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Trends of travel burdens to access cancer care among children with cancer: analysis of a population-based cancer registry data in Aichi, Japan

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ABSTRACT

Centralization of childhood cancer treatment in specialized hospitals is necessary for quality treatment and care, but imposes a time and cost burden for patients and their families. We investigated the 20-year trend in the patients' car travel burden to reach cancer-care hospitals in Aichi Prefecture, Japan. From the Aichi population-based cancer registry data, 1,741 cases diagnosed in 1998–2017 under 15 years of age were extracted and assigned to three treatment groups: invasive treatment (n = 697), radiotherapy (n = 371), or chemotherapy groups (n = 1,462), allowing for duplicate assignment. Their travels to access each treatment hospital were estimated and summarized as the estimated travel times (ETT), estimated travel distances (ETD), and direct distances (DD). The ETTs were compared using the Brunner–Munzel test. The average cases per year for each hospital were plotted. The annual trends during 1998–2017 on ETT, ETD, and DD were investigated using Joinpoint regression models. The ETTs were 0.38–0.45 hours on median for three periods (1998–2005, 2006–2012, and 2013–2017) in three treatment groups and increased by 0.02–0.07 hours from 2006–2012 to 2013–2017, with a statistically significant difference in the radiotherapy group (0.07 hours, $P = 0.037$). The average cases per year increased for the top hospital in each group, and regression model analyses showed no joinpoint on the annual median trend. In conclusion, the increases in travel times were small and not considered clinically significant, and treatment centralization was observed from 2006–2012 to 2013–2017.

Keywords: childhood cancer, health services accessibility, travel burden

Abbreviations:
API: application programming interface
APC: annual percent change
DD: direct distance
ETD: estimated travel distance
ETT: estimated travel time

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PBCR: population-based cancer registry

INTRODUCTION

Cancer in children who are < 15 years is a rare occurrence worldwide. The estimated age-standardized incidence rate per million person-years was 140.6 worldwide and 126.8 in Japan.[1,2] Due to the rarity of cancer in children, the number of cases treated at each hospital tends to be small. Therefore, cancer treatment ideally should be centralized in specialized childhood cancer centers that can provide state-of-the-art care for better outcomes.[3-5] This treatment centralization has been promoted globally for children with cancer, and multiple studies have reported the situations in the United States and European countries.[3,6,7] However, centralization may force patients and families to travel for a long duration and distance and thereby face problems related to prolonged travel.[8]

Under the Japanese universal healthcare insurance system and the provision of free access to healthcare, there existed a concern that many hospitals treat only a handful of new cases a year and thus may not be capable of providing state-of-the-art care.[9] However, as part of Japan's cancer-control measures, the specific goal for children with cancer was specified in the second phase of the Basic Plan to Promote Cancer Control Program in 2012, and in 2013, 15 hospitals were designated as childhood cancer hub hospitals. In 2014, a Japanese questionnaire survey-based study reported that the majority of parents of children with cancer felt positive about treatment centralization but found it unacceptable to travel more than an hour each way for hospitalization and clinic visits.[9] Travel time will be considered one of the key concerns for treatment centralization. However, the actual burden of travel duration and distances to access the hospitals for children with cancer in Japan, based on registry data, has not been evaluated. It is also unclear whether the travel burden increased after the childhood cancer hub hospitals were designated. Therefore, the long-term trend of travel burden should be investigated to understand the impact of travel burden.

This study aimed to investigate the 20-year trend in travel burden of driving travel times and distances to access the hospitals for children with cancer, based on data from a population-based cancer registry (PBCR) in the Aichi Prefecture, Japan, considering the influence of treatment-centralization measures since the early 2010s.

MATERIALS AND METHODS

Data sources

The PBCR, which contains data on patients diagnosed before the early 2010s and covers a large population, was needed to investigate the trend in the travel burden on children with cancer. As the Japanese nationwide PBCR data were available only for patients diagnosed since 2016, we analyzed data from a regional PBCR that was established in 1962 in the Aichi Prefecture. This prefecture has the fourth largest population in Japan, with 1.0 million children in the 2015 census, and is situated in the Chūbu region of Honshū, Japan's main island. Its capital, Nagoya City, is the largest city in the Chūbu region and has one designated childhood cancer hub hospital.

