Parotid lesions: Characterization with 3T-DWI and FDG-PET/CT

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Learning objectives

To illustrate imaging findings of parotid tumors focusing on 3T diffusion weighted MRI (3T-DWI) and 2-[Fluorine-18]-fluoro-2-deoxy-D-glucose positron emission tomography / CT (FDG-PET/CT).

To evaluate the correlation between 3T-DWI and FDG-PET/CT findings and parotid gland pathology.

To learn the use of 3T-DWI and FDG-PET/CT for clinical application in parotid examinations.

Background

Preoperative prediction of malignancy or benignancy, and characterization of the histologic subtype of parotid tumor are important.

FDG-PET is an established functional imaging modality for the evaluation of human disease. DWI is another rapidly evolving functional imaging modality that can be used to evaluate oncologic and nononcologic lesions throughout the body. The information provided by FDG-PET and DWI can be complementary, because the two methods are based on completely different biophysical underpinnings \(^1\).

FDG-PET takes advantage in the detection of malignant tumors and metastasis of the fact that glycometabolism increases in malignant tumors. On the other hand, the apparent diffusion coefficient (ADC) value is considered to be affected by any changes in water content in the cells and the interstitial tissues \(^2\). Furthermore, integrated FDG-PET/CT can also provide anatomic and morphologic information.

In parotid lesions, the usefulness of both FDG-PET \(^3, 4, 5, 6, 7\) and DWI \(^8-11\) for this purpose is still being discussed. In this exhibit, we reviewed the literature focusing on utilization of DWI and FDG-PET and FDG-PET/CT in parotid tumors, and retrospectively reviewed 20 patients with suspected parotid tumors who underwent 3T-MR examination including DWI and pathological examination from August 2009 to August 2010. Twelve of them had undergone FDG-PET/CT.
Imaging findings OR Procedure details

In our patients, ten lesions (five Warthin tumor, three metastatic lymphnode, and one each fibrosarcoma and diffuse large B-cell lymphoma) showed decreased ADC compared with the contralateral parotid gland. Other 10 lesions (two each basal cell adenoma, pleomorphic adenoma, mucoepidermoid carcinoma, and Warthin tumor, and one each salivary duct carcinoma and schwannoma) showed increased ADC. FDG-PET/CT was positive in all lesions.

Parotid lesions -differentiatial point-

I. DWI

1. Malignant tumors vs. Benign tumors

   DWI may be able to differentiate malignant tumors from benign ones except for Warthin tumor.

   Generally, malignant parotid tumors show lower ADC values than malignant ones. Wang et al. reported that mean ADC values of benign solid lesions were significantly higher than those of malignant tumors. A threshold ADC value of 1.22 × 10^3 mm^2/s provided an accuracy of 86%, sensitivity of 84% and specificity of 91% for predicting malignancy. However, ADC values of Warthin tumor, the second most frequent benign tumor after pleomorphic adenoma, overlap with those of malignant parotid tumors.

2. Warthin tumor vs. Malignant tumors

   DWI has limited value for identifying Warthin tumor versus malignant tumor in parotid lesions, especially in lymphoma.

   Although Ikeda et al. reported that the ADC values in Warthin tumors (0.96±0.13×10^{-3} mm^2/s) were significantly lower than malignant tumors (1.10.19×10^{-3} mm^2/s), other studies reported that calculating the ADC value did not help to differentiate Warthin tumors from malignant parotid tumors. Habermann et al. reported that ADC values of Warthin tumor ranged from 0.72×10^{-3} mm^2/s to 1.17×10^{-3} mm^2/s, showing an overlap with those of examined malignant lesions (0.79 ×10^{-3} mm^2/s to...
1.65×10^{-3}\text{mm}^2/\text{s})^{10}$. Yerli et al. also reported that the mean ADC for malignant tumors was not significantly different from the mean ADC for Warthin tumors$^{11}$.

3. Pleomorphic tumor vs. Warthin tumor (Figs. 1-3)

DWI may be able to distinguish Warthin tumor from pleomorphic adenoma, which should be more aggressively treated$^{9,11}$. Pleomorphic adenoma is usually solitary, round, and well circumscribed with a smooth but sometimes lobulated surface$^{13}$. It shows heterogeneous signal on MRI and calculated higher ADC values on DWI. On the other hand, Warthin tumor is spherical to ovoid and shows the same homogeneous signal and calculated lower ADC values as lymphoma$^{9,11,10}$.

Ikeda et al. proposed a low ADC value to be a noteworthy feature of Warthin tumor$^{14}$. Yerli et al. reported that the mean ADC values for lymphoma (mean 0.68±0.05×10^{-3}\text{mm}^2/\text{s}) and Warthin tumor (0.97±0.16×10^{-3}\text{mm}^2/\text{s}) are significantly lower than those for pleomorphic adenoma (mean 1.74±0.37×10^{-3}\text{mm}^2/\text{s})$^{11}$. However, they also reported that the ADC values for Warthin tumors ranged from 0.72×10^{-3}\text{mm}^2/\text{s} to 1.17×10^{-3}\text{mm}^2/\text{s}, showing an overlap with examined malignant lesions (0.79×10^{-3}\text{mm}^2/\text{s} to 1.65×10^{-3}\text{mm}^2/\text{s})$^{11}$. These results supported the findings of Habermann et al.$^{10}$ who noted the limited value of ADC-based tumor differentiation focused on Warthin tumors in individual cases.

