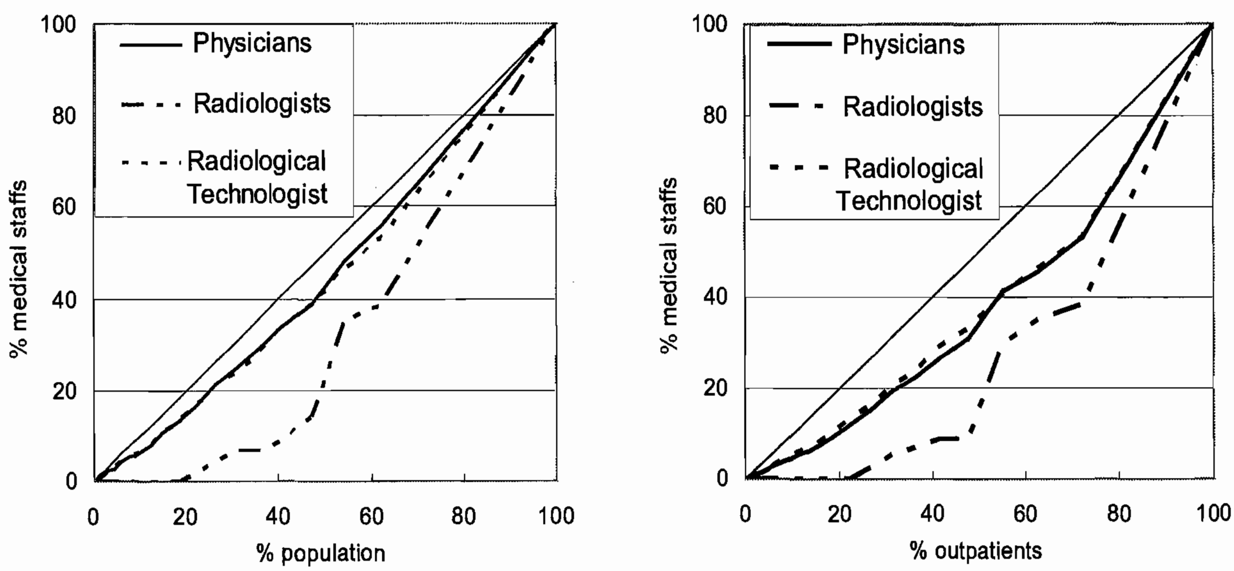

Figure 2 Lorenz curve for medical staff

radiologists was more unequal than that of other staff. The adjusted Locational Gini Index of population-based analysis for radiologists was 0.361, which was about 2.8 times larger than that for physicians. According to the population-based analysis, the shapes of the Lorenz curves for physicians and radiological technologists were almost identical. The adjusted Locational Gini indexes for physicians and radiological technologists were also almost equal, at 0.130 and 0.112 respectively. However, according to the outpatient-based analysis, the adjusted Locational Gini index for physicians was 0.238, which was larger than that determined in the population-based result.

Figure 3 indicate the Lorenz curves for the radiological equipment. The population- and outpatient-based analyses for the distribution of CT and MRI showed the same tendency. The population-based distribution of CT and MRI was identical all over the Hokkaido area. The distribution of irradiation equipment was disproportionate in comparison to that of CT and MRI. All of the outpatient-based Locational Gini indexes were larger than those of the population-based analysis. The outpatient-based Locational Gini index for MRI was 3.4 times larger than that determined by the population-based analysis (**Table 3**).

4. Discussion

We consider two reasons to explain non-identical distribution of CT and MRI equipment throughout the Hokkaido area. The main reason for the results we obtained is that the functions and responsibilities among medical facilities and medical staff are not clearly defined in Japan. For example, many physicians use image diagnostic equipment in their practices, and there is not always a radiologist available to read the images. The total number of radiologists in Hokkaido is only 114, accounting for 1.3% of all physicians.

The another reason is that many patients prefer large-scale hospitals with specialists and medical

Table 3 The number of Medical staff/Radiological equipment and Locational Gini Index

Medical staff/ Radiological equipment	Numbers	Locational Gini Index		Adjusted Locational Gini Index	
		Population base	Outpatient base	Population base	Outpatient base
Physician	10,279	0.124	0.227	0.130	0.238
Radiologist	114	0.344	0.438	0.361	0.460
Radiological Technologist	2,123	0.107	0.213	0.112	0.224
CT	447	0.024	0.127	0.025	0.133
MRI	140	0.043	0.144	0.045	0.151
Irradiation	33	0.196	0.287	0.206	0.301

equipment to the small-scale hospitals and clinics[13]. For these reasons, medical facilities must compete for patients. In order to reduce the differences among facilities and therefore collect more patients and make more benefit, many facilities located in rural areas has been introduced advanced diagnostic, CT and MRI equipment. As a result, radiological technologists were needed to operate this equipment. In this study, the Lorenz curves and Locational Gini indexes show the relationship between the presence of CT/MRI equipment and the availability of radiological technologists. On the other hand, the result showed that the distribution of irradiation equipment and radiologists was not identical in the Hokkaido area. Radiation therapy requires not only equipment for irradiation, planning and protection but also the services of radiation oncologists and radiation therapy technologists. Thus, compared with the diagnostic equipment, there were no factors to introduce the irradiation equipment. Therefore, the regional gap in the distribution of irradiation equipment is larger than that for diagnostic equipment.

