

# Association Between Immunoglobulin G4-related Disease and Malignancy within 12 Years after Diagnosis: An Analysis after Longterm Followup

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**ABSTRACT. Objective.** Because it is uncertain whether immunoglobulin G4-related disease (IgG4-RD) is associated with malignancy, we evaluated the incidence of cancer development in a large cohort of patients with IgG4-RD.

**Methods.** The study enrolled 158 patients diagnosed as having IgG4-RD between 1992 and 2012. We calculated the standardized incidence ratio (SIR) and cumulative rate of malignancies in this group and searched for risk factors associated with the occurrence of tumors.

**Results.** A total of 34 malignancies were observed in the patients with IgG4-RD over a mean followup period of  $5.95 \pm 4.48$  years. The overall SIR of malignancies was 2.01 (95% CI 1.34–2.69). The SIR of patients who exhibited a tumor within 1 year after IgG4-RD diagnosis was 3.53 (95% CI 1.23–5.83), while that of subjects forming a malignancy in subsequent years was 1.48 (95% CI 0.99–1.98). The cumulative rate of malignancy development was significantly higher in patients with IgG4-RD within 12 years after diagnosis than in the Japanese general population. Comparable results were obtained for an autoimmune pancreatitis subgroup. The serum concentrations of several disease activity markers at diagnosis were significantly higher in patients with malignancies than in those without.

**Conclusion.** We identified a close association between IgG4-RD and malignancy formation within 12 years after diagnosis, particularly during the first year. An active IgG4-RD state is presumed to be a strong risk factor for malignancy development. (J Rheumatol First Release October 15 2015; doi:10.3899/jrheum.150436)

## Key Indexing Terms:

IMMUNOGLOBULIN G4-RELATED DISEASE  
MALIGNANCIES

AUTOIMMUNE PANCREATITIS  
ACTIVITY MARKER

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Supported partially by the Research Program of Intractable Disease provided by the Ministry of Health, Labor, and Welfare of Japan and in part by Grants-in-aid for Scientific Research from the Ministry of Education, Science, Sports, and Culture of Japan (23591012).

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Accepted for publication July 23, 2015.

Immunoglobulin G4-related disease (IgG4-RD) is a systemic condition characterized by high serum IgG4 concentration and IgG4-bearing plasma cell infiltration in affected organs<sup>1,2,3</sup>. The concept of IgG4-RD was established through extensive evaluation of extrapancreatic lesions complicating autoimmune pancreatitis (AIP)<sup>2</sup>. IgG4-RD characteristically involves multiple organs, and is believed to manifest as Mikulicz disease<sup>4</sup>, respiratory disorders<sup>5</sup>, sclerosing cholangitis<sup>6</sup>, retroperitoneal fibrosis<sup>3</sup>, tubulointerstitial nephritis<sup>7</sup>, and prostatitis<sup>8</sup>. Although corticosteroid therapy is effective for IgG4-RD, relapses sometimes occur during dose tapering and maintenance phases<sup>9,10,11</sup>.

The longterm outcome of this new disease entity has been described to include the complication of malignancy development<sup>12,13,14</sup>. Yamamoto, *et al* reported that patients with IgG4-RD were significantly more prone to malignancies than the general population in a followup study of 105 patients<sup>15</sup>. Shiokawa, *et al* uncovered similar results in 108 patients with AIP<sup>16</sup>. Because the occurrence of malignancies in the first year after diagnosis was significantly higher than in subsequent years, the authors proposed that AIP may feature

aspects of a paraneoplastic syndrome and that the fate of patients with AIP was closely influenced by the occurrence and treatment of malignancies. On the other hand, Hirano, *et al* reported that IgG4-RD was not significantly associated with malignancy after evaluating 113 patients with IgG4-RD<sup>17</sup>. This may have been because Hirano excluded cases of malignancies that were diagnosed concomitantly with IgG4-RD, and Yamamoto and Shiokawa did not. Hart, *et al* also noted that 116 patients with type 1 AIP did not have significant numbers of malignancies when compared with 344 control subjects from a primary care clinic<sup>18</sup>. Accordingly, the issue of whether an association exists between IgG4-RD and malignancy remains controversial.

Close relationships have been identified between chronic inflammation and malignancy, including one between gastric cancer and gastritis from *Helicobacter pylori*<sup>19,20</sup> and another between hepatocellular carcinoma and viral hepatitis<sup>21,22</sup>. Similarly, the chronic inflammatory state of IgG4-RD may be related to malignancies in systemic organs in which IgG4-RD is found. Further, because IgG4-RD is recognized as an autoimmune disease that occurs predominantly in the elderly, a deficiency in immune surveillance may trigger the occurrence of this disease, which in turn induces associated malignancies<sup>23</sup>. Older patient age also appears to be a major contributing factor to the occurrence of malignancies in general<sup>24</sup>. It will be necessary to precisely identify the time of IgG4-RD onset, affected lesions, and various other risk factors in a large number of patients following longterm observation to clarify whether IgG4-RD is related to malignancy. The aim of our present study is to determine the key relationships between IgG4-RD and malignancy, such as whether IgG4-RD is significantly complicated by malignancy.

