European Journal of Surgical Oncology 45 (2019) 2131–2136

Contents lists available at ScienceDirect

European Journal of Surgical Oncology

journal homepage: www.ejso.com

The oral cavity tumor thickness: Measurement accuracy and consequences for tumor staging

S.G. Brouwer de Koning [a, *], M.B. Karakullukcu [a], C.A.H. Lange [b], T.J.M. Ruers [a, c]

[a] Department of Surgery, Netherlands Cancer Institute, Antoni van Leeuwenhoek Hospital, Amsterdam, the Netherlands
[b] Department of Radiology, Netherlands Cancer Institute, Antoni van Leeuwenhoek Hospital, Amsterdam, the Netherlands
[c] Faculty of Science and Technology, University of Twente, Enschede, the Netherlands

ARTICLE INFO

Article history:
Received 1 February 2019
Received in revised form
28 May 2019
Accepted 2 June 2019
Available online 4 June 2019

Keywords:
Oral cavity tumor
Tumor depth of invasion
Ultrasound
MR imaging
Histopathology
8th edition of the AJCC/UICC cancer staging system

ABSTRACT

Introduction: In the 8th edition of the AJCC/UICC cancer staging system (AJCC8), the depth of invasion (DOI) of the oral cavity tumor is the discriminative factor in tumor staging over the previously used greatest dimension (GD). In order to obtain a complete representation of how accurate we stage oral cavity cancer clinically, we evaluated the accuracy of measurements of the tumor dimensions on ultrasound (US) and magnetic resonance (MR) imaging by comparing this with the histopathology as the "golden standard". Secondly, we compared the pathological tumor staging of these tumors according to the AJCC7 and AJCC8, to evaluate the effect of the incorporation of the DOI in the AJCC8.
Materials and methods: In a retrospective analysis, including 85 oral cavity tumors, the GD and tumor thickness (TT) measured on US and MR, were compared to histopathology with a Pearson correlation coefficient (R) and a Bland-Altman plot. The tumors were staged according to both the AJCC7 and AJCC8.
Results: TT was more reliably measured with US ($R = 0.67$, limits of agreement = 10.7 mm), whereas GD was more reliably measured with MR ($R = 0.69$, limits of agreement = 25.7 mm). The AJCC8 staging resulted into a higher tumor stage in 21% of the cases, compared to the AJCC7.
Conclusion: For preoperative tumor staging, the TT is best estimated by the use of US. The incorporation of DOI in the AJCC8 can result in a higher tumor stage in more than twenty percent of the patients, with an associated worse prognosis for the patient.

Introduction

The AJCC/UICC cancer staging system is established to stage cancer according to the severity of the disease. The system describes the anatomical extent of the disease based on three components: T for the extent of the primary tumor, N for the involvement of regional lymph node metastasis and M for the presence of distant metastasis. The TNM stage of the cancer affects the planning of the treatment and gives an indication of prognosis and survival [1]. In the previously used T classification for oral cavity cancer, the tumor's greatest dimension (GD) was the discriminating factor to stage the tumor in the different T categories [2]. Because this measure has a suboptimal prognostic performance [3], the tumor's depth of invasion (DOI) has been evaluated for prognostic performance instead [4]. The DOI reflects the proximity to underlying lymph-vascular structures and thus, can be considered as a predictor of the presence of pathologic lymph nodes [5,6]. Ebrahimi et al. showed in a retrospective analysis including 3149 patients with oral squamous cell carcinoma, that the tumor's DOI is significantly associated with disease specific survival ($p < 0.001$) [4]. This analysis was reason for the Union for International Cancer Control to implement the DOI into the new AJCC8 (Table 1).

