RESEARCH ARTICLE

Undetectability of oral tongue cancer on magnetic resonance imaging; clinical significance as a predictor to avoid unnecessary elective neck dissection in node negative patients

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Objectives: We aimed to investigate the relationship between MR imaging detectability and its pathological depth of invasion (DOI) of oral tongue cancer, as well as its usefulness to assess the necessity of elective neck dissection.

Methods: We retrospectively reviewed early stage oral tongue cancer patients treated with radical surgery with clinically N0, between May 2009 and February 2016. Collected data include age, sex, pathological DOI, DOI on MRI, locoregional control rate, disease-free survival rate, and overall survival rate. These data were statistically compared between the detectable lesion (DL) group and undetectable lesion (UL) group on MRI. Interobserver agreement in evaluation of detectability of the oral tongue cancer was assessed by *k* statistics.

Results: Total of 53 patients were studied, and 28 were DLs and 25 ULs. Pathological DOI in UL was significantly smaller than that of DL (average 1.7 vs 4.6 mm, $p < 0.001$). Cut-off value between UL group and DL group was 3.5 mm (sensitivity 96 %, specificity 75 %). 96 % of ULs had pathological DOI smaller than 4 mm, the recommended cut-off value for neck dissection. There was no significant difference in locoregional control rate ($p = 0.24$), disease-free survival rate ($p = 0.24$) or overall survival rate ($p = 0.92$). Interobserver agreement in evaluation of detectability on MRI was very good (k -value = 0.89, $p < 0.001$).

Conclusions: When oral tongue cancer is not detected on MRI, it indicates pathological DOI being smaller than 4 mm, which may imply that elective neck dissection is unnecessary.

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Keywords: Depth of Invasion; Magnetic Resonance Imaging; Oral Tongue Cancer

Introduction

An early stage oral tongue cancer can sometimes be detected on MRI as a mass lesion, and other times undetected. Detectability on MRI would probably reflect the tumor size/volume, thickness and depth of invasion (DOI). In early stage oral tongue cancer with clinical N0

patients, the decision whether or not to perform elective neck dissection could be a difficult and controversial problem. The American Joint Committee on Cancer (AJCC) Cancer Staging Manual, eighth edition added modification of T categorization of the oral cavity cancer incorporating depth of invasion (≤ 5 mm; >5 mm but ≤ 10 mm; >10 mm)¹ because DOI is strongly associated with neck node metastasis which is the most important

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negative prognosticator. However, there is no description on specific details of pre-operative DOI measuring method in AJCC cancer staging manual, eighth edition. Therefore, an appropriate imaging modality to measure pre-operative DOI is yet to be standardized. MRI detectability of oral tongue cancer can be determined by pre-operative MRI relatively easily, and could have greater interobserver reproducibility and correlation with pathological DOI. The purpose of this study is to investigate the relationship between MRI detectability and pathological DOI, as well as its usefulness to assess the necessity of elective neck dissection.

Methods and materials

MRI of 53 Japanese patients with oral tongue cancer obtained between May 2009 and February 2016 were selected continuously and retrospectively evaluated. The subjects included patients who underwent radical surgery for primary oral tongue squamous cell cancer. We focused on early stage oral tongue cancer with the greatest dimension lesser than 4 cm (considered as T_1 – T_2 lesions only focusing on greatest dimension in previous AJCC cancer staging system, seventh edition)² as well as those clinically and radiologically diagnosed as N0 (no neck lymph node metastasis) for pre-surgical evaluation. The study excluded the lesions with extrinsic muscle invasion on pre-surgical MRI. Oral tongue cancers of the lateral border were included, and dorsal, inferior, and tip lesions were excluded.

The patients were divided into detectable lesion (DL) group and undetectable lesion (UL) group on MRI. DL was defined as a lesion which could be detected on T_1 weighted images, T_2 weighted images, or post-contrast

coronal fat suppression T_1 weighted images (Figure 1). UL was defined as those that could not be detected on any of respective MRI sequences (Figure 2).

Two radiologists retrospectively evaluated MRI detectability of oral tongue cancer for all patients independently. In evaluation of MRI detectability, if the two observers reached the same result, that result was used, however if the result differed, final result of the patients was decided by consensus. The average value was used in evaluation of DOI on MRI.

