Systematic Review of the Diagnostic Value of Magnetic Resonance Imaging for Early Glottic Carcinoma

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Objective: In early glottic cancer, accurate assessment of tumor extension, including depth infiltration, is of great importance for both staging, therapeutic approach and systematic comparison of data. Our goal was to assess the diagnostic value of MRI in pre-therapeutic staging of primary early stage (T1 and T2) glottic carcinoma.

Study design: Systematic review of literature.

Methods: We conducted a systematic search in Pubmed, Embase, and Scopus up to September 23, 2016. Included studies were selected and critically appraised for relevance and validity.

Results: Seven out of 938 unique articles were selected, including 64 cases. MRI over-staged 6% and under-staged 13% of cT1 and cT2 tumors. However, available data is heterogeneous, very limited and mainly based on subanalysis of a small amount of patients. Reported MRI protocols appear to be suboptimal for small laryngeal lesions. Diagnostic value of MRI for subtle depth infiltration or laryngeal anatomical subsites (eg, laryngeal ventricle, vocal cord, etc.) could not be assessed.

Conclusions: More studies are needed to assess the diagnostic value of MRI for small glottic tumors.

Key Words: MRI, early glottic carcinoma, pretherapeutic staging.

INTRODUCTION

Laryngeal squamous cell carcinoma (SCC) is one of the most common head and neck cancers, arising from the mucosal surface of the larynx. Early stage squamous cell carcinomas of the larynx, especially in the glottic area, have high local control rates (76.8–88.9%).[1–3] The aim of treatment is to ensure oncological cure with preservation of function. The most important factor in treatment planning is the accuracy of pre-therapeutic staging with detailed assessment of neoplastic extension.

For superficial midcord T1a glottic tumors, comparable local control rates for both endoscopic laser surgery and radiotherapy are described. However, for more extended lesions, including the anterior commissure, contralateral vocal cord (T1b) or T2 lesions, there still is no consensus on treatment strategy with optimal outcome.[2] The main factor that prohibits the systematic evaluation and pooling of data is the uncertainty of tumor comparability, due to an absence of

a standardized method that accurately measures tumor extent and depth. Furthermore, papers focusing on laser surgery do not uniformly categorize resection types. For endoscopic laser resections, tumor depth directly influences the type of European Laryngological Society (ELS) resection. With lesser resections, including subepithelial (type I) and subligamental (type II) and greater resections extending into the vocal muscle (type III), anterior commissure (type IV) or for example into the contralateral vocal cord (Va).

Detailed assessment of neoplastic invasion can be achieved with different modalities. Direct visualization of the tumor by indirect or direct laryngoscopy is the first step in diagnosis and evaluation of tumor extension. Although this can detect superficial tumor growth, subtle depth infiltration can only be estimated by palpation, and paraglottic invasion as well as deep tumor spread into the conus elasticus may be entirely occult. Also, endoscopic exposure of the AC area can be problematic. Reported rates of correct staging of AC invasion by direct laryngoscopy vary beteen 40–72%.[4,5] False-negative results are likely to result in insufficient treatment and recurrence, while false-positive evaluation results in overtreatment, unnecessary morbidity, and patient burden.

Detailed, high resolution imaging of the larynx can give additional information about tumor infiltration not visible with laryngoscopy. Cross-sectional imaging of the larynx can be performed with Computed Tomography (CT) or Magnetic Resonance Imaging (MRI). Although CT and MRI are routinely used to differentiate between limited or gross cartilage invasion and to evaluate deep soft-tissue extension, their role in early stage glottic carcinoma remains limited.

