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• Original Contribution

ULTRASONOGRAPHIC FEATURES OF IMMUNOGLOBULIN G4-RELATED SIALADENITIS

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Abstract—The aim of this study was to determine the role of ultrasonography in the diagnosis and follow-up evaluation of immunoglobulin G4-related sialadenitis. In this study, 42 patients with immunoglobulin G4-related sialadenitis underwent ultrasonography of the parotid and submandibular glands, and the sonographic appearance was compared with the pathologic findings. Post-treatment ultrasonographic appearance was compared with the pre-treatment findings in 30 patients who received immunomodulatory therapy. The ultrasonographic appearance of the affected glands was divided into five patterns: superficial hypo-echoic, multiple hypo-echoic foci, whole-gland heterogeneity, space occupying and normal echo. Histopathologic examination revealed marked lymphoplasmacytic inflammation and inter-lobular fibrosis, which were more severe in the superficial than deep portion of the affected glands. After treatment, the volume of the affected gland decreased significantly, the internal echo became more homogeneous and the superficial hypo-echoic area disappeared or was reduced. In conclusion, ultrasonography may play an important role in the diagnosis and follow-up evaluation of immunoglobulin G4-related sialadenitis. (E-mail: gyyu@263.net or gyyu2012@gmail.com and zhangzy-bj@vip.sina.com) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: Immunoglobulin G4-related sialadenitis, Ultrasonography, Salivary gland, Submandibular gland, Diagnosis.

INTRODUCTION

Immunoglobulin G4 (IgG4)-related sialadenitis (IgG4-RS) is a component of IgG4-related disease (IgG4-RD), the spectrum of which encompasses various body systems, such as the pancreas, salivary glands, periorbital tissue, kidneys, lungs, lymph nodes, meninges, aorta, breasts, prostate, thyroid, pericardium and skin (Dahlgren et al. 2010; Kamisawa et al. 2003, 2010; Saeki et al. 2006; Stone et al. 2009). The common clinical features of this disease include enlargement of the affected organs and elevated serum IgG4 levels. Histologic and immunohistochemical examinations reveal extensive infiltration with IgG- and IgG4-positive plasma cells, map-like lymphoid follicles and interstitial storiform fibrosis. The term *IgG4-RS* is used when the main organs involve the salivary glands. In

addition to the common features of IgG4-RD, IgG4-RS has the unique characteristics of salivary gland involvement.

Clinically, IgG4-RS is characterized by enlargement of the parotid and submandibular glands. Because of the superficial location of these glands, ultrasonography is a suitable method for their examination. Moreover, as a non-invasive method, ultrasonography can be performed repeatedly. However, the application of ultrasonography in IgG4-RS has been reported in only a small number of cases (Asai et al. 2012; Wang et al. 2014), and the ultrasonographic features of this condition are not well established. In this study, we collected data from a relatively large group of IgG4-RS patients and investigated the ultrasonographic features of IgG4-RS to determine the value of ultrasonography in the diagnosis of IgG4-RS and in the evaluation of treatment outcomes in these patients.

METHODS

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Patients
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The study was approved by the Ethics Committee for Human Experiments of Peking University Health

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Science Center and was conducted in accordance with the Declaration of Helsinki guidelines for human research. All patients provided informed consent before participation in the study. We recruited a total of 42 consecutive patients (17 men and 25 women; age range: 23–89 y; median age: 55 y) who had been diagnosed with IgG4-RS and treated in the Peking University School and Hospital of Stomatology between August 2011 and September 2014. Baseline data, including age, sex, clinical symptoms and serum IgG4 concentration, were recorded.

The diagnosis of IgG4-RS was confirmed by histopathology and immunohistochemistry in all patients. IgG4-RS is a newly recognized disease. A large number of patients in this study had undergone surgery of the submandibular or parotid gland based on a pre-operative misdiagnosis of tumor in other hospitals. The major salivary glands that had not been removed were continuously enlarged, and these patients were referred to our hospital. After histologic review and immunohistochemical staining of the previously obtained surgical specimens for IgG and IgG4 combined with serologic IgG4 examination, a final accurate diagnosis of IgG4-RS was made. The patients then received standardized immunomodulatory therapy. Of the 42 patients, 16 had undergone submandibular gland excision, and 2 had undergone partial parotidectomy. The other 24 patients were diagnosed with IgG4-RS on salivary gland biopsy (23 submandibular glands and 1 parotid gland). The biopsy was undertaken under local anesthesia. The superficial part of the glands was chosen for biopsy. Gland tissue 0.7×0.5 cm was excised for biopsy. The wound in the glands was closed carefully. No complications were found, and secretory function was not affected.

