

Assessment of salivary gland tumors using MRI and CT: impact of experience on diagnostic accuracy

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Abstract

Rationale and objectives To analyze the accuracy of radiological diagnosis in MRI and CT studies of salivary gland tumors depending on the radiologist's experience.

Materials and methods Three radiologists with differing experience (R1 > 20, R2 > 11, and R3 > 7 years, respectively) retrospectively reviewed 128 cases (116 MRI, 12 CT studies) with suspected salivary gland tumors regarding dignity and classification using histopathology as a reference standard. Sensitivity, specificity, positive/negative predictive value and inter-observer agreement (using Cohen's κ) were calculated to compare diagnostic performance.

Results Lesions were benign in 87 and in 23 cases malignant. Neoplasia was absent in 18 cases (15 cases without neoplasia and 3 cases without disease). The highest inter-observer agreement for determining dignity using CT was found between R1 and R2 ($\kappa = 0.74$, $p < 0.001$), and the lowest between R2 and R3 ($\kappa = 0.28$, $p < 0.001$). MRI sensitivity/specificity for classifying pleomorphic adenomas was as follows: R1 (100%/100%), R2 (76.92%/87.01%),

R3 (43.53%/67.53%), and for CT: R1 (100%/100%), R2 (100%/88.89%), R3 (66.67%/88.89%); for Warthin's tumor using MRI: R1 (100%/97.44%), R2 (68.42%/83.33%), R3 (50.00%/67.95%), and using CT: R1 (100%/100%), R2 (50.00%/100%), R3 (100%/100%); for squamous cell carcinomas using MRI: R1 (100%/100%), R2 (75.00%/97.12%), R3 (75.00%/99.04%), and using CT: R1 (100%/100%), R2 (66.67%/88.89%), R3 (66.67%/66.67%). The highest agreement was found between R1 and R2 for MRI ($\kappa = 0.62$, $p < 0.001$), and the lowest between R1 and R3 at MRI ($\kappa = 0.28$, $p < 0.001$).

Conclusion Diagnostic accuracy in the assessment of salivary gland tumors strongly depends on the observer's expertise and increases with higher experience.

Keywords MRI · CT · Salivary gland tumor · Radiological experience · Diagnostic accuracy

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Introduction

Salivary gland tumors represent approximately 5% of all head and neck tumors [15, 31]. The annual incidence of salivary gland tumors varies between 3.3 and 10.3 cases per 100,000 and for malignant tumors from 0.8 to 1.7 cases per 100,000 in Western countries [1, 3, 4, 9]. The majority (55–75%) of these lesions, however, are benign and consist mainly of pleomorphic adenomas. Mucoepidermoid carcinoma is the most common malignant tumor, while the parotid gland is most affected from all salivary glands [13, 34, 37]. Some studies predicted an increased incidence of salivary gland tumors as high as 5% per year [22].

Therefore, a correct pre-operative diagnosis of salivary gland tumors is particularly important for a correct, appropriate and instant treatment [12]. Since early diagnosis improves the prognosis of salivary gland tumors [17], it is essential for successful treatment of malignant salivary gland tumors of the first degree (“low grade”) with a 5-year survival rate of up to 90%. The 5-year survival rate in patients with high-grade tumors reaches 50% [11, 26].

The methods of diagnosis primarily depend on the location of lesions, and thus, fine-needle aspiration cytology (FNAC) and ultrasound are mainly applied to lesions of the superficial glands. For lesions of the small salivary glands, lower lobes or suspected cases of malignancy, other methods like MRI or CT should be used. One of the advantages of MRI and CT techniques is the ability to gauge the extent and invasion of the tumor, which can be additionally used for diagnosis [5, 6, 20]. CT allows a better diagnosis in case of bone infiltration, inflammation and vascular injury. When a tumor is suspected, however, MRI should be preferred as it allows a more accurate assessment of the extent of infiltration and tumor demarcation [35].

The value of the diagnostic methods (MRI, CT) in the diagnosis of salivary gland tumors was determined in several studies [18, 30], as well as the importance of multidetector CT (MDCT) for better assessment and investigation of inflammatory pathologies and tumor extension [24, 25]. Furthermore, enhancement in imaging of certain tumors is best assessed by dynamic CT/MRI [21]. However, the influence of radiological experience on the diagnostic accuracy and inter-observer agreement has not been investigated to date.

In the current era of oncology, salivary gland tumors are interdisciplinarily treated. As ear, nose and throat (ENT) physicians with varying amounts of experience in radiology have access to imaging data, CT and MR scans are routinely reviewed before surgery. Furthermore, experience levels of the initially reporting radiologists in radiology departments differ considerably.

This retrospective study includes the radiological evaluation of MR/CT images by three radiologists with differing

experience in order to determine the influence of experience on the radiological diagnosis of salivary gland tumors.