Fig. 1. Search Syntax.
A: PubMed
B: Embase
C: Scopus

MRI had several advantages over CT. It does not require exposure to ionizing radiation and it provides superior soft tissue contrast compared to CT. Furthermore, MRI is considered to be superior for detection of cartilage invasion.[6] Also, MRI allows a multiparameter analysis (T1 weighted, T2 weighted, diffusion weighted imaging (DWI) and post-contrast acquisition). This amplifies the contrast resolution. MRI images are, however, more likely to be degraded by motion caused by swallowing and breathing. Also, MRI cannot be performed in patients with metallic foreign bodies, such as cochlear implants, and certain implant devices.[7] The detection of subtle tumor spread by imaging can be difficult. However, detailed evaluation of submucosal areas can both change the disease stage, and reassess the therapeutic approach. Therefore, our goal is to assess the diagnostic value of MRI in pre-therapeutic staging of primary early stage (T1 and T2) glottic carcinoma.

METHODS

Search Strategy

We conducted a systematic search in Pubmed, Embase, Scopus, and Cochrane up to September 23, 2016. A search syntax was developed by using synonyms for MRI (determinant) and laryngeal carcinoma (outcome) (Fig. 1). Reporting of our data is done according to the PRISMA statement.[8]

Study Selection

Screening of publications was performed by two authors independently (SE, IS). Any difference in opinion was resolved by consensus. From the retrieved articles duplicates were removed. Title and abstract, and ultimately the full-text of potentially eligible articles were screened using criteria shown in Figure 2. A thorough analysis of selected articles was made, and their bibliographies were analyzed to identify any additional articles that could be relevant for this review. Histopathology was the reference standard in our study. Inclusion criteria were clinical T1 and T2 glottic squamous cell carcinomas.

MRI had to be performed in all patients.

Critical Appraisal of Included Studies

Using predefined criteria, articles were critically appraised for relevance and validity. Data collected included number of patients with T1 and T2 disease, MRI strength, standardized MRI protocol, reference standard, blinding, missing data. and selection bias (Table I).

Data Extraction and Statistics

To compare the diagnostic value of MRI, positive predictive value (PPV), negative predictive value (NPV), sensitivity (SN), and specificity (SP) were extracted from eligible articles or, when not described, calculated (when possible) from the original data.

RESULTS

Search Strategy and Study Selection

Our search strategy yielded 938 unique publications (Fig. 2). After title and abstract screening 80 articles were left for full-text assessment, of which 73 were excluded for various reasons. This resulted in a total of seven eligible studies.