The PBCR data that were analyzed in this study included sex, age at cancer diagnosis, year of the diagnosis, and residence information at cancer diagnosis at both secondary healthcare area-level and the community-level. The data included tumor data for the cancer stage and the

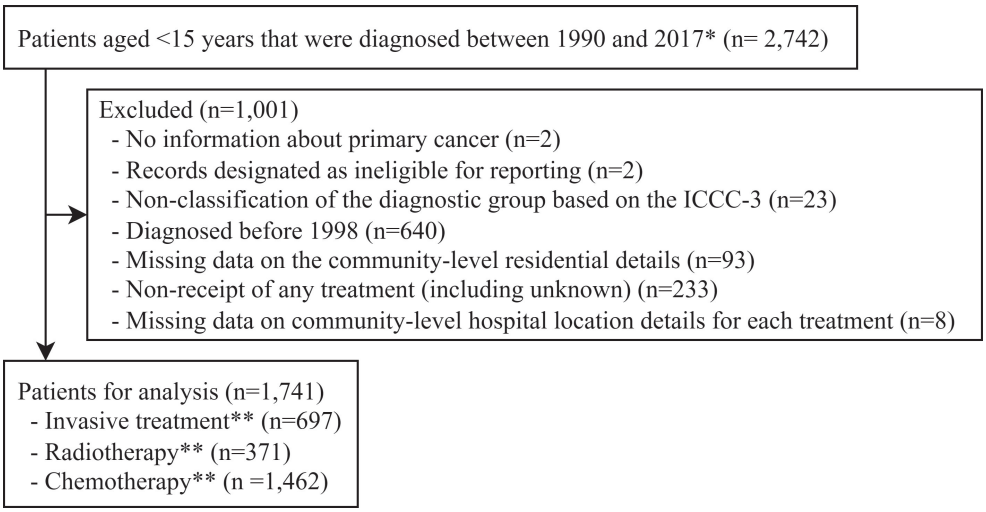

Fig. 1 Flow chart of the patient selection
*Death certification only (DCO) cases were not included in our study data.
**Patients who received more than one treatment were included in each treatment group.
ICCC-3: Third edition of International Classification of Childhood Cancer

diagnostic group that was based on the Third edition of the International Classification of Childhood Cancer (ICCC-3). The data also included the types of treatments that the patients received (invasive treatment, radiotherapy, and chemotherapy (chemotherapy and/or endocrine therapy)), and detailed information on the hospital where each treatment was performed, including the anonymized hospital code and hospital locations at the community level. Prior to the enactment of the Cancer Registration Promotion Act in 2013, this detailed information on the hospital was registered as one treatment hospital in the following order: invasive treatment, radiotherapy, and chemotherapy. For example, if patients received both invasive treatment and chemotherapy, only the details of the hospital where invasive treatment was performed were registered in the PBCR. In such cases, we assumed that the patient had received all treatments at the single hospital that was registered. In our data, most of the patients who were diagnosed after 2014 and received multiple treatments received both treatments in the same hospital (86% for invasive treatment and chemotherapy, 92% for invasive treatment and radiotherapy, and 96% for chemotherapy and radiotherapy).

We obtained anonymized data from the PBCR on non-death certification only (non-DCO) cases aged <15 years that were diagnosed between 1990 and 2017. Data on DCO cases were not obtained as only their place of death was confirmed by the PBCR registration agency, whereas the hospitals where the DCO cases were treated were unconfirmed and unknown. We identified 2,802 cancer records from 2,742 patients. From the data, the following records were excluded: the second and subsequent cancer, records designated as ineligible for reporting; non-classification of the diagnostic group; cancer diagnosed before 1998; missing data on the community-level residential details; non-receipt of any treatment (including unknown); and missing data on community-level hospital location details for each treatment (Fig. 1). Patients diagnosed before 1998 were excluded, even if their community-level residential details were available because these details were mostly unavailable for these patients. Furthermore, patients with hematologic cancer, classified as (I) leukemias or (II) lymphomas based on the ICCC-3, were considered as

not having received any invasive treatment even if receipts of invasive treatment were reported in the registry. Eventually, 1,741 cases were included in the analysis in three treatment groups: invasive treatment (n = 697), radiotherapy (n = 371), and chemotherapy (n = 1,462); patients who received more than one treatment were included in each treatment group.