Radiological DOI on MRI (rDOI) was measured from the adjacent normal mucosa to the deepest aspect of the tumor (Figure 3). This measurement method was according to pathological measurement of DOI on AJCC cancer staging system, eighth edition. It states that the “DOI is measured by first finding the ‘horizon’ of the basement membrane of the adjacent squamous mucosa. A perpendicular ‘plumb line’ is established from this horizon to the deepest point of tumor invasion.”¹

Collected data included age, sex, pathological DOI (pDOI), DOI in DL on MRI (rDOI), locoregional control rate, disease-free survival (DFS) rate, overall survival (OS), and whether or not neck dissection was performed. All MRI were performed for pretreatment evaluation. rDOI was measured on either T_1 -weighted images, T_2 -weighted images, or fat suppressed contrast-enhanced T_1 weighted images. When the rDOI was not measurable on certain MRI sequence, the order of preference of imaging sequence was T_1 -weighted images, fat suppressed contrast-enhanced T_1 weighted images, and then T_2 weighted images. This decision was based on the previous studies reporting that discrepancy between rDOI and pDOI was the smallest on T_1 weighted image, then fat suppressed contrast-enhanced

Figure 1 DL on MRI a 77-year-old female diagnosed with right oral tongue cancer. T_2 weighted axial image (a), T_1 weighted axial image (b), fat suppressed contrast-enhanced T_1 weighted axial image (c), T_2 weighted coronal image (d) and fat suppressed contrast-enhanced T_1 weighted coronal image (e) reveal a mass lesion in right lateral border of oral tongue (arrow). DL, detectable lesion.

Figure 2 UL on MRI a 54-year-old male diagnosed with right oral tongue cancer. Any of T_2 weighted axial image (a), T_1 weighted axial image (b), fat suppressed contrast-enhanced T_1 weighted axial image (c), T_2 weighted coronal image (d) and fat suppressed contrast-enhanced T_1 weighted coronal image (e) cannot detect the lesion in right lateral border of the oral tongue (within dotted circle) in which oral tongue cancer was proven clinically and pathologically. UL, undetectable lesion.

T_1 weighted images, and the largest on T_2 weighted images.^{3,4} These data were statistically compared between DL group and UL group.

MR imaging was performed on a 1.5 T system (Achieva; Philips Medical Systems, Best, Netherlands) using a maximum gradient field strength of 33 mT m⁻¹ and a 2-ch Flex S coil. All patients were examined in the dorsal position. All field of view (FOV) were set on maxillofacial region. First, axial T_2 weighted images were obtained by using the following parameters: repetition time (TR)/echo time (TE), 2800/90 ms; flip angle, 90°; FOV, 15×15 cm; matrix size, 288 × 230; slice thickness, 3.5 mm; gap, 0.3 mm; number of excitation

(NEX), 2. Axial T_1 weighted images were obtained by using the following parameters: TR/TE, 680/10 ms; flip angle, 90°; FOV, 15 × 15 cm; matrix size, 288 × 230; slice thickness, 3.5 mm; gap, 0.3 mm; NEX, 2. Coronal T_2 weighted images were obtained by using the following parameters: TR/TE, 4300/90 ms; flip angle, 90°; FOV, 15×15 cm; matrix size, 288×230; slice thickness, 3.5 mm; gap, 0.3 mm; NEX, 2. Post-contrast axial fat suppression T_1 weighted images were obtained by using the following parameters: TR/TE, 550/10 ms; flip angle, 90°; FOV, 15×15 cm; matrix size, 320×256; slice thickness, 3.5 mm; gap, 0.3mm; NEX, 2. Post-contrast coronal fat suppression T_1 weighted images were obtained by using the following parameters: TR/TE, 550/10 ms; flip angle, 90°; FOV, 15×15 cm; matrix size, 320×256; slice thickness, 3.5 mm; gap, 0.3mm; NEX, 2.

