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RESEARCH

Changes in the number of cancer diagnosis practices due to the COVID-19 pandemic: interrupted time-series analysis using the National Database of Japan

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Abstract

Purpose This study aimed to reveal the impact of coronavirus disease 2019 on the number of practices commonly used for cancer diagnosis in Japan.

Methods The sampling dataset of the National Database of Japan from January 2015 to January 2021 was used to generate 25-point time-series data for the number of practices (21 points before and 4 points during the pandemic outbreak). The decreased number was estimated by interrupted time-series analysis using a seasonal autoregressive integrated moving average model. Using the pre-pandemic data, expected counterfactual numbers during the pandemic were predicted, and decreased rate was calculated.

Results In most practices, the number dramatically decreased in the early stage of the pandemic and recovered rapidly thereafter. As of April 2020, gastric endoscopy decreased at the top of the practices (− 42.1%, with 95% confidence intervals of − 50.5% and − 33.7%), followed by gastric biopsy (− 38.6%, with 95% confidence intervals of − 46.7% and − 30.6%). The period of declined practices for lung cancer was relatively prolonged. The number of sentinel lymph node biopsies for breast cancer and colposcopies and biopsies for cervical cancer did not decrease in April 2020, but significantly decreased later in July 2020, which is assumed to be the time lapse after the primary testing before surgical treatment or intense scrutiny.

Conclusion In general, the number of practices for cancer diagnosis in Japan showed only a temporary decline, which was concordant with reports from several other countries.

Keywords COVID-19 · Health services · Cancer diagnosis · The National Database of Japan

Introduction

Coronavirus disease 2019 (COVID-19) has spread worldwide since it was recognized in December 2019 in Wuhan City, China, and it has been one of the most serious public health issues in the world.

The timeline of events related to the COVID-19 pandemic in Japan is shown in Table 1. After the first person was identified to be infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the infection spreads rapidly throughout the country. To date, the government has declared a state of emergency regarding COVID-19 three times based on the Act on Special Measures for Pandemic Influenza and New Infectious Diseases Preparedness and Response (the Act on Special Measures) to prevent the spread of the infection. Under a state of emergency, local prefectural governments were able to request their residents

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Table 1 Timeline of events related to the COVID-19 pandemic

Date	Event
January 15, 2020	Confirmation of the first person identified to be infected with severe acute respiratory syndrome coronavirus 2
April 7, 2020 (until May 25, 2020)	The first state of emergency was declared
April 14, 2020	The MHLW requested the postponement of cancer screening
May 26, 2020	The MHLW requested the appropriate implementation of cancer screening
January 8, 2021 (until March 21, 2021)	The second state of emergency was declared
April 25, 2021 (until September 30, 2021)	The third state of emergency was declared
April 26, 2021	The MHLW stated that cancer screening is not "nonessential outings"

MHLW Ministry of Health, Labour and Welfare

and institutions to implement preventive measures, but there was no enforcement of their actions and no penalties for violators. Specifically, prefectural governments instructed their residents to stay at home and refrain from "non-essential outings" and the managers of facilities, such as theaters, museums, libraries, hotels, bars, gymnasiums, and schools, to close their institutions (Looi 2020a, 2020b, 2021). Particularly, during the first state of emergency, it was aimed to reduce social contact with others by at least 80%, and the aim was successfully achieved with a reduction of 86% according to a previous study with mathematical modeling (Kuniya 2020).

Even under the state of emergency, according to the Act on Special Measures, visiting medical institutions was excluded from non-essential outings, and the governments did not ask to close medical institutions, such as hospitals and clinics. However, the Ministry of Health, Labour and Welfare (MHLW) requested the postponement of cancer screening, as in several other countries (Del Vecchio Blanco et al. 2020; Dinmohamed et al. 2020a; Kaufman et al. 2020; Zadnik et al. 2020), but this was retracted after about 1 month. In terms of cancer diagnosis and treatment, many Japanese academic societies and expert committees issued recommendations or opinions on treatment triage plans during the COVID-19 pandemic to allocate medical resources efficiently (Furuta et al. 2020; Irisawa et al. 2020; Japan Society of Clinical Oncology 2020; Nangaku et al. 2021; Japanese Breast Cancer Society 2020; Japan Surgical Society 2020; The Japan Lung Cancer Society 2020); these referred to the guidance of other countries for proposing the consideration of postponement of nonfatal and non-urgent treatment and examinations.