## MATERIALS AND METHODS

**Patients.** We enrolled 158 patients with IgG4-RD (119 men and 39 women, median age at IgG4-RD onset: 72 years) who had been diagnosed based on the Japanese Comprehensive Diagnostic Criteria for IgG4-RD<sup>25</sup> between 1992 and 2012 at our clinic or affiliated hospitals. The cohort included 109 patients with type 1 AIP (84 men and 25 women, median age at AIP onset: 66 yrs), among whom 103 patients possessed extrapancreatic lesions. AIP was diagnosed according to the International Consensus Diagnostic Criteria 2011 (ICDC 2011), which were based mainly on characteristic imaging findings, high serum IgG4 concentration, the presence of extrapancreatic lesions (other IgG4-RD), and steroid responsiveness and less on pathological findings because pancreatic biopsy samples have been difficult to obtain in sufficient sample sizes for correct diagnosis<sup>26</sup>. One hundred and eleven patients received steroid therapy when involved vital organs exhibited a risk of serious organ dysfunction or failure, such as obstructive jaundice due to pancreatic head swelling or urethral stenosis from retroperitoneal fibrosis, or when severe symptoms, including unbearable abdominal pain, were evident. Steroid treatment was carried out at our institute according to the Japanese consensus guidelines for AIP, which recommend a minimum of 3 years of maintenance therapy<sup>11</sup>.

**Survey for complication of malignancy.** Of the 158 patients, we searched for the complication of malignancy in 142 subjects by examining medical records dated until December 2013. For the 16 patients who discontinued treatment at our institutions during the study period, we sent questionnaires for the clinical survey of malignancy and obtained replies from 8 individuals.

We screened for the occurrence of malignancy up until the time of last contact for the remaining 8 patients with whom we had lost contact during the survey period. Malignancies before IgG4-RD diagnosis were not analyzed in our present study.

**Analysis for correlation between IgG4-RD and malignancy.** The standardized incidence ratio (SIR) of malignancy in our cohort was calculated to evaluate whether IgG4-RD was significantly complicated by malignancy by adopting the cancer incidence rates for the Japanese general population as stratified by sex, 5-year age groups, and calendar year<sup>27</sup>. The SIR was calculated by dividing the actual number of malignancies by the expected number if the cohort exhibited malignancies at the same age-stratified rate as the Japanese general population. Further, we determined the 95% CI using normal approximation based on Poisson's distribution. The occurrence of malignancy in IgG4-RD was considered to be significantly elevated when the lower value in this interval exceeded 1.00. We analyzed 2 patient groups in our present study: one that included patients who were diagnosed as having IgG4-RD and malignancy concurrently and another that excluded such patients. A concurrent diagnosis of IgG4-RD and malignancy meant that a malignancy was diagnosed during the period of intensive examination using computed tomography and magnetic resonance imaging for the detection of IgG4-RD, which usually lasted about 1-3 months after the suspicion of IgG4-RD. However, in most cases, intensive examination using these image tests continued about 3 months after diagnosis because of the evaluation for steroid effects and the check for relapse occurrence, suggesting that malignancies may be easily found in these periods 3 months after IgG4-RD diagnosis. Accordingly, we defined the period of a concurrent diagnosis as within 3 months before or after IgG4-RD diagnosis.

To evaluate the possibility of paraneoplastic syndrome manifesting in IgG4-RD, we calculated and compared the SIR of patients in whom malignancies were found to complicate IgG4-RD within 1 year and 1 year or more after diagnosis.

Identical procedures were performed for the AIP subgroup in our cohort because several previous studies were restricted to patients with AIP only.

The Kaplan-Meier method was used to estimate the cumulative rate of malignancy development. Cancer incidence rate curves were calculated using the data per 100,000 people according to year, age, and sex as reported by the Ministry of Health, Labor, and Welfare of Japan. The log-rank test was adopted to test hypotheses concerning the differences in malignancy development between the IgG4-RD group and the Japanese general population. Information on the Japanese general population was obtained with regard to sex, cancer site, 5-year age groups, and calendar year during the period of 1975-2008<sup>27,28</sup>. Because the general population sample size was very large, the widths of its 95% CI were nearly zero.

**Risk factors for the occurrence of malignancy in IgG4-RD.** We searched for risk factors of malignancy complications by comparing clinical variables between all patient groups with and without malignancies, including IgG4-RD onset age, sex, serum levels of various activity markers [IgG4, IgG, complement proteins, soluble interleukin 2 receptor (sIL-2R), and circulating immune complex (CIC)], number of lesions, experience of corticosteroid therapy, and occurrence of relapse. We defined relapse as a reappearance of IgG4-RD symptoms, elevation of disease activity markers, and identification of active lesions in diagnostic imaging. Because alcohol intake, smoking, and diabetes mellitus (DM) are also considered major risk factors for the development of malignancies, we evaluated the effects of those factors as well. Alcohol intake and smoking were defined as daily consumption of > 20 g of alcohol and > 10 cigarettes, respectively, at the diagnosis of IgG4-RD. DM was assessed before or around IgG4-RD diagnosis, whereby a fasting glucose level of > 126 mg/dl and/or glycosylated hemoglobin level of > 6.5% was judged as indicative of DM<sup>29</sup>. The same procedures were done for the AIP subgroup.