GD and tumor thickness (TT) can be measured on pre-operative imaging, and can be very different from each other in e.g. large superficial tumors. Both the magnetic resonance imaging (MR) or ultrasound (US) have difficulties to overcome in accurate imaging of oral cavity cancer. Especially the imaging of small primary tumors can be challenging. The acquisition of an intra-oral US image can be hampered by the limited space in the oral cavity or in case the tumor is located too distant, making it difficult to reach (e.g. palate tumors). Artefacts due to tooth prostheses and movement from the

* Corresponding author. The Netherlands Cancer Institute Plesmanlaan, 121 1066, CX, Amsterdam, the Netherlands.
E-mail address: s.brouwerdekoning@nki.nl (S.G. Brouwer de Koning).

https://doi.org/10.1016/j.ejso.2019.06.005
0748-7983/

Table 1
Primary tumor staging (T) in 7th and 8th editions of the AJCC/UICC cancer staging system.

Tumor stage primary tumor	AJCC7[a], 2009	AJCC8[b], 2017	
	Greatest dimension	Greatest dimension	Depth of invasion
T1	≤2 cm	≤2 cm	≤5 mm
T2	>2–4 cm	≤2 cm 2–4 cm	5–10 mm <10 mm
T3	>4 cm	>4 cm	>10 mm

[a] 7th edition of the AJCC/UICC cancer staging system.
[b] 8th edition of the AJCC/UICC cancer staging system.

swallowing reflexes make interpretation of the MR images difficult. Still, when comparing TT measured with US or MR and histopathology, Pearson correlation coefficients of up to 0.98 are reported in literature [7–10].

TT and DOI can be measured on the histopathology sections. Before the introduction of the AJCC8, TT and DOI measures were often incorrectly used interchangeably, while these two measures can be very different in an ulcerative tumor, for example. With the AJCC8, the definitions of the terms TT and DOI have become more specific [11]. The TT is solely the thickness of the tumor, while the DOI is measured specifically from the basement membrane to the closest intact squamous mucosa. The latter is measured specifically on histopathological sections.

In order to obtain a complete representation of how accurate we measured oral cavity cancer, we conducted a retrospective study including all oral cavity cancer patients treated in our institute during the last 5 years. Our oral cavity tumor diagnostic protocol includes US and MRI of the oral cavity and neck. We compared GD and TT measurements from US and MR with the histopathology as the “gold standard”. Secondly, we compared the pathological T staging of these patients according to the 7th and 8th edition of the AJCC/UICC cancer staging system to evaluate the effect of incorporating the DOI in the new T staging.

Materials and methods

Patient population

We selected all oral cavity cancer patients with a tumor that was clinically staged as T1 or T2, and of which US or MR images were acquired in our institute between 2011 and 2016. The tumor dimensions were measured with three modalities: US, MR and histopathology (Fig. 1).

GD and TT measurements on US and MR

US images were acquired by the radiologist, with the Hitachi, EUB-900, and a 13-7 MHz transducer (EUP-O54J). The probe was positioned directly on the lesion, so that the TT and GD could be measured along the length and width axes. This is the standard way our radiologists use to describe the tumor with US.

MR examinations were performed on a Philips Achieva 3T scanner using a dedicated 16-channel SENSE neurovascular coil (Philips Medical Systems, Best, The Netherlands). The following MR sequences were used to measure GD and DOI: T1W TSE TRA, TR (repetition time), TE (echo time) 538/10 ms, flip angle 90, matrix 288/248, slice thickness 4 mm; STIR TSE COR, TR/TE 2500/60 ms, flip angle 90, matrix 216/170, slice thickness 4 mm; T1 3D Thrive fat-saturation, after intravenous injection of 15 cc gadoterate meglumine, TR/TE 9.86/4.59 ms, flip angle 10, matrix 200/179, slice thickness 1 mm. According to the standard protocol, the tumor dimensions were measured in 3D: the length and width axes were measured on all axial, sagittal and coronal slices. The radiologist reported on the tumor dimensions, thereby suggesting the T stage for diagnosis discussions at the tumor board. These reported measurements were used for this study rather than renewing the measurements in a second read of the scan. We believe that these values represent the day to day practice better than careful re-measurements. The tumor dimensions were measured on the histopathology sections by the pathologist and recorded in the pathological report.

TT and GD were used for the correlation and agreement analysis with histopathology.