4. Warthin tumor vs. Lymphoma (Figs. 2-4)

Both Warthin tumor and lymphoma show a homogeneous signal pattern on MRI and DWI. Their ADC values are not significantly different. They are sometimes difficult to distinguish on imaging findings. Histopathologically, lymphoma shows diffuse infiltration of atypical lymphoid cells. Warthin tumor similarly consists of abundant lymphoid tissue that includes polyclonal lymphocytes with conspicuous follicles and germinal centers. Thus, the mean ADC values for the Warthin tumors and lymphomas are not surprising$^{11}$. Though Hirokawa et al. reported infiltration into adjacent tissues on CT and MRI correlated with malignant lymphoma$^{15}$, infiltrative margin sometimes cannot be identified especially in small tumors$^{9}$. Furthermore, lymphomas can occasionally originate in Warthin tumor$^{16}$. 
5. Lymphoma vs. Carcinomas (Figs. 4-7)

DWI is suggested to be able to differentiate lymphoma from other malignant tumors. In contrast to salivary gland cancers, malignant lymphomas arising in the salivary glands were associated with extremely low ADCs throughout the lesions; this was consistent with the homogeneous growth patterns of lymphoma cells.

The lymphomas have a homogenous signal pattern with hypointensity on T1-weighted images and hyperintensity on T2-weighted sequences, while most parotid cancers show heterogeneous signal intensity and conspicuous necrosis or cysts on MRI.

6. Lymphoma vs. metastatic lymphadenomathy (Figs. 4 and 8)

DWI is suggested to be able to differentiate lymphoma from metastatic lymphadenopathy due to squamous cell carcinoma (SCC). King et al. reported that an ADC value of greater than $0.824 \times 10^{-3} \text{ mm}^2/\text{s}$ could be used to distinguish SCC and an ADC value of less than $0.767 \times 10^{-3} \text{ mm}^2/\text{s}$ could be used to distinguish lymphoma, with a specificity of 100% while a high sensitivity is maintained.

II. FDG-PET, FDG-PET/CT (Figs 2, 4-9)

FDG-PET has limited value for identifying benign versus malignant tumor in parotid lesions, while integrated FDG-PET/CT still provides potent information for differentiation based on a combination of metabolic and anatomic data; thus, its clinical value should not be dismissed.

The majority of parotid tumors, both benign and malignant, revealed a high FDG uptake (SUVmax), especially in pleomorphic adenomas, Warthin's tumors, and malignancies. Wang et al. reported that the SUVmax of the two most common benign parotid tumors, Warthin tumor and pleomorphic adenoma, are not significantly different from those of malignancies. SUVmax of pleomorphic adenoma and Warthin tumor overlap and are not significantly different ($9.55 \pm 4.18$ vs. $10.67 \pm 5.15$, $Z=-0.384$ $P=0.701$). Neither showed a statistically significant difference compared with malignant parotid tumors ($Z=-0.149$, $P=0.881$; $Z=-0.488$, $P=0.625$). However, pleomorphic adenomas, Warthin tumors, and malignant tumors all had higher FDG uptake than benign parotid lesions ($3.65 \pm 2.59$) ($Z=-2.338$, $P = 0.019$; $Z=-2.204$, $P = 0.028$; $Z = -2.028$, $P = 0.043$).
Parotid lesions -Detailed discussion-

1. Pleomorphic adenoma (Fig. 1 on page 21)

-Etiology-

Pleomorphic adenoma is the most common benign neoplasm of salivary gland origin. The average age of patients with pleomorphic adenomas is about 43 years, but this tumor is the most common neoplasm of the salivary gland even in children and adolescents. Women are more likely to be affected than men.

It is usually solitary, round, and well circumscribed with a smooth but sometimes lobulated surface. Tumors larger than 1 cm often have numerous protuberances, which give them a lobulated appearance. In the major salivary glands, pleomorphic adenomas are commonly encapsulated.

The risk for local recurrence in pleomorphic adenoma is known to be higher than that of other benign parotid lesions such as Warthin tumor. It has been estimated that nearly 25% of untreated pleomorphic adenomas show malignant degeneration, usually a carcinoma ex pleomorphic adenoma, after a long history of disease.

-Pathology-

Pleomorphic adenomas are renowned for their cytomorphological and architectural variability. Despite their protean histopathology, all tumors share the essential diagnostic features of being composed of both epithelial and myxoid tissues. The proportions of these components vary widely, and one or the other is often predominant.

-Conventional MRI-

There are a variety of MR findings of pleomorphic adenomas that reflect their cytomorphological and architectural variability, and MR imaging features of the tumors may overlap with those of malignant salivary gland tumors. Pleomorphic adenomas typically have a characteristic heterogeneous high intensity on T2-weighted images, representing myxoid tissue. The cellular component with less-myxoid tissue is considered responsible for the reduced signal intensities on T2-weighted images, with the reduction ratio being dependent on the proportion of cellular components. Motoori et al.
proposed the significance of myxomatous tissue detection on MR images in differentiating between pleomorphic adenomas and malignant tumors.