Ultrasonography

Ultrasound examination was performed using a GE LOGIQ3 Expert scanner (GE Healthcare, Milwaukee, WI, USA). The transducer frequency was 7–10 MHz. Bilateral parotid and submandibular glands were scanned by a radiologist with 20 y of experience and interest in the field of salivary gland diseases.

Image analysis

Gland size, border, internal echogenicity, occupying lesion and enlarged lymph nodes were evaluated on the ultrasound images. The maximum longitudinal diameter (MLD) and depth of the glands were measured on the images.

Pathologic examination

The excised glandular biopsy specimens were fixed in 10% formaldehyde, embedded in paraffin, sectioned into 4- μ m slices, stained with hematoxylin and eosin or subjected to immunohistochemistry (polyclonal anti-IgG antibody and monoclonal anti-IgG4 antibody, both from Epitomics, Burlingame, CA, USA) and examined using light microscopy (BX53, Olympus, Tokyo, Japan).

The pathologic diagnostic criteria for IgG4-RS were as follows: (i) preservation of the lobular architecture, marked lymphoplasmacytic infiltration, large irregular lymphoid follicles with expanded germinal centers, acinar atrophy and prominent cellular interlobular storiform fibrosis caused by activated fibroblasts; and (ii) massive IgG- and IgG4-positive plasma cell infiltration, >50 IgG4-positive plasmacytes per high-power field and an IgG4/IgG ratio greater than 40% (Umehara et al. 2012).

Follow-up imaging

Thirty patients received standardized immunomodulatory therapy with corticosteroid and immunosuppressive agents, including those patients who had one or two major salivary glands removed. Twelve patients did not receive immunomodulatory therapy because they were afraid of the side effects of the treatment. Immunomodulatory therapy consisted of intravenous methylprednisolone at a dose of 200 mg for 3 d and 40 mg for 3 d, followed by oral prednisone 0.6 mg/kg/d, which was gradually tapered to a maintenance dose of 5 mg/d. Cyclophosphamide was also administered at a dose of 400 mg once every 2-4 wk. Twenty-eight patients received combined therapy, and two patients were treated with prednisone only. The follow-up time ranged from 3 to 34 mo (mean: 20.8 mo). Post-treatment ultrasonography was performed in all patients. The interval between ultrasonographic follow-up assessments in patients who had received conservative treatment was 3 mo.

Statistical analysis

Differences in gland size between pre- and postimmunomodulatory therapy were assessed using the paired *t*-test and SPSS (Version 13.0) software. Data were expressed as means \pm SD. Statistical significance was set at p < 0.05.

RESULTS

Clinical manifestations

Of the 42 patients, 35 had submandibular gland enlargement, including 26 patients with bilateral gland involvement and 9 with unilateral involvement. Eight patients presented with parotid gland enlargement, including six with bilateral involvement and two with unilateral involvement. Fifteen patients had bilateral sublingual gland enlargement. All but one patient denied having periodic episodes of swelling of the involved gland followed by remission of swelling. There were no complaints of gland swelling when eating. Duration of the symptoms ranged from 3 to 120 mo (mean: 30.1 mo).

Other lesions included 17 cases of lacrimal gland enlargement, three cases of autoimmune pancreatitis, seven cases of asthma, six cases of interstitial pneumonia, 24 cases of rhinosinusitis and two cases of dysaudia.

Serum IgG4 levels were elevated in 40 patients (95.2%). Reactions to anti-Sjögren syndrome antigen A, anti-SSB and antinuclear antibody were negative in all patients, except one (anti-Sjögren syndrome antigen A positive).