In this research, we obtained both population-based and outpatient-based analyses. The results showed that the regional gap between physicians, radiological technologists and diagnostic equipment according to the outpatient-based analysis was larger than that revealed by the population-based analysis. This result will be explained by large regional gaps that the number of patients in rural areas is larger than that in urban areas[4].

There are some problems in our analysis. First, the results by Lorenz curve and Locational Gini index could reflect tendencies but could not make absolute comparisons because the results are relative values. Secondly, there are only 33 sets of irradiation equipment in all of Hokkaido area, so the line of the Lorenz curve is irregularities. We assessed the results by considering overall population and number of outpatients, but we did not consider the area of the regions or the density of the population. Finally, although we determined

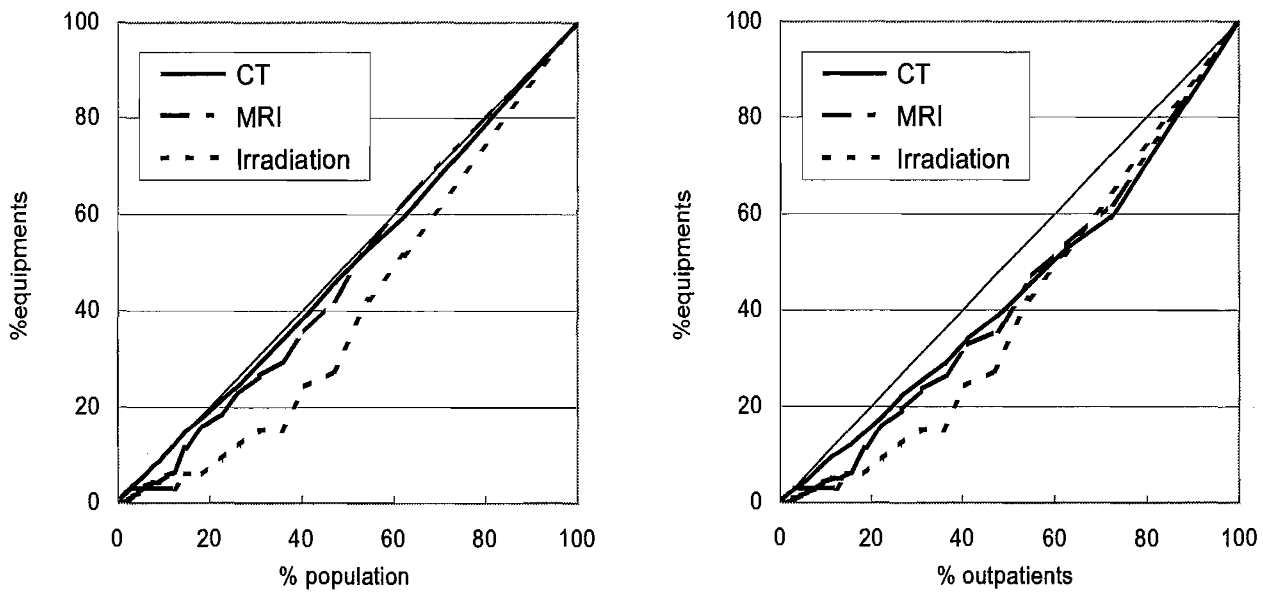

Figure 3 Lorenz curve for radiological equipment

how much equipment there is, we did not investigate the rate of equipment operation. In the future, we want to study and discuss the results we obtained by comparing them with other methods of analysis that will help overcome these problems.

In this study, the geographic distribution of radiological medicine is analyzed some problems such as the cost effectiveness and introduction effects for rural citizens must be solved when teleradiology systems are introduced into rural area.

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北海道における放射線診療の分布に関する考察

－ローレンツ曲線と地域集中化ギニ係数による解析－

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［目的］北海道における放射線診療の地域的な不均一性を評価するために、ローレンツ曲線とサンプル数（2次医療圏数）で補正された地域集中化Gini係数（以下、補正Gini係数）を用いて分析を行った。［方法］分析対象はCT、MRI、放射線治療装置などの放射線機器及び、医師、放射線科医、放射線技師など医療従事者とした。調査地域は北海道全域とし、分析は人口を基準としたもの及び、外来患者数を基準としたものの双方で推計を行った。［結果］分析の結果、医師数と放射線技師の人口を基準とした補正Gini係数はそれぞれ、0.130、0.112でありほぼ均一であったが、放射線科医は0.361であり不均一であった。同様に、人口を基準とした推計では、CTやMRIなど画像診断機器は北海道全域で均一に分布していたが、放射線治療機器は不均一であった。外来患者数を基準としたものでは、医療従事者および放射線機器の双方において、人口を基準にしたもの以上に補正Gini係数が大きくなった。［考察］ 医師・放射線技師および画像診断機器がほぼ均一に普及している理由として、医療機関間・医師間の不明確な役割分担、患者の大病院指向が考えられた。また、放射線治療機器および放射線治療医においては、その診療の特殊性によるものと考えられた。今回の分析の問題点として、放射線治療機器など導入が少ない機器ではローレンツ曲線が歪むこと、人口密度が考慮されず北海道の地域性が十分に反映されていないこと、などが挙げられた。

キーワード：地域集中化ギニ係数、ローレンツ曲線、放射線診療、不均一分布

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