Considering this situation, the spread of COVID-19 was assumed to affect cancer screening and diagnostic practices. In Japan, there is a clear distinction between cancer screening for preventive purposes and practice for diagnostic purposes. Cancer screening is conducted as an organized screening, which is provided by municipalities in general, or opportunistic screening. If a positive result is obtained from screening, individuals are recommended to undergo practices for diagnostic purposes in medical institutions. Otherwise, individuals with symptoms directly visit a medical institution and undergo diagnostic practices without screening. Cancer screening is not covered by medical insurance, whereas diagnostic practice is covered. The number of cancer screenings in Japan declined during the COVID-19 pandemic according to the Report on Regional Public Health Services and Health Promotion Services in FY2020 (MHLW 2022). Nevertheless, studies related to the number of practices for diagnostic purposes in medical institutions during the pandemic are limited in Japan, which evaluated only the number of gastrointestinal endoscopies and had a limitation for generalizability (Iijima et al. 2022; Kuzuu et al. 2021; Mizuno et al. 2012; Yoshida et al. 2020). Accumulating the actual reports in Japan, in addition to the reports in other countries (Castonguay et al. 2022; Lantinga et al. 2021; Longcroft-Wheaton et al. 2021; Tachibana et al. 2021), is necessary to know the global impact of the COVID-19 pandemic.

This study aimed to investigate changes in the number of practices commonly used to diagnose cancer before and during the COVID-19 pandemic. The results should provide important real-world basic data to understand the impact of the spread of COVID-19 on cancer medical practices.

Methods

This was a repeated cross-sectional study using a sampling dataset from the National Database of Health Insurance Claims and Specific Health Checkups of Japan (NDB). This design allows the determination of the patterns of change in the aggregate level.

The sampling dataset

The NDB is a database administered by the MHLW in which insurance claims and annual health checkup data have been

Table 2 Estimated decreased counts and rates of practices for stomach, colorectal, and lung cancer

	Time	Decreased count			Decreased rate		
		Number	95% CI		%	95% CI	
Stomach							
Endoscopy	Apr-2020	**−236,481**	**−285,861**	**−187,100**	**−38.6**	**−46.7**	**−30.6**
	Jul-2020	−22,007	−77,963	33,948	−3.2	−11.5	5.0
	Oct-2020	−25,964	−89,512	37,584	−3.4	−11.7	4.9
	Jan-2021	−52,534	−110,850	5782	−9.4	−19.9	1.0
Biopsy	Apr-2020	**−77,341**	**−92,709**	**−61,973**	**−42.1**	**−50.5**	**−33.7**
	Jul-2020	−13,477	−34,845	7892	−6.7	−17.4	3.9
	Oct-2020	−21,365	−48,436	5706	−9.3	−21.1	2.5
	Jan-2021	−13,681	−43,517	16,155	−8.3	−26.4	9.8
Colon or rectum							
Endoscopy	Apr-2020	**−65,442**	**−82,458**	**−48,427**	**−28.5**	**−35.9**	**−21.1**
	Jul-2020	**−42,981**	**−64,473**	**−21,489**	**−16.3**	**−24.5**	**−8.2**
	Oct-2020	5538	−16,946	28,022	2.0	−6.2	10.3
	Jan-2021	−13,385	−36,914	10,143	−6.2	−17.1	4.7
Biopsy	Apr-2020	**−11,872**	**−15,935**	**−7809**	**−24.1**	**−32.3**	**−15.8**
	Jul-2020	**−9183**	**−13,954**	**−4412**	**−15.1**	**−22.9**	**−7.2**
	Oct-2020	2734	−2331	7799	4.9	−4.2	14.1
	Jan-2021	175	−4923	5272	0.4	−11.2	11.9
Lung							
Radiography	Apr-2020	**−53,441**	**−70,933**	**−35,949**	**−20.4**	**−27.1**	**−13.8**
	Jul-2020	**−22,041**	**−39,533**	**−4549**	**−8.1**	**−14.4**	**−1.7**
	Oct-2020	**−18,241**	**−35,733**	**−749**	**−6.5**	**−12.8**	**−0.3**
	Jan-2021	**−35,641**	**−53,133**	**−18,149**	**−13.7**	**−20.4**	**−7.0**
CT	Apr-2020	**−51,359**	**−71,118**	**−31,600**	**−20.8**	**−28.8**	**−12.8**
	Jul-2020	**−30,059**	**−49,818**	**−10,300**	**−11.2**	**−18.6**	**−3.8**
	Oct-2020	−3359	−23,118	16,400	−1.2	−8.5	6.0
	Jan-2021	**−25,159**	**−44,918**	**−5400**	**−10.2**	**−18.2**	**−2.2**
Endoscopy	Apr-2020	**−3849**	**−5812**	**−1887**	**−28.0**	**−42.2**	**−13.7**
	Jul-2020	−1784	−3624	55	−12.0	−24.4	0.4
	Oct-2020	−57	−2176	2063	−0.4	−14.2	13.5
	Jan-2021	**−2397**	**−4242**	**−553**	**−17.2**	**−30.4**	**−4.0**
Biopsy	Apr-2020	**−2736**	**−4280**	**−1192**	**−32.1**	**−50.2**	**−14.0**
	Jul-2020	−546	−2039	947	−6.2	−23.3	10.8
	Oct-2020	1473	−110	3055	16.8	−1.3	34.8
	Jan-2021	−1530	−3113	53	−18.5	−37.7	0.6

