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HEAD AND NECK RADIOLOGY

The ability to identify the intraparotid facial nerve for locating parotid gland lesions in comparison to other indirect landmark methods: evaluation by 3.0 T MR imaging with surface coils

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Abstract
Introduction It is important to know whether a parotid gland lesion is in the superficial or deep lobe for preoperative planning. We aimed to investigate the ability of 3.0 T magnetic resonance (MR) imaging with surface coils to identify the intraparotid facial nerve and locate parotid gland lesions, in comparison to other indirect landmark methods.
Methods We retrospectively evaluated 50 consecutive patients with primary parotid gland lesions. The position of the facial nerve was determined by tracing the nerve in the stylomastoid foramen and then following it on sequential MR sections through the parotid gland. The retromandibular vein and the facial nerve line (FN line) were also identified. For each radiologist and each method, we determined the diagnostic ability for deep lobe lesions and superficial lobe lesions, as well as accuracy. These abilities were compared among the three methods using the Chi-square test with Yates' correction.
Results Mean diagnostic ability for deep lobe lesions, the diagnostic ability for superficial lobe lesions, and accuracy were 92%, 86%, 87%, respectively, for the direct identification method; 67%, 89%, 86%, respectively, for the retromandibular vein method; and 25%, 99%, 90% , respectively, for the FN line method. The direct identification method had significantly higher diagnostic ability for deep lesions than the FN line method ($P<0.01$), but significantly lower diagnostic ability for superficial lobe lesions than the FN line method ($P<0.01$).
Conclusion Direct identification of the intraparotid facial nerve enables parotid gland lesions to be correctly located, particularly those in the deep lobes.

Keywords Parotid gland · Facial nerve · Magnetic resonance imaging

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Introduction

In general, the parotid gland is divided into a deep and a superficial lobe by the facial nerve. These are not true “lobes” in that no fascia divides them; they are merely separated by the facial nerve. This distinction has important clinical implications in parotid gland lesions. When planning surgery, it is important to know where to find the parotid gland lesion in relation to the facial nerve. The location of the lesion can influence the duration and difficulty of the operation. Lesions in the superficial lobe can be treated by superficial parotidectomy, but those in the deep lobe sometimes require total parotidectomy. The surgical aim in parotid gland is complete excision of the lesion while anatomically and functionally preserving the facial nerve [1]. Therefore, prior knowledge of the course of the intraparotid facial nerve allows the surgeon to determine the optimal surgical approach for preventing facial nerve damage and to appropriately counsel the patient.

In the past, a curvilinear structure of low signal intensity in the parotid gland on T1-weighted images was reported as the facial nerve [2]. Several years later, Thibault et al. performed a study of the parotid glands in two cadavers to determine the nature of these structures. They found that many areas of low signal within the gland seen on T1-weighted images represented the main duct and some tributaries [3]. It was therefore thought that the intraparotid facial nerve was not visible on MR imaging; hence, other indirect landmarks were used to predict its location within the gland [4–8]. A variety of methods have been proposed for tracing the facial nerve and differentiating the superficial from the deep lobe. The facial nerve (FN) line, which extends from the lateral surface of the posterior belly of the digastric muscle to the lateral surface of the ascending ramus of the mandible, was proposed as a marker [5]. As another marker, the retromandibular vein has been used because the parotid segment of the facial nerve courses lateral to this vein [6]. Recently, with improvements in MR imaging quality, some studies have demonstrated that MR imaging can depict the intraparotid facial nerve [9, 10]. However, these studies were conducted in a small population. Therefore, we consider that the ability of MR imaging to identify the intraparotid facial nerve has not been fully investigated.