-DWI-

Pleomorphic tumor shows heterogeneous signal and calculated ADC values. Histopathological variability is speculated to affect these findings. Hypercellularity contributes to reducing the extracellular space and the diffusion space of water protons, with a resultant decrease in ADC values. These values and findings overlapped with those of malignant tumor. On the other hand, abundant myxoid area shows increased ADC values because water protons move relatively freely in the area.

Eida et al. suggested that the presence of high ADC tumor areas could be an important criterion in differentiating benign salivary gland tumors from malignant ones, though, some malignant tumors such as squamous cell carcinoma may show necrotic cystic areas with very high ADC values. Yerli et al. proposed that calculating the ADC value may help to differentiate pleomorphic adenomas (mean 1.74±0.37 ×10^{-3} mm²/s) from Warthin tumors and malignant parotid tumors (mean ADC values: 0.97±0.16×10^{-3} mm²/s and 1.04±0.35 ×10^{-3} mm²/s, respectively).

-FDG-PET-

Pleomorphic adenoma is known to particularly show FDG uptake. Uchida et al. suggested that FDG-PET could reflect tumor growth ability more clearly than other nuclear or imaging modalities since the accumulation of FDG was significantly correlated with the tumor size in pleomorphic adenoma.

2. Warthin tumor (Figs. 2 and 3)

-Etiology-

Warthin tumors, the second most common benign tumors of parotid glands, are treated much more conservatively than pleomorphic adenomas and, of course, all malignant lesions. They occur largely in middle-aged and older men and usually in the parotid gland or periparotid region, mostly involving the inferior pole of the gland. Multicentric occurrence is seen more often with Warthin tumor than any other salivary gland tumor.
Warthin tumors usually are spherical to ovoid, have a smooth surface, and normally are 2 to 4 cm in diameter.

Pathological finding:

Warthin tumor is an adenoma with a variable number of cysts filled with mucoid or brown fluid. The cysts are lined with papillary proliferations of bilayered oncocyctic epithelia and supporting stroma composed of copious amounts of follicle-containing lymphoid tissue. The tumor occasionally contains focal hemorrhage and necrosis.

Conventional MRI:

Warthin tumors show well-defined margins, and appear spherical to ovoid on T1- and T2-weighted images. Sometimes large cysts could be detected as high-signal-intensity foci on T2-weighted images, but small cysts shown on microscopy are not detected on MRI. Sometimes T1-hyperintense areas are noted. They are speculated to correspond to areas including complicated cysts containing proteinous fluid with foamy cells, red cells, and neutrophils.

DWI:

Ikeda et al. suggested that the lower ADC value of Warthin tumors could be explained by the higher protein content in the cystic portions of those lesions. Yerli et al. reported that mean ADC values for the Warthin tumors and lymphomas in their study (mean ADC values: 0.97×10⁻³mm²/s and 0.68×10⁻³mm²/s, respectively) were lower than the corresponding mean for the pleomorphic adenomas (mean 1.74±0.37×10⁻³mm²/s) and proposed that calculating the ADC value may help to differentiate pleomorphic adenomas from Warthin tumors and malignant parotid tumors.

FDG-PET:

Although the mechanisms causing FDG accumulation to be seen in Warthin’s tumor are not determined, hyper accumulation of FDG in Warthin tumor is well known.

3. Basal cell adenoma (BCA) (Figs. 9 and 10)

Etiology:
BCAs account for 1%-2% of all salivary gland epithelial tumors, and 80% arise in
the major salivary glands, mostly the superficial lobe of the parotid gland. These
tumors frequently affect patients between their fifth and seventh decades, in contrast
to observations in benign mixed tumours. Clinically, though it is difficult to differentiate
BCAs from pleomorphic adenoma, BCAs tend to be smaller.

-Pathology-

Histopathologically, four characteristic patterns have been described: solid, trabecular,
tubular and membranous. The presence of a basaloid cellular layer with a stockade
pattern and surrounded by a hyaline substance is characteristic. The absence of
myoepithelial cells, present in benign mixed tumors and other salivary gland neoplasms,
has been noted as being characteristic of this tumour.

-Conventional MRI-

BCAs tend to be smaller (mean 2.8cm, range 1.0-5.8cm) than pleomorphic adenomas. MR imaging findings of BCAs include well-defined and smooth marginal morphologies, dissimilar to the lobulated contour seen in pleomorphic adenomas, and relative hypointensity on both T1- and T2-weighted images. Sometimes large cystic change is shown.

-DWI-

Yerli et al. reported a single case of BCA that had an ADC value of $1.40 \times 10^{-3}$ mm$^2$/s and exhibited diffusion characteristics similar to those of pleomorphic adenomas. They attributed these to its adenomatous nature and concluded that it may be difficult to differentiate uncommon basal cell adenoma from pleomorphic adenoma.

-FDG-PET-

Wang et al. reported two cases of basal cell adenoma (SUVmax Range 2.8-6.2, Mean ±SD 4.50 ± 2.40) and they concluded that the SUVmas is not significantly different from SUVmax of malignant tumors or other benign tumors such as pleomorphic adenoma or Warthin tumor. This indicated that FDG-PET/CT is not useful to differentiate basal cell adenoma form other parotid tumors.

4. Lymphoma (Fig. 4 on page 23)
-Etiology-
Lymphoma originating in the parotid gland is relatively rare and occurs in 1-5% of tumors where the parotid gland is the original site of the tumor\textsuperscript{15}. Sjogren syndrome increases the risk of parotid lymphoma by more than 4400%\textsuperscript{26}. Most parotid lymphomas are diffuse-large B cell type and the non-Hodgkin lymphoma:Hodgkin lymphoma = 85:15\textsuperscript{27}.

