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Ultrasound can help to indirectly predict contact of parotid tumors to the facial nerve, correct intraglandular localization, and appropriate surgical technique

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Abstract

Background: The purpose of this prospective study is to evaluate the role of ultrasound in benign parotid tumor surgery, particularly by helping to identify the tumor location and its relationship to the facial nerve (FN) and by predicting the appropriate surgical approach.

Methods: Fifty patients underwent preoperative ultrasound. The course of the FN was indirectly defined, and the following predictions were made: contact of the tumor with the FN, the necessity for intraoperative nerve exposure, localization in the correct parotid lobe, and choice of the appropriate surgical technique.

Results: Contact of parotid tumors with the FN was determined with an accuracy of 96%. The need for intraoperative nerve exposure was incorrectly determined only once. The appropriate surgical technique was correctly predicted in 98% of the patients.

Conclusions: Ultrasound is helpful for indirectly predicting the relationship between parotid tumors and the FN. The retromandibular vein is the most important landmark.

KEYWORDS
facial nerve, parotid neoplasms, parotid surgery, salivary glands, ultrasonography

1 | INTRODUCTION

In recent years, benign parotid tumor surgery has evolved toward less invasive techniques. Currently, the most frequently performed surgery at some centers is extracapsular dissection (ECD), during which the facial nerve (FN) is not routinely identified.[1] To select the appropriate surgical technique, preoperative estimation of whether the tumor is in contact with the FN is very important. If the tumor has long-term contact with the nerve, superficial or partial superficial parotidectomy (SP) is necessary. If the lesion is located on the inner side of the FN in the deep parotid lobe, total parotidectomy (TP) is usually performed.

The various surgical possibilities have a great impact on the operative time (ranging from 40 minutes to 4 hours), on the incidence of FN paralysis both immediately postoperatively (10%-40%) and after sufficient recovery (1%-5%), and on the probability of postoperative Frey's syndrome.[2,3] Even the risk of a postoperative salivary fistula and thus the duration of wound healing vary greatly depending on the surgical method used.[4] It is of great importance to choose the appropriate surgical procedure preoperatively as precisely as possible in order to select a qualified surgeon and minimize

Abbreviations: DL, deep lobe; EAC, external auditory canal; ECD, extracapsular dissection; FN, facial nerve; SP, superficial parotidectomy; TP, total parotidectomy; US, high-resolution ultrasonography; RMV, retromandibular vein.

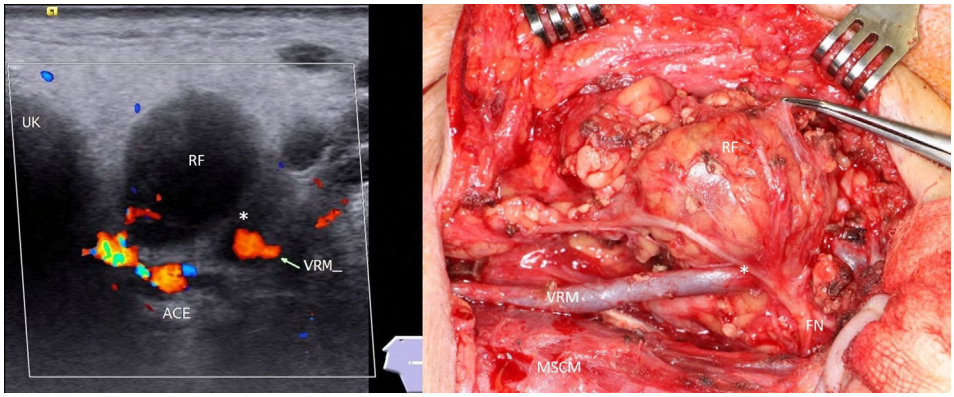

FIGURE 1 Ultrasound picture and surgical photo of a tumor (RF) in contact with the retromandibular vein (RMV) and the facial nerve (FN). Asterisk shows FN between tumor and RMV. ACE, external carotid artery; MSCM, sternocleidomastoid muscle; UK, mandible [Color figure can be viewed at wileyonlinelibrary.com]

intraoperative complications, as surgical skills vary among different surgeons. To date, there is no satisfactory method of preoperative diagnosis to determine the relationship of parotid tumors to the FN and to elect the most appropriate surgical technique.