Fig. 1 MR images of a 53-year-old woman with histopathologically proven pleomorphic adenoma in the superficial lobe of the parotid gland. **a**–**h** Axial contrast-enhanced T1-weighted images, **i** T2-weighted image at the level corresponding to **a**, **j** T2-weighted image at the level corresponding level to **d**, **k** T2-weighted image at the level corresponding to **f**, **l** T2-weighted image at the level corresponding to **h**. *Arrows* main trunk of the facial nerve, *arrowheads* temporofacial branch of the facial nerve, *open arrowheads* cervicofacial branch of the facial nerve, *dashed arrows* buccal branch of facial nerve, *open arrows* retromandibular vein, *dashed line* facial nerve (FN) line, *asterisk* the parotid gland lesion, *arrows with tram lines* parotid duct. The figures show images in cranial to caudal order. **a**–**c**, **i** contrast-enhanced T1-weighted and T2-weighted images show the main trunk of the facial nerve (*arrows*) as a structure of low signal intensity. The main trunk of the facial nerve divides into temporofacial and cervicofacial branches at the level of **c**. **b**, **c** The temporofacial branch of facial nerve (*arrowheads*) runs laterally. **d**–**h**, **j**–**l** The cervicofacial branch of the facial nerve (*open arrowheads*) runs caudally. **d**, **e**, **j** The parotid duct (*tram lines*) shows hypointensity on contrast-enhanced T1-weighted imaging and hyperintensity on T2-weighted imaging. **f**, **k** The buccal branch of the facial nerve (*dashed arrows*) runs laterally. **f**–**h**, **k**–**l** On the caudal side, the cervicofacial branch (*open arrowheads*) runs medially to the parotid gland lesion (*asterisks*). This finding suggests that the parotid gland lesion is in the superficial lobe. The retromandibular vein (*open arrows*) and the FN line (*dashed line*) are also located medially to the lesion. These findings also suggest that the parotid lesion is in the superficial lobe. Surgical findings confirmed that the lesion was in the superficial lobe

MR imaging at 3.0 Tesla (T), which is based on high signal-to-noise ratio (SNR), has major advantages. In the head and neck region, several studies have compared the capabilities of MR imaging at 3.0 T to that at 1.5 T in imaging small anatomical structures [11–13]. However, to the best of our knowledge, identification of the intraparotid facial nerve has not been evaluated. In the present study, we investigated the usefulness of 3.0 T MR imaging with surface coils in the identification of the intraparotid facial nerve in comparison to indirect landmark methods.

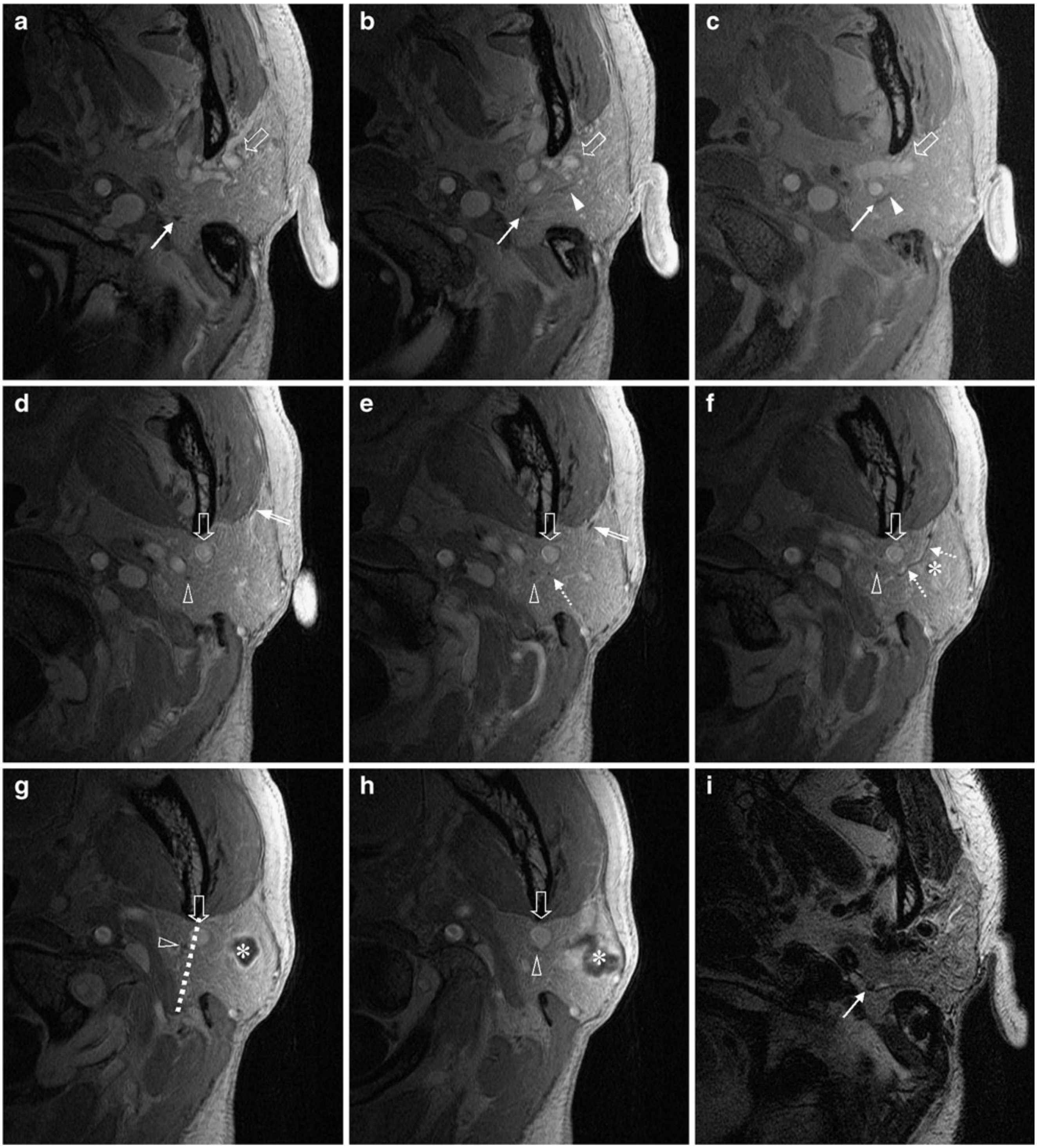
Table 1 Histological types and frequencies of parotid gland lesions.