Correlation and agreement US and MR with histopathology

To compare GD and TT measured on US and MR, with the histopathology as a “gold standard”, two different statistical methods were used. First the correlation between US/MR and histopathology was evaluated with Pearson's correlation coefficient. Two modalities were considered significantly correlated when $p < 0.05$. The use of Pearson's correlation coefficient allows us to compare our results with that of other studies in this field. Pearson correlation coefficient and its p-value were calculated using SPSS statistical

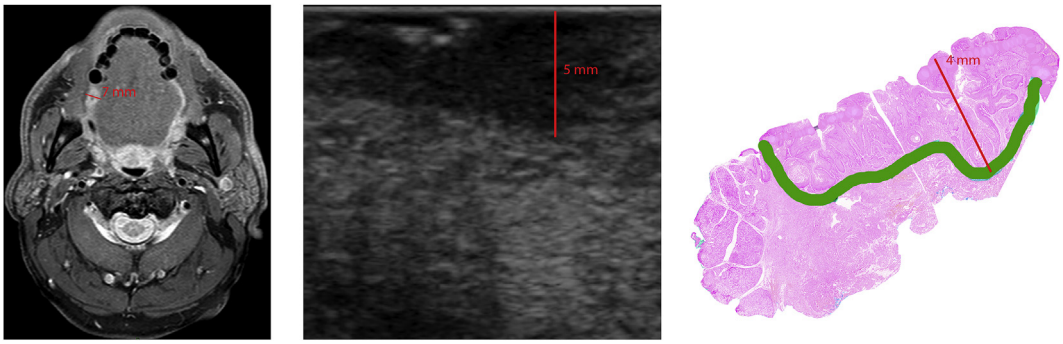

Fig. 1. TT measured on MR, US and histopathology, respectively.

package version 22 (SPSS Inc, Chicago, IL).

Although Pearson's correlation coefficient gives insight in whether data of two data sets are correlated, it does not indicate agreement between two data sets [12]. To evaluate the agreement between US/MR and histopathology, we analyzed the data with a Bland-Altman plot. A Bland-Altman plot shows the mean difference of two modalities with 95% confidence intervals as 'limits of agreement'. This allows easy interpretation of whether the difference of the two modalities is clinically relevant. The Bland-Altman plot measures the variation between the observations on US/MR and histopathology.

T staging according to the 7th and 8th editions of the AJCC/UICC cancer staging system

GD and DOI were used in comparing T stage according to AJCC7 and AJCC8. Using the GD measured on histopathology, the tumors were classified into T stage according to AJCC7. Taking also the DOI into account, the same cases were classified into T stage according to the AJCC8. Agreement between the classifications according to AJCC7 and AJCC8 was evaluated and rates of over/under staging using AJCC8 were calculated.

Results

Patient population

A total of 142 patients with oral cavity cancer were treated in our institute between 2011 and 2016. In 32 cases, tumor dimensions were reported by only one modality. Histopathology data was not available for 11 patients, because of their treatment with photodynamic therapy (PDT) instead of surgery. In 5 cases, US was acquired after the excision and in one patient, histopathology showed scar tissue instead of tumor tissue. In addition, the tumor was not assessable on US in 10 cases. Thus, the study population consisted of 83 patients, for whom at least one of the measures (GD/TT/DOI) was reported on histopathology and US or MR.

The mean age of the 83 included patients was 61 (ranging from 31 to 88). The population consisted of 45 men and 38 women. Two patients had two tumors, so that 85 tumors were included in the study. The site of disease within the oral cavity was at the tongue (n = 58), floor of the mouth (n = 24), the palate (n = 2) and the lip (n = 1). All tumors were squamous cell carcinoma.

Table 2
Number of tumors where TT and GD was measured on US and MR. Total number of tumors included in the study was 85.

	US and pathology	MR and pathology
Number of tumors where TT was measured on:	76	46
Number of tumors where GD was measured on:	44	47

GD and TT data on US, MR and histopathology

US and MR measures were not reported for all included tumors (Table 2). TT was measured on US and histopathology in 76 of the 85 tumors. TT was measured on 46 of the 85 tumors using MR.

The GD was measured on US and histopathology for 44 of the 85 tumors, and on MR and histopathology for 47 of the 85 tumors.