Materials and methods

Patients

This study was approved by the local ethics committee with a waiver for written informed consent. From 2006 to 2012, 203 patients were examined at our institute with suspected salivary gland tumors; 75 of those were excluded either due to missing histopathological findings or because of conspicuous features in MRI/CT images resulting from a prior iatrogenic procedure. The remaining 128 cases were retrospectively analysed in this study (Table 1). The diagnosis was performed based on 116 MRI or 12 CT examinations. In 127 cases, a resection (99%), and in one case (1%) an FNAC was performed for histopathological evaluation. The average time between radiological examination and surgery was 28 days (range 1–243 days).

Magnetic resonance imaging (MRI)

MRI examinations were performed using a head and neck coil combination with 1.5 Tesla units (Magnetom Avanto, Siemens, Erlangen, Germany). Turbo spin-echo (TSE) (TR/TE 539/13 ms) and spin-echo (SE) (TR/TE 600/17 ms)

Table 1 Histological findings, with morphology codes of international classification of diseases for oncology (ICD-O) [14]

Medical findings	Cases
Squamous cell carcinoma (SCC) 8070/3	15
Other malignant tumors	8
Adenoid cystic carcinoma (ACC) 8200/3	3
Adenocarcinoma (NOS) 8140/3	2
Non-Hodgkin's lymphomas (NHLs) 9680/3, 9699/3	2
Melanoma 8720/3	1
Pleomorphic adenoma 8940/0	42
Warthin's tumor 8561/0	40
Other benign tumors	5
Cystadenoma 8440/0	2
Hemangioma 9120/0	1
Neurofibroma 9540/0	1
Oncocytoma 8290/0	1
Diseases without neoplasm	15
Cyst	7
Sialadenitis	4
Lymphadenitis	2
Sialadenosis	2
No pathological finding	3

sequences of T1-weighted images in transverse direction were acquired before and after contrast administration. Additional images with fat suppression in coronal (TR/TE 773/17 ms) and sagittal planes were acquired. The T2-weighted images (TSE) with fat suppression were included in transverse plane (TR/TE 4200/110 ms); 113 of 116 patients received Gd-DOTA as contrast agent (Dotarem, Guerbet, France) with 0.1 ml/kg of body weight. In three cases, no contrast agent was administered.

Computed tomography (CT)

The CT examinations were performed with a dual-source CT scanner (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany). The rotation time was 0.28 s with a collimation of 64×0.6 mm, and temporal resolution of 75 ms. The images were obtained with a tube voltage of 80–140 kV and a slice thickness of 4 mm. Contrast agent was intravenously injected with 2 ml/s flow-rate (80 ml Iopamidol, Imeron 400, Bracco, Konstanz, Germany).

Radiological performance

All imaging data were reviewed by three radiologists with varying amounts of experience. The first radiologist (R1) had more than 20 years of experience, the second radiologist (R2) 11 years, and the third radiologist (R3) 7 years of experience in head and neck imaging. Readers were blinded to histopathological results, medical history and prior radiological reports. To provide a better comparability of readouts, observers were allowed to evaluate each case for a maximum time of 10 min.

Image analysis

Evaluation of imaging data was performed on regular PACS workstations (Centricity 4.2, GE Healthcare, Dornstadt, Germany); 116 (91%) MRI and 12 (9%) CT scans were diagnosed.

To determine malignancy or benignity, reviewers rated tumor dignity on the basis of presented images. The differentiation between malignant or benign lesions was made based on criteria that have been thoroughly described elsewhere [2, 8, 16, 23, 27, 36]. Images were randomly presented to reviewers and their diagnoses were documented on evaluation sheets. The evaluation sheets contained free description text for diagnosis without any predefined diagnoses and fields with pre-defined values for localization and affected glands.

For tumor classification, the entity was regarded as correct when the radiological diagnosis corresponded to histopathological findings. Differential diagnoses were

not considered. For dignity determination, diagnoses with benign tumors were rated as benign and with the same method assessed for malignant tumors. If incorrectly affected glands or localization were reported, the diagnosis was considered wrong.

Statistical analysis

Statistical evaluation of the results was performed using commercially available software (MedCalc statistical software version 12.7.2; MedCalc Software bvba, Ostend, Belgium, and BiAS 8.6.0, Epsilon Verlag, Frankfurt am Main, Germany). A p value < 0.05 was considered as statistically significant. To assess patient distribution, a t test and a Chi-square test with regard to gender and age were used. The values for sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the three raters (R1, R2, R3) were calculated regarding dignity and entity. For measuring the agreement among the readers, Cohen's kappa values (κ) were calculated and interpreted as follows: $\kappa < 0.2$ slight; $0.2 \leq \kappa < 0.4$ fair; $0.4 \leq \kappa < 0.6$ moderate; $0.6 \leq \kappa < 0.8$ substantial; $\kappa > 0.8$ almost perfect agreement [19].

Results

Dignity

R1 achieved the highest values of all raters for malignancy/benignity assessment, both using MRI and CT with values of 100% for sensitivity, specificity, NPV and PPV. One exception was the determination of benignity by MRI, which ranged from 91.6 to 98.7%. For benignity assessment using MRI, R3 obtained higher sensitivity values than R2 (difference: 7.3%). In benignity assessment using CT, R2 and R3 reached the same values. However, they differed slightly in specificity (2.0%) and PPV (5.8%) for malignancy assessment (Table 2).