Critical Appraisal

Appraisal of the seven eligible studies is presented in Table I.[9–15] All seven studies were prospective. Only two articles only included glottic laryngeal carcinoma
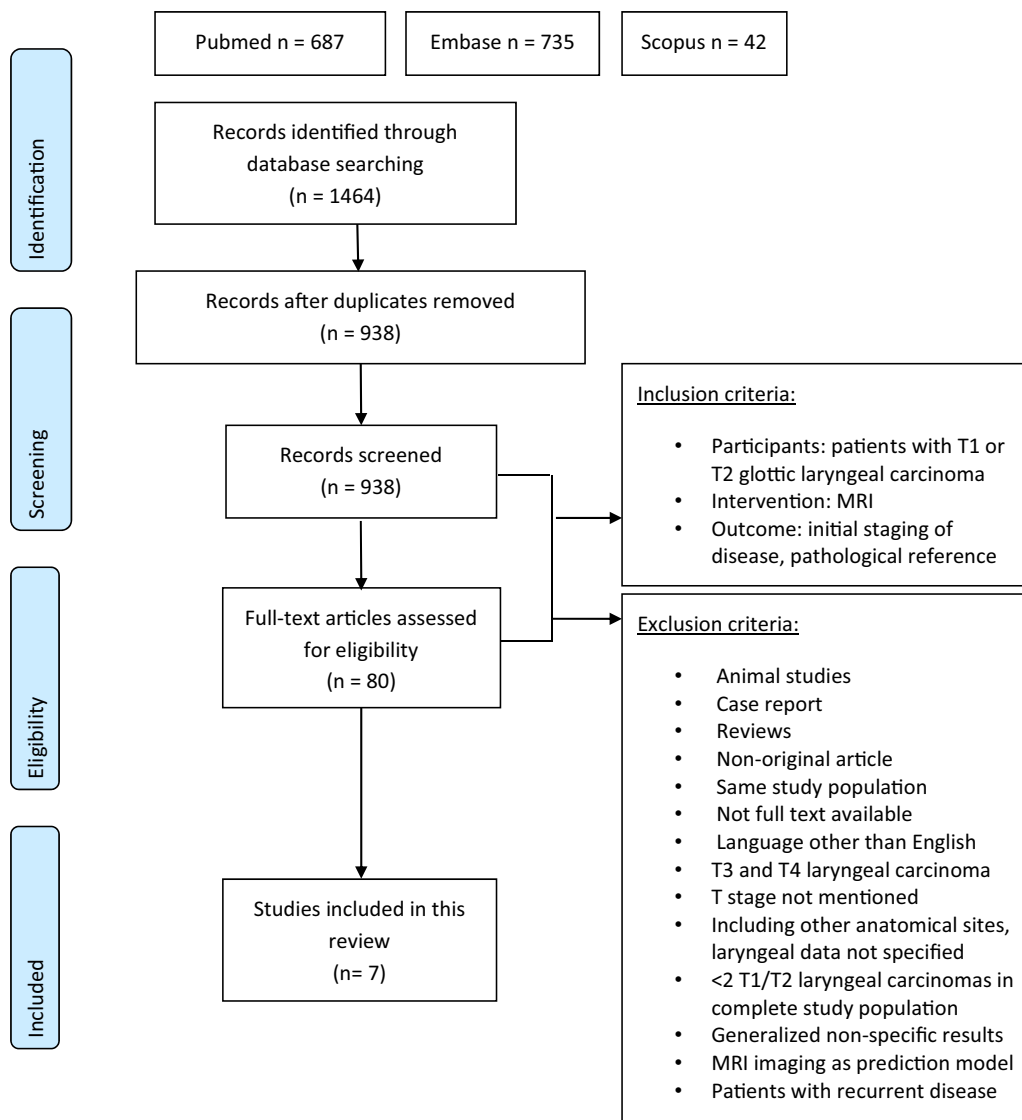
Fig. 2. Flow Diagram

and were therefore considered most relevant.[10,13] Two articles included supraglottic, glottis, and subglottic carcinomas.[12,15] Banko et al. included supraglottic and glottic tumors and Carriero and Wu evaluated "laryngeal tumors" in which laryngeal level is not further specified, although Wu only included patients with involvement of the anterior vocal commissure. No subanalysis was done for glottic tumors only.[9,14]

Furthermore, five articles included T1-T4 tumors, one article included T2-T4 tumors, and one article included T1-T3 tumors.[10] MRI evaluation was done by one to three observers. Standardized MRI protocol was reported in six studies. Kraft et al. did not specify MRI settings or field strength. Missing data were not reported in two articles.[11,15] No cases of selection bias were found, although only Zbaren et al. and Hu et al. specifically report the inclusion of consecutive patients. Allegra et al. and Kraft et al. and excluded six and eight patients, respectively, receiving curative

radiotherapy instead of surgery. Carriero et al. excluded 12 patients because they were considered inoperable.

Study Characteristics

Study characteristics are shown in Table II. Studies were heterogeneous in study methods and outcomes. Five studies describe completely excised tumors.[9,10,12,13,15] Allegra et al. performed two excision biopsies, four chordectomies, and 10 supracricoid laryngectomies (CHEP), all for T1 and T2 glottic carcinomas. Hu et al. performed an endoscopic laser resection in five cases of T1 glottic carcinoma and partial laryngectomy in 12 cases of T2 disease.[13] Both studies performed analysis of laryngeal subsites for the whole study population only, including T3 and T4 tumors. Histopathologic correlation method for T1 and T2 disease is not described. Wu et al. performed complete (8) or partial (18) laryngectomies in all 26 patients,

TABLE I.
Critical Appraisal.