**Statistics.** Differences between groups were analyzed using the Mann-Whitney test for continuous data and the chi-squared test or Fisher's exact test for categorical data. Statistical analyses were performed using Stat Flex version 6 software (Artech Co. Ltd.). All tests for Kaplan-Meier

analysis were calculated with the IBM SPSS Statistics Desktop for Japan (version 19.0; IBM Japan Inc.). A p value of < 0.05 was considered statistically significant.

*Ethics.* Our present study was approved by the ethics committee of our institute (Approval Code 2602).

RESULTS

*Malignancies complicating IgG4-RD.* Among the 158 patients with IgG4-RD who were followed for a mean period of  $5.95 \pm 4.48$  years, we identified 36 malignancies in 34 patients, which included 5 cases each of lung, colon, and prostate cancer and 4 cases each of gastric and pancreatic cancer (Table 1). Among the 109 patients with AIP, we detected 30 malignancies in 28 patients, which included 5 cases of prostate cancer and 4 cases each of lung and pancreatic cancer (Table 1). When malignancies other than those occurring concurrently with IgG4-RD diagnosis were analyzed in our cohort, a total of 29 malignancies were found in 27 patients. When the period for developing malignancies after IgG4-RD diagnosis was set at before and after 5 years, 26 patients demonstrated the occurrence of malignancies before 5 years versus 8 patients afterward. Consequently, the occurrence of malignancies tended to be most frequent within 5 years after IgG4-RD diagnosis (Figure 1).

In our present study, the malignancies found in 11 patients were successfully treated by surgery, chemotherapy, or radiotherapy, after which 8 patients experienced no relapse during or after subsequent corticosteroid therapy. The remaining 3 patients did not receive corticosteroid therapy. We encountered no cases of genuine paraneoplastic syndrome that were apparently improved following surgery and/or chemotherapy alone.

Table 1. Number of malignancies in patients with IgG4-RD and AIP.

Type of Malignancy	Total No. Malignancies in Patients with IgG4-RD	Total No. Malignancies in Patients with AIP
Total	36	30
Lung	5	4
Colon	5	3
Prostate	5	5
Stomach	4	3
Pancreas	4	4
Kidney	2	1
Lymphoma	2	2
Biliary tract	1	1
Liver	1	1
Esophagus	1	0
Breast	1	1
Ovary	1	1
Thyroid	1	1
Skin	1	1
Tongue	1	1
Myelodysplastic syndrome	1	1

IgG4-RD: immunoglobulin G4-related disease; AIP: autoimmune pancreatitis.

We observed that 12 patients experienced malignancy in the same organ affected by IgG4-RD: pancreatic and lung cancer in 4 patients each, prostate in 2, and bile duct and kidney cancer in 1 each.

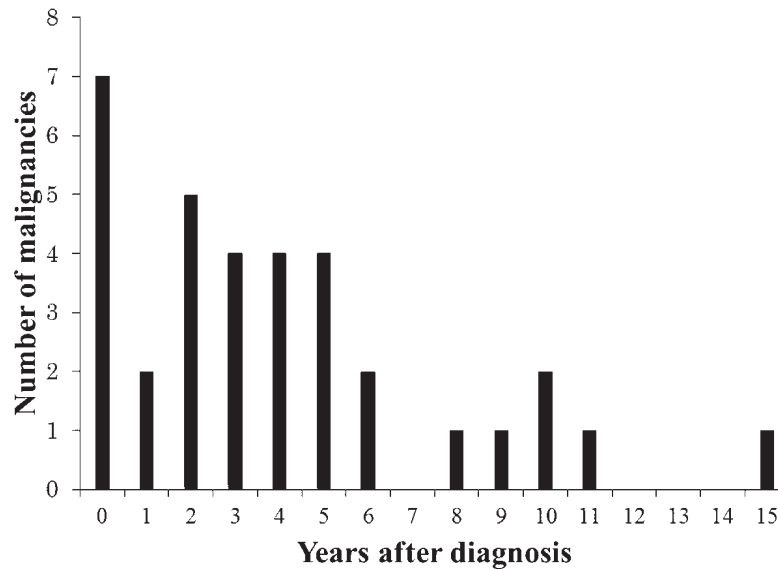
*Overall analysis of IgG4-RD's association with the occurrence of malignancy.* The expected incidence of cancer in our IgG4-RD cohort according to rates for the Japanese general population during an overall followup of 940 person-years was 16.9. Based on this, we first calculated the overall SIR of malignancies after IgG4-RD diagnosis, which was 2.01 (95% CI 1.34–2.69) and indicative that IgG4-RD was significantly complicated by malignancy (Table 2). Next, we selected the patients whose malignancies were not diagnosed concurrently with IgG4-RD and witnessed an SIR of 1.60 (95% CI 1.07–2.13), which also represented a significant result.