For malignancy assessment using CT, the radiological performance was proportional to the radiological experience, except for the sensitivity and NPV, where R2 reached the same results as R1 (100%).

The agreement (k) among readers ranged from 0.45 to 0.50 ($p < 0.001$) for MRI. For CT, a more distinct distribution of the Cohen's kappa values was found. The greatest agreement was detected between R1 and R2 ($\kappa = 0.74$; $p < 0.001$) and the lowest between R2 and R3 ($\kappa = 0.28$; $p < 0.001$); the value of R1–R3 was in between ($\kappa = 0.50$; $p < 0.001$).

Table 3 (continued)

		Histopathological findings																					
		MRI							CT														
<i>n</i> =		Pleo- mor- phic ade- noma	Warthin	SCC	Adeno- carci- noma	Mela- noma	Non- Hodg- kin's lym- phoma	ACC	Cyst	Lym- phad- enitis	Sialad- enitis	Sialaden- osis	Hae- man- gioma	Neu- rofi- broma	Cys- tad- enoma	Onco- cytoma	With- out path. find- ings	Pleo- mor- phic ade- noma	Warthin	SCC	Lym- phad- enitis	Sialad- enitis	With- out path. find- ings
39		17	17	3	2	1	2	3	7	1	2	2	1	1	2	1	2	3	2	3	1	2	1
R3	Pleomor- phic adenoma	17	17	3			1	1	2						1		2						
	Warthin	17	19	9			1	3	1	1	1	1	1	2	2		2		2				
	SCC																		2				
	Adenocar- cinoma			2																			
	Melanoma				1																		
	Carcinoma	2					2	1	1	1	1	1	1	1			1	1				2	
	Lymph node pathol- ogy	1									1	1									1		1
	Cyst	1							1														
	Sialadenitis	1																					
	Sögren syn- drome	1																					
	Neurogenic tumor	1																					
	No diag- nosis										1												

Fig. 1 Calculated values for dignity for MRI (a) and CT (b) sorted by observers (R1 > 20, R2 = 11, R3 = 7 years of radiological experience)

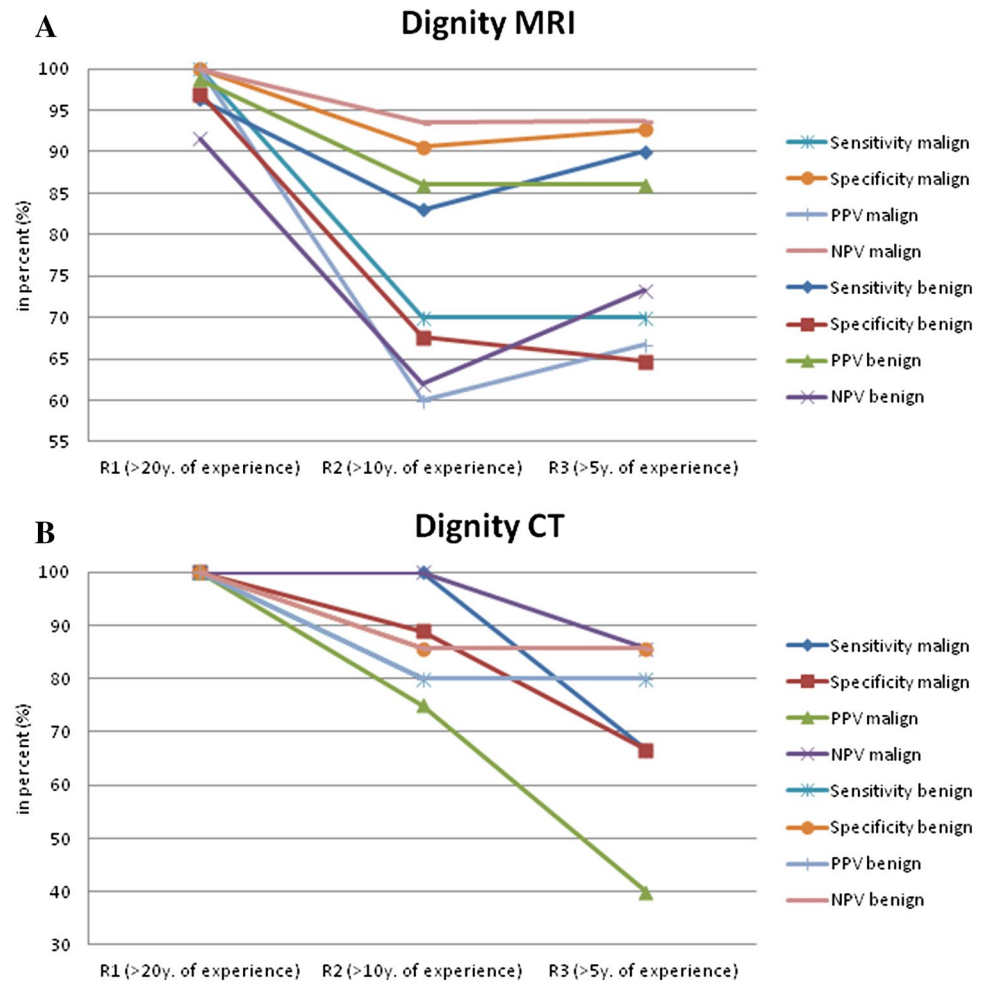
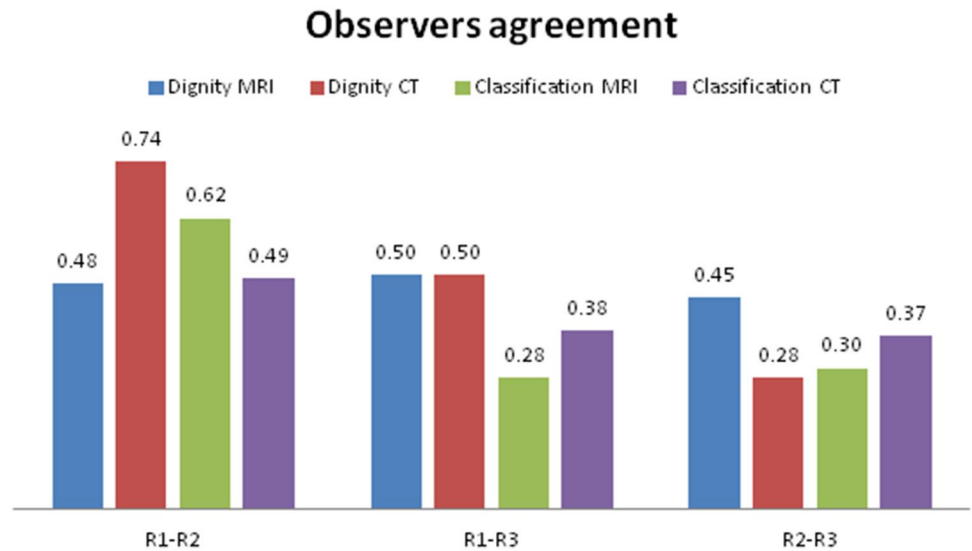