-Pathology-
Lymphoma shows diffuse infiltration of atypical lymphoid cells\textsuperscript{11}. Small foci of necrosis are seen in 56% of patients\textsuperscript{28}.

-Conventional MRI-
The lymphomas have a homogenous signal pattern with hypointensity on T1-weighted images and hyperintensity on T2-weighted images (Figs. 4A and B). On gadolinium-enhanced T1-weighted images, homogenous enhancement are observed (Fig. 4C). Although this MRI pattern is highly suggestive\textsuperscript{17}, necrosis or cystic changes of the internal structures may be seen in some cases\textsuperscript{15}.

-DWI-
Lymphomas arising in the salivary glands were associated with extremely low ADCs throughout the lesions (Fig. 4D). Aggregates of cells with scanty cytoplasm and an extracellular matrix were commonly observed in patients with lymphoma (Fig.4G). Gio et al. and this finding speculated this finding to possibly explain the lower ADC values obtained for lymphoma\textsuperscript{29}.

-FDG-PET-
Wang et al. reported a case of lymphoma (SUVmax=16.20) in their study\textsuperscript{18}. Although lymphoma shows extensive SUVmax (Fig. 4E), pleomorphic adenoma and Warthin tumor are not differentiated from lymphoma on FDG-PET only. FDG-PET and PET/CT is useful for staging (Fig. 4F).

5. Mucoepidermoid carcinoma (MEC) (Figs. 5 and 6)
-Etiology-

MEC is the most frequently encountered parotid malignancy and comprises 12%-29% of malignant salivary gland tumors, whereas acinic cell carcinoma comprises 7.0%-17.5% of all salivary malignancies. Women are more commonly affected than men (3:2), and the mean age at onset is in the 5th decade of life. MEC is also the most common salivary gland malignancy in children.

-Pathology-

MECs contain three cellular elements in varying proportions: squamous cells, mucus-secreting cells, and "intermediate" cells. Cysts of variable sizes are often present. The cysts may be lined with intermediate, mucous, or epidermoid cells and are filled with mucus. Higher-grade tumors show evidence of cytologic atypia, a high mitotic frequency, and areas of necrosis, and they are more likely to show neural invasion. Stromal hyalinization is common and sometimes extensive.

-Conventional MRI-

Most tumors are smaller than 4 cm in diameter. MECs may be circumscribed and variably capsulated or infiltrative and fixed; the latter characteristics generally apply to higher-grade tumors. Areas of scarffing are relatively common. Eida et al. reported that two cases of salivary (at least one of which in a sublingual gland) mucoepidermoid carcinomas displayed homogeneous architectures on T1-weighted and slightly heterogeneous architectures on T2-weighted images.

-DWI-

Habermann et al. reported ADC values of 16 cases of parotid MEC (mean±SD 1.05 ±0.03 (range 0.97-1.14)). Eida et al. reported that the ADC map demonstrated relatively homogeneous areas of low ADCs, corresponding to tumor areas with polygonal or round-cell proliferation. Although it is said that higher-grade tumors show areas of necrosis, in our cases, grade I MEC (Fig. 5) showed cystic areas showing hyperintensity on STIR images while grade III MEC (Fig. 6) showed no cystic areas and a more invasive margin. In grade III MEC, the ADC values were lower and SUVmax was higher than those of grade I MEC in our cases. This may be due to the amount of cystic change in grade I tumor.

6. Salivary duct carcinoma (SDC) (Fig. 7 on page 26)
-Etiology-

SDC is a high-grade malignancy occurring predominantly in the major salivary glands of older male patients. Distant metastases are the most common cause of death.

-Pathology-

SDC is composed of atypical epithelial cells arranged in varying proportions of cribriform, papillary, micropapillary, or solid growth patterns with fibrotic stromata. Incomplete capsules and invasive borders are identified. Comedonecrosis is present in most cases. Perineural, venous, and lymph duct invasions are also common findings. According to Motoori et al., SDCs showed dense fibrosis in the center, whereas in the peripheral zone of the tumors, fibrosis, necrosis, comedonecrosis, tumor cells, and lymphoplasmacytic infiltration were present in various proportions.

-Conventional MRI-

SDC shows invasive or ill-defined margins on conventional MRI. On T1-weighted images, tumors show hypointensity to muscle. On T2-weighted images, tumor shows low to moderately high signal intensity to the contralateral parotid gland. Motoori et al. speculate that hypointensity on T2-weighted images corresponds to areas with desmoplasia.

-DWI-

Generally, ADC values of SDC are lower than the $1.22 \times 10^{-3} \text{mm}^2/\text{s}$ that Wang et al. reported as a criterion for predicting malignancy. In our case, the ADC value of the tumor is $1.22 \times 10^{-3} \text{mm}^2/\text{s}$. Motoori et al. reported one case with a slightly elevated ADC value ($1.43 \times 10^{-3} \text{mm}^2/\text{s}$) and speculated that the tumor had abundant microscopic necrotic foci that could not be detected on MR images. There was a possibility that these numerous microscopic necroses were the cause of the elevated ADC value. Usually, the mean ADC value of cystic and necrotic components is higher than that of cellular tissue, because the mobility of water protons is relatively freer in fluid than in other tissues.