Histological types	Number of patients
Benign tumors	
Pleomorphic adenoma	22
Warthin's tumor	13
Lymphoepithelial cyst	4
Schwannoma	1
Lipoma	1
Lymph node	1
Malignant tumors	
Salivary duct carcinoma	2
Adenoid cystic carcinoma	1
Squamous cell carcinoma	1
Mucoepidermoid carcinoma	1
Acinic cell carcinoma	1
Small cell carcinoma	1
Malignant lymphoma	1
Total	50

Materials and methods

Patient population

The study protocol was approved by our institutional review board. The patients provided written informed consent to the use of their data for research purposes. Included in this retrospective study were 50 consecutive patients with primary parotid gland lesions that had been identified by previous conventional MR imaging. They underwent 3.0 T MR imaging using surface coils for further preoperative examination. There were 26 men and 24 women, with a mean age of 62 years (age range 21–91 years). All patients underwent surgery within 1 week after preoperative MR imaging. The frequencies and histological types of parotid gland lesions are shown in Table 1.



MR imaging technique

MR imaging with a 3.0 T MR system (Signa Excite HD, General Electric, Milwaukee, WI, USA) was obtained using custom-designed four-element phased-array surface coils with two left and two right channels. Each array consisted of two transverse pairs of 70-mm-diameter coils with a 20-mm overlap. Technologists located the center of the surface coil above the parotid area on the affected side. Axial and coronal fast spin echo T2-weighted images (repetition time (TR)/echo time (TE), 4,500–6,500/84.1–105.6 ms, echo train length 10, 512×320 matrix, 120 mm field of view (FOV), section thickness/intersection gap, 2.0/0.5–1.0 mm, band width 390 Hz/pixel, number of excitations 1), and