Baseline ultrasound findings

Pre-treatment submandibular gland ultrasonograms were acquired in 39 patients (61 glands). Thirteen patients had undergone unilateral submandibular gland resection before the examination. In four patients, only one submandibular gland was examined. The remaining three patients had undergone bilateral submandibular gland resection. Parotid gland ultrasonograms were acquired in 29 patients (57 glands); one patient had undergone unilateral parotidectomy. The remaining 13 of our 42 patients, with no parotid gland enlargement, refused to undergo ultrasonographic examination of the parotid gland.

A total of 38 patients (90.5%) exhibited ultrasonographic abnormalities of the submandibular gland and/ or parotid gland. The submandibular gland was the most commonly affected salivary gland in patients with IgG4-RS; the parotid gland was less commonly involved. Among the 39 patients who underwent submandibular gland examination (61 glands), 35 patients (89.7%) and 55 glands (90.2%) manifested ultrasonographic abnormalities. In contrast, among the 29 patients who underwent parotid gland examination (57 glands), only 10 patients (34.5%) and 15 glands (26.3%) manifested abnormalities.

The involved glands, especially the submandibular glands, appeared enlarged with a clear border. Nodular margins were found in the submandibular gland (Fig. 1a). The sonographic appearance could be divided into five patterns: (i) superficial hypo-echoic pattern, a hypo-echoic area with a coarse echotexture in the superficial portion of the gland (Fig. 2a); (ii) multiple hypo-echoic foci, a reticulated pattern with multiple rounded hypo-echoic or cystic foci within the gland parenchyma, as has been reported previously in patients with Sjögren syndrome (Fig. 2b); (iii) whole-gland heterogeneity, coarse gland texture and decreased echogenicity (Fig. 2c); (iv) space-occupying pattern, a circumscribed area of decreased echogenicity within the gland (Fig. 2d); and (v) normal pattern, fine homogenous echo, as seen in normal salivary glands.

The distributions of the five sonographic patterns in the submandibular and parotid glands are summarized in Table 1. The superficial hypo-echoic pattern was the most common, especially in submandibular glands, accounting for 60.7% of abnormal submandibular glands. It was followed by the multiple hypo-echoic foci pattern, which accounted for 23% of abnormal submandibular glands. Whole-gland heterogeneity was relatively uncommon, accounting for only 4.9% of abnormal submandibular glands. Most examined parotid glands (22 [75.9%] patients, 41 [71.9%] glands) had a normal pattern (Table 1).

The space-occupying pattern appeared as a localized hypo-echoic mass with posterior acoustic enhancement on ultrasonograms (Fig. 2d). In two glands (one submandibular gland and one parotid gland), the space-occupying lesions were found to be continuous with normal glandular tissues in some scanning planes, different from the case in tumors. However, in one patient, the parotid gland lesion had a clear border, difficult to differentiate from a tumor (Fig. 3a).

Lymph node enlargement was observed in 28 patients (71.8%), including 3 patients who had undergone bilateral submandibular gland resection previously. The enlarged nodes featured hypo-echoic areas with clear borders.

Histopathologic findings

Gross views of the excised submandibular glands revealed that the involved glands were enlarged. On cross-sectional view, the lesions were found to differ in different areas of the same gland. Homogenous tissue without glandular structure, indicating a severe lesion, was observed in the superficial part, whereas in the deep part of the gland, the glandular structure was still visible, indicating a mild lesion (Fig. 1b, c). The histopathologic manifestations were as follows: preservation of the lobular architecture, marked lymphoplasmacytic infiltration, large irregular lymphoid follicles with expanded germinal centers, acinar atrophy and interstitial storiform fibrosis caused by activated fibroblasts. Immunohistochemistry revealed obvious IgG- and IgG4positive plasma cell infiltration.

The patient with a "space-occupying lesion" in the parotid gland underwent superficial parotidectomy. The surgical specimen had a mass with a clear border, and a large cyst containing clear liquid was found on crosssectional view (Fig. 3b). Pathologic examination revealed acinar atrophy, obvious lymphoplasmacytic infiltration and interstitial fibrosis without tumor cells (Fig. 3c). Immunohistochemistry revealed a large number of IgG4-positive plasma cells (Fig. 3d). By considering the above findings combined together with the high serum IgG4 levels, we made a definite diagnosis of IgG4-RS in this patient.