The purpose of this prospective study is to evaluate the role of high-resolution ultrasound (US) imaging for better planning benign parotid tumor surgery, particularly for indirectly identifying the tumor location and its relationship to the FN and for helping to choose the appropriate surgical approach. Our hypothesis is that the simultaneous application of B-mode US and color-coded duplex US can help surgeons to preoperatively detect the most important anatomical landmarks in the parotid region (the retromandibular vein [RMV], external carotid artery, sternocleidomastoid muscle, posterior belly of the digastric muscle, mandible, and the distance to surface of the parotid gland) that provide indirect indications of the course of the FN and in particular, to assume the relationship of the FN to parotid tumors by the anatomical course of the RMV (Figure 1). It is known that the main trunk of the FN usually meets the RMV approximately 1.5-2 cm after it exits the stylomastoid foramen and runs directly along its superficial side (Figure 1). This constant relationship between the FN and the RMV and precise localization of the RMV may indirectly allow prediction of the relationship between the FN and a parotid lesion.

2 | MATERIALS AND METHODS

This prospective study was conducted between July 2016 and July 2017 in the department of Otorhinolaryngology, University Hospital Augsburg Germany. Each patient who was seen with a parotid lesion underwent an US examination of both parotid glands and the neck. If a benign tumor was suspected, a finding-adapted parotidectomy was planned. Additional MRI scans were performed only in patients with tumors of the deep lobe (DL) or large tumors that could not be completely assessed with US. Malignant tumors were excluded because total parotidectomies should always be performed in these patients. During the study course, one patient with a suspected benign tumor was ultimately determined to have a malignant tumor, and this patient was also excluded. Preoperative US examinations were performed with an Acouson S 2000 (Siemens, Erlangen, Germany) and linear transducer (4-9 MHz) usually at 9 MHz. The study was approved by the Ethics Committee (2016/22). Each patient provided informed consent. All adult patients with benign parotid tumors who underwent US examinations performed by one of two experienced clinical investigators (with >12 years of experience performing US scans) were included. The following objectives were determined preoperatively:

- Is there contact between the tumor and the facial nerve? Yes:__ No:__
- In which parotid lobe is the tumor located? Superficial parotid lobe: __; Caudal-superficial parotid lobe:__; or Deep parotid lobe: __
- Which surgical technique will be appropriate? 1. Extracapsular dissection; 2. Partial parotidectomy with main trunk exposure; 3. Superficial parotidectomy; or 4. Subtotal/total parotidectomy
- Will intraoperative exposure of a facial nerve branch be necessary? Yes: __ No: __ (relevant only in the case of extracapsular dissection)

Detailed documentation including video documentation of the structures that were closely related to parotid tumors was performed. The following landmarks were important for indirectly defining the course of the FN and for decision making: the RMV, external carotid artery, sternocleidomastoid muscle, posterior belly of the digastric muscle, mandible, and the distance to surface of the parotid gland. The US examination findings were documented preoperatively but were not shared with the other clinical investigator who performed the surgical procedures. The intraoperative findings were documented with photography, and the actual intraoperative characteristics and surgical method used were also documented and then compared with the preoperative US findings. Lesions that were between the FN branches were classified as being in the DL of the parotid because in those cases at least one part of the tumor was in the DL, and subtotal/TP was necessary.

Caudal-superficial lobe tumors were defined as those that were inferior to the FN and those in which the main body of the tumor was not medial to the FN (Figure 2).

Statistical analysis was performed to assess the sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy of preoperative US evaluations. Statistical analysis was performed using SPSS v.23 (SPSS Inc, Chicago, Illinois). Statistical significance was set at $P < .05$.

2.1 | Surgical techniques

The following surgical techniques are available.

2.1.1 | Extracapsular dissection (ECD)

If the tumor is located in the inferior part of parotid gland (caudal pole) and there is sonographic evidence of slight or no contact with the FN, an ECD can be performed. The parotid capsule is opened, and the tumor is dissected along with a few millimeters of healthy parotid tissue without trying to identify the FN.[5] ECD is a form of partial parotidectomy that does not involve identification of the main trunk of the FN.