Estimated travel times and distances and direct distances

Before obtaining the endpoints of both travel times and distances and direct distances (DD), we performed two data processing on the location information to protect the confidentiality of personal information. First, we applied these location details to the address geocoding, which converts this information into geographic coordinates of latitude and longitude. Second, we revised these coordinates randomly by moving them within a circle with a radius of 3 seconds in the unit of degrees, minutes, and seconds (DMS) centered on each coordinate. The coordinates eventually moved a maximum of 92.4 meters in the DD. This revision was independently undertaken three times for each patient's residence–hospital pair. Hence, based on these revised coordinates, each endpoint was eventually obtained per pair three times, and the average value was used in the subsequent statistical analysis.

Using the abovementioned revised geographic coordinates, we obtained estimated travel times (ETT), estimated travel distances (ETD), and DD. DD was calculated by Vincenty's formula. The ETT and ETD were estimated using Google Directions Application Programming Interface (API), which provides a route-planner service similar to that on the Google Maps website (https://www.google.com/maps). API included in the service name means a set of definitions and protocols that enable two software programs to communicate with each other. The Google Directions API is one of the web APIs that can be accessed on the web, which enables researchers to access the web service programmatically. Once the API received a search request from a user, it sent back a response, including an ETT, an ETD, and detailed directions of the most efficient routes. The route was calculated by accounting for travel time as the primary optimization factor along with other factors.[10] This approach was adopted recently[11,12] and had several advantages over the commonly used ArcGIS Network Analyst module.[13]

We specified the search settings for the request as follows. The origin and destination were the abovementioned revised geographic coordinates of the patient's residence and the treating hospital, respectively. The arrival date–time was 10 am on December 2, 2020. The travel mode was "Driving," which assumed that patients would choose a car or ferry, in accordance with the actual situation in the studied prefecture, as ferries are the main means of transportation from a remote island. The traffic information we used was the information on average time-independent traffic conditions. The date of using the API was October 2, 2020.

Statistical methods

All analyses were conducted by treatment groups, and specific analysis was further conducted by the three periods based on the year of diagnosis (1998–2005, 2006–2012, and 2013–2017). First, we summarized the descriptive statistics of the number of patients and medians for ETT by period. Furthermore, we calculated the differences in medians of ETTs for two periods, 2006–2012 and 2013–2017, and compared ETTs for these two periods using the Brunner–Munzel test. Second, the median ETT per secondary healthcare area in 2013–2017 was visualized using a choropleth plot. Third, to investigate the trend of treatment centralization, the number of average cases per year was obtained for each hospital for two periods, 2006–2012 and 2013–2017, and then plotted. Finally, the annual trends of the median values of ETT, ETD, and DD were plotted for all observational periods and were analyzed by fitting Joinpoint regression models to identify any statistically significant trend changes (ie, joinpoints).[14] This analysis fitted a series

of joined straight lines on a logarithmic scale and then calculated the annual percent change (APC) and its 95% confidence intervals (CI) for each line segment. The analysis also calculated the *P*-value for a two-sided test where the true APC is zero; this hypothesis implies that the trend is neither increasing nor decreasing. In our analysis, the model was allowed to include up to three joinpoints, provided the errors were uncorrelated with constant variance.

The grouping variables were: 12 diagnostic groups based on the ICCC-3, cancer stage, three residential areas (western, central, and eastern), 12 secondary healthcare areas, and three periods based on the year of diagnosis (1998–2005, 2006–2012, and 2013–2017). The 2013–2017 period includes the years since 2013 when the childhood cancer hub hospitals were introduced.