Follow-up ultrasound findings

During a follow-up of 3-34 mo, ultrasonographic examination was performed in a total of 30 patients



Fig. 1. Ultrasonography and histopathology of the superficial part of an affected submandibular gland. (a) This ultrasonogram reveals a nodular margin (*white arrow*). (b) Gross observation of the surgical specimen reveals a nodular appearance (*white arrow*). (c) Cross-sectional view reveals a homogenous appearance without glandular structure in the superficial part (*white arrow*) and the glandular architecture in the deeper part of the gland.

who had received immunomodulatory therapy. Ultrasound follow-up after immunomodulatory therapy was conducted every 3 mo. Follow-up sonographic images of the submandibular gland were acquired in 29 patients (50 glands), and those of the parotid gland, in 23 patients (45 glands).

Sonographic follow-up was characterized by a reduction in the size of the affected salivary glands and lymph nodes in all patients. The MLD and depth of the

submandibular glands measured on ultrasound images before immunomodulatory therapy were 35.6 \pm 4.2 and 18.5 \pm 4.0 mm, respectively. After therapy, the MLD and depth decreased to 32.8 \pm 7.7 mm (p < 0.05) and 16.7 \pm 2.3 mm (p < 0.01), respectively.

As for the ultrasonographic appearance of the submandibular glands, the nodular borders of the involved glands became smooth. The previous superficial hypoechoic area disappeared in 100% (25/25) of the glands



Fig. 2. Ultrasonographic patterns of affected salivary glands. (a) Superficial hypo-echoic area (*white arrows*). (b) Multiple hypo-echoic foci (*white arrows*). (c) Whole-gland heterogeneity (*white arrow*). (d) "Space occupying" lesion (*white arrow*).

after treatment (Fig. 4a, b). The previous multiple hypoechoic foci also disappeared in 100% (12/12) of glands, and the previous whole-gland heterogeneous echo became homogenous in 100% (3/3) of glands after treatment. The "space-occupying lesion" in the submandibular gland also disappeared.

Re-evaluation of the parotid glands after treatment revealed that the previous peripheral heterogeneous hypo-echoic area had disappeared in 100% (11/11) of glands. In the only case of a superficial hypo-echoic area and the only case of multiple hypo-echoic foci, the hypo-echogenicity also disappeared after treatment.

DISCUSSION

Immunoglobulin G4-related sialadenitis is a newly recognized disease, characterized by the swelling of multiple salivary glands with dysfunction of the involved glands (Kamisawa et al. 2003). According to the literature, IgG4-RS is characterized by a male preponderance, with a male-to-female ratio of 1:0.64 (Masaki et al. 2009; Yamamoto et al. 2005). The mean age at diagnosis is 61.7 y; the youngest patient ever to be diagnosed with IgG4-RS was 11 y old at the time of diagnosis, and the oldest was 89 y old (Hori et al. 2010; Matsui et al.

Table1. Distribution of five ultrasonographic patterns in the examined submandibular and parotid glands affected by IgG4-RS

Group	Total No.	Ultrasonographic pattern									
		Superficial hypo-echoic		Multiple hypo-echoic foci		Whole-gland heterogeneity		Space occupying		Normal	
		No.	%	No.	%	No.	%	No.	%	No.	%
Submandibular gland											
Cases	39	27	69.2	11	28.2	3	7.7	1	2.6	5	12.8
Glands	61	37	60.7	14	23.0	3	4.9	1	1.6	6	9.8
Parotid gland											
Cases	29	1	3.4	1	3.4	1	3.4	2	6.9	22	75.9
Glands	57	1	1.8	1	1.8	1	1.8	2	3.5	41	71.9



Fig. 3. Ultrasonography and histopathology of a "space-occupying" lesion in the parotid gland. (a) This ultrasonogram reveals a tumor-like mass (*white arrow*). (b) Gross observation of the surgical specimen reveals a cystic mass (*white arrow*). (c) Histopathologic examination reveals the typical immunoglobulin G4-related sialadenitis appearance without tumor cells (hematoxylin and eosin staining, $\times 100$). (d) Immunohistochemical examination reveals a large number of immunoglobulin G4-related sialadenitis-positive plasma cells infiltrating the tissue (hematoxylin and eosin staining, $\times 100$).