Fig. 2 Inter-observer agreement regarding classification and dignity for MRI/CT, assessed by Cohen’s Kappa *k* for the most experienced observer R1 (> 20 years), the less experienced R2 (11 years) and the least experienced R3 (7 years)



different cases. For benignity assessment using MRI, R3 achieved better results in up to 11% of cases in comparison to R2. The difference in sensitivity between R1 and R3 was 6.10 and 7.31% between R3 and R2. A similar study

including two radiologists with at least 5 years of experience resulted in similar values [39]. In our study, however, there was always a difference (6–33%) between R1 and the other two reviewers.

For malignancy assessment using MRI, R2 and R3 achieved the same sensitivity and almost the same values for specificity. These results are similar to the results of a study with two observers, who had 5 and 10 years of experience, respectively [7]. However, in contrast to our study, the results were not calculated separately for each radiologist. The results of R1 for the sensitivity in malignancy assessment using MRI or CT are similar to a study conducted with experienced radiologists [29]. Furthermore, the results of

our study are based on histopathology, resulting in a higher accuracy of the reference standard [32].

For tumor classification using MRI, we noted a confusion of Warthin's tumors with pleomorphic adenomas. R3 assessed 17 of 38 (R2:6; R1:0) cases with Warthin's tumors as pleomorphic adenomas and 17 of 39 (R2:4; R1:0) cases with pleomorphic adenomas as Warthin's tumor (Figs. 3, 4). This might also explain the relatively good results of R3 for dignity assessment, since R3 distinguished benign from