*Comparison of SIR of malignancies found within 1 year after IgG4-RD diagnosis with that of tumors detected in subsequent years.* The SIR of malignancies identified within 1 year after IgG4-RD diagnosis was 3.53 (95% CI 1.23–5.83), whereas that for subsequent years was 1.48 (95% CI 0.99–1.98), indicating a significant occurrence of malignancies in the first year after IgG4-RD diagnosis that became less frequent afterward (Table 2).

*Analysis of type 1 AIP in IgG4-RD.* The expected incidence of cancer in our AIP cohort according to rates for the Japanese general population during an overall followup of 740 person-years was 13.4. Based on this, the calculated SIR restricted to type 1 AIP was 2.08 (95% CI 1.32–2.85), indicating that type 1 AIP was significantly associated with malignancy as well. Moreover, the SIR of malignancies within 1 year after type 1 AIP diagnosis was 3.91 (95% CI 1.02–6.80), whereas that for subsequent years was 1.57 (95% CI 0.90–2.23), suggesting that the occurrence of malignancies in type 1 AIP was also significantly more frequent within the first year and less frequent afterward (Table 2). Next, we selected the patients whose malignancies were not diagnosed concurrently with AIP and witnessed an SIR of 1.71 (95% CI 1.01–2.41), also a significant result.

*Kaplan-Meier analysis of cumulative malignancy rate between the IgG4-RD group and the Japanese general population.* In Kaplan-Meier testing, the lower limit of the 95% CI for cumulative malignancy rate for the IgG4-RD group was higher than that for the Japanese general population during the first 12 years after diagnosis, according to log-rank testing (Figure 2).

*Analysis of malignancy type.* SIR calculations for each malignancy type uncovered no significant results. Pancreatic cancer demonstrated an SIR of 5.48 (95% CI 0.11–10.85), which suggested a non-significant association with IgG4-RD. Comparable results were obtained for each malignancy type for the AIP group, in which the SIR for pancreatic cancer was markedly higher (Table 3).



**Figure 1.** Incidence of malignancies according to time after IgG4-RD diagnosis. Twenty-six patients experienced malignancies within the first 5 years after diagnosis versus 8 patients afterward, indicating that the occurrence of malignancies tended to be most frequent soon after IgG4-RD diagnosis. IgG4-RD: immunoglobulin G4-related disease.

**Table 2.** SIR of malignancies in IgG4-RD and AIP.

	IgG4-RD		AIP	
	SIR	95% CI	SIR	95% CI
Overall	2.01	1.34–2.69	2.08	1.32–2.85
Without concurrent diagnosis	1.60	1.07–2.13	1.71	1.01–2.41
Years after IgG4-RD diagnosis				
< 1	3.53	1.23–5.83	3.91	1.02–6.80
≥ 1	1.48	0.99–1.98	1.57	0.90–2.23

SIR: standardized incidence ratio; IgG4-RD: immunoglobulin G4-related disease; AIP: autoimmune pancreatitis.

**Risk factors associated with malignancy development.** To identify the risk factors associated with the formation of malignancies, we compared several clinical variables between IgG4-RD patients with malignancies and those without (Table 4). Serum concentrations of IgG, IgG4, sIL-2R, and CIC were significantly higher in patients with malignancies ( $p = 0.002, 0.005, 0.005, \text{ and } 0.019$ , respectively). In contrast, a history of corticosteroid treatment, number of recurrences, alcohol intake, smoking, and DM all showed no significant associations with risk (Table 4). Similar results were obtained for the AIP group apart from a negative result for CIC (Table 4).

## DISCUSSION

Our present study showed that IgG4-RD and AIP were significantly associated with the occurrence of malignancies, which was consistent with reports by Yamamoto, *et al* and Shiokawa, *et al*<sup>15,16</sup>. However, Hirano, *et al* found that the

incidence of total malignancies in IgG4-RD was similar to that of the Japanese general population<sup>17</sup>. This discrepancy may be attributed to differences in study protocols; whereas Hirano excluded patients who were concomitantly diagnosed as having IgG4-RD and malignancies to avoid selection bias, the Yamamoto and Shiokawa studies included those subjects. We were able to confirm that IgG4-RD (AIP) was significantly associated with malignancy even in patients without a concurrent diagnosis of malignancy. In Kaplan-Meier testing, the cumulative malignancy rate for the IgG4-RD group was significantly higher than that for the Japanese general population up to 12 years after diagnosis, according to log-rank testing. These results indicated that IgG4-RD was significantly associated with the occurrence of malignancies within this period. This significant association disappeared afterward, likely due to a higher malignancy rate attributed to older age.