2012). However, in our series of 42 patients, there were more female patients than male patients, with a male-to-female ratio of 1:1.47. The mean age at diagnosis (55 y) was similar to that described in the literature. IgG4-RD mostly affects Asians, especially the Japanese

(Brito-Zeron et al. 2014). The reason for this is unclear, but this phenomenon may be associated with the first identification of IgG4-RD in Japan (Kamisawa et al. 2003).

The affected submandibular or parotid glands had frequently been removed based on a pre-operative



Fig. 4. Ultrasonography of a patient with immunoglobulin G4-related sialadenitis before and after treatment. (a) Before treatment, the ultrasonogram reveals a superficial hypo-echoic pattern (*white arrow*). The outlines of the lesion and gland in the ultrasonogram are represented by the *broken line* and *solid line*, respectively. (b) After treatment, the superficial hypo-echoic area has disappeared (*white arrow*).

misdiagnosis of tumor before the disease was well recognized. In this study, 18 patients had undergone surgery in other hospitals to remove one or even two major salivary glands before being referred to our hospital. This indicates that it is very important to include IgG4-RS in differentiation of salivary gland enlargement, to prevent unnecessary surgery.

Ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) are the main methods for the diagnosis of salivary gland diseases, including diseases of both the parotid and submandibular glands. The CT and magnetic resonance imaging characteristics of IgG4-RS have been reported in the literature (Katsura et al. 2012; Toyoda et al. 2012). Ultrasound examination is a non-invasive, non-radioactive and repeatable imaging modality for evaluation of salivary glands (Dost and Kaiser 1997). It has been used for the diagnosis of IgG4-RD, and some sonographic features of this condition have been described (Farrell et al. 2004; Kakudo et al. 2011, 2012; Papi et al. 2002; Sahani et al. 2004). Our results indicated that the sonographic appearance of IgG4-RS had the following characteristics:

- Superficial hypo-echoic area: This area had a coarse echotexture and indicated that the superficial region of the gland was the most prominently affected. Asai et al. (2012) also found that more hypo-echoic foci were observed in the periphery of the gland. In our study, a superficial hypo-echoic pattern was observed in 60.7% (37/61) of the submandibular glands examined. Thus, this should be regarded as an important feature for the ultrasonographic diagnosis of IgG4-RS. Ultrasonography usually reveals hypo-echoic areas in IgG4-RD–affected organs (Kakudo et al. 2011; Sahani et al. 2004), and it should be noted that the internal echoes in different areas of the salivary gland may have different echoic patterns.
- Multiple hypo-echoic foci: These foci refer to a reticulated pattern with multiple rounded hypo-echoic or cystic foci within the gland parenchyma, as reported previously in patients with Sjögren syndrome (Zhou et al. 2005) and are also consistent with the "mottled pattern" reported by Asai et al. (2012) and the "netlike or honeycomb appearance" reported by Wang et al. (2014). This pattern was found in 23% (14/61) of the submandibular glands examined.
- 3. Lymph node enlargement: Twenty-eight patients (71.8%) had enlarged regional lymph nodes with smooth borders, which is consistent with the literature (Hamano et al. 2006). Therefore, lymph nodes in the upper neck should be included in the sonographic examination of the submandibular gland.
- 4. Compared with parotid gland involvement (26.3%), submandibular gland involvement (90.2%) was much

more prominent in IgG4-RS, and the ultrasonographic features of the submandibular gland were more readily recognizable and noticeable.

Enlargement of the major salivary glands is one of the main clinical characteristics of IgG4-RS. It is difficult to quantitatively evaluate the major salivary glands and establish a criterion for their normal size with ultrasonography owing to differences in transducer frequency, operators, individual discrepancies and the irregular anatomy of the parotid gland. Gland size can be quantitatively measured with CT volume rendering (Li et al. 2014). CT volume rendering is more accurate than ultrasonography for the diagnosis of enlarged major salivary glands, especially the parotid gland. However, changes in the size of enlarged glands can be assessed with ultrasonography during post-treatment follow-up (Uzun et al. 2011). We measured the MLD and depth of the glands and evaluated changes in gland size before and after treatment.