The address geocoding was performed using the MAPPLE address-matching tool, Version 3.2.9.329 Rel.1912 (MAPPLE, Inc, Chiyoda, Tokyo, Japan). Data fitting was performed using the Joinpoint Regression Program, Version 4.9.0.0—March 2021 (Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute, Bethesda, MD, USA). The Brunner–Munzel test was performed using R, version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria) and the Package 'lawstat'.[15] SAS 9.4 (SAS Institute Inc, Cary, NC, USA) was used for the other analyses and for using the web API. In statistical hypothesis testing, the significance level was set to $P < 0.05$.

Ethics statement

The study protocol was approved by the ethics review board of Osaka University Hospital (Approval No. 19522-6), the Council for Aichi Cancer Registry Information Utilization (Approval No. A2020-0001), and the ethics committee of the Aichi Cancer Center Research Institute (Approval No. 2021-0-030).

RESULTS

Table 1 shows a summary of patient characteristics. The most common tumors were (I) leukemias. Among solid tumors, (III) central nervous system tumors were the most common. The latest period from 2013 to 2017, with the shortest observation period of 5 years, had the highest average annual number of patients who were diagnosed and registered.

Table 2 shows the number of patients, and median ETT for all three periods. Table 3 shows the median differences of ETTs for two periods, 2006–2012 and 2013–2017, and *P*-values from the Brunner–Munzel test. Period medians of ETTs for all patients ranged from 0.38 to 0.45 hours during three periods (Table 2). As indicated in Table 3, the median differences of ETTs between the above-mentioned two periods for all patients were 0.02–0.07 hours among the three treatment groups, with a statistically significant difference in the radiotherapy group (0.07 hours, $P = 0.037$). In the other values by category, most of the groups showed no statistically significant difference. Although part of the groups showed statistically significant differences, the difference of the median was 0.11 hours at maximum, except for 0.96 hours in the radiotherapy group with patients who lived in the eastern area ($n < 23$, $P = 0.031$).

Figure 2 indicates both the period medians of ETTs in 2013–2017 by the secondary healthcare area and the location of a hospital designated as one of the childhood cancer hub hospitals. The further away the patients resided from the secondary healthcare area with the hub hospital, the longer the median ETT. For the chemotherapy group, the central and eastern residential areas had one secondary healthcare area where the patient accessed the treatment hospital in less than a median ETT of 0.5 hours.

Table 1 Patient characteristics

Category	Invasive treatment (n=697)	Radiotherapy (n=371)	Chemotherapy (n=1,462)
Age, years (Mean ± Standard deviation)	5.8 ± 4.9	6.9 ± 4.3	5.9 ± 4.5
Diagnostic group (n (%))			
I. Leukemias	–	53 (14.3)	666 (45.6)
II. Lymphomas	–	<10 (–)	130 (8.9)
III. Central nervous system tumors	206 (29.6)	170 (45.8)	170 (11.6)
IV. Neuroblastoma	89 (12.8)	26 (7.0)	105 (7.2)
V. Retinoblastoma	51 (7.3)	<10 (–)	51 (3.5)
VI. Renal tumors	54 (7.7)	17 (4.6)	48 (3.3)
VII. Hepatic tumors	37 (5.3)	<10 (–)	41 (2.8)
VIII. Malignant bone tumors	48 (6.9)	10 (2.7)	76 (5.2)
IX. Soft tissue sarcomas	65 (9.3)	33 (8.9)	74 (5.1)
X. Germ cell tumors	87 (12.5)	41 (11.1)	70 (4.8)
XI. Other malignant epithelial neoplasms	47 (6.7)	<10 (–)	18 (1.2)
XII. Other and unspecified	13 (1.9)	<10 (–)	13 (0.9)
Cancer stage (n (%))			
Localized	377 (54.1)	166 (44.7)	306 (20.9)
Regional	93 (13.3)	42 (11.3)	116 (7.9)
Distant	97 (13.9)	48 (12.9)	167 (11.4)
Unknown	130 (18.7)	62 (16.7)	202 (13.8)
Not applicable	0	53 (14.3)	671 (45.9)
Year of diagnosis (n (%))			
1998–2005	234 (33.6)	120 (32.3)	375 (25.6)
2006–2012	234 (33.6)	139 (37.5)	549 (37.6)
2013–2017	229 (32.9)	112 (30.2)	538 (36.8)

Of all patients (n=1,741), those who received more than one treatment were included in each treatment group. Those with either (I) leukemias or (II) lymphomas were considered as not having received any invasive treatment in our analysis.