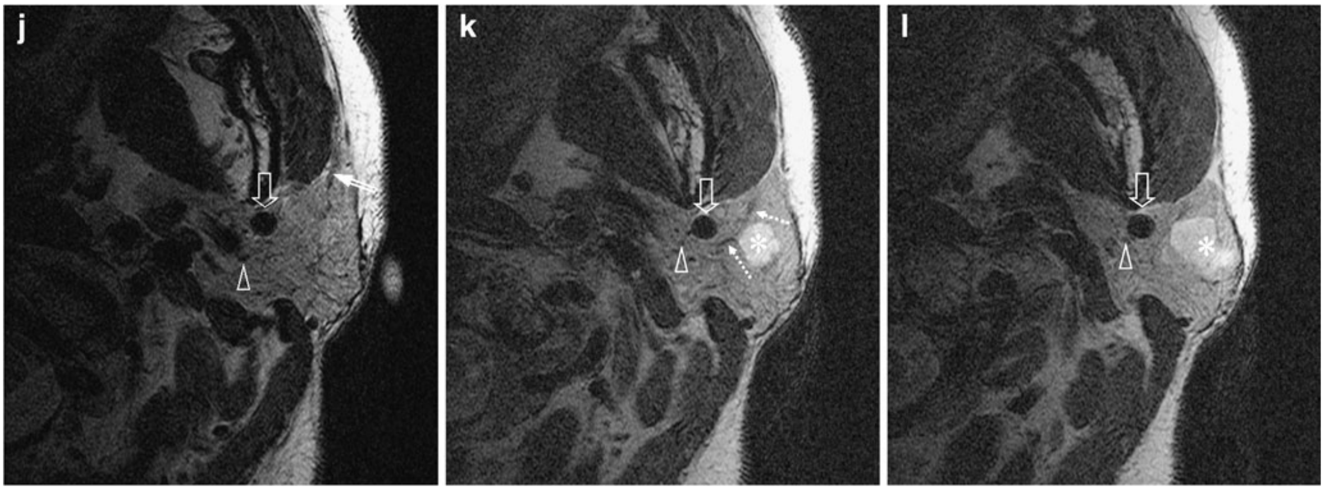


Fig. 1 (continued)

axial and coronal contrast-enhanced T1-weighted images (fast spoiled gradient recalled acquisition in the steady state: FSPGR) (TR/TE/flip angle 7/2.1/13 ms, 512×256 matrix, 120 mm FOV, section thickness, 1.4 mm without gap, band width 244 Hz/pixel, number of excitation 1, number of slices 60×2 (ZIP)) was obtained. Using Advantage Windows (General Electric), contrast-enhanced T1-weighted images were then generated with a slice thickness and inter-slice gap identical to those of T2-weighted images to allow accurate comparison between both sequences. So as to minimize the motion artifacts by time-consuming examinations, we did not obtain unenhanced T1-weighted imaging.

Evaluation of parotid gland lesion location

Two radiologists (9 and 11 years of experience in head and neck MR diagnosis) independently and retrospectively assessed the location of the parotid gland lesions on the MR images. For each patient, original axial and coronal images in both sequences were analyzed simultaneously. The surgical location of each lesion was determined by an otorhinolaryngologist, based on the operative findings. The surgical results were compared with the radiologists' assessment for each patient. When the lesion was equally located in both lobes, it was classified as a total parotid lesion in both radiological and surgical evaluations.

Evaluation by direct identification of the intraparotid facial nerve

The position of the facial nerve was determined by tracing it in the stylomastoid foramen and then following it on sequential MR sections through the parotid gland according to previous study [10]. On the cross section showing the parotid gland lesions, lesions located lateral to the intraparotid facial nerve (main trunk, temporofacial and cervicofacial branch) or those that displaced the nerve medially were predicted to be in the superficial lobe. Lesions found medial to the medial margin of the nerve or those that displaced the nerve laterally were determined to be in the deep lobe.

Evaluation by retromandibular vein

The retromandibular veins were determined as hyperintense continuous structures throughout the parotid gland on contrast-enhanced T1-weighted images. On the cross section showing the parotid gland lesions, lesions lateral to the vein were considered to be in the superficial lobe, whereas those medial to the vein were predicted to be in the deep lobe.

Evaluation by FN line

The FN line connecting the lateral surface of the posterior belly of the digastric muscle and the lateral surface of the ascending ramus of the mandible was determined as described in the previous study [5]. On the cross section showing the parotid gland lesions, if more than half of the lesion was lateral to the FN line, it was considered to be located in the superficial lobe, and if more than half was medial to the FN line, it was determined to be in the deep lobe.

Statistical analysis

The diagnostic ability for deep lobe lesions (the ability of MR imaging to correctly predict the location of parotid gland lesions found to be in the deep lobe from surgical findings), the diagnostic ability for superficial lobe lesions (the ability of MR imaging to correctly predict the location of lesions found to be confined to the superficial lobe from surgical findings), and accuracy (the ability of MR imaging correctly predicted the location of lesions found to be confined to the lobe from surgical findings) were determined for each radiologist and each method. If any of the landmarks could not be identified, we determined that the lesion could not be correctly diagnosed.