All patients included in this study underwent histopathologic examination; therefore, we explored the pathologic basis of the identified sonographic features. Histopathologic examination revealed remarkable lymphoplasmacytic inflammation; the swelling of the glands was likely the result of this inflammatory response (Li et al. 2015). Gross examination of the excised submandibular glands revealed homogenous tissues without glandular structures in the superficial part, whereas the glandular architecture was retained in the deeper part of the glands, indicating that the lesion was much more severe in the superficial part of the gland. In our CT study, heterogeneous enhancement with gland swelling was more prominent in the peripheral subfascial regions of the glands on CT scanning (data not shown). In the study by Asai et al. (2012), color Doppler sonography revealed prominent intra-glandular vascularity and remarkable blood flow signals, with no mass effect. These findings were not discussed in this study because color Doppler analysis was performed in few of our patients. However, this is likely the pathologic basis of the superficial hypoechoic area. Furthermore, we speculate that the marked lymphoplasmacytic infiltration and lymphoid follicle formation led to a change in the tissue acoustic interface, which might be correlated with the formation of multiple hypo-echoic foci.

Enlargement of the submandibular and parotid glands can be observed in a variety of diseases, and so differential diagnosis is very important. Sjögren syndrome, for instance, is a chronic inflammatory autoimmune disease that has clinical characteristics similar to those of IgG4-RS. The former can affect the parotid and lacrimal glands, causing dry mouth, dry eye and swelling of the involved organs (Pavlidis et al. 2007). The typical sonographic appearance of Sjögren syndrome consists of an inhomogeneous echo, multiple hypoechoic areas and honeycomb changes (Zhou et al. 2005), and is similar to the ultrasonographic appearance of IgG4-RS. However, a superficial hypo-echoic area is a major feature for differentiation. Moreover, swelling of the submandibular glands is relatively uncommon in Sjögren syndrome.

Enlargement and hardness of the submandibular and parotid glands, important clinical characteristics of IgG4-RS, are similar to findings obtained in cases of tumors of the major salivary glands (Chow et al. 2008). This similarity might lead to unnecessary gland resection, as was done in some of the patients in our series before they were referred to our hospital. In general, on ultrasonography, submandibular and parotid gland tumors have localized hypo-echoic lesions, with clear or obscured boundaries. In contrast, IgG4-RS is typically associated with diffuse enlargement of the whole gland on ultrasonography. However, in the present study, the sonograms of three patients (7.1%) with IgG4-RS revealed localized hypo-echoic lesions with posterior acoustic enhancement, resembling a tumor. In two glands, the lesions were found to extend directly from the normal glandular tissues in some scanning planes, which is different from the observation in tumors. Therefore, when ultrasonography reveals a localized hypo-echoic lesion, the gland should be continuously scanned to determine whether or not the boundary of the lesion is intact. However, in one patient, the parotid gland lesion was found to have a definite border, and thus, this lesion was difficult to differentiate from a tumor. The patient underwent superficial parotidectomy, and the lesion was found to be a cyst-like mass on gross examination. Pathologic examination confirmed the diagnosis of IgG4-RS. Therefore, for patients with multiple swellings of the parotid or submandibular glands, and when serologic examination reveals elevated levels of IgG4, the tumor-like sonographic appearance of the affected glands should be first considered a manifestation of IgG4-RS.

In this study, 30 patients received immunomodulatory therapy. Post-treatment follow-up ultrasonography in these patients revealed that the volume of the enlarged glands and cervical lymph nodes had decreased, and the superficial hypo-echoic areas and multiple hypo-echoic foci in the submandibular glands had disappeared. Furthermore, the heterogeneous hypo-echoic areas in the parotid glands became more homogeneous. This indicates that ultrasonography can provide valuable information for the follow-up evaluation of the results of immunomodulatory therapy for IgG4-RS. Ultrasonography could be used as an essential imaging modality for follow-up evaluation as proposed previously (Shimizu et al. 2009; Wang et al. 2014).

CONCLUSIONS

The submandibular and parotid glands involved in IgG4-RS have ultrasonographic characteristics that are useful for the diagnosis of IgG4-RS. On ultrasonography, IgG4-RS should be differentiated from Sjögren syndrome and tumors. Ultrasonography provides valuable information for the follow-up evaluation of immunomodulatory therapy for IgG4-RS.

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