Tumor thickness

Mean TT measured on US images was 5.1 mm (standard deviation STD: 3.1 mm) and the mean TT on the associated histopathology sections was 5.1 mm (STD: 3.5 mm). The TT measures for the MR dataset, using different data (see section above), showed a mean TT of 7.4 mm (STD: 3.5 mm) that was found on MR and a mean TT of 6.1 mm (STD: 3.2 mm) that was reported on the histopathology sections.

There was a significant relationship between the TT measured on both US and MR with histopathology. US and histopathology measures of the TT were correlated with a Pearson's correlation coefficient of $r(76) = 0.67$, $p < 0.001$. MR and histopathology measures of the TT were correlated with a Pearson's correlation coefficient of $r(46) = 0.38$, $p = 0.009$.

The 95% limits of agreement (1.96*STD) comparing US and histopathology measurements were −5.3 mm to 5.4 mm (Fig. 2a). Mean difference between TT measured on US and histopathology was 0.05 mm (STD 2.7 mm). For MR and histopathology, the 95% limits of agreement were −6.1 mm to 8.6 mm (Fig. 2b). The mean difference between measurements on MR and histopathology was 1.3 mm (STD 3.7 mm).

In all, compared to MR, the TT measured on US showed a higher correlation and agreement with histopathology.

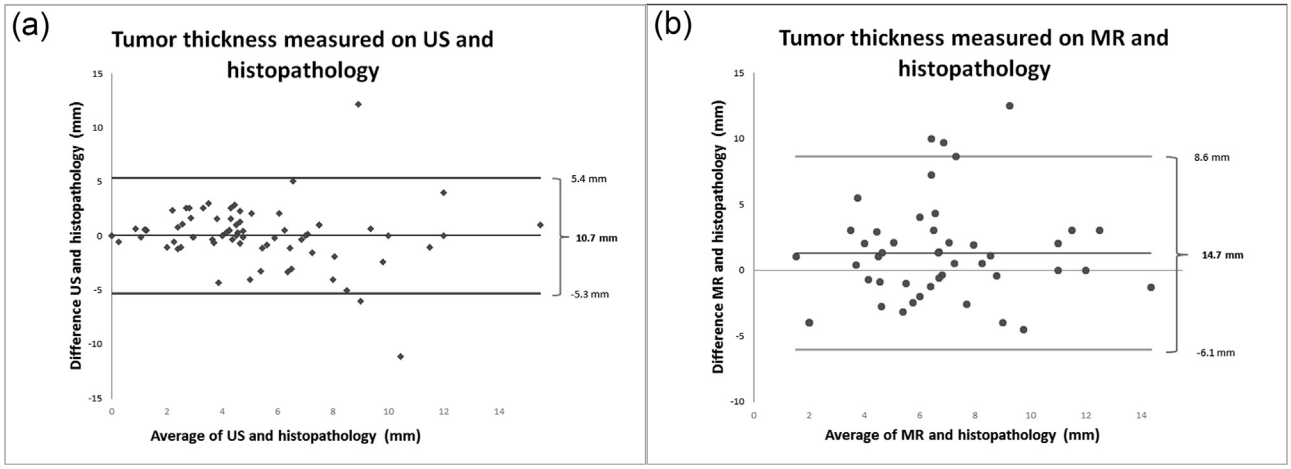

Fig. 2. Bland Altman plot of TT measured on US (a, $n = 76$) and MR images (b, $n = 46$) compared to the TT measured on histopathological sections. Mean difference between the TT measured on US and histopathology was 0.05 mm, 95% limits of agreement −5.3 to 5.4 mm. Mean difference between the TT measured on MR images and histopathology was 1.3 mm, 95% limits of agreement −6.1 to 8.6 mm.