Table 2 Number of patients and median ETT (hours) by category and period

Category / Period	Invasive treatment [a]			Radiotherapy [a]			Chemotherapy [a]		
	1998–	2006–	2013–	1998–	2006–	2013–	1998–	2006–	2013–
All patients	234/0.40	234/0.43	229/0.45	120/0.41	139/0.38	112/0.45	375/0.41	549/0.44	538/0.45
Diagnostic group									
I. Leukemias	–	–	–	29/0.43	15/0.36	<10/0.50	168/0.40	247/0.41	251/0.45
II. Lymphomas	–	–	–	<10/0.19	<10/0.30	<10/1.43	29/0.53	55/0.39	46/0.45
III. CNS tumors	60/0.29	82/0.37	64/0.43	49/0.34	64/0.36	57/0.43	48/0.34	69/0.38	53/0.43
IV. Neuroblastoma	40/0.44	31/0.60	18/0.46	11/0.58	13/0.58	<10/0.46	31/0.49	36/0.58	38/0.45
V. Retinoblastoma	16/0.58	14/0.76	21/0.55	<10/0.44	<10/0.16	<10/1.57	10/0.53	21/0.64	20/0.51
VI. Renal tumors	16/0.33	14/0.49	24/0.54	<10/0.28	<10/0.53	<10/0.51	13/0.36	13/0.45	22/0.54
VII. Hepatic tumors	13/0.46	<10/0.39	16/0.53	<10/0.13	0/–	0/–	10/0.51	10/0.43	21/0.39
VIII. Malignant bone tumors	23/0.48	15/0.43	10/0.64	<10/0.33	<10/0.42	<10/0.20	25/0.48	29/0.63	22/0.40
IX. Soft tissue sarcomas	24/0.50	18/0.53	23/0.46	10/0.56	10/0.44	13/0.59	18/0.53	26/0.52	30/0.55
X. Germ cell tumors	19/0.32	35/0.33	33/0.38	<10/0.32	19/0.38	15/0.51	12/0.35	26/0.41	32/0.46
XI. Other malignant epithelial neoplasms	17/0.41	13/0.36	17/0.38	<10/0.63	<10/0.58	<10/0.80	<10/0.35	<10/0.50	<10/0.92
Cancer stage									
Localized	130/0.38	123/0.40	124/0.42	38/0.36	65/0.35	63/0.44	85/0.46	114/0.45	107/0.42
Regional	24/0.38	29/0.51	40/0.40	12/0.48	14/0.47	16/0.35	23/0.39	38/0.44	55/0.37
Distant	42/0.51	28/0.58	27/0.59	20/0.47	19/0.52	<10/0.59	50/0.49	59/0.52	58/0.52
Residential area									
Western area	156/0.40	153/0.38	162/0.42	83/0.36	91/0.36	91/0.43	271/0.41	347/0.40	357/0.41
Central area	63/0.46	61/0.65	52/0.63	29/0.57	35/0.64	13/0.63	82/0.46	137/0.61	137/0.64
Eastern area	15/0.30	20/0.62	15/1.00	<10/0.44	13/0.35	<10/1.31	22/0.42	65/0.44	44/0.54

CNS: central nervous system
ETT: estimated travel time
1998–: 1998–2005
2006–: 2006–2012
2013–: 2013–2017
[a] n/median ETT (hour)