There may have been detection bias in our present study for the diagnosis of malignancy because patients with IgG4-RD were likely followed more closely than the general population, which could have resulted in a more timely and frequent detection of malignancy. In addition, many patients were referred to a tertiary care center that promptly made the diagnosis of malignancy using intensive imaging examination. To mitigate this selection bias, we also examined subjects after excluding those with a concurrent diagnosis of malignancy. This group showed a significant association with malignancy as well. On the other hand, Hart, *et al* compared the occurrence of malignancies between type 1 AIP and control subjects from a primary care clinic, in which the risk of detection bias could be ignored, and found no significant

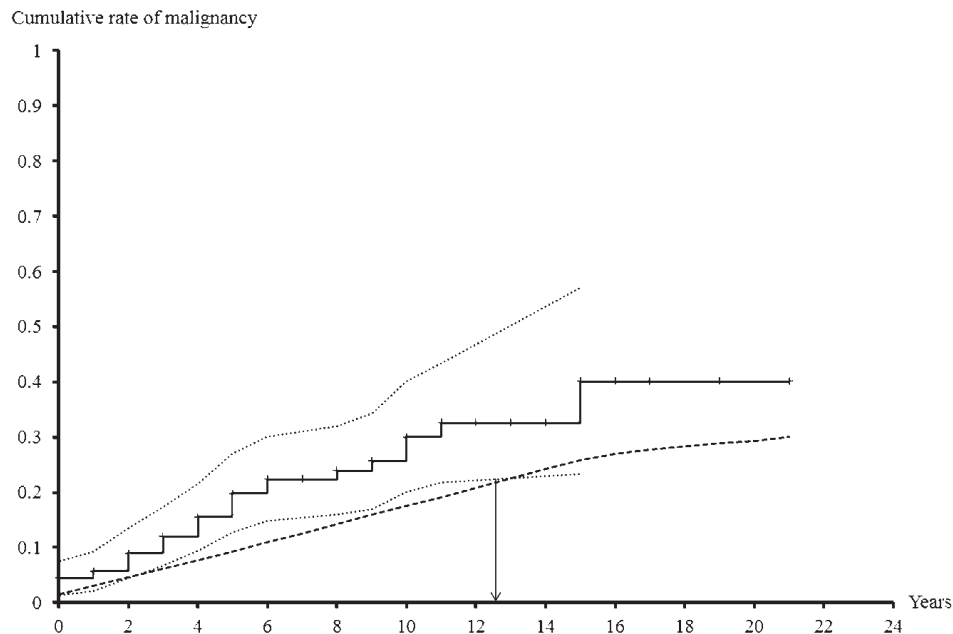


Figure 2. Cumulative malignancy rate for patients with IgG4-RD (solid line) and for the Japanese general population (broken line). The development rate of malignancy was higher for patients with IgG4-RD until 12 years after IgG4-RD diagnosis, according to log-rank testing. IgG4-RD: immunoglobulin G4-related disease.

Table 3. SIR for each malignancy in IgG4-RD and AIP.

Type of Malignancy	IgG4-RD		AIP	
	SIR	95% CI	SIR	95% CI
Lung	2.09	0.26–3.93	2.10	0.26–3.94
Colon	1.75	0.22–3.29	1.33	0.17–2.48
Prostate	2.05	0.25–3.85	2.07	0.26–3.88
Stomach	1.43	0.03–2.83	1.35	0.03–2.66
Pancreas	5.48	0.11–10.8	6.81	0.13–13.5

SIR: standardized incidence ratio; IgG4-RD: immunoglobulin G4-related disease; AIP: autoimmune pancreatitis.

association of malignancy occurrence between the groups<sup>18</sup>. However, the control subjects from the primary care clinic likely carried the risk of more frequent complications of malignancies than the general population because their visit may have been due to malignancy-related complaints.

The question arises of whether some cases of IgG4-RD and AIP should be regarded as types of paraneoplastic syndrome. The occurrence of malignancies was significantly more frequent within the first year after IgG4-RD diagnosis compared with that of subsequent years. This was in agreement with the study by Shiokawa, *et al*, showing that IgG4-RD may be considered as a type of paraneoplastic syndrome, which was found to be the case for AIP<sup>16</sup>. Paraneoplastic syndrome is described as systemic inflammatory diseases provoked by inflammatory mediators generated by malignancies<sup>30</sup>. If IgG4-RD is indeed a paraneoplastic syndrome, treatment of the underlying malignancy

may result in amelioration of IgG4-RD<sup>31</sup>. In our present study, 8 patients whose malignancies were successfully treated by surgery, chemotherapy, or radiotherapy experienced no relapse during or after subsequent corticosteroid therapy, thus strengthening the hypothesis that IgG4-RD can be regarded as a type of paraneoplastic syndrome, although we have encountered no cases of genuine paraneoplastic syndrome that were apparently improved following surgery and/or chemotherapy alone. Several cases of pancreatic cancer complicated with AIP have been described as showing abundant IgG4-bearing plasma cell infiltration, suggesting that pancreatic cancer could initiate an immune response with subsequent plasma cell infiltration in pancreatic and peripancreatic tissue, a hallmark of AIP<sup>32,33,34</sup>. However, because not all of the cases of IgG4-RD were associated with malignancies, it is possible that another mechanism apart from paraneoplastic syndrome, such as a failure in immune surveillance, leads to a loss in inflammation control or tumor growth suppression and subsequent systemic inflammation and malignancy<sup>35,36</sup>.

We uncovered 36 malignancies in 158 patients with IgG4-RD, among which 5 cases each of lung, colon, and prostate cancer and 4 cases each of gastric and pancreatic cancer were noted. In Shiokawa, *et al*'s analysis of 18 malignancies of 108 patients with AIP, gastric (7 cases) and lung (5 cases) cancers were most commonly seen, but pancreatic cancer was not observed<sup>16</sup>. In the Hirano, *et al* study of 14 malignancies of 113 patients with IgG4-RD, lung cancers were most frequently detected (5 cases), followed by

Table 4A. Comparison of clinical variables between IgG4-RD patients with malignancies and those without.