Welch *t*-test was used to compare age and rDOI between DL group and UL group, and rDOI between MRI on respective sequences and pDOI. The cut-off value of pDOI between DL group and UL group was calculated from receiver operating characteristic analysis. Spearman correlation test was used to evaluate the correlation between DOI between MRI on respective sequence and pDOI. Locoregional control rate, DFS and OS were calculated using the Kaplan–Meier method. Significance was evaluated using the log-rank test. Interobserver agreement in evaluation of detectability of the oral tongue cancer was assessed by κ statistics. A value of 0–0.20 indicated a moderate agreement, 0.21–0.40 indicated fair agreement, 0.41–0.60 indicated a moderate agreement, 0.61–0.80 showed a good agreement, and 0.81–1.00 meant very good agreement. All statistical analyses were performed by using BellCurve for Excel (SSRI, Tokyo, Japan). A

Figure 3 DOI measuring a 55-year-old male with right oral tongue cancer. Post-contrast fat suppression T_1 weighted coronal images (A), reveal oral tongue cancer in right lateral border. Radiological DOI on MRI (two direction arrow) which is defined as the longest distance of the lesion from normal mucosal surface line (dotted line) is 6.6 mm. The distance is measured by establishing a perpendicular plumb line from the normal surface. 5.5 mm-measured pathological DOI measurement (two direction arrow) is shown on HE stained image (B). The DOI was 1.1 mm (20%) larger in radiological measurement. DOI, depth of invasion; HE, hematoxylin and eosin.

Table 1 The detectability of in respective MRI sequences in DL ($n = 28$)

	<i>Axial T_1 weighted image</i>	<i>Axial T_2 weighted image</i>	<i>Coronal T_2-weighted image</i>	<i>Axial post-contrast fat suppression T_1 weighted image</i>	<i>Coronal post-contrast fat suppression T_1 weighted image</i>
Detectable	23	22	22	26	26
Undetectable	5	6	6	2	2

DL, detectable lesion.

p -value less than 0.05 was considered to indicate statistical significance.

This retrospective study was approved by the IRB and Ethic Committee at Tokyo Dental Collage, Ichikawa General Hospital (Approval number: I 16–07). The requirement of an informed consent was waived.

Results

53 patients with oral tongue cancer were evaluated, among which 28 were DL and 25 were UL. Overall there were 35 males (71%) and 19 females (29 %); age range: 31–86 years; and average age [$\pm$ standard deviation (SD)], 65.2 ± 13.6 years. The mean post-operative follow-up period was 1628.9 days (range, 373–6062 days) for all. The locoregional recurrence rate and DFS was 30.2% (16/53) during follow-up period. The mean period that had relapsed until locoregional and distant metastasis was 852 days (range, 121–2,868 days). The OS was 96.2% (51/53). The mean pathological DOI was 3.2 mm (range, 0.5–8.0 mm).

The detection rate of the oral tongue cancer on MRI were 82.1% in T_1 weighted image, 78.6% in T_2 weighted image and 89.3% in post-contrast fat suppression T_1 weighted image, respectively. The detectability of in respective MRI sequences in DL is presented in [Table 1](#).

Among 28 DL's, 18 were males and 10 females; age range: 31–86 years; average age ($\pm$ SD), 66.2 ± 15.2 years. The mean post-operative period was 1572.4 days (range, 373–2,868 days). The locoregional recurrence rate and DFS was 35.7% (10/28) during follow-up period. The mean period that had relapsed until locoregional and distant metastasis was 790 days (range, 121–2,868 days). The OS was 96.4% (27/28). Mean pDOI was 4.6 mm.

Among 25 UL's were 16 males and 9 females; age range: 36–78 years; average age ($\pm$ SD), 66.8 ± 13.4 years. The mean post-operative period was 1692.1 days (range, 451–6,062 days). The locoregional recurrence rate and DFS was 24% (6/25) during follow-up period. The mean period that had relapsed until locoregional and distant metastasis was 955 days (range, 303–1,963 days). The OS was 96.0% (24/25). Mean pDOI was 1.7 mm.

In univariate analyses, pDOI of UL was smaller than that of DL (average 1.7 vs 4.6 mm, $p < 0.001$). The cutoff value of pDOI between DL and UL on MRI was 3.5 mm [sensitivity (96.2%) and specificity (75.0%), area under the curve (0.88)]. The pDOI was smaller than 4 mm in 96% of ULs. Findings of rDOI and pDOI are

presented in [Table 2](#). Neck dissections were performed in five patients (four DL's and one UL). The decision to perform neck dissection was made by each clinician and there was no definite consensus or guidelines. None of the patients who underwent dissections pathologically revealed neck lymph node metastasis.

Regarding the DOI comparison among different modalities (analyzed for DL patients), T_1 weighted image, T_2 weighted image, and post-contrast fat suppression T_1 weighted image showed larger rDOI than pDOI in univariate analyses ($p = <0.001$). The correlation coefficient between rDOI and pDOI were 0.58 in T_1 weighted image, 0.68 in T_2 weighted image and 0.67 in post-contrast fat suppression T_1 weighted image, respectively.