Table 3 Median differences (hours) of ETT for 2006–2012 and 2013–2017

Category	Invasive treatment		Radiotherapy		Chemotherapy	
	Diff[a]	*P*-value[b]	Diff[a]	*P*-value[b]	Diff[a]	*P*-value[b]
All patients	0.03	0.142	0.07	0.037	0.02	0.125
Diagnostic group						
I. Leukemias	–	–	0.14	0.184	0.04	0.011
II. Lymphomas	–	–	1.13	nc	0.07	0.113
III. Central nervous system tumors	0.06	0.160	0.07	0.176	0.05	0.843
IV. Neuroblastoma	–0.14	0.052	–0.12	0.773	–0.13	0.142
V. Retinoblastoma	–0.21	0.345	1.41	nc	–0.13	0.053
VI. Renal tumors	0.06	0.201	–0.02	0.451	0.09	0.234
VII. Hepatic tumors	0.14	0.157	nc	nc	–0.04	0.404
VIII. Malignant bone tumors	0.21	0.207	–0.22	0.667	–0.23	0.094
IX. Soft tissue sarcomas	–0.07	0.905	0.15	0.430	0.03	0.670
X. Germ cell tumors	0.05	0.080	0.13	0.166	0.06	0.244
XI. Other malignant epithelial neoplasms	0.02	0.922	0.21	1.000	0.42	0.494
Cancer stage						
Localized	0.02	0.296	0.09	0.027	–0.03	0.801
Regional	–0.11	0.855	–0.11	0.197	–0.07	0.414
Distant	0.00	0.846	0.06	0.744	–0.00	0.666
Residential area						
Western area	0.04	0.079	0.07	0.023	0.01	0.967
Central area	–0.01	0.711	–0.01	0.934	0.03	0.069
Eastern area	0.39	0.365	0.96	0.031	0.10	0.178

ETT: estimated travel time

nc: Not calculable because of the lack of number of patients to calculate median or *P*-value

[a] Median difference (hours) : median for 2013–2017 minus median for 2006–2012

[b] *P*-value from the Brunner–Munzel test

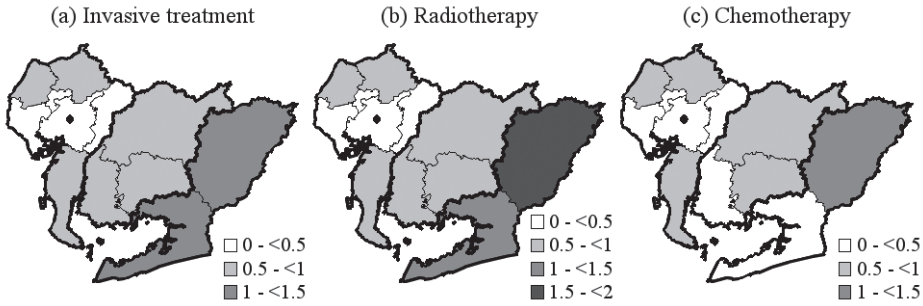

Fig. 2 Period medians of estimated travel times (hours) by secondary healthcare area in 2013–2017
The thin border indicates each secondary medical area. The thick border lines indicate the western, central, and eastern areas. The black circle in the western area indicates a hospital designated as one of the childhood cancer hub hospitals.

Figure 3 shows the number of average cases per year for each hospital and the ranking order of the hospitals in 2006–2012 and 2013–2017. The average number had increased in the top hospital for each treatment group from 2006–2012 to 2013–2017. Focusing on the hospital locations, hospitals in the western area accounted for the largest number of cases. However, for chemotherapy, the central and eastern areas each had one hospital with at least 4.8 cases per year on average.

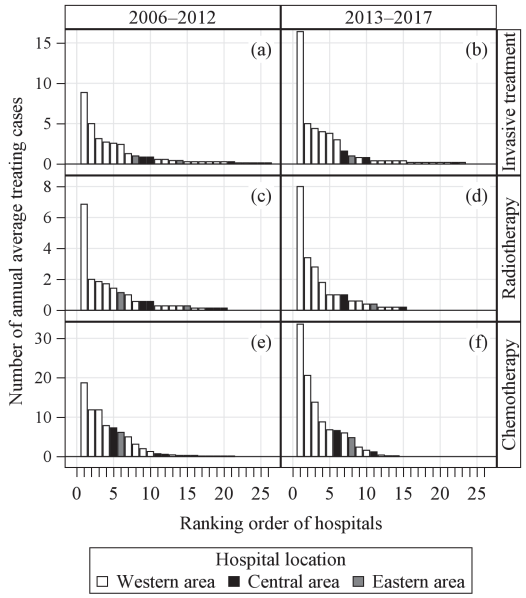

Fig. 3 Number of average cases per year for each hospital (y) and ranking order of hospitals for average cases per year (x) by the period in 2006–2017