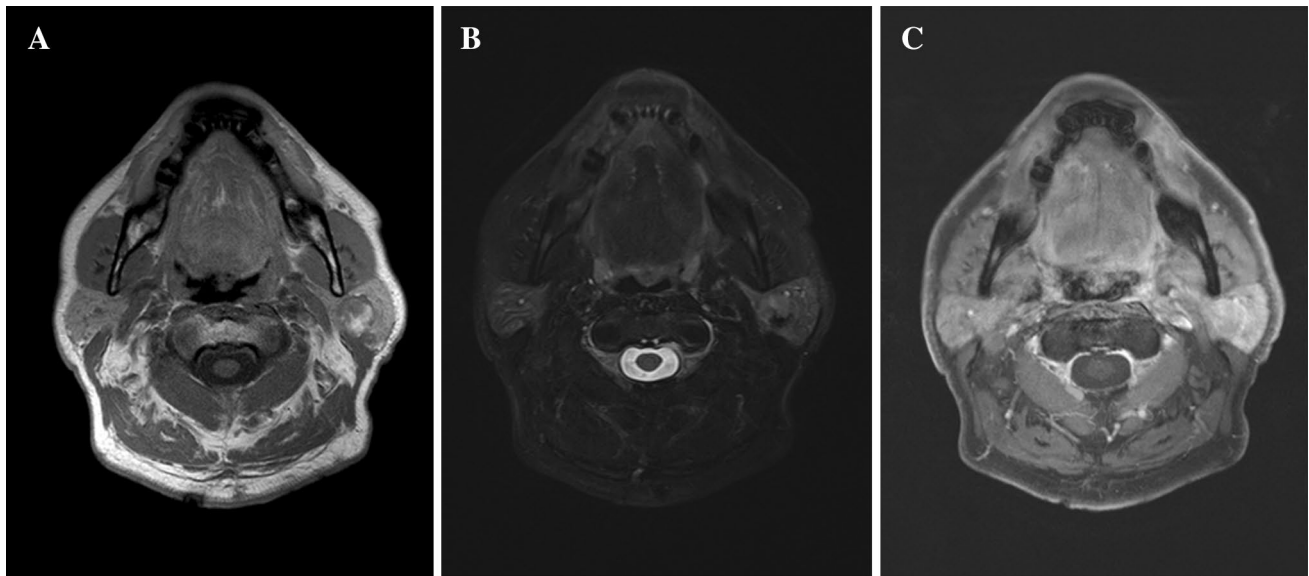


Fig. 3 A 69-year-old man with a histologically confirmed Warthin's tumor of the left parotid gland. R1 diagnosed it correctly as Warthin's tumor and diagnoses of R2/R3 were incorrect (pleomorphic ade-

noma/malignancy). **a** axial T1; **b** fat-saturated T2 and **c** contrast-enhanced T1 image with fat-saturation

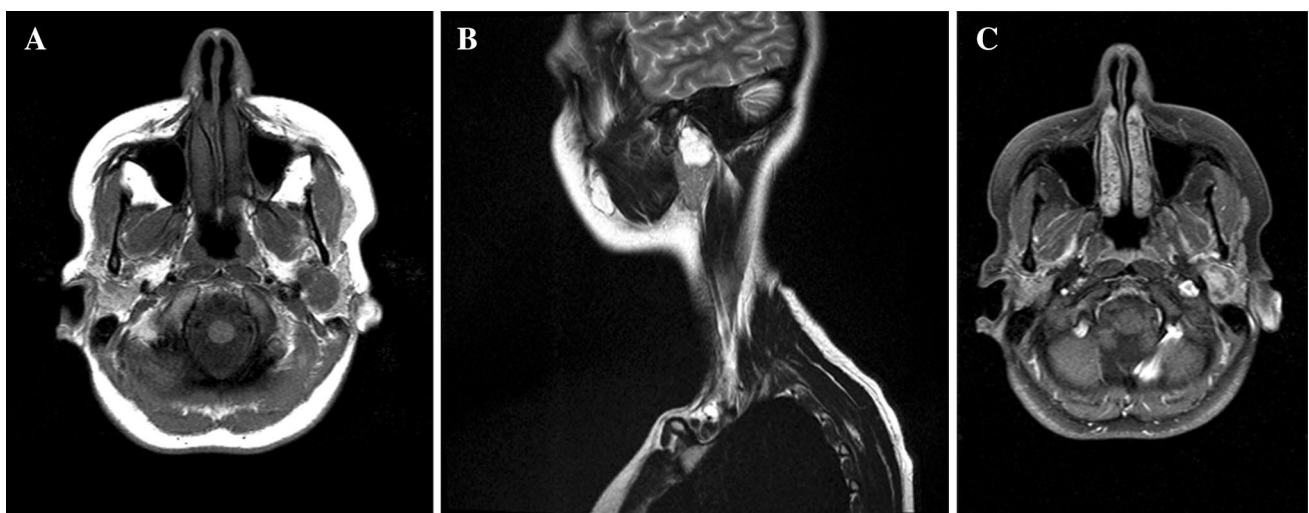


Fig. 4 MRI of pleomorphic adenoma on the left parotid gland of a 35-year-old woman correctly diagnosed by R1 and incorrectly diagnosed by R2 as a cyst and by R3 as a Warthin's tumor. **a** axial

turbo spin-echo (TSE) T1; **b** sagittal T2 W TSE and **c** axial contrast-enhanced spin-echo sequence