For endoscopy and biopsy for the lung cancer, outpatient, inpatient, and diagnosis procedure combination claims were used for aggregation and for remaining practices, outpatient claims were used. Bold font represents statistically significant

CI confidence interval, *CT* computed tomography

accumulated comprehensively since 2008 based on the Act on Assurance of Medical Care for Elderly People. As of November 2020, 98.6% of all insurance claims were registered. To utilize the NDB for research purposes, the MHLW has provided data to third parties on a trial basis since 2011 and full-scale operation since 2013. Three different extraction methods are available for providing NDB data to third parties. Among these, we used the sampling dataset, whose features are as follows:

1. The data are created for 4 months per year at 3-month intervals: January, April, July, and October.
2. The data are randomly extracted with the same composition of sex and age (every 5 years) with the population who used medical insurance in each target month. Extracted rates for medical outpatient claims and pharmacy claims are 1%, and those for medical inpatient claims and diagnosis procedure combination (DPC) claims are 10%.

Table 3 Estimated decreased counts and rates of practices for breast and cervical cancer

	Time	Decreased count			Decreased rate		
		Number	95% CI		%	95% CI	
Breast							
Mammography	Apr-2020	**−62,300**	**−99,699**	**−24,901**	**−34.6**	**−55.3**	**−13.8**
	Jul-2020	−1300	−38,699	36,099	−0.7	−19.4	18.1
	Oct-2020	4600	−32,799	41,999	2.0	−14.1	18.0
	Jan-2021	−4000	−41,399	33,399	−2.4	−24.9	20.1
Biopsy	Apr-2020	**−7300**	**−12,194**	**−2406**	**−29.3**	**−49.0**	**−9.7**
	Jul-2020	−1000	−5894	3894	−4.1	−24.1	15.9
	Oct-2020	1100	−3794	5994	3.9	−13.6	21.4
	Jan-2021	−3100	−7994	1794	−12.4	−32.0	7.2
Sentinel lymph node biopsy	Apr-2020	−72	−833	689	−1.3	−15.4	12.7
	Jul-2020	**−1276**	**−2102**	**−450**	**−23.2**	**−38.3**	**−8.2**
	Oct-2020	−770	−1661	122	−13.8	−29.8	2.2
	Jan-2021	−644	−1601	314	−11.4	−28.4	5.6
Cervix							
Cytology	Apr-2020	**−86,130**	**−108,507**	**−63,754**	**−24.4**	**−30.8**	**−18.1**
	Jul-2020	25,751	528	50,974	6.8	0.1	13.4
	Oct-2020	13,008	−16,528	42,544	3.1	−4.0	10.3
	Jan-2021	6448	−20,128	33,023	1.9	−5.8	9.5
Colposcopy	Apr-2020	−3532	−8318	1254	−10.5	−24.7	3.7
	Jul-2020	**−6215**	**−11,409**	**−1022**	**−15.2**	**−27.9**	**−2.5**
	Oct-2020	−3236	−8486	2015	−8.1	−21.3	5.1
	Jan-2021	−1258	−6515	3998	−3.9	−19.9	12.2
Biopsy	Apr-2020	−900	−4743	2943	−4.4	−23.0	14.3
	Jul-2020	**−4000**	**−7843**	**−157**	**−16.0**	**−31.4**	**−0.6**
	Oct-2020	−500	−4343	3343	−1.9	−16.9	13.0
	Jan-2021	−1800	−5643	2043	−8.3	−26.0	9.4

For sentinel lymph node biopsy for the breast cancer, inpatient, and diagnosis procedure combination claims were used for aggregation, and for remaining practices, outpatient claims were used. Bold font represents statistically significant

CI confidence interval

3. The data are anonymized while generating the dataset by the MHLW.

The sampling dataset from January 2015 to January 2021, the latest available data, was provided on July 27, 2022. Quarterly 25-point time-series data (4 points per year × 6 years + 1 point × 1 year = 25) were created.