2.1.2 | Partial SP

This technique is also defined as partial parotidectomy with exposure of the main trunk of the FN. If the tumor is near the auditory canal or very close to the ascending mandibular branch, a partial parotidectomy with exposure of the main trunk of the FN is often performed. First, the main trunk of the FN is dissected, and after the bifurcation, only the cervicofacial branch is followed peripherally. The tumor is then removed along with the entire caudal portion of the parotid gland.

FIGURE 2 Drawing of a tumor in the "caudal superficial parotid lobe" [Color figure can be viewed at wileyonlinelibrary.com]

2.1.3 | Superficial parotidectomy

If the tumor is central and there is a suspicion of a close relationship to both the cervicofacial and temporofacial branches of the FN, lateral or SP is usually required.

2.1.4 | Subtotal/TP

If the tumor is medial to the FN in the DL of the parotid gland, complete mobilization of the nerve and TP is required.

3 | RESULTS

This study included 50 patients who were preoperatively examined and surgically treated by one of the two clinical investigators in the department of Otorhinolaryngology. Twenty-nine patients were men, and 21 were women, with a mean age at the time of diagnosis of 59.2 years (±17.1 years), with a range from 8 to 91 years. In 27 patients, the lesions were in the right parotid gland, and in 23 patients, they were in the left parotid gland. Fifty-three lesions were detected in the 50 patients. The mean tumor size was (length × width × height) 22.2 × 17.3 × 29.2 mm (±9.6 mm). The mean tumor volume was 7.7 cm^3 (±8.7 cm^3). Histological examinations of the parotid tumors revealed the following entities: pleomorphic adenomas (n = 23), Warthin's tumors (n = 22), cyst (n = 3), intraparotid lymph nodes (n = 2), an oncocytoma (n = 1), a lipoma (n = 1), and a myoepithelioma (n = 1). Two patients had two Warthin's tumors each, and one patient had a simultaneous Warthin's tumor and a pleomorphic adenoma.

The following landmarks could always be identified: the tumor borders, the sternocleidomastoid muscle, the posterior belly of the digastric muscle, the surface of the mandible, and the surface of the parotid gland. The RMV could be preoperatively identified in 49 of 50 patients (98%), and external carotid artery in 42 of 50 cases (84%).

Contact of the parotid tumor with the FN was preoperatively assumed in 29 patients, and no contact was assumed in 21 patients. In 48 patients, contact or lack of contact with the FN was confirmed intraoperatively. In one patient, there was no contact of the FN with the tumor. Although the tumor was in contact with the RMV, it was very far anterior and caudal, so that the marginal mandibular branch of the FN had no contact with the tumor (Figure 3). In the second

patient, the tumor was small (14 × 10 × 19 mm), caudal and anteriorly located near the mandible and was falsely believed not to be in contact with the FN (Figure 4). Thus, in terms of nerve contact, a diagnostic accuracy of 96% was achieved (Table 1). Intraoperatively, a contact of the parotid tumor with the FN was identified in 29 of 50 cases (58%).

Despite these two errors, US incorrectly predicted the need for intraoperative nerve exposure only once. This is partly because the necessity for nerve exposure is only questionable when performing an ECD. All other surgical procedures require preparation of the main trunk of the FN and at least one additional nerve branch (21 patients). In 29 patients, ECD was performed. In all of 18 patients, the need for nerve exposure was correctly identified, and in 10 of 11 patients, the lack of a need for nerve exposure was also correctly identified. Thus, the diagnostic accuracy was 96.5% (in 28 of 29 patients).

The location of tumors within the parotid lobes is important information that is useful in order to choose the appropriate surgical technique. In all of 23 patients, the tumor was correctly localized to the caudal-superficial parotid lobe (the inferior part of the parotid gland). In 20 of 21 (95.2%) patients, the tumor was correctly localized to the superficial lobe. In one patient, the tumor was small and deep within the gland (4.2 mm from the surface) and was incorrectly estimated to be in the DL although lateral to the RMV (Figure 5). In 6 of 7 patients, the tumor was correctly localized to the DL. In one patient, the tumor was incorrectly assumed to be in the superficial lobe but was actually in the DL (Figure 6). Overall, the accuracy of tumor localization to the correct lobe was 48 of 50 (96%) (Table 1).