Differences among the three methods in mean diagnostic ability for deep lobe lesions, diagnostic ability for superficial lobe lesions, and accuracy were analyzed by performing Chi-square test with Yates' correction separately for each radiologist. A difference with a P value of <0.05 was considered statistically significant. For each method, interobserver agreement between the two radiologists was calculated using kappa statistics.

Results

Surgical location of parotid gland lesions

Six parotid lesions, including one lesion that extended to both lobes, involved the deep lobes. Forty-four lesions were confined to the superficial lobe.

Evaluation by direct identification of the intraparotid facial nerve

Facial nerves appeared as linear structures of low signal intensity surrounded by fat and parotid gland tissue of high signal intensity on both T2-weighted and contrast-enhanced T1-weighted images (Figs. 1, 2, and 3). Facial nerves were easily identified in patients with small parotid gland lesions; however, large lesions produced some distortion of the normal course of the facial nerve and made its identification relatively difficult.

The main trunk of the intraparotid facial nerve could be identified in all cases. At the level of the parotid gland lesions, the intraparotid facial nerve of temporofacial or cervicofacial branch could be identified in 90% (45/50) of cases for radiologist 1 and in 88% (44/50) for radiologist 2. Radiologist 2 could not identify the facial nerve in the lesion involving the entire parotid gland. In five different superficial parotid gland lesions for each radiologist, the facial nerve could not be identified because it was difficult to distinguish from other linear structures such as septa. One parotid gland lesion located in the caudal side of the superficial lobe was incorrectly located by both radiologists. Table 2 shows diagnostic abilities for deep and superficial lobe lesions and accuracy of this method. Interobserver agreement was moderate (κ=0.41).

Evaluation by retromandibular vein

The retromandibular veins were identified in 94% (47/50) of cases for radiologist 1 and in 96% (48/50) for radiologist 2. In the case involving the entire gland, the retromandibular vein could not be detected by either radiologist because it had become stenosed. In another case in the deep lobe, radiologist 1 could not identify the vein, while radiologist 2 misinterpreted another vein as the retromandibular vein (Fig. 2). In one different superficial lobe case for each radiologist, the vein could not be identified. Two of six parotid gland lesions involving the deep lobe were not correctly located by this method by either radiologist. Three superficial parotid gland lesions for radiologist 1 and five superficial parotid gland lesions for radiologist 2 were misinterpreted as involving the deep lobes because the retromandibular vein was displaced laterally (Fig. 3). Table 2 shows diagnostic abilities for deep and superficial lobe lesions and accuracy of this method. Interobserver agreement was almost perfect (κ=0.93).

Evaluation by FN line

Deep parotid gland lesions were correctly located using this method in only one case for radiologist 1 and two cases for radiologist 2; the other deep lobe lesions were misdiagnosed. In one superficial parotid lesion, radiologist 1 misinterpreted the superficial lesion as deep because it was so large that more than half of the lesion was medial to the FN line. Table 2 shows diagnostic abilities for deep and superficial lobe lesions and accuracy of this method. Interobserver agreement was moderate (κ=0.48).

Comparison between direct and indirect methods

For deep lobe lesions, mean diagnostic ability of the direct identification method was significantly higher than that of the FN line method ($P<0.01$) but did not differ significantly from that of the retromandibular vein method. For superficial lobe lesions, mean diagnostic ability of the direct identification method was significantly lower than that of the FN line method ($P<0.01$) but did not differ significantly from that of the retromandibular vein method. Mean accuracy did not differ significantly among the three methods.

Discussion

The surgical aim for parotid gland lesions is complete excision while anatomically and functionally preserving the facial nerve [1]. In cases where the lesion is in close proximity to the nerve, from which it then needs to be dissected, and in inflammatory conditions that frequently lead to parenchymal fibrosis, safe nerve dissection is