Method for extraction of insurance claims and aggregation

This study investigated changes in the number of medical practices commonly used to diagnose the five major cancers of the stomach, colon or rectum, lung, breast, and cervix. The medical practices examined were endoscopy and biopsy for stomach or colorectal cancer; radiography, computed tomography (CT), endoscopy, and biopsy for lung cancer; mammography, biopsy, and sentinel lymph node biopsy for breast cancer; and cytology, colposcopy, and biopsy for cervical cancer. The extraction sequences are shown in Online Resource 1, and the codes of medical practice used for extraction are shown in Online Resource 2. When insurance claims for radiography or CT for lung cancer were extracted, we also used the code of disease name because these practices are conducted for various diseases. The codes of disease names are shown in Online Resource 3, which correspond to C34.X and D02.2 in the ICD-10 code. Insurance claims with a flag of "possible" were also included. In many practices, target claims were focused on medical outpatients, as shown in Online Resource 1, because these practices for diagnostic purposes are mainly performed on an outpatient basis. As exceptions, endoscopy and biopsy for lung cancer targeted medical outpatients, medical inpatient, and DPC insurance claims, and sentinel lymph node biopsy for breast cancer targeted medical inpatient and DPC insurance claims. After extracting the target insurance claims, the

number of claims for each month (25 points) was determined using the following procedure:

- The number of insurance claims for each month (25 points), practice, and claim type (outpatient, inpatient, and DPC) was counted.
- When the claims type was outpatient, the counted number was multiplied by 100, and when the claims type was inpatient or DPC, it was multiplied by 10 (multiplied by the reciprocal of the extraction rate).
- For endoscopy and biopsy for lung cancer, the multiplied counted numbers of outpatient, inpatient, and DPC claims were summed up for each month and for each practice. For sentinel lymph node biopsy for breast cancer, the multiplied counted numbers of inpatient and DPC claims were summed for each month and for each practice.

Statistical methods

All statistical analyses were performed using R version 4.2.0, a free software environment for statistical computing and graphics. We analyzed 25-point time-series data by interrupted time-series analysis using seasonal autoregressive integrated moving average (SARIMA) models according to the methods introduced in a previous study (Schaffer et al. 2021). We defined January 2015 to January 2020 as before pandemic (21 points) and April 2020 to January 2021 as during pandemic (4 points). The SARIMA model requires some components, which are expressed as $(p, d, q) \times (P, D, Q)_s$. Here, p is the order of the autoregressive (AR) part of the model; d is the degree of nonseasonal differencing; q is the order of the moving average (MA) part of the model; D is the degree of seasonal differencing; P and Q are the AR and MA terms for the seasonal component, respectively; and s is the seasonality, which is 4 in this study because the data were quarterly. First, these components were determined using auto.arima in the forecast package for R. This algorithm iteratively searches over a series of potential SARIMA models for the model with the lowest Akaike information criterion. In this step, all 25-point data were used, and step change variables for each month during the COVID-19 pandemic were also included in the model as external regressors (model 1). The step change variables for each month (S_i) take the value of 1 for each month during the pandemic (i = 2020/4, 2020/7, 2020/10, and 2021/1) and 0 otherwise. For example, the step change variable for April 2020 ($S_{2020/04}$) takes the value of 1 in April 2020 and 0 in the other 24 points. The estimated step changes for each month indicated a decrease in the number of insurance claims. Second, using only data prior to the pandemic (21 points), the number of insurance claims during the pandemic was predicted by the SARIMA model with the components (p, d, q, P, D, and Q) determined by model 1, which is the expected counterfactual numbers. The expected numbers with 95% confidence intervals (CIs) and observed numbers were compared in the figure, and decreased rate was calculated using the following formula:

$$\text{Decreased rate (\%)} = \frac{\text{Estimated decreased number}}{\text{Expected counter factual number}} \times 100.$$