The needed surgical technique was always reevaluated during surgical procedure. The appropriate surgical technique was correctly assumed in 49 of 50 cases (98%). All 29 ECD procedures and 6 partial parotidectomies with exposure of the main trunk were correctly chosen. A total of 5 of 6 superficial parotidectomies were correctly assumed. In one patient, the tumor was incorrectly localized to the DL, and sub-TP was planned. However, only SP was determined to be necessary intraoperatively (Figure 5). In nine patients, TP was correctly chosen; this procedure was chosen twice because of multiple intraoperative tumors.

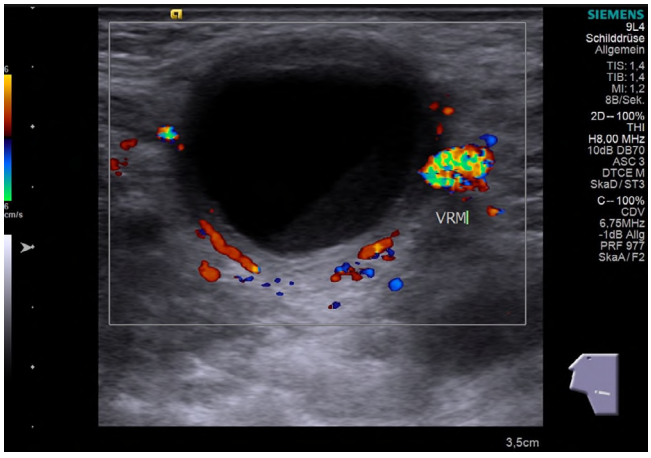

FIGURE 3 Tumor in contact with retromandibular vein (RMV) but without contact to the facial nerve [Color figure can be viewed at wileyonlinelibrary.com]

4 | DISCUSSION

In recent years, there has been a development of parotid gland surgery toward less invasive procedures.[6] Therefore, accurate preoperative evaluation of the relationship between tumors and the FN has become important, in order to better plan the appropriate surgical technique and minimize the risk of FN paralysis, which has a great impact on patients' quality of life.[2]

Direct visualization of the FN in its extratemporal route with routine imaging is very difficult, although it is seems possible.[7-9] The intraparotid variability of the FN and its complex branching pattern hinder accurate identification.[10] Initial studies of tractographic reconstructions of the extracranial FN are promising but are very time consuming and are not adequate in routine clinical practice.[11] The use of indirect landmarks and hypothetical lines connecting anatomical structures to predict the relationship between parotid lesions and the FN have been studied mainly in the context of MRI or CT.[12,13]

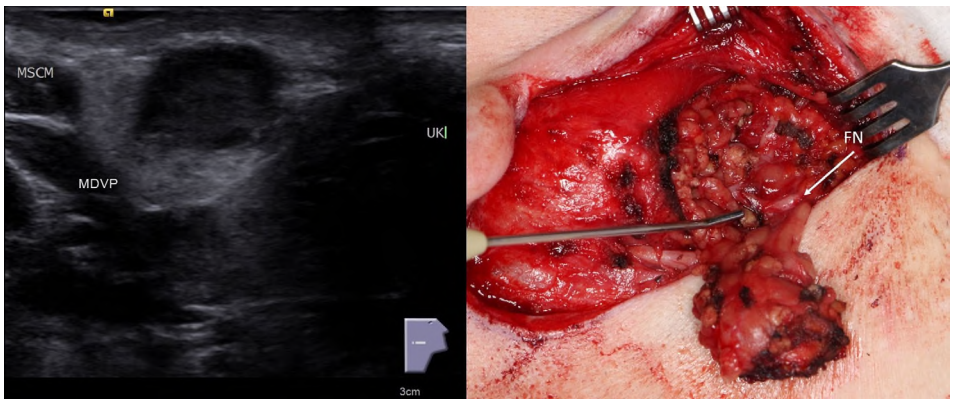

FIGURE 4 Tumor near the mandible (UK) with contact to the facial nerve (FN). MDVP, musculus digastricus venter posterior; MSCM, sternocleidomastoid muscle [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Diagnostic accuracy of ultrasound assessing contact of parotid tumor with the facial nerve and determining the tumor in the right parotid lobe (n = 50)

