INTRODUCTION

As advancements in radiotherapy technology contributed to improve outcomes among cancer patients, radiotherapy became widely used for cancer treatment in Japan. Hence, the number of radiotherapy facilities in Japan increased from 586 in 1996 to 733 in 2008.1) However, radiotherapy equipment and medical staffs need to be optimally allocated so that these limited resources can be efficiently used.

Several studies compare the distribution of radiotherapy resources between countries.2–6) These studies indicated that Japan had fewer medical resources such as equipment and staff than the US and European countries did. Others have investigated the equitable and efficient use of medical resources for radiotherapy in European countries.7–9) In Japan, since 1990, the Japanese Society for Therapeutic Radiology and Oncology (JASTRO) has conducted a national survey on the structure of radiation oncology. However, the distribution of medical resources for radiotherapy within Japan remains unclear. Hence, in this study, we evaluated the magnitude of the regional disparities in this distribution.

The Japanese medical care system includes 52 tertiary medical service areas and 348 secondary medical service areas across 47 prefectures. In order to establish a cancer care system, the Japanese government has formulated the 3rd Term Comprehensive 10-year Strategy for Cancer Control. This strategy aimed to reduce disparities in the allocation of the medical technology in order to provide citizens equitable access to standard professional cancer care wherever they live, regardless of the time at and place from which they seek care. In order to fulfill this aim, this policy recommends that a cancer care system be established in each secondary medical service area based on the daily living area.10) However, this policy does not clarify the targets to be achieved in each area and the division of roles between the second and the tertiary medical service areas. Since 1997, the government-funded Cancer Professional Training Program has aimed to develop specialized physicians and other medical staffs for the treatment of cancer. Thus, the number...
of oncologists and medical physicists was expected to improve. Given this expectation, we have conducted a pilot study to investigate the optimum allocation of radiotherapy resources from the viewpoint of equity. The results of our study could be used for policy evaluation by comparison of survival rates and the allocation of medical resources in the future.

From the viewpoint of health policy, a new indicator for measuring regional disparities should be developed so that medical resources can be allocated optimally. However, researchers currently use only a few indicators in order to measure regional disparities: the 5-year survival rate, mortality rate, and morbidity rate. The disadvantage of these indicators is that they measure the level of medical care, and not regional disparities. In addition, they are influenced by the stages of disease, prevention activities, and factors affecting the patient’s prognosis. Hence, the present study employs an alternative indicator—the Gini coefficient (GC)—in order to measure regional disparities in the distribution of radiotherapy resources.

The GC is a measure of inequality in a distribution and is used for comparison in economic surveys in Japan, such as the National Survey of Family Income and Expenditure and the Survey of Income Redistribution. The Organization for Economic Co-operation and Development (OECD) uses the GC for a cross-national comparison of income inequality. In recent years, the GC has also been applied to study the allocation of medical resources. Ohba appeared the inequalities in the distribution of radiotherapy resources among 11 prefectures in Japan by GC and proposed the medical cooperation among secondary medical care zones. The GC can be considered an appropriate tool to fulfill the purpose of the present study—to elucidate the distribution of radiotherapy resources and regional disparities in this distribution.

### MATERIALS AND METHODS

#### Analytic methods

The GC measure the concentration of a frequency distribution. The value of the GC ranges from 0, which indicates complete equality in the distribution, to 1, which indicates complete inequality. The GC is calculated as twice the area enclosed by the Lorenz curve and the equality line. In the present study, the Lorenz curve is described by the cumulative percentage of the number of medical resources and patients. The GC is obtained as follows:

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G = \left( \frac{1}{n} \sum_{i=1}^{n} x_i \cdot y_i \right) - \left( \frac{1}{n} \sum_{i=1}^{n} x_i \cdot y_i \right)
\]

where \( G \) is the GC, \( n \) is the number of districts, \( x_i \) is the cumulative percentage of the ratio of population or patients of district \( i \), and \( y_i \) is the cumulative percentage of the ratio of radiotherapy resources. A high GC indicates high regional disparities in the allocation of medical resources.

#### Data and analysis

The data were obtained from the 2005 and 2007 national surveys on the structure of radiation oncology in Japan, conducted by the JASTRO. In the present study, the term “radiotherapy resources” refers to full-time equivalent (FTE) radiation oncologists, FTE radiotherapy technologists, and FTE medical physicists. The number of patients was defined as the total cancer patients (new + repeat) receiving radiotherapy per year. We calculated the number of radiotherapy resources per one million population and 1,000 patients with respect to each prefecture. We assumed that the medical resources and population were distributed equitably within the prefecture. We compared the GCs for each type of resource for two years in order to evaluate changes in regional disparities.

### RESULTS AND DISCUSSION

Table 1 shows the Gini coefficients for various resources. The GC for the number of radiation oncologists per one million population increased from 2005 to 2007, while the GC for the number of radiation oncologists per 1,000 patients decreased. The GC was also increased for the number of radiotherapy technologists. The GC for the number of medical physicists was larger than those of radiation oncologists and radiotherapy technologists.

This study presents regional disparities in the allocation of radiotherapy resources visually and quantitatively. Our findings clearly show that the GC was small for oncologists, radiation oncologists, and radiotherapy technologists, indicating that these professionals are distributed almost equitably among prefectures. However, medical physicists are inequitably distributed. Thus, policymakers should create and implement measures to train and retain medical physicists in areas with limited radiotherapy resources.

We attribute this observation to the existence of tertiary medical service areas, and almost all of prefectures face a shortage of such resources. Although the regional disparities between the tertiary medical service areas are small, 26% of

| Table 1. Gini Coefficients of Radiotherapy Resources |
|-----------------------------------------------|----------|----------|
| FTE Radiation Oncologist | 2005 | 2007 |
| Per one million population | 0.149 | 0.155 |
| Per 1,000 patients | 0.134 | 0.126 |
| FTE Radiotherapy Technologist | | |
| Per one million population | 0.132 | 0.151 |
| Per 1,000 patients | 0.106 | 0.115 |
| Medical Physicist | | |
| Per 10 institutions | 0.430 | 0.519 |
the secondary service areas do not have any institution that provides radiotherapy. Patients’ accessibility to these resources in such areas should be improved.

Even though the number of radiation oncologists in Japan has gradually increased, this number is much less than that of the US and European countries with regard to FTE professionals. Physical accessibility to medical resources affects treatment options. Therefore, it is necessary to determine the regional unit for optimum allocation of medical resources, and to increase medical resources in secondary or tertiary medical service areas. This study shows that regional disparities in the distribution of medical resources are low and hence justifies the viewpoint that the allocation of medical resources should be decided centrally. Further, decision-makers should consider tertiary medical service areas, rather than their secondary counterparts, as the unit to be targeted in the allocation of such resources.

However, this study has several limitations. First, surpluses or deficiencies in the quality of medical resources were not taken into account. Further, although a longitudinal study is necessary to analyze the requirement of medical resources, our analysis was limited to data for a specific point in time. Moreover, the current cancer registration system is effective in only some districts in Japan, which made it difficult for us to use the survival rate in order to calculate regional disparities. Further study should analyze disparities among secondary medical service areas or institutions.

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REFERENCES


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