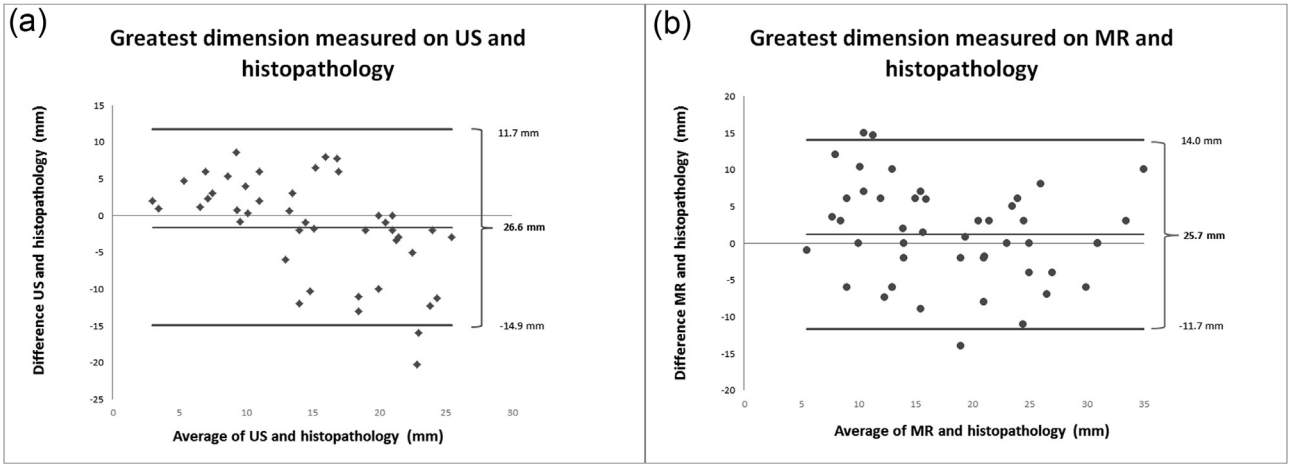

Fig. 3. Bland Altman plot of GD of the tumor measured on US (a, $n = 44$) and MR images (b, $n = 47$) compared to the GD measured on histopathological sections. Mean difference between the GD measured on US and histopathology was −1.6 mm, 95% limits of agreement −14.9 to 11.7 mm. Mean difference between the GD measured on MR images and histopathology was 1.1 mm, 95% limits of agreement −11.7 to 14.0 mm.

Greatest dimension

The GD was reported on US images (mean GD: 14.3 mm, STD: 5.1 mm) with associated histopathology sections (mean GD: 15.9 mm, STD: 8.6 mm). Similarly, but using a different data set (see section above), the GD was reported from MR images (mean GD: 18.8 mm, STD: 7.6 mm) and associated histopathology sections (mean GD: 17.6 mm, STD: 8.8 mm).

There was a significant relationship between the GD measured on both US and MR with histopathology. US and histopathology measures of the GD were correlated with a Pearson's correlation coefficient of $r(44) = 0.61$, $p < 0.001$. MR and histopathology measures of the GD were correlated with a Pearson's correlation coefficient of $r(47) = 0.69$, $p < 0.001$.

The 95% limits of agreement of US and histopathology measurements of the GD were −14.9 mm to 11.7 mm (Fig. 3a). Mean difference between US and histopathology was 1.6 mm (STD 6.8 mm). The 95% limits of agreement of MR and histopathology measurements of the GD were −11.7 mm to 14 mm (Fig. 3b). Mean difference between MR and histopathology was 1.1 mm (STD 6.6 mm).

Compared to US, the GD measured on MR showed a higher correlation and agreement with histopathology.

T staging according to the 7th and 8th editions of the AJCC/UICC cancer staging system

Using the GD and DOI measured on the histopathology sections, AJCC7 and AJCC8 agreed in 67 out of 85 tumors (79%): 48 tumors were classified as T1 according to both staging systems, and 19 as T2 (Table 3). However, 18 out of 85 tumors (21%) were classified into a higher T class when staging with AJCC8. No tumors were classified in a lower category with AJCC8.

Discussion

In the AJCC8, DOI of the oral cavity tumor is the discriminative factor in tumor staging over the previously used GD. In this study, we have evaluated the accuracy of the tumor dimensions, measured preoperatively on US and MR images, that were performed before the introduction of AJCC8. This was done by comparing them with the histopathology as the “gold standard”. With two different statistical analyses, we found that TT is more reliably measured with US ($R = 0.67$, limits of agreement = 10.7 mm) and GD is more reliably measured with MR ($R = 0.69$, limits of agreement = 25.7 mm). Secondly, we evaluated the pathological T staging of patients in our hospital according to both the AJCC7 and AJCC8, to assess the effect of incorporating the DOI in the new T staging. When staging according to the 8th edition, 21% of the tumors would have been classified into a higher T class.