Variable	Tumor-nerve contact	Caudal-superficial parotid pole	Superficial parotid lobe	Deep parotid lobe
TP	28	23	20	6
FP	1	0	1	1
TN	20	27	28	42
FN	1	0	1	1
Sensitivity (95% confidence interval)	0.965 (0.86-0.99)	1 (0.88-1)	0.952 (0.76-0.99)	0.857 (0.48-0.98)
Specificity	0.952 (0.80-0.99)	1 (0.90-1)	0.965 (0.86-0.99)	0.977 (0.92-0.99)
PPV	0.965 (0.86-0.99)	1 (0.79-1)	0.952 (0.80-0.99)	0.857 (0.48-0.98)
NPV	0.952 (0.80-0.99)	1 (0.88-1)	0.965 (0.86-0.99)	0.977 (0.92-0.99)
Accuracy	0.96 (0.84-0.99)	1 (0.90-1)	0.96 (0.84-0.99)	0.96 (0.86-0.99)

Abbreviations: FN, false negative; FP, false positive; NPV, negative predictive value; PPV, positive predictive value; TN, true negative; TP, true positive.

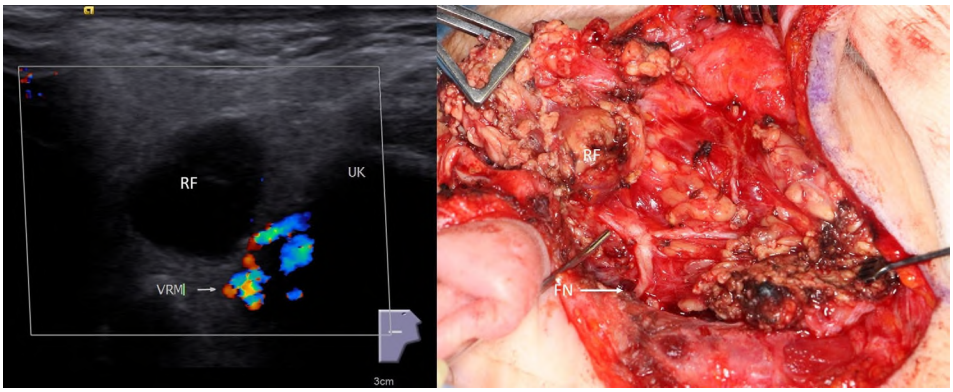

FIGURE 5 Tumor (RF) lying deeply into the parotid gland but retromandibular vein (RMV) is even deeper. FN, facial nerve; UK, mandible [Color figure can be viewed at wileyonlinelibrary.com]

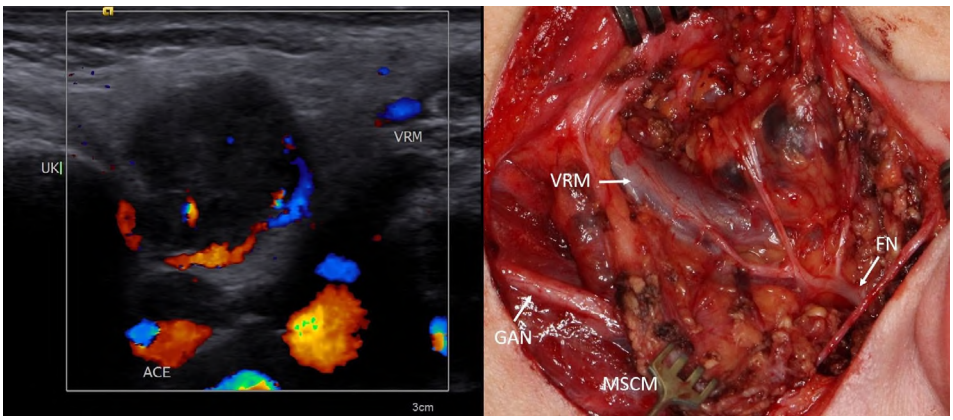

FIGURE 6 Tumor falsely assumed in the superficial lobe. ACE, external carotid artery; FN, facial nerve; GAN, great auricular nerve; MSCM, sternocleidomastoid muscle; UK, mandible; RMV, retromandibular vein [Color figure can be viewed at wileyonlinelibrary.com]