Variables	Malignancies (+)	Malignancies (–)	p
Onset age of IgG4-RD, yrs, mean	67.6	65.0	0.211
Sex, male/female	29/5	90/34	0.194
Number of involved organs, mean	3.03	2.56	0.054
Corticosteroid use, ±	26/8	85/39	0.467
Recurrence of IgG4-RD, ±	7/26	20/58	0.799
Alcohol intake, ±	10/22	36/79	0.834
Smoking, ±	20/14	69/46	0.939
Diabetes mellitus, ±	8/26	31/93	0.860
IgG, median, mg/dl	2420	1986	0.002
IgG4, median, mg/dl	749	430	0.005
C3, median, mg/dl	100	107	0.638
C4, median, mg/dl	19.3	22.8	0.229
CIC, median, µg/ml	8	5.1	0.019
sIL-2R, median, U/ml	1250	755	0.005

Table 4B. Comparison of clinical variables between AIP patients with malignancies and those without.

Variables	Malignancies (+)	Malignancies (–)	p
Onset age of AIP, yrs, mean	67.0	64.1	0.226
Sex, male/female	24/4	60/21	0.316
Number of involved organs, mean	3.14	2.95	0.404
Corticosteroid use, ±	22/6	62/19	0.968
Recurrence of IgG4-RD, ±	6/21	23/57	0.682
Alcohol intake, ±	7/19	26/48	0.601
Smoking, ±	17/11	45/31	0.931
Diabetes mellitus, ±	7/21	24/57	0.640
IgG, median, mg/dl	2419	1997	0.019
IgG4, median, mg/dl	749	442	0.027
C3, median, mg/dl	99.5	103	0.705
C4, median, mg/dl	20.6	22.2	0.451
CIC, median, µg/ml	7.7	5.35	0.097
sIL-2R, median, U/ml	1233	755	0.011

IgG4-RD: immunoglobulin G4-related disease; AIP: autoimmune pancreatitis; CIC: circulating immune complex; sIL-2R: soluble interleukin 2 receptor.

pancreatic and gastric cancers (2 cases each)<sup>17</sup>. Similarly to these reports, our results revealed a higher prevalence of gastric and lung cancers, both of which are also more common in the Japanese general population. Pancreatic malignancies are considerably rare among the Japanese. However, their relatively high occurrence in Hirano's study and ours suggests that pancreatic cancer may be closely associated with IgG4-RD or AIP<sup>17</sup>.

The high prevalence of pancreatic cancer in patients with IgG4-RD may have been due to the large proportion of AIP (109 of 158 patients) in our cohort. Four cases of pancreatic cancer were found in the AIP cohort at 3, 5, 5, and 9 years after IgG4-RD diagnosis, suggesting that an inflammatory state of pancreatic tissue induced malignancy and possibly accounted for the association between AIP and pancreatic cancer. Because IgG4 values are generally not measured for typical pancreatic cancer cases, instances of pancreatic cancer with an AIP background may have largely been ignored<sup>16</sup>.

We examined whether the chronic inflammatory state of IgG4-RD causes malignancies. It is well known that chronic inflammation induces malignancies under some circumstances<sup>37</sup>. Mediators of the inflammatory response, such as cytokines, free radicals, prostaglandins, and growth factors can induce genetic and epigenetic changes, including point mutations in tumor suppressor genes, DNA methylation, and posttranslational modifications, and lead to the development of cancer<sup>38</sup>. Chronic pancreatitis was reported to be a significant risk factor for pancreatic cancer<sup>39</sup>, and some cases of AIP were prone to transformation into chronic pancreatitis after calcification<sup>40</sup>. Further, Kamisawa, *et al* found that *K-ras* mutations occurred significantly more frequently in the pancreatobiliary regions of patients with AIP, suggesting a close association between AIP and pancreatic cancer<sup>41</sup>. Our present study showed that the SIR of malignancies occurring after 1 year following IgG4-RD diagnosis was 1.48 (95% CI 0.99–1.98), indicating a possible association between a

chronic inflammatory state of IgG4-RD and malignancy. Considering that a period of more than a decade is often needed for chronic inflammation to lead to carcinogenesis, we cannot conclude with certainty that a chronic inflammatory state in IgG4-RD induces malignancies because most of the tumors in our cohort were detected within 5 years after IgG4-RD diagnosis. In addition, the fact that the majority of malignancies occurred in organs different from those affected by IgG4-RD inflammation indicated a weak correlation between chronic inflammatory state and malignancy in IgG4-RD, although pancreatic cancer demonstrated a high SIR in the AIP subgroup.