7. Schwannoma (Fig. 11 on page 30)
The presented case was proved to be a case of parapharyngeal schwannoma originating from the inferior alveolar nerve.

-Etiology-

Up to 45% of all schwannomas originate in the head and neck region. They are reported to occur in the face, scalp, intracranial cavity, orbit, nasal and oral cavities, parapharyngeal space, middle ear, mastoid, larynx, and medial and lateral regions of the neck. Preoperative differentiation of the deep lobe of parotid schwannoma from parapharyngeal schwannoma is sometimes difficult because of the low frequency of the disease and the few typical signs associated with nerve dysfunction.

-Pathology-

Schwannomas are composed of varying proportions of hypercellular (Antoni A) and hypocellular (Antoni B) areas. The global degree of cellularity varies widely among lesions.

-Conventional MRI-

Schwannomas are well-circumscribed masses that exhibit hyperintensity on T2-weighted images and a relatively homogeneous hypointensity on T1-weighted images. Sometimes the tumors show a target sign characterized by peripheral hyperintensity and central hypointensity on T2-weighted images. In schwannoma, the target sign corresponds to more cellular Antoni A regions centrally and to more myxoid Antoni B regions peripherally.

-DWI-

Sener et al. reported that the mean ADC value of acoustic neurinoma was higher (1.42 ± 0.17 ×10⁻³ mm²/s) as compared with that of normal brain parenchyma (0.80 ± 0.11 ×10⁻³ mm²/s). They speculated that the relatively loose matrix of the tumors is the reason for the relatively high ADC values and proposed that the DWI findings may aid in differentiating acoustic neuromas at least from other tumors with a high nuclear-to-cytoplasmic ratio.

-FDG-PET-
FDG-PET has limited value for identifying benign versus malignant peripheral nerve sheath tumors or other malignant soft-tissue tumors. The FDG uptake of schwannomas can be variable.

Beaulieu et al. reported that the SUVmax of schwannomas varied from 1.9 to 7.2 (mean = 4.6) \(^{34}\). The mean SUV (SUVmax and SUVav) of the hypocellular schwannomas was significantly lower than the mean SUV (SUVmax and SUVav) of the hypercellular schwannomas (p = 0.010 for SUVmax and p = 0.010 for SUVav) \(^{34}\). They attributed the wide range of SUVs for FDG to the different degrees of cellularity of each lesion \(^{34}\). In large tumors, FDG uptake can be heterogeneous because of cystic changes and necrosis \(^{34}\). They suggest the mechanism of FDG uptake in schwannoma is overexpression of one of the glucose transporter proteins by tumor cells, but this remains to be proven \(^{34}\).

8. Fibrosarcoma (Fig. 12 on page 31)

The presented case was proved to be a case of an extra parotid tumor in the periosseous area of mandibular bone.

-Etiology-

Fibrosarcoma is a malignant tumor that arises from the fibroblasts. This is a type of sarcoma that is predominantly found in the area around the bones or in soft tissue. Of all the fibrosarcomas occurring in man, only 0.05% occur in the head and neck region \(^{37}\).

-Pathology-

Fibrosarcomas are tumors of malignant fibroblasts and collagen. They vary in histologic grade \(^{38}\). Higher grades are extremely anaplastic and pleomorphic, with bizarre nuclei that bring to mind the histologic features of malignant fibrous histiocytoma \(^{38}\). Fibrosarcoma elsewhere in the body develops in people between the ages of 25 and 79 years. The peak incidence is 55-69 years. However, fibrosarcomas in the head and neck region tend to develop in the 3rd and 5th decades of life, but there is a wide age range and many patients are below 20 years of age. Generally, the tumors develop with equal frequency in males and females.

Figure legends
Fig. 1: Pleomorphic adenoma; A 65-year-old man with Pleomorphic adenoma of the right parotid gland on page 21

A, T2-weighted image of the maximal diameter section shows a lobulated tumor. This tumor shows moderate hyperintensity (yellow arrowhead) with a markedly hyperintense lesion (yellow arrow).

B, T1-weighted image shows isointense mass to muscle.

C, Fat-suppression contrast-enhanced T1-weighted image shows heterogeneous enhancement. The lateral region showing hyperintensity on T2-weighted image (yellow arrow) is not enhanced, while the medial region (yellow arrowhead) is enhanced.

D, Axial ADC map shows that the high ADC area corresponds to the hyperintense area shown on T2-weighted image. Also, central area shows high ADC. The round cursor marks the region of interest (ROI) selected for measurement of the ADC value. The ADC value of solid lesion (yellow ROI) is \(0.94 \times 10^3\) mm\(^2\)/s while cystic lesion (black ROI) is \(2.52 \times 10^3\) mm\(^2\)/s. Mean ADC of this tumor is \(1.54 \times 10^3\) mm\(^2\)/s while that of contralateral normal parotid is \(0.54 \times 10^3\) mm\(^2\)/s.

E and F, Pathologic specimen with hematoxylin and eosin (HE) stain shows area with proliferating tumor cells (E), or abundant myxoid tissue (F).