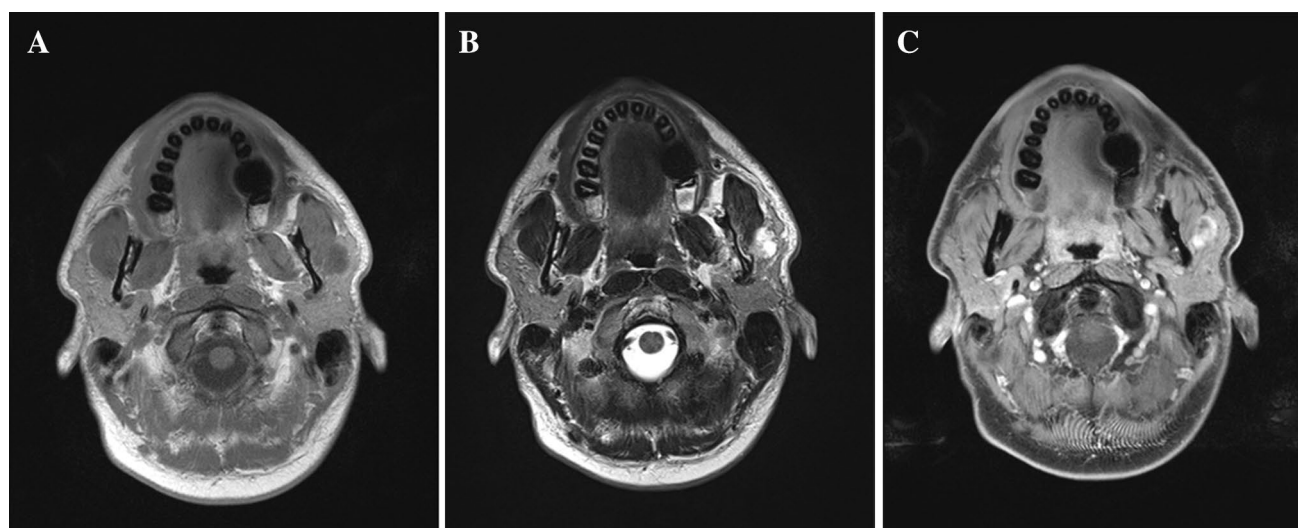


Fig. 5 A 40-year-old man with a histologically confirmed pleomorphic adenoma on the left parotid gland. All observers (R1–R3) diagnosed it correctly as pleomorphic adenoma. **a** axial T1; **b** axial T2 TSE and **c** contrast-enhanced axial T1 image

malignant tumors, but made less precise classification of tumors. R1 reached values higher than 95% for Warthin's tumor assessment using MRI. A study of two radiologists with 6 months and 8 years of experience performing the preoperative diagnosis of Warthin's tumors showed similar results [10]. Our study furthermore indicates that the values of diagnostic performance are higher for experienced radiologists vs less experienced ones. Thus, our results suggest that especially radiologists with greater levels of experience should primarily be involved in reporting CT and MRI examinations of salivary gland tumors.

Regarding classification of pleomorphic adenoma using CT, R1 reached values of 100%, R2 more than 88.8% and R3 ranged from 66.6 to 88.8%. These results are comparable with other studies [38].

An according observation can be made for the groups "other benign tumors" and "diseases without neoplasm". All three reviewers partially diagnosed some cases of "other benign tumors" incorrectly as Warthin's tumor (R1: 1 of 5; R2 and R3: 2 of 5). In the group "diseases without neoplasm" this was even more pronounced, where R1 misdiagnosed 1 of 13 cases in MRI as Warthin (R2: 6; R3: 9).

Similar to other studies, the most common benign tumor in our study was pleomorphic adenoma [33]. However, the most common malignant tumor in our study was SCC, which is in contrast to other studies where this is the mucoepidermoid carcinoma or adenocystic carcinoma [28]. The absence of mucoepidermoid carcinoma may somewhat bias the results and should be considered in future studies.

Regarding malignant tumors, some cases with SCC were incorrectly diagnosed as pleomorphic adenomas ($n = 3$) by R3 and as pleomorphic adenoma and Warthin's

tumor ($n = 1$ in each case) by R2 [Fig. 5]. It is also important to note that SCC using MRI was mainly misdiagnosed as pleomorphic adenoma by less experienced radiologists, but not using CT scans. None of the healthy patients without neoplasm were correctly diagnosed by R3.

The highest inter-observer agreement was documented between R1 and R2, reaching from moderate to substantial agreement. The agreement between R3 and the two experienced radiologists, however, was fair to moderate.

There were several limitations to this study. The ratio between benign and malignant tumors was not balanced, resulting in a limited comparison between the results for malignant and benign tumors. Another limitation is the ratio of MRI and CT being 1:10, thus the results regarding CT have limited reliability and should be verified in a larger study. In three cases of MRI, no contrast agents were administered, and this may mildly have influenced our results. The majority of cases consisted of Warthin's tumor, pleomorphic adenoma and carcinoma. This study should be extended in future investigations including more cases with other tumor entities for more accurate and reliable results. This study is highly dependent on the expertise of the individual raters. The selection of the reviewing radiologists could also be extended with an exacter gradation of radiological experience of the observers.

In conclusion, our results indicate that increasing levels of radiological experience leads to a higher accuracy in classification of salivary gland tumors using both CT and MRI. Furthermore, a long radiological experience (> 20 years) is required for accurate radiological diagnosis of uncommon benign salivary gland tumors.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this retrospective type of study formal consent is not required and was waived by the institutional review board.