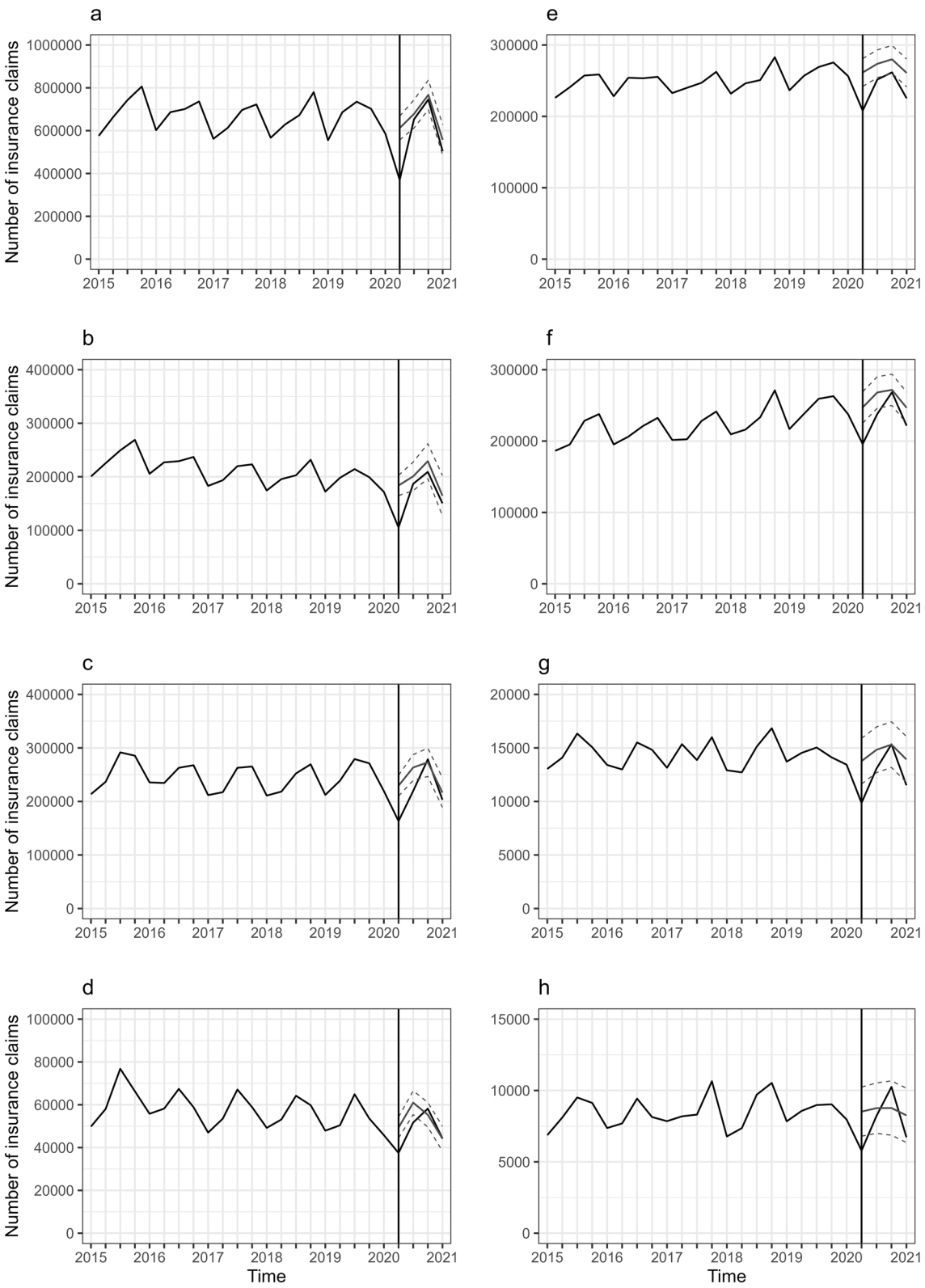
Sex-specific analyses were also performed for the diagnosis of stomach, colorectal, and lung cancers. Statistical significance was set at $P < 0.05$.

Ethics statement

We used the NDB sampling dataset for this study, which is regularly generated by the MHLW. To ensure anonymity of the patients, personal information, such as name, address, and telephone number, was not included in the dataset. Age was converted into a 5-year category. In addition, if the medical expenses were extremely high, ≥ 7,000,000 JPN (51,166 USD with the exchange rate on August 26, 2022: USD 1 = JPY 136.81) for medical inpatient claims and ≥ 500,000 JPN (3655 USD) for medical outpatient claims were excluded before generating the dataset. In terms of code, such as disease name code and medical practice code, when the frequency was rare, the code was replaced with specific numbers, e.g., "9999999" for disease name code and "888888888" for medical practice code, until the cumulative percentage from the fewest reached 0.1%. When researchers use the NDB data for research purposes, they must submit a research plan to the MHLW for review and approval. As the sampling dataset of the NDB was anonymized through these procedures, the requirement for informed consent was waived. This study was approved by the Research Ethics Committees of the Chiba Foundation for Health Promotion and Disease Prevention (approval number R3-4) and was conducted in accordance with the principles of the Declaration of Helsinki and the Ethical Guidelines for Medical and Biological Research Involving Human Subjects.

Results

The decreased count and rate for each practice during the COVID-19 pandemic, estimated by interrupted time-series analysis using the SARIMA model, are shown in Tables 2 and 3, respectively. Furthermore, the observed numbers during the entire period and the expected counterfactual numbers during the pandemic outbreak are shown in Figs. 1 and 2. The numbers of endoscopies and biopsies for stomach cancer, mammographies and biopsies for breast cancer, and cytology tests for cervical cancer significantly decreased in


a
b
c
d
e
f
g
h
Number of insurance claims
Time
2015
2016
2017
2018
2019
2020
2021