The two different components of pleomorphic adenomas are considered to reflect the differences in ADC values. Abundant myxoid areas showed high ADC values; on the other hand, the cellular areas consisting of numerous small cells and scanty myxoid stromata showed relatively low ADC values. {Motoori, 2004 #71}

Fig. 2: Warthin tumor; A 75-year-old man with bilateral Warthin tumors on page 21

A, A T2-weighted image shows a masses with well-defined and smooth margin in bilateral parotid gland. The tumor shows homogeneous slight hypointensity relative to the normal parotid gland.

B, On T1-weighted image, the tumor is hypointense and homogeneous.

C, On contrast-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement.
D. An ADC image shows the lesion (yellow arrow) with an ADC of $0.80 \times 10^{-3}$ mm$^2$/s while that of normal appearing parotid area is $0.94 \times 10^{-3}$ mm$^2$/s.

E. FDG-PET/CT shows intense accumulation in the mass with SUV max of 14.8.

F. Pathologic specimen with HE stain shows proliferation of oncocytic epithelia and lymphoid tissue. Small cysts are also seen (*).

Fig. 3: Large Warthin tumor; A 64-year-old man with bilateral Warthin tumors on page 22

A. T2-weighted image shows bilateral well-defined masses.

Striated low-signal-intensity area (yellow arrow) can be detected in the left parotid tumor.

B. On T1-weighted image, the tumors show slight hypointensity to the parotid gland. In the left parotid tumor, hyperintense area (yellows arrow) can be detected corresponding to the hypointense area shown on T2-weighted image.

C. On Gd-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement. The hyperintense area on T1-weighted image shows no enhancement (yellow arrow).

D. An ADC image shows the left parotid mass (yellow arrowhead) with an ADC value of $0.79\times10^{-3}$ mm$^2$/s and right parotid mass (white arrowhead) with an ADC value of $0.84\times10^{-3}$ mm$^2$/s. An ADC value of normal appearing parotid is $0.89\times10^{-3}$ mm$^2$/s.

E. Pathologic specimen with HE stain shows large necrotic area (*) and papillary proliferation of oncocytic epithelia, with supporting stroma composed of lymphoid tissue.

Fig. 4: Diffuse large B-cell lymphoma; A 68-year-old woman with Diffuse large B-cell lymphoma of the right parotid gland on page 23

A. T2-weighted image shows a lobulated tumor of homogeneous moderate hyperintensity. Left tonsillar lesion is also detected.

B. T1-weighted image shows homogeneous isointense masses to muscle.
C, Contrast-enhanced T1-weighted image shows homogeneous enhancement.

D, ADC map shows that the signal intensity of the mass (yellow arrows) is homogeneous. The ADC values of the parotid mass and tonsillar lesion are $0.67 \times 10^{-3} \text{ mm}^2/\text{s}$ and $0.61 \times 10^{-3} \text{ mm}^2/\text{s}$ respectively while that of normal appearing parotid gland is $1.08 \times 10^{-3} \text{ mm}^2/\text{s}$.

E, FDG-PET/CT shows that the mass is positive with SUVmax of 18.0.

F, Pathologic specimen with HE stain shows lymphoma cell proliferation (B cell, diffuse large-sized cell type).

G, The MIP image of FDG-PET shows contralateral cervical lymphnode and tonsillar involvement. No other involvement is noted.

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**Fig. 5: Mucoepidermoid carcinoma, grade I; A 27-year-old woman with mucoepidermoid carcinoma, grade I on page 24**

A, A short-inversion-time inversion recovery (STIR) image shows a mass with ill-defined and lobulated margin in the deep lobe of the left parotid gland. The tumor is hyperintense relative to the normal parotid gland with some very hyperintense foci.

B, On T1-weighted image, the mass shows isointensity with muscle.

C, On contrast-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement of the solid component.

D, ADC map shows that the signal intensity of the mass (yellow arrow) is heterogeneous. ADC of the mass is $1.27 \times 10^{-3} \text{ mm}^2/\text{s}$, while that of contralateral normal parotid is $0.82 \times 10^{-3} \text{ mm}^2/\text{s}$.

E, FDG-PET/CT shows that the mass is positive with SUVmax of 3.2.

F, Pathologic specimen with HE stain shows proliferation of polygonal, clear cancer cells (*) and cancer cell nests in attenuated fibrous connective tissues (**).

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**Fig. 6: Mucoepidermoid carcinoma, grade III; A 29-year-old man with mucoepidermoid carcinoma, grade III on page 25**

on page 25
A, A T2-weighted image shows a mass with ill-defined and lobulated margin in the left parotid gland. The tumor shows hypo- to isointensity to the normal contralateral parotid gland.

B, On T1-weighted image, the mass shows homogeneous hypointensity to the normal contralateral parotid gland.

C, On contrast-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement.

D, ADC map shows central hypointensity with ADC value of \(0.83 \times 10^{-3} \text{ mm}^2/\text{s}\). Mean ADC of this tumor is \(1.06 \times 10^{-3} \text{ mm}^2/\text{s}\) while that of contralateral normal parotid is \(0.61 \times 10^{-3} \text{ mm}^2/\text{s}\).

E, Pathologic specimen with HE stain shows dense proliferation of cancer cells (*). The low ADC area may correspond to the fibrous change area (**).