There was no significant difference in locoregional control rate ($p = 0.24$), DFS rate ($p = 0.24$) or OS rate ($p = 0.92$). Interobserver agreement in evaluation of detectability of oral tongue cancer on MRI ([Table 3](#)) was very good (k -value = 0.89, $p < 0.001$).

Discussion

An early stage oral tongue cancer sometimes can be detected on MRI as a mass lesion, but other times undetected. The rDOI and its relation to pDOI as well as oral tongue cancer prognosis have not been fully evaluated. The most important prognostic factor in oral tongue cancer is nodal metastasis^{3,4} and it results in 50% decrease in 5-year survival.^{5,6} Occult metastasis to the cervical lymph nodes may occur in approximately 20–40% of patients with early stage (T_1 and T_2) oral cancer^{7,8} and the most common cause of surgical treatment failure in oral tongue cancer is neck nodal recurrence.⁹ Thus, the pre-treatment evaluation of the clinical N0 patients is a very difficult problem especially in resectable oral tongue cancer patients.

In our study, there was no significant difference between DL's and UL's on locoregional control, DFS, or OS. On the other hand, there was a strong correlation between rDOI and pDOI. When comparing pDOI of DL and UL, pDOI of UL was significantly smaller than that of DL (average 1.7 vs 4.6 mm, $p < 0.001$). These findings mean that detectability on MRI reflects the tumor size/volume, represented by pDOI. There also was a tendency of rDOI being larger than pDOI with statistical significance ($p < 0.001$).

Though there is no study yet focusing on rDOI and prognosis, there are several studies focusing on pDOI and prognosis. In one study, one of the primary

Table 2 DOI on MRI and pathological DOI (mm)

	<i>rDOI</i>	<i>pDOI</i>	Univariate <i>p</i> -value ^a	DOI difference between <i>rDOI</i> and <i>pDOI</i>	Rho between <i>rDOI</i> and <i>pDOI</i>
MR imaging sequence					
T1 weighted image	7.5	4.9	<.001	2.6 [-1.4–6.6]	0.58
T2 weighted image	8.0	4.8	<.001	3.1 [0.1–6.7]	0.68
Post-contrast fat suppression T1 weighted image	7.2	4.6	<.001	2.6 [-1.5–9]	0.67

DOI, depth of invasion.

Note—Data show the average, and upper and lower limit in parentheses. *rDOI* stands for radiological depth of invasion and *pDOI* stands for pathological depth of invasion.^aWelch's *t*-test were used.

predictors of nodal metastases and determinants of prognosis was reported as *pDOI*.¹⁰ A strong relationship of the *pDOI* to DFS, OS, and neck metastasis was reported in some studies.^{11,12} The review article by Huang et al previously reported that a *pDOI* greater than 4 mm was a strong predictor for cervical lymph node involvement.¹³ Another study also showed that the neck failure occurred predominantly in patients with tumor *pDOI* greater than 4 mm, in T_1-T_2 N0 oral tongue cancer.¹⁴ Tan et al also reported that the group with *pDOI* greater than 4 mm showed higher local recurrence rate, 5 year overall survival, disease-specific survival, local recurrence-free survival.¹⁵ National Comprehensive Cancer Network recommends the neck dissection in patients with DOI greater than 4 mm.¹⁶

Although recommended “DOI” cut-off value is set, its definition is obscure. The AJCC cancer staging manual, eighth edition, states some standards for DOI. It says that “palpation is essential to assess DOI,” but it also states that “DOI should be distinguished from tumor thickness, and its determination is predicted on invasion beneath the plane defined by surrounding normal mucosa”.¹ Though there is a study saying that preoperative MRI could help us define tumor extent and DOI¹⁸ and the manual also recognizes that the lesion is often evaluated with CT or MRI, the manual somewhat denies its usefulness as it states that “the distinction between 4 mm DOI and 6 mm DOI may not be possible.”¹

In this study, the absolute difference between *rDOI* and *pDOI* varied widely among individuals in DL cases (Table 1). DL's included *pDOI* both smaller and larger than 4 mm. The biggest difference between *rDOI* and *pDOI* was 6.7 mm, well over a cut-off value of 4 mm.