One explanation for the difference in tumor thickness measurements based on MR- and US images might be the difference in indication of the two imaging modalities. US is performed with the focus on the TT. This is important for the decision on further treatment. On the contrary, the MR is indicated for staging of the disease, e.g. tumor dimension and tumor extension towards the neck. The MR was not indicated to measure TT specifically, because this was not required for tumor staging according to the AJCC7.

The Pearson correlation coefficient has often been used to compare tumor dimensions measured on US/MR with histopathology (Table 4). In literature, the correlation coefficient ranges between $R = 0.80–0.99$ for US and histopathology, and between $R = 0.54–0.99$ for MR and histopathology. In contrast to our retrospective analysis, most of these studies were prospective and did set up very specific selection criteria (e.g. specific tumor size and site). Alsaffar et al. argues that the correlation between MR and histopathology is less accurate for tumors smaller than 5 mm ($R(9) = -0.211$, $p = 0.56$), compared to tumors larger than 5 mm ($R(40) = 0.856$, $p < 0.001$) [13]. Lwin et al. shows bad correlation ($R(24) = 0.45$, $p = 0.03$) between MR and histopathology for

Table 3
T staging based on histopathology according to 7th and 8th editions of the AJCC/UICC cancer staging system. The number of tumors classified into a higher T stage by using the 8th edition over the 7th edition are shown in the aligned cells are shown in bold. The last row of the table shows this number of tumors classified into a higher T stage, as a percentage of the total number of tumors included.

Tumor stage Histopathology		AJCC7[a]	
		T1	T2
AJCC8[b]	T1	48	0
	T2	**10**	19
	T3	**1**	**7**
		21%	

[a] 7th edition of the AJCC/UICC cancer staging system.
[b] 8th edition of the AJCC/UICC cancer staging system.

Table 4
Articles reporting on Pearson correlation coefficient of US or MR imaging compared to histopathology, FOM = Floor of the mouth.

Reviewed articles	Study type	Tumor site	Measure	US[a] vs histopathology			MR[b] vs histopathology		
				Number of patients	Pearson's correlation coefficient	p-value	Number of patients	Pearson's correlation coefficient	p-value
Lodder, 2011[17]	Retrospective	Tongue, FOM[c], elsewhere	Tumor thickness	32	0.87	–	22	0.54	–
Alsaffar, 2016 [13]	Prospective	Tongue	Depth of invasion				53	0.907	<0.001
Goel, 2016[8]	Prospective	Tong, elsewhere	Depth of invasion				61	0.988	<0.0001
Kodama, 2010 [9]	Prospective	Tongue	Tumor thickness	13	0.981	<0.05			
Lwin, 2011 [14]	Retrospective	Tong, FOM	Tumor thickness				91	0.63	<0.001
Park, 2011 [18]	Retrospective	Tongue, elsewhere	Depth of invasion				114	0.825	<0.001
Taylor, 2010 [10]	Prospective	Tongue, FOM	Tumor thickness	21	0.981	<0.001			
Songra, 2006 [19]	Prospective	Tongue, FOM, lip, mucosa	Tumor thickness	14	0.95	<0.01			
Yesuratnam, 2014 [15]	Prospective	Tongue	Tumor thickness	79	0.80		78	0.69	
Yuen, 2008 [20]	Prospective	Tongue	Tumor thickness	45	0.94	<0.005			
Yamane, 2006 [11]	Prospective	Tongue	Tumor thickness	109	0.985	<0.001			
Lam, 2003 [21]	Prospective	Tongue	Tumor thickness				18	0.934	
This study	Retrospective	Tongue, FOM, elsewhere	Greatest dimension	44	0.61	<0.001	47	0.69	<0.001
			Tumor thickness	76	0.67	<0.001	46	0.38	<0.01

[a] Ultra Sound.
[b] Magnetic Resonance.
[c] Floor Of the Mouth.

tumors located in the floor of the mouth [14]. When the latter performs their analysis on tongue tumors only, a much better correlation is found ($R(43) = 0.87$, $p < 0.001$). Our aim was to give a reflection of the daily clinical situation and thus our analysis includes all types of oral cavity cancers, including tumors located in the floor of the mouth (23/85).