As far as risk factors for developing malignancies in patients with IgG4-RD, our study showed that among various clinical variables, serum concentrations of IgG, IgG4, sIL-2R, and CIC were significantly higher in patients with malignancies than in those without, indicating that such activity markers may be associated with the development of tumors. Shiokawa, *et al* found a similar result, in which serum IgG4 was significantly higher in patients with a malignancy compared with those without<sup>16</sup>. Such findings imply that patients with IgG4-RD may harbor a weakened defense system, such as an immunodeficient state, or a paraneoplastic condition in affected organs, such as deranged oncogenes, and that a highly active disease state may exacerbate weakened immune defenses to result in the development of cancer. Accordingly, IgG4-RD patients with high serum concentrations of activity markers should be carefully followed for early detection of complicating malignancies.

IgG4-RD is believed to have a close association with the development of malignancy within 12 years after diagnosis, most notably during the first year. High concentrations of activity markers are a risk factor for cancer onset and should be monitored closely.

## ACKNOWLEDGMENT

We thank Trevor Ralph for his English editorial assistance.

## REFERENCES

1. Kawa S, Hamano H, Kiyosawa K. Autoimmune pancreatitis and IgG4-related disease. In: Rose N, MacKay I, eds. *The autoimmune diseases*, 5th edition. St. Louis: Academic Press; 2013:935-49.
2. Hamano H, Kawa S, Horiuchi A, Unno H, Furuya N, Akamatsu T, et al. High serum IgG4 concentrations in patients with sclerosing pancreatitis. *N Engl J Med* 2001;344:732-8.
3. Hamano H, Kawa S, Ochi Y, Unno H, Shiba N, Wajiki M, et al. Hydronephrosis associated with retroperitoneal fibrosis and sclerosing pancreatitis. *Lancet* 2002;359:1403-4.
4. Yamamoto M, Takahashi H, Ohara M, Suzuki C, Naishiro Y, Yamamoto H, et al. A new conceptualization for Mikulicz's disease as an IgG4-related plasmacytic disease. *Mod Rheumatol* 2006;16:335-40.
5. Kobayashi H, Shimokawaji T, Kanoh S, Motoyoshi K, Aida S. IgG4-positive pulmonary disease. *J Thorac Imaging* 2007;22:360-2.
6. Nakazawa T, Naitoh I, Hayashi K, Okumura F, Miyabe K, Yoshida M, et al. Diagnostic criteria for IgG4-related sclerosing cholangitis based on cholangiographic classification. *J Gastroenterol* 2012;47:79-87.
7. Kawano M, Saeki T, Nakashima H, Nishi S, Yamaguchi Y, Hisano S, et al. Proposal for diagnostic criteria for IgG4-related kidney disease. *Clin Exp Nephrol* 2011;15:615-26.
8. Yoshimura Y, Takeda S, Ieki Y, Takazakura E, Koizumi H, Takagawa K. IgG4-associated prostatitis complicating autoimmune pancreatitis. *Intern Med* 2006;45:897-901.
9. Sugumar A, Chari S. Autoimmune pancreatitis: an update. *Expert Rev Gastroenterol Hepatol* 2009;3:197-204.
10. Sandanayake NS, Church NI, Chapman MH, Johnson GJ, Dhar DK, Amin Z, et al. Presentation and management of post-treatment relapse in autoimmune pancreatitis/immunoglobulin G4-associated cholangitis. *Clin Gastroenterol Hepatol* 2009;7:1089-96.
11. Kamisawa T, Okazaki K, Kawa S, Ito T, Inui K, Irie H, et al. Amendment of the Japanese Consensus Guidelines for Autoimmune Pancreatitis, 2013 III. Treatment and prognosis of autoimmune pancreatitis. *J Gastroenterol* 2014;49:961-70.
12. Uchida K, Yazumi S, Nishio A, Kusuda T, Koyabu M, Fukata M, et al. Long-term outcome of autoimmune pancreatitis. *J Gastroenterol* 2009;44:726-32.
13. Nishino T, Toki F, Oyama H, Shimizu K, Shiratori K. Long-term outcome of autoimmune pancreatitis after oral prednisolone therapy. *Intern Med* 2006;45:497-501.
14. Hart PA, Kamisawa T, Brugge WR, Chung JB, Culver EL, Czako L, et al. Long-term outcomes of autoimmune pancreatitis: a multicentre, international analysis. *Gut* 2013;62:1771-6.
15. Yamamoto M, Takahashi H, Tabeya T, Suzuki C, Naishiro Y, Ishigami K, et al. Risk of malignancies in IgG4-related disease. *Mod Rheumatol* 2012;22:414-8.
16. Shiokawa M, Kodama Y, Yoshimura K, Kawanami C, Mimura J, Yamashita Y, et al. Risk of cancer in patients with autoimmune pancreatitis. *Am J Gastroenterol* 2013;108:610-7.
17. Hirano K, Tada M, Sasahira N, Isayama H, Mizuno S, Takagi K, et al. Incidence of malignancies in patients with IgG4-related disease. *Intern Med* 2014;53:171-6.
18. Hart PA, Law RJ, Dierkhising RA, Smyrk TC, Takahashi N, Chari ST. Risk of cancer in autoimmune pancreatitis: a case-control study and review of the literature. *Pancreas* 2014;43:417-21.
19. Uemura N, Okamoto S, Yamamoto S, Matsumura N. Helicobacter pylori infection and the development of gastric cancer. *N Engl J Med* 2001;345:784-9.
20. Sugiyama T, Asaka M. Helicobacter pylori infection and gastric cancer. *Med Electron Microsc* 2004;37:149-57.
21. Simonetti RG, Camma C, Fiorello F, Cottone M, Rapicetta M, Marino L, et al. Hepatitis C virus infection as a risk factor for hepatocellular carcinoma in patients with cirrhosis. A case-control study. *Ann Intern Med* 1992;116:97-102.
22. Kiyosawa K, Umemura T, Ichijo T, Matsumoto A, Yoshizawa K, Gad A, et al. Hepatocellular carcinoma: Recent trends in Japan. *Gastroenterol* 2004;127:S17-26.
23. Zitvogel L, Tesniere A, Kroemer G. Cancer despite immunosurveillance: immunoselection and immunosubversion. *Nat Rev Immunol* 2006;6:715-27.
24. Henderson BE, Bogdanoff E, Gerkins VR, SooHoo J, Arthur M. Evaluation of cancer risk factors in a retirement community. *Cancer Res* 1974;34:1045-8.
25. Umehara H, Okazaki K, Masaki Y, Kawano M, Yamamoto M, Saeki T, et al. Comprehensive diagnostic criteria for IgG4-related disease (IgG4-RD), 2011. *Mod Rheumatol* 2012;22:21-30.
26. Shimosegawa T, Chari ST, Frulloni L, Kamisawa T, Kawa S, Mino-Kenudson M, et al. International consensus diagnostic criteria for autoimmune pancreatitis: guidelines of the International Association of Pancreatology. *Pancreas* 2011;40:352-8.
27. Matsuda A, Matsuda T, Shibata A, Katanoda K, Sobue T, Nishimoto H. Cancer incidence and incidence rates in Japan in 2008: a study of 25 population-based cancer registries for the Monitoring of Cancer