It seems very difficult to estimate precise *pDOI* based on *rDOI*. On the other hand, almost all UL's showed *pDOI* lesser than 4 mm. Based on previous studies recommending 4 mm as a cut-off value, this finding may suggest that neck dissection would not improve the prognosis of UL patients. Our study implies that the undetectable lesion indicates that its *pDOI* is smaller than 4 mm. When the lesion is detected, it is inconclusive as to its *pDOI* is smaller than 4 mm or not, regardless of its *rDOI* measurement.

When focusing on the modality, we have chosen MRI over CT imaging due to its excellent soft-tissue resolution and low influence of metal artifact, due to the dental prosthesis. MRI can demonstrate the more detailed degree of tumor extension and is used widely to stage the head and neck malignant disease. A few reports stated that radiologic tumor thickness measured on contrast-enhanced T_1 weighted images had significant correlation with histologic tumor thickness.^{3,17,18} Strong correlation between tumor thickness on MRI and pathological thicknesses (correlation coefficient = 0.68, $p < 0.001$) was reported.¹⁹ Alsaffar et al reported strong correlation between MRI and pathological thicknesses especially in deep tumor than superficial one.²⁰ In our study, the *rDOI* correlated moderately or strongly to the *pDOI* on respective MRI sequences (correlation coefficient = 0.58–0.68, $p \leq 0.001$). The *rDOI* tended to measure greater compared to *pDOI* with significance ($p \leq 0.001$). The possible cause of this discrepancy is due to the shrinkage of specimen during formalin fixation²¹ and MRI effect by adjacent inflammation and edema.¹⁸

There were several limitations to our study. It was retrospective, included only a small number of patients, and single-center study. Larger studies would be needed to confirm our results.

Conclusion

The oral tongue cancer undetectable on MRI (*i.e.* UL) has a high possibility of *pDOI* smaller than 4 mm, which can be used as a criterion to avoid unnecessary neck dissection in node negative patients.

Table 3 Interobserver agreement of MRI detectability

		Observer 2		
		Detectable	Undetectable	Total
Observer 1	Detectable	28	0	28
	Undetectable	3	23	26
	Total	31	23	54