◂**Fig. 1** Trajectory of the number of practices for stomach, colorectal, and lung cancers. **a** is the number of endoscopies for stomach cancer. **b** is the number of biopsies for stomach cancer. **c** is the number of endoscopies for colorectal cancer. **d** is the number of biopsies for colorectal cancer. **e** is the number of radiographies for lung cancer. **f** is the number of computed tomography scans for lung cancer. **g** is the number of endoscopies for lung cancer. **h** is the number of biopsies for lung cancer. **a**, **b**, **c**, **d**, **e**, and **f** were calculated using outpatient insurance claims, and **g** and **h** were calculated using outpatient, inpatient, and diagnosis procedure combination insurance claims. The observed numbers during all observation periods and the expected counterfactual numbers with 95% confidence intervals during the COVID-19 pandemic were drawn. Data are represented by quarterly series, January, April, July, and October

April 2021 and recovered rapidly thereafter. Similarly, the number of endoscopies and biopsies for colorectal cancer significantly decreased in April and July 2021 and recovered thereafter. In April 2020, the first and second places for decreased numbers were observed in biopsy (− 42.1%, with 95% CI of − 50.5% and − 33.7%) and endoscopy (− 38.6%, with 95% CI of − 46.7% and − 30.6%) both for stomach cancer. The period of declined number of diagnostic practices for lung cancer was prolonged. In particular, the number of radiographies for lung cancer significantly decreased over the entire study period. In terms of CT and endoscopy for lung cancer, the numbers decreased during the pandemic, recovered, and decreased again in January 2021, when the second state of emergency was declared. These relatively long-term declines in lung cancer practice were more prominent in women than in men, as shown in Online Resources 4 and 5. The numbers of sentinel lymph node biopsies for breast cancer and colposcopies and biopsies for cervical cancer did not decrease in April 2020 but significantly decreased later in July 2020.

Discussion

Using the NDB sampling dataset, we revealed changes in the number of diagnostic practices commonly used for five major cancers of the stomach, colon or rectum, lung, breast, and cervix before and during the COVID-19 pandemic outbreak.

In most cancer diagnosis practices, the numbers declined temporarily and recovered in July 2020 or October 2020. According to a report based on hospital-based cancer registries in Japan, the number of cancer diagnoses dropped temporarily during the pandemic outbreak but rapidly recovered thereafter (Okuyama et al. 2022). A similar trajectory has also been reported for a relatively small population in Japan (Fujita et al. 2022). Our results are consistent with those of previous studies. Contrary to our initial concerns, it is encouraging that the number of cancer diagnosis practices recovered in a relatively short period of time. However, during the current observation period, no increase in the number of practices to compensate for this decrease was observed. Considering that delaying surgery for 12 weeks may decrease overall survival in breast, lung, and colon cancers (Johnson et al. 2021), even short-term declines in the number of practices can worsen cancer prognosis.

Among the practices analyzed, in the early stage of the pandemic, biopsy for stomach cancer decreased the most, followed by endoscopy for stomach cancer. A report analyzing hospital-based cancer registries in Japan revealed that the sharpest decline in cancer diagnosis in the first wave of the COVID-19 pandemic was observed in stomach cancer, and the authors hypothesized that the drop may occur because healthcare workers had strictly followed the recommendation of the Japan Gastroenterological Endoscopy Society, in which postponement of non-urgent gastrointestinal endoscopy was recommended during the pandemic (Okuyama et al. 2022). Our results are consistent with those of previous studies.

A drastic decline in the number of diagnostic practices and diagnosis in the early stages of the initial COVID-19 pandemic has been observed in several countries and have recovered within a short period of time (Castonguay et al. 2022, Caswell-Jin et al. 2022, Dinmohamed et al. 2020b, Tachibana et al. 2021, Vrdoljak et al. 2021). In Japan, the first state of emergency was declared from April 7, 2020, to May 25, 2020, but no lockdown was implemented. The prefectural governments requested their residents and institutions to implement certain measures without enforcing action and penalties for violators. Additionally, the spread of SARS-CoV-2 infection during this period was limited in Japan. Despite these situations, a drastic decline in the number of diagnostic practices was observed in Japan, as well as in other countries. In the early stages of the COVID-19 pandemic, information about routes and prevention measures of the viral infection was overwhelmingly lacking; therefore, both patients and healthcare workers were assumed to experience extreme fear. Individuals with some symptoms may have hesitated to visit medical institutions, and healthcare workers might have given an order of priority to practice for cancer diagnosis according to the opinion of expert committees on treatment triage plans during the pandemic (Furuta et al. 2020, Irisawa et al. 2020, Japan Society of Clinical Oncology 2020, Nangaku et al. 2021, Japanese Breast Cancer Society 2020, Japan Surgical Society 2020, The Japan Lung Cancer Society 2020). In addition, there was a shortage of human resources and personal protective equipment (PPE), such as face masks and protective clothing, in medical institutions, and cancer screening was suspended. These confusions are thought to have occurred commonly worldwide, regardless of the strictness of lockdown and social distancing or the extent of the spread of the infection. As a result, the number of cancer diagnosis practices dramatically