Fig. 7: Salivary duct adenocarcinoma (SDC); A 67-year-old woman with Salivary duct adenocarcinoma on page 23

A, T2-weighted image shows a partially ill-defined lobulated mass in the right parotid gland. The tumor is hypo- to hyperintense to the contralateral parotid gland.

B, On T1-weighted image, the mass shows isointensity to the contralateral parotid gland.

C, On contrast-enhanced T1-weighted image, the tumor shows irregular enhancement.

D, On ADC map, the mass contains some foci of central high ADC area (\(2.25 \times 10^{-3} \text{ mm}^2/\text{s}\)) and peripheral intermediate ADC area (\(0.82 \times 10^{-3} \text{ mm}^2/\text{s}\)). Mean ADC of this tumor is \(1.22 \times 10^{-3} \text{ mm}^2/\text{s}\) while that of contralateral normal parotid is \(0.83 \times 10^{-3} \text{ mm}^2/\text{s}\).

E, FDG-PET/CT shows intense accumulation in the mass with SUVmax of 6.4.

G, Pathologic specimen with HE stain shows abundant atypical epithelial cells with fibrotic stromata (asterisk) and foci of comedonecrosis (double asterisks).

Fig. 8: Metastatic lymphadenopathy (Mesopharyngeal SCC); A 74-year-old man with lymphadenopathy due to mesopharyngeal SCC. on page 27
A, T2-weighted image shows a mass with partially ill-defined margin in the left parotid gland. The tumor is heterogeneous hyperintensity to the muscles. Primary lesion is also noted (yellow arrows).

B, On T1-weighted image, the mass shows homogeneous hypointensity to the normal parotid gland.

C, On contrast-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement.

D, On ADC map, the ADC value of primary mass is $0.96 \times 10^{-3}$ mm$^2$/s while metastatic lymphnode is $0.92 \times 10^{-3}$ mm$^2$/s. The ADC value of this tumor is lower than that of contralateral normal appearing parotid is $1.31 \times 10^{-3}$ mm$^2$/s.

E, FDG-PET/CT shows that the mass is positive with SUVmax of 13.0 while that of the primary lesion is 12.7.

Fig. 9: Basal cell adenoma; A 70-year-old woman with basal cell adenoma (BCA) on page 28

A, T2-weighted image shows a mass with well-defined and smooth margin in the deep lobe of the right parotid gland. The tumor is slightly more hyperintense than the normal parotid gland with hyperintense area.

B, On T1-weighted image, the tumor shows a homogeneous intensity.

C, On contrast-enhanced T1-weighted image, the tumor shows homogeneous moderate enhancement.

D, The round cursor marks the ROI selected for measurement of the ADC value. The ADC value of solid area (yellow ROI) is $1.42 \times 10^{-3}$ mm$^2$/s while cystic lesion (black ROI) is $2.54 \times 10^{-3}$ mm$^2$/s. Mean ADC of this tumor is $2.02 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid gland is $1.06 \times 10^{-3}$ mm$^2$/s.

E, Pathologic specimen with HE stain shows a trabecular pattern of a BCA. The tumor is composed of small proliferating cells, necrotic tissue (**), and large cystic change (*).

Fig. 10: Basal cell adenoma with large cystic change; A 66-year-old woman with basal cell adenoma (BCA) (large cystic change) on page 29
A. T2-weighted image shows a cystic mass with fluid-fluid collection in the deep lobe of the left parotid gland.

B. On T1-weighted image, the tumor shows a fluid-fluid collection.

C. Coronal view of STIR image, the tumor shows a mural nodule (yellow arrow).

D. ADC map shows the fluid is homogenous with an ADC value of 2.56×10⁻³ mm²/s while that of contralateral normal parotid is 0.63 × 10⁻³ mm²/s.

E. Pathologic specimen with HE stain shows a large cyst with mural nodule.

**Fig. 11: Schwannoma; A 60-year-old man with mandibular nerve Schwannoma** on page 30

A. T2-weighted image shows a mass with well-defined and smooth margin of the left parapharyngeal space adjacent to the deep lobe of left parotid gland. The tumor is hyperintense with a hypointense area.

B. On T1-weighted image, the tumor is hypointense to parotid gland and homogeneous.

C. On contrast-enhanced T1-weighted image, the tumor shows heterogeneous enhancement.

D. On ADC map, the mass consists of high ADC area and intermediate ADC area. The area that shows intermediate ADC corresponds to the hypointense area on T2-weighted image. The round cursors mark the ROI selected for measurement of the ADC value. The ADC value of solid area (yellow ROI) is 1.15×10⁻³ mm²/s while cystic area (black ROI) is 2.56 × 10⁻³ mm²/s. Mean ADC of this tumor is 1.94×10⁻³ mm²/s while that of contralateral normal parotid is 0.93 × 10⁻³ mm²/s. The two different components of schwannoma may reflect the differences in ADC values.

E. FDG-PET/CT shows moderate accumulation in the mass with SUVmax of 3.2.

F. Pathologic specimen with HE stain shows large cystic lesion and solid lesion with hypercellular Antoni A and hypocellular Antoni B.

**Fig. 12: Fibrosarcoma; A 34-year-old woman with Fibrosarcoma** on page 31

A. T2-weighted image shows a mass of the pterigoid space with partially ill-defined but almost smooth margin. The tumor is hyper intense with hypointense area.
B, On T1-weighted image, the tumor is hypointense to parotid gland and homogeneous.