The RMV is a frequently used anatomical landmark with a diagnostic accuracy of 81%-87% in MRI studies.[14-16] The Stensen duct has also been studied as an indirect landmark for the FN with CT sialography, which is an invasive technique and therefore is currently obsolete, and later with MRI.[12,14,17] A major drawback of the parotid duct criterion is that the duct cannot always be visualized, and it is only visible and relevant in the anterior parts of the gland. However, most lesions are located in the posterior and inferior parts of the parotid gland. Other landmarks are the FN line, the Conn's arc, and the Utrecht line, which have accuracies ranging between 60% and 90% in various studies.[13,18-20]

To the best of our knowledge, this is the first prospective study to indirectly examine the diagnostic accuracy of the relationship between the FN and benign parotid lesions with US. In our study, the most important landmark was the RMV, which is considered a "hard" criterion (Figures 1 and 7). Localizing the RMV with US can be challenging sometimes

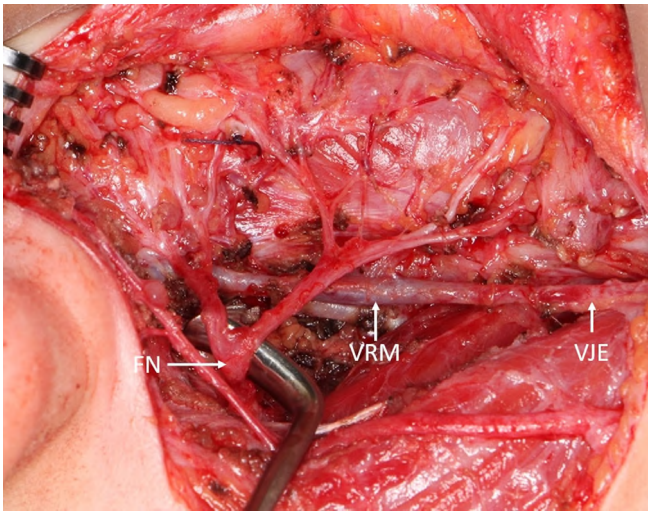

FIGURE 7 Surgical photo showing the external jugular vein (VJE) turning into retromandibular vein (RMV) and the tight correlation of facial nerve (FN) with RMV [Color figure can be viewed at wileyonlinelibrary.com]

and in some cases impossible.[16] We routinely identified the external jugular vein at the middle of the sternocleidomastoid muscle with duplex US and followed it cranially toward the parotid gland until it changed into the RMV (Figure 7). During this procedure, it is important to apply as less pressure as possible in order to avoid eliminating blood flow in the vessel. In some patients, it was necessary to follow the facial vein cranially in order to identify the RMV. Furthermore, in difficult situations, we identified the external carotid artery and followed it cranially to locate the maxillary artery, which lies deeper in the DL of the parotid gland but can sometimes be confused with the RMV (Figure 1). This procedure, allowed an identification rate of the RMV in 98% of the cases which is above that described in literature but is sometimes time consuming. Nevertheless, the variability of the vein and preoperative inflammation and displacement caused by large lesions can be misleading.[21] Lim et al found that the accuracy of the RMV landmark was higher in patients with tumors <2 cm.[13] Seldom the RMV can run superficially to the FN and lead to misinterpretation of the US findings.[22] Therefore, the relationship of tumors to other anatomical landmarks has also been considered in this study. Tumors in the inferior part of the gland near the posterior belly of the digastric muscle and the sternocleidomastoid muscle are always far away from the FN and suitable for ECD. Tumors near the mandible, on the other hand, usually contact the marginal mandibular branch of the FN. Lesions that are directly inferiorly to the cartilage of the external auditory canal (EAC) usually contact the main trunk of the FN and are not suitable for ECD. Tumors that are anterior to the EAC and near the temporomandibular joint usually contact the cranial part of the FN and mostly require lateral parotidectomy. Furthermore, tumors more than 3 mm from the surface of the parotid gland have an increased probability of being in the DL.[23,24] This multifactorial assessment based on US examination improves the diagnostic accuracy but is sometimes time consuming and requires an experienced investigator.