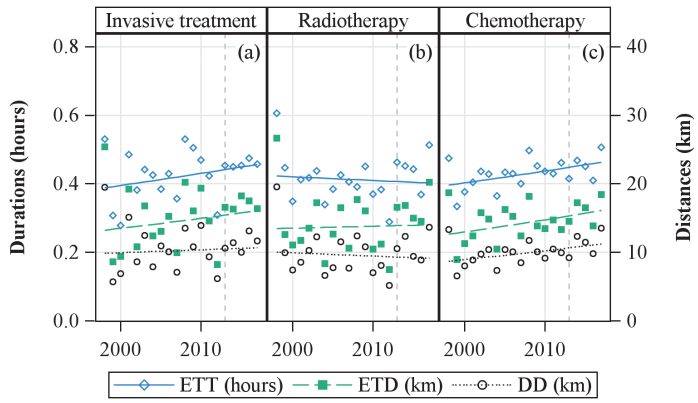

Fig. 4 Median of ETT (hours) and ETD (km), and of DD (km) over the years in 1998–2017
The lines of the same color with each symbol represent the final models on the Joinpoint regression model, whereas the dotted line at x = 2013 indicates the year when the childhood cancer hub hospitals were designated.
DD: direct distance
ETD: estimated travel distance
ETT: estimated travel time

Table 4 Annual percent change of median of ETT, ETD, and DD based on the Joinpoint regression model in 1998–2017

Variable	Treatment group	Segment	Annual percent change (%)	
		Start–End	Estimate (95% CI)	*P*-value
Median ETT	Invasive treatment	1998–2017	0.9 (–0.6, 2.3)	0.235
	Radiotherapy	1998–2017	–0.3 (–1.6, 1.1)	0.686
	Chemotherapy	1998–2017	0.8 (0.1, 1.6)	0.032
Median ETD	Invasive treatment	1998–2017	1.0 (–1.5, 3.6)	0.403
	Radiotherapy	1998–2017	0.2 (–2.3, 2.8)	0.868
	Chemotherapy	1998–2017	1.3 (–0.2, 2.8)	0.089
Median DD	Invasive treatment	1998–2017	0.4 (–2.2, 3.1)	0.737
	Radiotherapy	1998–2017	–0.5 (–3.0, 2.0)	0.675
	Chemotherapy	1998–2017	1.3 (–0.1, 2.8)	0.058

CI: confidence intervals
DD: direct distance
ETD: estimated travel distance
ETT: estimated travel time

Figure 4 shows the medians of ETT, ETD, and DD over the years and each final model on the Joinpoint regression model. Table 4 presents the APC summary based on that model. The annual medians of ETT were between 0.28 and 0.61 hours in all treatment groups (Fig. 4). From the Joinpoint regression model, all final models had no joinpoint (Fig. 4 and Table 4). The APC of the median ETT in the chemotherapy group was 0.8% (95% CI: 0.1–1.6%, $P = 0.032$) in 1998–2017, suggesting a significantly increasing trend. No other APCs showed statistical significance (Table 4).

DISCUSSION

This population-based study investigated the long-term trends in travel burdens of childhood cancer patients to access hospitals in Aichi Prefecture, Japan. Period medians of ETTs for all patients ranged from 0.38 to 0.45 hours during three periods. Their median increases from 2006–2012 to 2013–2017 were ≤0.07 hours (4 minutes). Nevertheless, treatment centralization was observed in terms of an increase in the average number of patients treated in the top hospital.

Previous studies have reported centralized treatment for childhood cancer patients at specialized hospitals.[3,6,7,16] Another study also reported that patients' travel increased from the centralization of cancer surgery, although the study focused on adult patients.[17] As expected, the trend of centralization was observed in terms of an increase in average cases per year in the top hospitals. The increases in median ETTs were low even if they were statistically significant, as shown in Table 3 and Fig. 4, which would not be considered clinically significant. Thus, we could not conclude that the travel burden has increased since 2013 following the implementation of the national cancer control measure. There are three possible reasons for this finding, which are related to the surveyed prefecture characteristics. First, the area of the prefecture was small. Second, the prefecture had established multiple hospitals that could provide specialized treatment, including

a hospital designated as a childhood cancer hub hospital. Third, the transportation network was well developed. The patients tended to move around within the prefecture, which would have led to their travel burdens being suppressed.