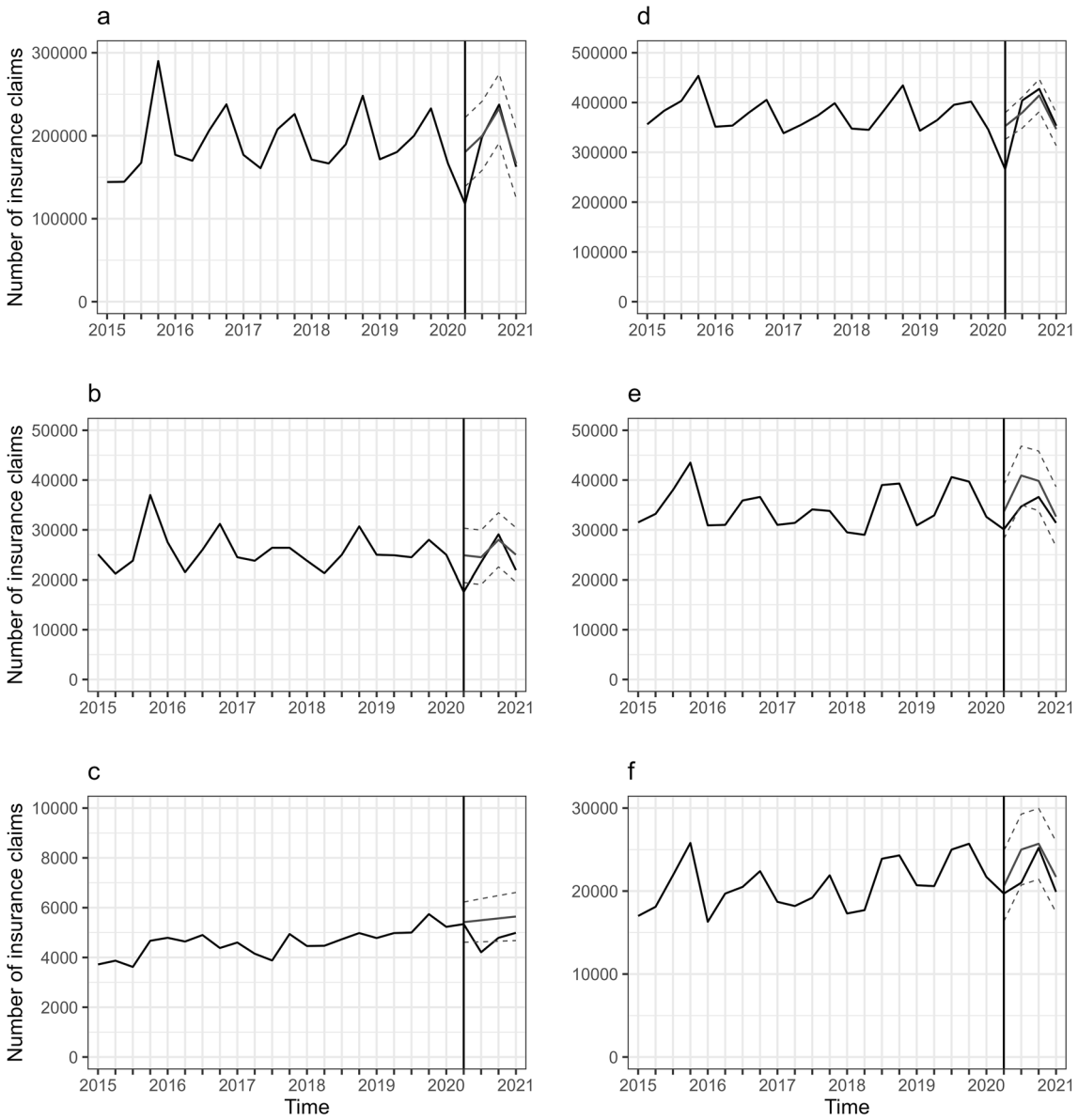


Fig. 2 Trajectory of the number of practices for breast and cervical cancers. **a** is the number of mammographies for breast cancer. **b** is the number of biopsies for breast cancer. **c** is the number of sentinel lymph node biopsies for breast cancer. **d** is the number of cytology tests for cervical cancer. **e** is the number of colposcopies for cervical cancer. **f** is the number of biopsies for cervical cancer. **a**, **b**, **d**, **e**, and **f** were calculated using outpatient insurance claims, and **c** was calculated using inpatient insurance claims and diagnosis procedure combination insurance claims. The observed numbers during all observation periods and the expected counterfactual numbers with 95% confidence intervals during the COVID-19 pandemic were drawn. Data are represented by quarterly series: January, April, July, and October

and temporarily decreased in various countries. This trajectory in the number of cancer practices and diagnoses was likely to be common worldwide.