C, On contrast-enhanced T1-weighted image, the tumor shows heterogeneous enhancement.

D, The ADC value of the mass is $0.94 \times 10^3 \text{ mm}^2/\text{s}$ while that of contralateral normal parotid gland is $1.01 \times 10^3 \text{ mm}^2/\text{s}$.

Images for this section:

**Fig. 1: Pleomorphic adenoma of the right parotid gland in a 65-year-old man**

Axial ADC map shows that the high ADC area corresponds to the hyperintense area shown on T2-weighted image. Also, central area shows high ADC. The round cursor marks the region of interest (ROI) selected for measurement of the ADC value. The ADC value of solid lesion (yellow ROI) is $0.94 \times 10^3 \text{ mm}^2/\text{s}$ while cystic lesion (black ROI) is $2.52 \times 10^{-3} \text{ mm}^2/\text{s}$. Mean ADC of this tumor is $1.54 \times 10^{-3} \text{ mm}^2/\text{s}$ while that of contralateral normal parotid is $0.54 \times 10^{-3} \text{ mm}^2/\text{s}$.
Fig. 2: Warthin tumor in a 75-year-old man

Mean ADC of left parotid tumor is $0.80 \times 10^{-3}$ mm$^2$/s while that of normal appearing parotid is $0.94 \times 10^{-3}$ mm$^2$/s.
Fig. 3: Warthin tumors in a 64-year-old man

Mean ADC of left and right parotid tumors are $0.79 \times 10^{-3} \text{ mm}^2/\text{s}$ and $0.84 \times 10^{-3} \text{ mm}^2/\text{s}$ respectively, while that of normal appearing parotid is $0.89 \times 10^{-3} \text{ mm}^2/\text{s}$.
Fig. 4: Diffuse large B-cell lymphoma in a 68-year-old woman

The ADC value of parotid mass is $0.67 \times 10^{-3}$ mm$^2$/s while tonsillar lesion is $0.81 \times 10^{-3}$ mm$^2$/s. The ADC value of normal left parotid gland is $1.08 \times 10^{-3}$ mm$^2$/s.
Fig. 5: Mucoepidermoid carcinoma, grade I in a 27-year-old woman

Mean ADC of this tumor is $1.27 \times 10^{-3}$ mm²/s while that of contralateral normal parotid is $0.82 \times 10^{-3}$ mm²/s.
Fig. 6: Mucoepidermoid carcinoma, grade III in a 29-year-old man.

ADC map shows central hypointensity with ADC value of $0.83 \times 10^{-3}$ mm$^2$/s.
Mean ADC of this tumor is $1.06 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid is $0.61 \times 10^{-3}$ mm$^2$/s.
The round cursor marks the ROI selected for measurement of the ADC value. The ADC value of peripheral solid area is $0.82 \times 10^{-3}$ mm$^2$/s while that of central cystic area (black ROI) is $2.25 \times 10^{-3}$ mm$^2$/s. Mean ADC of this tumor is $1.22 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid is $0.83 \times 10^{-3}$ mm$^2$/s.
Fig. 8 Metastatic lymphadenopathy in a 74-year-old man (Mesopharyngeal Ca.)

The ADC value of primary mass is $9.6 \times 10^{-3}$ mm$^2$/s while metastatic lymph node is $9.2 \times 10^{-3}$ mm$^2$/s. The ADC value of this tumor is lower than that of contralateral normal appearing parotid gland is $1.31 \times 10^{-3}$ mm$^2$/s.
Fig. 9: Basal cell adenoma in a 70-year-old woman

The round cursor marks the ROI selected for measurement of the ADC value. The ADC value of solid area (yellow ROI) is $1.42 \times 10^{-3}$ mm$^2$/s while cystic lesion (black ROI) is $2.54 \times 10^{-3}$ mm$^2$/s. Mean ADC of this tumor is $2.02 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid is $1.06 \times 10^{-3}$ mm$^2$/s.
Fig. 10: Basal cell adenoma in a 66-year-old woman

Mean ADC of this tumor is $2.66 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid gland is $0.63 \times 10^{-3}$ mm$^2$/s.
Fig. 11: Schwannoma in a 60-year-old man

The round cursors mark the ROI selected for measurement of the ADC value. The ADC value of solid area (yellow ROI) is $1.15 \times 10^{-3}$ mm$^2$/s while cystic area (black ROI) is $2.56 \times 10^{-3}$ mm$^2$/s. Mean ADC of this tumor is $1.94 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid is $0.93 \times 10^{-3}$ mm$^2$/s.
The ADC value of the mass is $0.94 \times 10^{-3}$ mm$^2$/s while that of contralateral normal parotid gland is $1.01 \times 10^{-3}$ mm$^2$/s.
Conclusion

Although the diagnostic value of FDG-PET/CT and DWI in the differentiation of malignant from benign parotid gland tumors is limited because of the high FDG uptake and low ADC in some benign tumors,

- DWI can differentiated pleomorphic adenomas from Warthin tumors and other malignant tumors.

- DWI may be able to differentiated malignant parotid tumors from benign ones except for Warthin tumor.

- FDG-PET/CT may be useful in detecting the primary lesion of metastatic lesions and is useful for staging of primary tumors or lymphomas.

A combination of FDG-PET/CT and other 3T-MR techniques, may be even more useful.

Personal Information

References


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