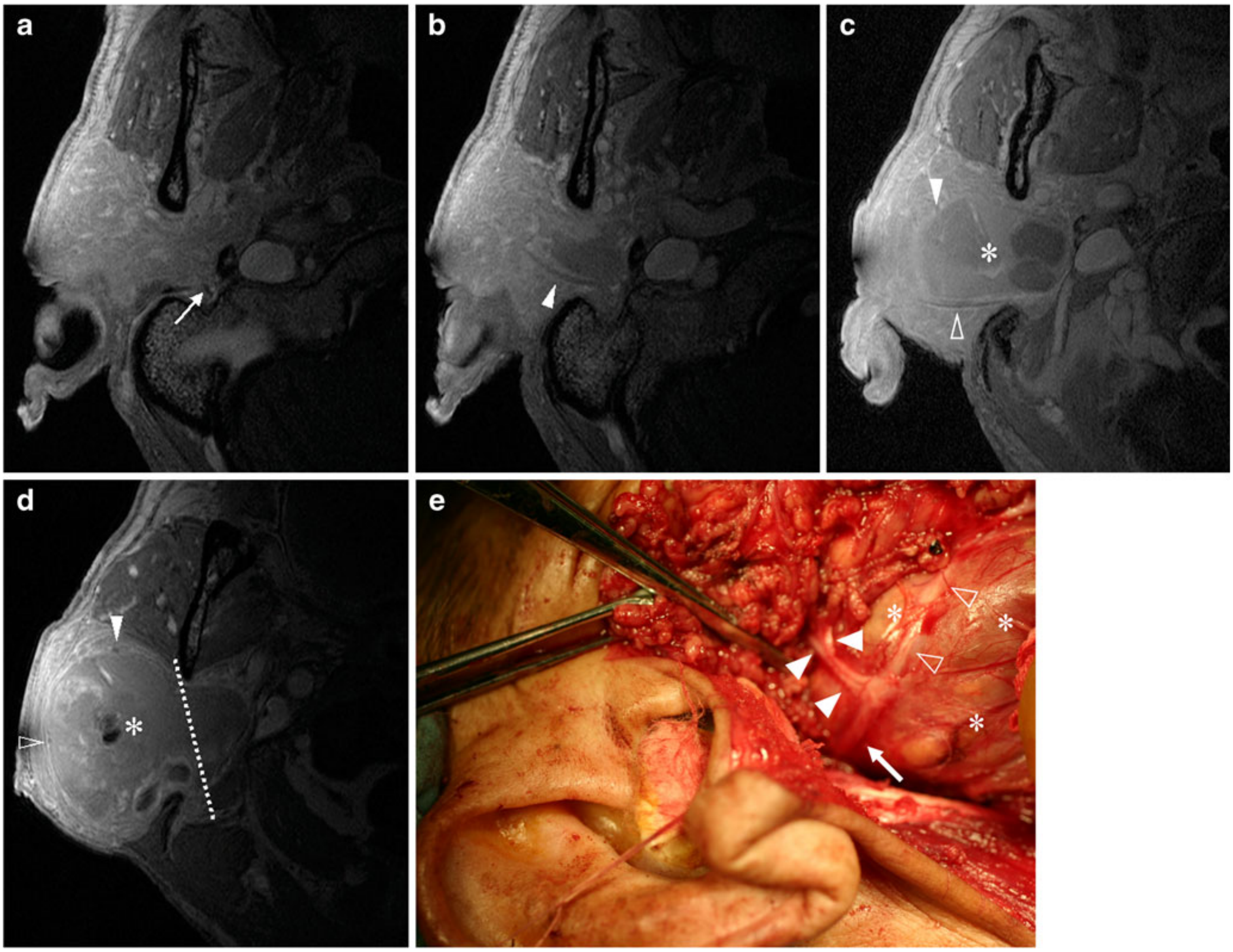


Fig. 2 MR images of a 78-year-old man with histopathologically proven Warthin's tumor in the deep lobe of the parotid gland. The figures show images in cranial to caudal order. **a** Axial contrast-enhanced T1-weighted imaging shows the main trunk of the facial nerve (*arrow*) as a structure of low signal intensity in the stylomastoid foramen. **b** The temporofacial branch of facial nerve (*arrowhead*) runs laterally. **c** On the caudal side, the cervicofacial branch of the facial nerve (*open arrowhead*) runs posterior to the parotid gland lesion (*asterisk*). **d** The temporofacial branch of the facial nerve (*arrowhead*) is displaced anteriorly and the cervicofacial branch (*open arrowhead*) is displaced laterally. These findings suggest that the parotid gland lesion is in the deep lobe. The retromandibular vein cannot be detected as it has become stenosed due to compression by the lesion. Most of the lesion is lateral to the FN line (*dashed line*). The position of the lesion relative to the FN line suggests that the lesion is in the superficial lobe. Surgical findings confirmed that the lesion was in the deep lobe

technically challenging. The incidence of permanent post-parotidectomy facial nerve damage is between 1.2% and 5.6% [14–17]. Deep localization of the parotid gland lesion is a major risk condition for facial nerve damage [17].