Nevertheless, regional differences in travel time were observed. The eastern area, a suburban area far from the urban city of the prefecture, showed a higher increase in the median ETT than the other areas (Table 3). This finding is considered concordant with other studies, suggesting that travel burdens can be greater for those living in the countryside, although those studies focused on adult patients with cancer.[18-20] Our results also suggested that the patients in the eastern area traveled longer durations for radiotherapy and invasive treatment but not for chemotherapy (Fig. 2). This was attributed to the fact that only a limited number of hospitals had the equipment and staff to provide up-to-date or appropriate treatments. Conversely, chemotherapy is generally administered over several months to several years, depending on the type of cancer. The patients and their families may have given more importance to proximity to home when choosing a hospital, despite the designating of childhood cancer hub hospitals for centralized treatment in 2013. Childhood cancer affects the lives of the sick children, their parents, siblings, and families,[21] and they need improvements in support and care.[8,9] More enrichment of support systems, such as accommodations near hospitals, will be necessary to reduce the burdens on families with the centralization of childhood cancer treatment.

A key strength of this research is that we showed the exact burdens of travel time and distance incurred by children with cancer with the web API and detailed location information at the community-level. However, we could not control the maps and traffic data, algorithm, or their versions, and consequently could not consider the differences in traffic conditions over time. The patients with an older diagnosis time point would have taken local roads if freeways did not exist at that time. Our study results may have underestimated their ETT and overestimated their ETD. However, the DD, which was not influenced by traffic development, showed a similar trend as the ETT and ETD in our analysis. Even if past traffic conditions were considered, the outcome would not have differed significantly.

Our study has five main limitations. First, travel by public transportation was not evaluated because this setting was unavailable in Japan on the web service that we used.[22] Although patients are generally likely to prefer car travel during treatment to avoid crowds and sick people because of their immunosuppressed state due to the side effects of treatment,[21] further studies are needed to investigate the trends in the travel burden among patients who use public transportation. Second, we assumed that specific patients with multiple treatments received all their treatments at one treatment hospital if the PBCR data had only detailed hospital information for one treatment. As the registration of the detailed information was prioritized in the order of hospitals providing invasive treatment, radiotherapy, and chemotherapy at the time of the registration, this may have reduced the accuracy of the results for the radiotherapy and chemotherapy groups. Third, the Aichi PBCR has shown a data-quality indicator in cases with death certificate notification, with annual percentages of approximately 40% until the early 2000s and improved to <10% since 2013.[23] Furthermore, hospital information outside the prefecture became available only in 2016. We used medians, which are less susceptible to outliers, and not the means, for the analysis; however, cautious interpretation is advisable for the results of data that were reported before 2013. Fourth, the results estimated by the web service might change because of future updates. The reproducibility of the study results cannot be guaranteed indefinitely. Since the onset of the coronavirus disease (COVID-19) pandemic, the predictive model was updated to prioritize historical traffic patterns from the last 2–4 weeks.[24] To minimize this influence, we set the study's search date to approximately four months after Japan had lifted the state of emergency, encouraging residents to stay at home. Fifth, the study data had information on the location of

the hospital where the first treatment for each therapy was performed. Further studies based on real-world data are needed to determine the travel burden for patients who were transferred to another facility to receive long-term follow-up care.

In conclusion, children with cancer in Aichi Prefecture traveled 0.38–0.45 hours on the median during three periods. The medians of the travel times increased from 2006–2012 to 2013–2017, but the increases were 0.02–0.07 hours, which would not be considered clinically significant. Nevertheless, treatment centralization was observed, and patients in suburban areas traveled longer durations for the radiotherapy and invasive treatments. Our findings could provide key basic data to help centralize cancer care for children with cancer.

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DISCLOSURE STATEMENT

The authors have no conflicts of interest to declare for this study.

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