References

- Ridge JA, Lydiatta WM, Patel SG, Glastonbury CM, Brandwein-Gensler M, Ghossein RA. Lip and Oral Cavity. In: Amin M. B, Edge S, Greene F, Byrd D. R, Brookland R. K, Washington M. K, eds. *AJCC cancer staging manual*. 8th ed. New York: Springer; 2017. pp. 79–94.
- Trotti A, Compton C. C, Fritz A. G, Greene F. L, Trotti A et al. eds. *AJCC cancer staging manual*, 7th ed. New York: Springer; 2010.
- Iwai H, Kyomoto R, Ha-Kawa SK, Lee S, Yamashita T. Magnetic resonance determination of tumor thickness as predictive factor of cervical metastasis in oral tongue carcinoma. *Laryngoscope* 2002; **112**: 457–61. doi: <https://doi.org/10.1097/00005537-200203000-00010>
- Layland MK, Sessions DG, Lenox J. The influence of lymph node metastasis in the treatment of squamous cell carcinoma of the oral cavity, oropharynx, larynx, and hypopharynx: N0 versus N+. *Laryngoscope* 2005; **115**: 629–39. doi: <https://doi.org/10.1097/01.mlg.0000161338.54515.b1>
- Snow GB, Annys AA, van Slooten EA, Bartelink H, Hart AA. Prognostic factors of neck node metastasis. *Clin Otolaryngol Allied Sci* 1982; **7**: 185–92. doi: <https://doi.org/10.1111/j.1365-2273.1982.tb01581.x>
- Grandi C, Alloisio M, Moglia D, Podrecca S, Sala L, Salvatori P, et al. Prognostic significance of lymphatic spread in head and neck carcinomas: Therapeutic implications. *Head Neck Surg* 1985; **8**: 67–73. doi: <https://doi.org/10.1002/hed.2890080202>
- Fukano H, Matsuura H, Hasegawa Y, Nakamura S. Depth of invasion as a predictive factor for cervical lymph node metastasis in tongue carcinoma. *Head Neck* 1997; **19**: 205–10. doi: [https://doi.org/10.1002/\(SICI\)1097-0347\(199705\)19:3<205::AID-HED7>3.0.CO;2-6](https://doi.org/10.1002/(SICI)1097-0347(199705)19:3<205::AID-HED7>3.0.CO;2-6)
- Pentenero M, Gandolfo S, Carrozzo M. Importance of tumor thickness and depth of invasion in nodal involvement and prognosis of oral squamous cell carcinoma: A review of the literature. *Head Neck* 2005; **27**: 1080–91. doi: <https://doi.org/10.1002/hed.20275>
- Yuen AP, Lam KY, Wei WI, Lam KY, Ho CM, Chow TL, et al. A comparison of the prognostic significance of tumor diameter, length, width, thickness, area, volume, and clinicopathological features of oral tongue carcinoma. *Am J Surg* 2000; **180**: 139–43. doi: [https://doi.org/10.1016/S0002-9610\(00\)00433-5](https://doi.org/10.1016/S0002-9610(00)00433-5)
- Patel RS, Clark JR, Dirven R, Wyten R, Gao K, O'Brien CJ. Prognostic factors in the surgical treatment of patients with oral carcinoma. *ANZ J Surg* 2009; **79**(1-2): 19–22. doi: <https://doi.org/10.1111/j.1445-2197.2008.04791.x>
- Tshering Vogel DW, Zbaeren P, Thoeny HC. Cancer of the oral cavity and oropharynx. *Cancer Imaging* 2010; **10**: 62–72. doi: <https://doi.org/10.1102/1470-7330.2010.0008>
- Arya S, Rane P, Deshmukh A. Oral cavity squamous cell carcinoma: Role of pretreatment imaging and its influence on management. *Clin Radiol* 2014; **69**: 916–30. doi: <https://doi.org/10.1016/j.crad.2014.04.013>
- Huang SH, Hwang D, Lockwood G, Goldstein DP, O'Sullivan B. Predictive value of tumor thickness for cervical lymph-node involvement in squamous cell carcinoma of the oral cavity: A meta-analysis of reported studies. *Cancer* 2009; **115**: 1489–97. doi: <https://doi.org/10.1002/cncr.24161>
- Ganly I, Goldstein D, Carlson DL, Patel SG, O'Sullivan B, Lee N, et al. Long-term regional control and survival in patients with “low-risk,” early stage oral tongue cancer managed by partial glossectomy and neck dissection without postoperative radiation: the importance of tumor thickness. *Cancer* 2013; **119**: 1168–76. doi: <https://doi.org/10.1002/cncr.27872>
- Tan WJ, Chia CS, Tan HK, Soo KC, Iyer NG. Prognostic significance of invasion depth in oral tongue squamous cell carcinoma. *ORL J Otorhinolaryngol Relat Spec* 2012; **74**: 264–70. doi: <https://doi.org/10.1159/000343796>
- NCCN clinical practice guidelines in oncology head and neck cancers v.1. 2018. Available from: https://www.nccn.org/professionals/physician_gls/pdf/head-and-neck.pdf [Accessed February 28, 2018].
- Tetsumura A, Yoshino N, Amagasa T, Nagumo K, Okada N, Sasaki T. High-resolution magnetic resonance imaging of squamous cell carcinoma of the tongue: An in vitro study. *Dentomaxillofac Radiol* 2001; **30**: 14–21. doi: <https://doi.org/10.1038/sj.dmf.4600565>
- Lam P, Au-Yeung KM, Cheng PW, Wei WI, Yuen AP, Trendell-Smith N, et al. Correlating MRI and histologic tumor thickness in the assessment of oral tongue cancer. *AJR Am J Roentgenol* 2004; **182**: 803–8. doi: <https://doi.org/10.2214/ajr.182.3.1820803>
- Preda L, Chiesa F, Calabrese L, Latronico A, Bruschini R, Leon ME, et al. Relationship between histologic thickness of tongue carcinoma and thickness estimated from preoperative MRI. *Eur Radiol* 2006; **16**: 2242–8. doi: <https://doi.org/10.1007/s00330-006-0263-9>
- 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**: 61. doi: <https://doi.org/10.1186/s40463-016-0172-0>
- Johnson RE, Sigman JD, Funk GF, Robinson RA, Hoffman HT. Quantification of surgical margin shrinkage in the oral cavity. *Head Neck* 1997; **19**: 281–6. doi: [https://doi.org/10.1002/\(SICI\)1097-0347\(199707\)19:4<281::AID-HED6>3.0.CO;2-X](https://doi.org/10.1002/(SICI)1097-0347(199707)19:4<281::AID-HED6>3.0.CO;2-X)