References

- Bello IO, Salo T, Dayan D, Tervahauta E, Almangoush A, Schnaiderman-Shapiro A, Barshack I, Leivo I, Vered M (2012) Epithelial salivary gland tumors in two distant geographical locations, Finland (Helsinki and Oulu) and Israel (Tel Aviv): a 10-year retrospective comparative study of 2218 cases. *Head Neck Pathol* 6:224–231. doi:10.1007/s12105-011-0316-5
- Bisdas S, Baghi M, Wagenblast J, Knecht R, Thng CH, Koh TS, Vogl TJ (2007) Differentiation of benign and malignant parotid tumors using deconvolution-based perfusion CT imaging: feasibility of the method and initial results. *Eur J Radiol* 64:258–265. doi:10.1016/j.ejrad.2007.02.032
- Bjørndal K, Krogdahl A, Therkildsen MH, Overgaard J, Johansen J, Kristensen CA, Homøe P, Sørensen CH, Andersen E, Bundgaard T, Primdahl H, Lambertsen K, Andersen LJ, Godballe C (2011) Salivary gland carcinoma in Denmark 1990–2005: a national study of incidence, site and histology. Results of the Danish Head and Neck Cancer Group (DAHANCA). *Oral Oncol* 47:677–682. doi:10.1016/j.oraloncology.2011.04.020
- Bradley PJ, McGurk M (2013) Incidence of salivary gland neoplasms in a defined UK population. *Br J Oral Maxillofac Surg* 51:399–403. doi:10.1016/j.bjoms.2012.10.002
- Burke CJ, Thomas RH, Howlett D (2011) Imaging the major salivary glands. *Br J Oral Maxillofac Surg* 49:261–269. doi:10.1016/j.bjoms.2010.03.002
- Cardello P, Trinci M, Messineo D, Tuccimei M, Massa R, Marini M, Trinci M (1998) Diagnostic imaging of the salivary glands in patients undergoing radiotherapy of head and neck neoplasms. *Radiol Med (Torino)* 95:224–231
- Christe A, Waldherr C, Hallett R, Zbaeren P, Thoeny H (2011) MR imaging of parotid tumors: typical lesion characteristics in MR imaging improve discrimination between benign and malignant disease. *Am J Neuroradiol* 32:1202–1207. doi:10.3174/ajnr.A2520
- Davachi B, Imanimoghaddam M, Majidi MR, Sahebalam A, Johari M, Javadian Langaroodi A, Shakeri MT (2014) The efficacy of magnetic resonance imaging and color doppler ultrasonography in diagnosis of salivary gland tumors. *J Dent Res Dent Clin Dent Prospects* 8:246–251. doi:10.5681/joddd.2014.044
- de Ridder M, Balm AJM, Smeele LE, Wouters MWJM, van Dijk BAC (2015) An epidemiological evaluation of salivary gland cancer in the Netherlands (1989–2010). *Cancer Epidemiol* 39:14–20. doi:10.1016/j.canep.2014.10.007
- Espinoza S, Felter A, Malinvaud D, Badoual C, Chatellier G, Siauve N, Halimi P (2014) Warthin's tumor of parotid gland: surgery or follow-up? Diagnostic value of a decisional algorithm with functional MRI. *Diagn Interv Imaging*. doi:10.1016/j.diii.2014.11.024
- Fakhry N, Aldosari B, Michel J, Giorgi R, Collet C, Santini L, Giovanni A, Dessi P (2013) Clinical and oncological outcomes after surgical excision of parotid gland tumours in patients aged over 80 years. *Int J Oral Maxillofac Surg* 42:1385–1390. doi:10.1016/j.ijom.2013.06.010
- Fernandes H, D'souza CRS, Khosla C, George L, Katte NH (2014) Role of FNAC in the preoperative diagnosis of salivary gland lesions. *J Clin Diagn Res JCDR* 8:FC01–FC03. doi:10.7860/JCDR/2014/6735.4809
- Fonseca FP, de Vasconcelos Carvalho M, de Almeida OP, Rangel ALCA, Takizawa MCH, Bueno AG, Vargas PA (2012) Clinicopathologic analysis of 493 cases of salivary gland tumors in a Southern Brazilian population. *Oral Surg Oral Med Oral Pathol Oral Radiol* 114:230–239. doi:10.1016/j.oooo.2012.04.008
- Fritz AG (2013) International classification of diseases for oncology: ICD-O, third edition, first revision. World Health Organization, Geneva
- Ho K, Lin H, Ann DK, Chu PG, Yen Y (2011) An overview of the rare parotid gland cancer. *Head Neck Oncol* 3:40. doi:10.1186/1758-3284-3-40
- Joe VQ, Westesson PL (1994) Tumors of the parotid gland: MR imaging characteristics of various histologic types. *Am J Roentgenol* 163:433–438. doi:10.2214/ajr.163.2.8037045
- Kafi MAH, Bhuyan MAH, Bhuiyan MJH, Alam MK (2010) Management of salivary gland neoplasm—study of 32 cases. *Bangladesh J Med Sci* 9:87–94. doi:10.3329/bjms.v9i2.5656
- Kato H, Kanematsu M, Makita H, Kato K, Hatakeyama D, Shibata T, Mizuta K, Aoki M (2014) CT and MR imaging findings of palatal tumors. *Eur J Radiol* 83:e137–e146. doi:10.1016/j.ejrad.2013.11.028
- Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* 33:159–174. doi:10.2307/2529310
- Lee YYP, Wong KT, King AD, Ahuja AT (2008) Imaging of salivary gland tumours. *Eur J Radiol* 66:419–436. doi:10.1016/j.ejrad.2008.01.027
- Liu Y, Li K, Shi H, Tao X (2014) Solitary fibrous tumours in the extracranial head and neck region: correlation of CT and MR features with pathologic findings. *Radiol Med (Torino)* 119:910–919. doi:10.1007/s11547-014-0409-9
- Louie KS, Mehanna H, Sasieni P (2015) Trends in head and neck cancers in England from 1995 to 2011 and projections up to 2025. *Oral Oncol*. doi:10.1016/j.oraloncology.2015.01.002
- Mack MG, Vogl TJ (1999) MR imaging of the head and neck. *Eur Radiol* 9:1247–1251. doi:10.1007/s003300050830
- Mazziotti S, Blandino A, Gaeta M, Bottari A, Sofia C, D'Angelo T, Ascenti G (2015) Postprocessing in maxillofacial multidetector computed tomography. *Can Assoc Radiol J* 66:212–222. doi:10.1016/j.carj.2014.12.004
- Mazziotti S, Pandolfo I, D'Angelo T, Mileto A, Visalli C, Racchiusa S, Blandino A, Ascenti G (2014) Diagnostic approach to retromolar trigone cancer by multiplanar computed tomography reconstructions. *Can Assoc Radiol J* 65:335–344. doi:10.1016/j.carj.2014.04.001
- Nagarkar NM, Bansal S, Dass A, Singhal SK, Mohan H (2004) Salivary gland tumors—our experience. *Indian J Otolaryngol Head Neck Surg* 56:31–34. doi:10.1007/BF02968769
- Noij DP, Martens RM, Marcus JT, de Bree R, Leemans CR, Castelijns JA, de Jong MC, de Graaf P (2017) Intravoxel incoherent motion magnetic resonance imaging in head and neck cancer: a systematic review of the diagnostic and prognostic value. *Oral Oncol* 68:81–91. doi:10.1016/j.oraloncology.2017.03.016
- Parkins G, Boamah MO (2009) Tumours of the salivary gland in Ghana. *Asian J Oral Maxillofac Surg* 21:96–100. doi:10.1016/S0915-6992(09)80004-6
- Raine C, Saliba K, Chippindale AJ, McLean NR (2003) Radiological imaging in primary parotid malignancy. *Br J Plast Surg* 56:637–643. doi:10.1016/S0007-1226(03)00358-8
- Rudack C, Jörg S, Kloska S, Stoll W, Thiede O (2007) Neither MRI, CT nor US is superior to diagnose tumors in the