- Incidence in Japan (MCIJ) project. *Jpn J Clin Oncol* 2014; 44:388-96.
28. Yoshizawa K, Matsumoto A, Ichijo T, Umemura T, Joshita S, Komatsu M, et al. Long-term outcome of Japanese patients with type 1 autoimmune hepatitis. *Hepatology* 2012;56:668-76.
  29. Committee of the Japan Diabetes Society on the Diagnostic Criteria of Diabetes Mellitus, Seino Y, Nanjo K, Tajima N, Kadowaki T, Kashiwagi A, et al. Report of the committee on the classification and diagnostic criteria of diabetes mellitus. *J Diabetes Investig* 2010;1:212-28.
  30. Racanelli V, Prete M, Minoia C, Favoino E, Perosa F. Rheumatic disorders as paraneoplastic syndromes. *Autoimmun Rev* 2008;7:352-8.
  31. Naschitz JE. Rheumatic syndromes, clues to occult neoplasia. *Semin Arthritis Rheum* 1999;29:43-55.
  32. Kamisawa T, Chen PY, Tu Y, Nakajima H, Egawa N, Tsuruta K, et al. Pancreatic cancer with a high serum IgG4 concentration. *World J Gastroenterol* 2006;12:6225-8.
  33. Witkiewicz AK, Kennedy EP, Kenyon L, Yeo CJ, Hruban RH. Synchronous autoimmune pancreatitis and infiltrating pancreatic ductal adenocarcinoma: case report and review of the literature. *Hum Pathol* 2008;39:1548-51.
  34. Yoneda M, Inada H, Kanayama K, Shiraishi T. A case of pancreatic ductal adenocarcinoma with marked infiltration with IgG4-positive cells. *J Cytol* 2013;30:46-8.
  35. Senovilla L, Vitale I, Martins I, Tailler M, Pailleret C, Michaud M, et al. An immunosurveillance mechanism controls cancer cell ploidy. *Science* 2012;337:1678-84.
  36. Cohen IR. Activation of benign autoimmunity as both tumor and autoimmune disease immunotherapy: a comprehensive review. *J Autoimmun* 2014;54:112-7.
  37. Ohnishi S, Ma N, Thanan R, Pinlaor S, Hammam O, Murata M, et al. DNA damage in inflammation-related carcinogenesis and cancer stem cells. *Oxid Med Cell Longev* 2013;2013:387014.
  38. Hussain SP, Harris CC. Inflammation and cancer: an ancient link with novel potentials. *Int J Cancer* 2007;121:2373-80.
  39. Lowenfels AB, Maisonneuve P, Cavallini G, Ammann RW, Lankisch PG, Andersen JR, et al. Pancreatitis and the risk of pancreatic cancer. International Pancreatitis Study Group. *N Engl J Med* 1993;328:1433-7.
  40. Maruyama M, Watanabe T, Kanai K, Oguchi T, Asano J, Ito T, et al. Autoimmune pancreatitis can develop into chronic pancreatitis. *Orphanet J Rare Dis* 2014;9:77.
  41. Kamisawa T, Tsuruta K, Okamoto A, Horiguchi S, Hayashi Y, Yun X, et al. Frequent and significant K-ras mutation in the pancreas, the bile duct, and the gallbladder in autoimmune pancreatitis. *Pancreas* 2009;38:890-5.