Similar to our analysis, Yesuratnam et al. evaluated the US and MR agreement with histopathology also by using Bland-Altman plots. For US and histopathology, they found a mean difference of 1.28 mm (STD 3.55 mm, 79 patients) [15]. Similarly, for MR and histopathology, they report on a mean difference of 2.99 mm (STD 4.41 mm) (78 patients). The associated measures in our findings were a difference of 0.05 mm (STD 2.7 mm, 76 patients) for US and histopathology and 1.3 mm (STD 3.7 mm, 44 patients) for MR and histopathology. Thus, for both US and MR, the agreement with histopathology was more accurate in our studies.

Many institutions use computerized tomography (CT) to stage patients preoperatively. Madana et al. compared the TT measured on preoperative CT scan and histopathology [16]. Their retrospective study included 116 patients with a diagnosis of oral tongue squamous cell carcinoma, and they found a highly significant correlation between the TT measured on CT and histopathology. They suggest that although MRI may be superior to CT in the evaluation of soft tissue lesions, that their results support the use of CT in measuring TT.

Overall, it can be argued whether the histopathology is the best measurement to use as a “gold standard”, due to the pathological processing of the resected specimen. This process can result in specimen shrinkage [14]. Also, the direction of the sliced histopathology sections is not the same as the slicing direction of MR slices, or the same angle of the US probe positioning.

According to our comparison between T staging according to the AJCC7 and AJCC8, more than twenty percent of the tumors will be classified into a higher T stage, due to the incorporation of the DOI in the T staging system. Clinically, this will mean that patients will receive radiotherapy and chemotherapy more often.

Conclusion

This retrospective analysis has shown that the oral cavity tumor thickness is more accurately measured with US than MR for preoperative tumor staging. More value should be acknowledged to the TT measured by US when staging the tumor during tumor board. We predict that with the incorporation of the DOI in the AJCC8, more than twenty percent of the oral cavity tumors will be classified into a higher T stage, with an associated worse prognosis for the patient.

Declarations of interest

None.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review board (IRBd18116). The study does not meet the WMO criteria and can be considered as a non-WMO statement, meaning amongst others, that no informed consent is necessary from the patients.

References

[1] O'Sullivan B, Brierley J, Gospodarowicz M, Wittekind C. UICC TNM classification of Malignant Tumours. Eighth ed. Wiley; 2017.

[2] Sobin L, Gospodarowicz M, Wittekind C. UICC TNM classification of Malignant Tumours. Seventh ed. Wiley; 2009.

[3] Kreppel M, Drebber U, Rothamel D, Eich HT, Kubler A, Scheer M, et al. Prognostic impact of different TNM-based stage groupings for oral squamous cell carcinoma. Head Neck 2011;33(10):1467–75.

[4] International Consortium for Outcome Research in Head and Neck Cancer, Ebrahimi A, Gil Z, Amit M, Yen TC, Liao CT, et al. Primary tumor staging for oral cancer and a proposed modification incorporating depth of invasion: an international multicenter retrospective study. JAMA Otolaryngol Head Neck Surg 2014;140(12):1138–48.

[5] Pinto FR, de Matos LL, Palermo FC, Kulcsar MA, Cavalheiro BG, de Mello ES, et al. Tumor thickness as an independent risk factor of early recurrence in oral cavity squamous cell carcinoma. Eur Arch Otorhinolaryngol 2014;271(6):1747–54.

[6] Mucke T, Kanatas A, Ritschl LM, Koerdt S, Tannapfel A, Wolff KD, et al. Tumor thickness and risk of lymph node metastasis in patients with squamous cell carcinoma of the tongue. Oral Oncol 2016;53:80–4.