In our study, the period of decreased number of practices for lung cancer, especially radiography, was relatively prolonged. Since COVID-19 is a respiratory disease, shortages of human resources and PPE in respiratory departments might have occurred for a longer period of time. However, the fact that this phenomenon was conspicuous among women denies the cause of the health system because healthcare workers are thought not to selectively avoid cancer diagnostic practices in women, even under resource shortages. Although a convincing explanation is not possible, women might have avoided visiting the respiratory department for a longer period of time than men during the pandemic. The number of radiographies, CT scans, and endoscopies for lung cancer decreased again in January 2021, when the second state of emergency was declared, although the infection

status was more moderate compared with the early stage of the pandemic. The numbers may have fluctuated after our observation period, depending on the extent of the spread of the infection and government requests. Extension of observation period is required to fully understand the impact of the COVID-19 pandemic on cancer practices.

The numbers of sentinel lymph node biopsies for breast cancer and colposcopies and biopsies for cervical cancer did not significantly decrease in April 2020 but decreased in June 2020. The time lag due to diagnostic sequences could explain this phenomenon. The first step in breast cancer diagnosis involves mammography and biopsy. Sentinel lymph node biopsy is performed only when breast cancer is diagnosed using these practices, in addition to surgical treatment in general. A delay in the decline in the number of sentinel lymph node biopsies represents a time lag between testing and treatment. Similarly, the first step in the diagnosis of cervical cancer involves cervical cytology; if the result is positive, colposcopy and biopsy are performed. Therefore, the delay in the declines observed in the number of colposcopies and biopsies for cervical cancer would also represent a time lag between primary and diagnostic testing. The sampling dataset for the NDB was a quarterly series. The monthly fluctuations may provide more details about the timing of the reduction in these practices.

This study had some limitations. First, we could not distinguish between the patients who visited the medical institutions due to a positive result of the cancer screening and those who directly visited medical institutions, not via cancer screening, who were thought to be symptomatic cases. Reports suggest that the effects of the COVID-19 pandemic on cancer diagnoses differ between the two (Dinmohamed et al. 2020b, Okuyama et al. 2022). A study analyzing hospital-based cancer registries in Japan reported that the decreased number of cancer diagnoses in patients via cancer screening was greater than that in those not via screening in all five cancers: stomach, colon or rectum, lung, breast, and cervix (Okuyama et al. 2022). A study analyzing the Netherlands Cancer Registry revealed that individuals who were eligible for breast or colorectal cancer screening, which was determined by age, had a delayed recovery from the decline in cancer diagnoses compared to those who were not eligible for screening (Dinmohamed et al. 2020b). In Japan, the number of cancers diagnosed via cancer screening is significantly lower than that of symptomatic cases (Okuyama et al. 2022). Therefore, there are concerns that our results masked the trajectory of patients who visited medical institutions via cancer screening. The second limitation was the accuracy of disease names in insurance claims. We used the disease name code described in the insurance claims to determine the claims with radiography or CT for lung cancer because these practices are performed in several diseases. However, this name is provided for billing purposes, not for diagnosis. Therefore, the accuracy of names often fluctuates. However, this study had some strengths. We used the sampling dataset of the NDB, in which insurance claims data in Japan have been accumulated comprehensively. This is one of the most reliable data that can capture the actual situation of clinical practice in Japan promptly with generalizability. Another strength is the application of interrupted time-series analysis using the SARIMA model, which is a more robust method as it controls for preexisting underlying short- and long-term trends (Schaffer et al. 2021).

In conclusion, we revealed the impact of the COVID-19 pandemic on diagnostic practices in Japan. There are many differences between countries, such as medical care systems, extent of the spread of COVID-19, doctor's treatment policies, and patients' behavior; therefore, in these situations, it is meaningful to analyze the impact in each country. Our results contribute to assessing the global impact of the COVID-19 pandemic. In our study, the number of practices commonly used for cancer diagnosis in Japan dramatically decreased in the early stage of the COVID-19 pandemic, and most of them recovered within 4 or 7 months. These results are consistent with previous results that reported a decrease in cancer diagnosis due to the pandemic in Japan. We used the latest data available; however, extension of the observation period is required to determine the full effects of the pandemic on cancer practices.

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Data availability The datasets generated during the current study are available in Online Resource 6.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval This study was conducted in accordance with the principles of the Declaration of Helsinki. Approval was granted by the Research Ethics Committees of the Chiba Foundation for Health

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Consent to participate As the sampling datasets of the NDB were anonymized when they were generated, informed consent was waived.

Consent to publish Not applicable.

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