- salivary glands— an extended case study. *Head Face Med* 3:19. doi:[10.1186/1746-160X-3-19](https://doi.org/10.1186/1746-160X-3-19)
31. Shishegar M, Ashraf MJ, Azarpira N, Khademi B, Hashemi B, Ashrafi A (2011) Salivary gland tumors in maxillofacial region: a retrospective study of 130 cases in a Southern Iranian population. *Pathol Res Int* 2011:1–5. doi:[10.4061/2011/934350](https://doi.org/10.4061/2011/934350)
 32. Speight P, Barrett A (2002) Salivary gland tumours. *Oral Dis* 8:229–240. doi:[10.1034/j.1601-0825.2002.02870.x](https://doi.org/10.1034/j.1601-0825.2002.02870.x)
 33. Subhashraj K (2008) Salivary gland tumors: a single institution experience in India. *Br J Oral Maxillofac Surg* 46:635–638. doi:[10.1016/j.bjoms.2008.03.020](https://doi.org/10.1016/j.bjoms.2008.03.020)
 34. Torabinia N, Khalesi S (2014) Clinicopathological study of 229 cases of salivary gland tumors in Isfahan population. *Dent Res J* 11:559–563
 35. Vogl TJ (2010) Different imaging techniques in the head and neck: assets and drawbacks. *World J Radiol* 2:224. doi:[10.4329/wjr.v2.i6.224](https://doi.org/10.4329/wjr.v2.i6.224)
 36. Vogl TJ, Dresel SH, Späth M, Grevers G, Wilimzig C, Schedel HK, Lissner J (1990) Parotid gland: plain and gadolinium-enhanced MR imaging. *Radiology* 177:667–674. doi:[10.1148/radiology.177.3.2243966](https://doi.org/10.1148/radiology.177.3.2243966)
 37. Wang Y-L, Zhu Y-X, Chen T-Z, Wang Y, Sun G-H, Zhang L, Huang C-P, Wang Z-Y, Shen Q, Li D-S, Wu Y, Ji Q-H (2012) Clinicopathologic study of 1176 salivary gland tumors in a Chinese population: experience of one cancer center 1997–2007. *Acta Otolaryngol (Stockh)* 132:879–886. doi:[10.3109/00016489.2012.662715](https://doi.org/10.3109/00016489.2012.662715)
 38. Xu Z-F (2013) Different histological subtypes of parotid gland tumors: CT findings and diagnostic strategy. *World J Radiol* 5:313. doi:[10.4329/wjr.v5.i8.313](https://doi.org/10.4329/wjr.v5.i8.313)
 39. Yerli H, Aydin E, Haberal N, Harman A, Kaskati T, Alibek S (2010) Diagnosing common parotid tumours with magnetic resonance imaging including diffusion-weighted imaging vs fine-needle aspiration cytology: a comparative study. *Dentomaxillofac Radiol* 39:349–355. doi:[10.1259/dmfr/15047967](https://doi.org/10.1259/dmfr/15047967)