[7] Goel V, Parihar PS, Parihar A, Goel AK, Waghwani K, Gupta R, et al. Accuracy of MRI in Prediction of Tumour Thickness and Nodal Stage in Oral Tongue and Gingivobuccal Cancer With Clinical Correlation and Staging. J Clin Diagn Res 2016;10(6). TC01-5.

[8] Kodama M, Khanal A, Habu M, Iwanaga K, Yoshioka I, Tanaka T, et al. Ultrasonography for intraoperative determination of tumor thickness and resection margin in tongue carcinomas. J Oral Maxillofac Surg 2010;68(8):1746–52.

[9] Mark Taylor S, Drover C, Maceachern R, Bullock M, Hart R, Psooy B, et al. Is preoperative ultrasonography accurate in measuring tumor thickness and predicting the incidence of cervical metastasis in oral cancer? Oral Oncol 2010;46(1):38–41.

[10] Yamane M, Ishii J, Izumo T, Nagasawa T, Amagasa T. Noninvasive quantitative assessment of oral tongue cancer by intraoral ultrasonography. Head Neck 2007;29(4):307–14.

[11] Lydiatt WM, Patel SG, O'Sullivan B, Brandwein MS, Ridge JA, Migliacci JC, et al. Head and Neck cancers-major changes in the American Joint Committee on cancer eighth edition cancer staging manual. CA Cancer J Clin 2017;67(2):122–37.

[12] Khan K, Chien P. Evaluation of a clinical test. I: Assessment of reliability. Br. J. Obstet. Gynaecol. 2001;108:562–7.

[13] Alsaffar HA, Goldstein DP, King EV, de Almeida JR, Brown DH, Gilbert RW, et al. Correlation between clinical and MRI assessment of depth of invasion in oral tongue squamous cell carcinoma. J Otolaryngol Head Neck Surg 2016;45(1):61.

[14] Lwin CT, Hanlon R, Lowe D, Brown JS, Woolgar JA, Triantafyllou A, et al. Accuracy of MRI in prediction of tumour thickness and nodal stage in oral squamous cell carcinoma. Oral Oncol 2012;48(2):149–54.

[15] Yesuratnam A, Wiesenfeld D, Tsui A, Iseli TA, Hoorn SV, Ang MT, et al. Preoperative evaluation of oral tongue squamous cell carcinoma with intraoral ultrasound and magnetic resonance imaging-comparison with histopathological tumour thickness and accuracy in guiding patient management. Int J Oral Maxillofac Surg 2014;43(7):787–94.

[16] Madana J, Laliberte F, Morand GB, Yolmo D, Black MJ, Mlynarek AM, et al. Computerized tomography based tumor-thickness measurement is useful to predict postoperative pathological tumor thickness in oral tongue squamous cell carcinoma. J Otolaryngol Head Neck Surg 2015;44:49.

[17] Lodder WL, Teertstra HJ, Tan IB, Pameijer FA, Smeele LE, van Velthuysen ML, et al. Tumour thickness in oral cancer using an intra-oral ultrasound probe. Eur Radiol 2011;21(1):98–106.

[18] Park JO, Jung SL, Joo YH, Jung CK, Cho KJ, Kim MS. Diagnostic accuracy of magnetic resonance imaging (MRI) in the assessment of tumor invasion depth in oral/oropharyngeal cancer. Oral Oncol 2011;47(5):381–6.

[19] Songra AK, Ng SY, Farthing P, Hutchison IL, Bradley PF. Observation of tumour thickness and resection margin at surgical excision of primary oral squamous cell carcinoma–assessment by ultrasound. Int J Oral Maxillofac Surg 2006;35(4):324–31.

[20] Yuen AP, Ng RW, Lam PK, Ho A. Preoperative measurement of tumor thickness of oral tongue carcinoma with intraoral ultrasonography. Head Neck 2008;30(2):230–4.

[21] Lam P, Au-Yeung K, Cheng P, Wei W, Yuen A, Smith N, et al. Correlating MRI and Histologic Tumor Thickness in the Assessment of Oral Tongue Cancer. Am. J. Roentgenol. 2004;182:803–8.