We determined the position of the facial nerve by tracing it in the stylomastoid foramen and then following it on sequential sections through the parotid gland, as described in a previous study [10]. Using these methods, the intraparotid facial nerve could be identified in most cases using 3.0 T MR imaging with surface coils, and direct identification of the intraparotid facial nerve was useful in correctly locating parotid gland lesions, particularly in the deep lobe. In general, surface coils generate the highest SNR peripherally, but typically are associated with degraded image quality because of the signal drop-off. However, we consider that these favorable findings result from increase of the spatial resolution by reducing the FOV, and by increasing the matrix size using the surface coil. Further, 3.0 T MR imaging could prevent decreased SNR due to increased matrix sizes. Despite relatively degraded imaging such as shading, the MR images were useful enough to depict the main trunk of the facial nerve located in the deep region, and consequently could depict the facial nerve in most cases. However, 3.0 T MR imaging is more susceptible than that at 1.5 T to motion artifacts [18]. Therefore, the facial nerve could not be routinely depicted

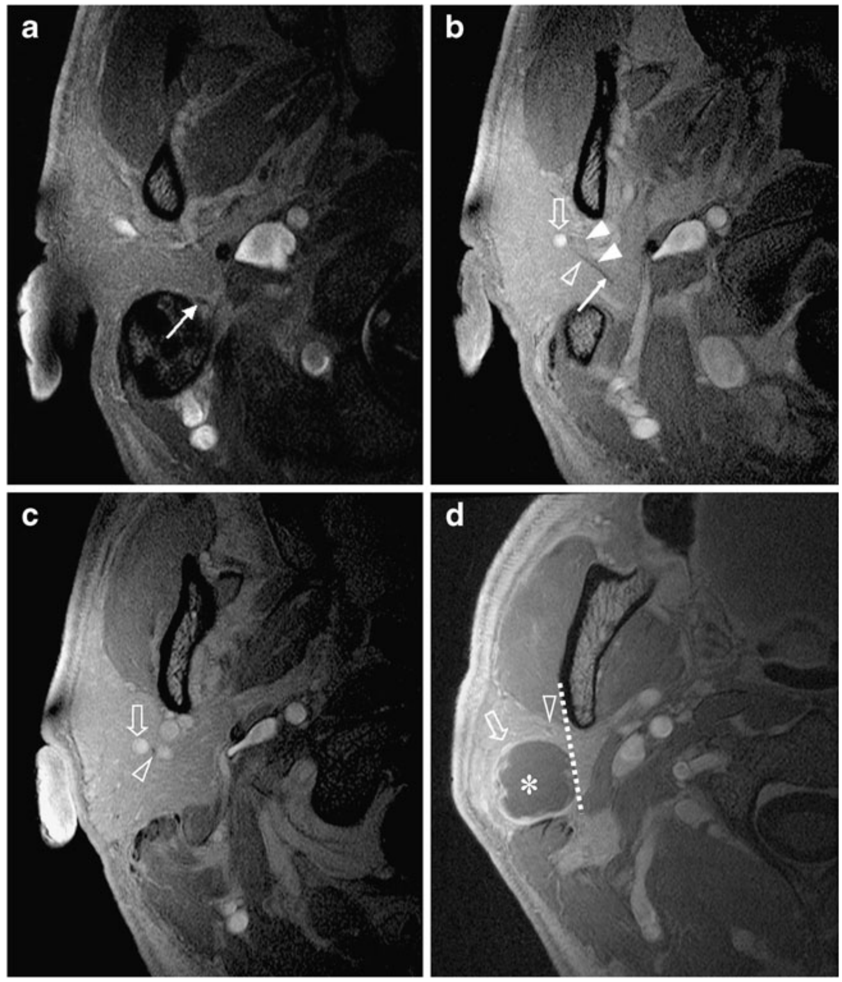


Fig. 3 MR images of a 54-year-old man with histopathologically proven lymphoepithelial cyst in the superficial lobe of the parotid gland. The figures show images in cranial to caudal order. **a** Axial contrast-enhanced T1-weighted imaging shows the main trunk of the facial nerve (*arrow*) as a structure of low signal intensity. **b**, **c** The cervicofacial branch of the facial nerve (*open arrowheads*) runs medial to the retromandibular vein (*open arrow*). **d** The cervicofacial branch (*open arrowhead*) is seen anteromedially to the lesion (*asterisk*); this displacement of the nerve suggests that the lesion is in the superficial lobe. The retromandibular vein (*open arrow*) is displaced anterolaterally to the lesion; this suggests that the lesion is in the deep lobe. Most of the lesion is lateral to the FN line (*dashed line*). The position of the lesion relative to the FN line suggests that the parotid lesion is in the superficial lobe. Surgical findings confirmed that the lesion was in the superficial lobe

in all cases because we could not differentiate this small structure from surrounding tissues when images were unqualified due to motion artifact, particularly in the caudal region of the parotid gland, in spite of reduced scan time of the potential characteristic in 3.0 T MR imaging; interobserver agreement remained moderate.

The results of the present study indicate that the retromandibular vein method is relatively reliable in

Table 2 Diagnostic ability for deep lobe lesions and for superficial lobe lesions and accuracy of each method in predicting the position of parotid gland lesions.

	Diagnostic ability for deep lobe lesions	Diagnostic ability for superficial lobe lesions	Accuracy
Facial nerve			
Radiologist 1	100% (6/6)	86.4% (38/44)	88% (44/50)
Radiologist 2	83.3% (5/6)	86.4% (38/44)	86% (43/50)
Mean	91.6%	86.4%	87%
Retromandibular vein			
Radiologist 1	66.7% (4/6)	90.9% (40/44)	88% (44/50)
Radiologist 2	66.7% (4/6)	86.4% (38/44)	84% (42/50)