The diagnostic accuracy of our procedure is superior compared to the existing studies.[11-14,24] Lesion contact with the FN and localizing the lesion in the correct lobe were correctly predicted in 96% of the patients. As the FN is the boundary between the superficial lobe and the DL of the parotid gland, accurately localizing the nerve is crucial for predicting the correct lobe. In our study, we decided to extend this technical (not natural) division in the superficial lobe and the DL with the use of the "caudal-superficial parotid lobe." Our data (23 of 50), which are in accordance with current studies, indicate that most benign parotid tumors are located in the caudal-superficial lobe.[25] With the introduction of ECD, the identification of a lesion in the caudal-superficial parotid lobe has also gained important clinical relevance.[2] Furthermore, the sonographic identification of a tumor in this region of the parotid gland is comparatively easy. In our study, this new classification was always correctly applied and played a major role in the high accuracy of US. The probability of postoperative facial palsy or Frey's syndrome in patients with tumors of this region was significantly lower than in those with tumors in other locations in a recent study, which is in agreement with our experience.[26]

As ECD does not require the exposure of any branch of the FN, it was interesting to preoperatively predict whether intraoperative exposure of the FN would be needed. Because most of the tumors that were removed with ECD were in the caudal-superficial parotid lobe, which can be excellently evaluated with US, the prediction was accurate (96.5%). Nevertheless, it should be noted that ECD was performed only in 29 patients; thus, the results should be verified in a larger population. Furthermore, in our study the tumor was in contact with the FN only in 58% of the cases, which is comparable to existing literature.[11]

Prediction of the appropriate surgical technique is important in order to evaluate the risk of complications, the operative time, and the difficulty of surgery. Excellent planning for the appropriate surgical technique was achieved in our study because of accurate preoperative identification of the relationship between tumors and the FN. Of course, the appropriate technique was reevaluated during surgery and changed if necessary.

The sonographic assessment of the parotid gland is fast, cost-effective, and safe and even provides better spatial resolution of the examined structures than standard MRI sequences.[27] In addition, the possibility an otolaryngologist (who has experience in the surgical treatment of parotid tumors) performing preoperative US allows for better assumption of the

intraoperative situation. In contrast to common opinion, lesions in the DL of the parotid can also be studied.[28] In patients with tumors located behind the mandible (iceberg tumors), however, MRI has a clear advantage.[29] The main disadvantage of US is the limited reproducibility and the variability in the results depending on the experience of the examiner.[30] The investigators in our study were very experienced both in US (more than 50 examinations/year) and in parotid surgery (intensive surgical experience of more than 10 years). Thus, the results of this study cannot be undoubtedly transferred to less experienced examiners. Furthermore, both investigators prefer performing ECD in suitable cases. This influenced the results of question 3 and 4 which were dependent from their preferences. For surgeons who prefer lateral parotidectomy in all cases, questions 3 and 4 would be irrelevant. Nevertheless, this is the first study to show the importance of the RMV for indirectly identifying the course of the FN, which may help less experienced ultrasound examiners to reproduce these results. Furthermore, since the region of the FN can now be better predicted, US (14 or 18 MHz) may be able to directly identify the FN.[8] Lastly, it would be interesting to determine if the importance of the RMV landmark could also be verified on MRI examinations.

5 | CONCLUSION

Modern US is helpful for indirectly predicting the relationship between parotid tumor and the FN, for correctly identifying the parotid lobe involved, and for helping to choose the appropriate surgical technique; however, a high degree of expertise is needed and results are not easily reproductive. The RMV was the most important landmark identified in our study.

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