Mean	66.7%	88.6%	86%
FN line			
Radiologist 1	16.7% (1/6)	97.7% (43/44)	88% (44/50)
Radiologist 2	33.3% (2/6)	100% (44/44)	92% (46/50)
Mean	25%	98.9%	90%

helping to localize parotid gland lesions. The retromandibular vein usually courses medial to the intraparotid facial nerve and is consequently used as a landmark. However, the vein only runs close to the temporofacial and cervicofacial branches at a distance of 5 mm from the bifurcation of the intraparotid facial nerve [19, 20]; it does not course along the main trunk and peripheral branches of the intraparotid facial nerve. This difference in course may cause a discrepancy with the results of the direct identification method, despite the fact that we did not find a significant difference between the results of the two methods. The retromandibular vein method is straightforward and has good interobserver agreement, although the retromandibular vein is not always visible in the caudal portion of the parotid gland or in very large lesions [8]. Therefore, the vein method may be recommended as an alternative when the facial nerve cannot be identified.

Meanwhile, the FN line is a good landmark to help localize parotid gland lesions in the superficial lobe. However, because in most cases we could not correctly predict the location parotid gland lesions found surgically to be in the deep lobe, this method does not appear to be useful for localization of such lesions. The FN line may be useful landmark when the lesion is likely to be in the superficial lobe. Similarly, it may be useful when the lesion is small because the reliability of the FN line is considerably influenced by lesion size. However, to prevent facial nerve damage, it is more important to correctly diagnose parotid gland lesions in the deep lobes [17]. Therefore, the results of the present study suggest that the FN line is not recommended for determining the location of parotid gland lesions.

The present study has some limitations. First, it included a limited number of patients, particularly for lesions in the deep lobe and malignancies. Therefore, further studies are required to validate the present results in a larger population. Second, the parameters for imaging sequences may need to be optimized, although not all sequence options used with 1.5 T are available in the 3.0 T MR system. To obtain better results, not only higher resolution but also faster imaging may be needed for more adequate evaluation of the facial nerve. Additionally, the surface coils used in the present study are not widely available. Nevertheless, once surface coils at 3.0 T become more widely available, this study might make sense in more optimized sequences designed to better visualize the facial nerve.

Conclusions

Other than in the caudal region of the parotid gland, the majority of intraparotid facial nerves could be identified on 3.0 T MR imaging with surface coils. The present study suggests that identification of the intraparotid facial nerve allow more accurate location of the parotid gland lesions in the deep lobes when compared with indirect methods.

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Conflict of interest statement We declare that we have no conflict of interest.

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