Author	Publication Year	Patients with Primary T1/T2 Laryngeal Carcinomas	MRI	Outcome	No. Glottic Carcinomas	No CT1 Carcinomas (T1A-T1B)	No CT2 Carcinomas	Selection Bias Patient Sampling	Missing Data	Index Test: MRI Standardized Protocol	Index Test: MRI Blinding (No. Observers)	Reference Test Standardized Protocol	Reference Test Blinding (No. Observers)
Wu[9]	2016	•	○	?/26	0	10	•	0	•	•(2)	•	•(2)
Allegra[10]	2014	•	•	20	14(8-6)	2	•	6/26	•	•(2)	•	•(2)
Banko[11]	2014	•	○	28/40	0	14	•	?	•	?	N/A	N/A
Kraft[12]	2013	•	○	27/76	11	26	•	8/84	?	•(1)	•	•(1)
Hu[13]	2011	•	•	30	5	12	•	0	•	•(2)	•	•(2)
Carriero[14]	2000	•	○	?/25	9	8	•	12/37	•	•(2)	N/A	N/A
Zbaren[15]	1996	•	○	34/40	0	5	•	?	•	•(3)	•	•(3)

Categories: • Accurate; ○ Not Accurate; ? Unknown; N/A: not applicable
../. number of glottic laryngeal episodes versus number of total laryngeal episodes (including supra- and subglottis)

of which 10 patients had a T2 carcinoma, and specimens underwent serial section.[9] However, only radiological and pathological T stages were compared, with no specifications on laryngeal subsites. Zbaren et al. evaluated only four patients with (laryngeal) cT2 tumors of a total of 40 included patients.[15] After histopathological verification, 10 were finally staged as pT2. Four patients underwent voice preserving laryngectomy (supraglottic laryngectomy in three cases and partial laryngectomy in one case), all others underwent total laryngectomy. Whole organ slices were cut parallel to the plane of the axial MRI. Kraft et al. included 76 patients of which 11 T1 and 26 T2 tumors, both glottic and subglottic.[12] T stage according to laryngeal level is not further specified. Only patients undergoing complete surgical excision were included (chordectomy, laser resection, partial laryngectomy, or total laryngectomy). Ten criteria, eg, infiltration of the vocal fold, paraglottic space, midline crossing, and maximum tumor diameter, were scored.

In both studies of Banko et al. and Carriero et al., "surgery" and "histology" are mentioned but not further specified. It is therefore unclear if complete surgical excision was carried out.[11,14] MRI field strengths varied between 1 and 3 Tesla and was not reported in one study.[12] Imaging consisted mostly of T2 and T1W contrasts with scans in several directions. Contrast was not used routinely in the study by Hu et al.[13] Three studies used contrast before a second T1W scan was performed.[10,11,14] The in-plane resolution was not always clearly described and (when reported) varied between 0.5×0.5 mm^2 and 1×1 mm^2. Slice thickness was 3–4 mm in all included studies.

Data Extraction and Statistics

Concordance between MRI and pathological TNM staging. A total of 64 patients were radiologically staged as T1 or T2 carcinomas (Table III).[9,10,13–15] Kraft et al. only reported final tumor staging and no comparison could be made between radiological and histopathological staging. Banko did not specify number of patients that were over- or under-staged and numbers could therefore not be calculated. Using TNM Classification of Malignant Tumors (TNM) classification, overall concordance between MRI and histopathology was 81% (52 out of 64 patients). Six percent (4 out of 64) of tumors were over-staged; 13% (8 out of 64) were under-staged.

Four undetected lesions by MRI were finally confirmed as three T1 tumors and one T2 tumor.[13] These undetected tumors were small and without deep extension. On the contrary, two lesions classified as cT1a were squamous cell papillomas at pathological examination (no tumor).[10] Subanalysis of T1a and T1b staging only, done by Allegra et al., further shows overstaging of two lesions classified as cT1b by MR, which were pT1a on histopathological conformation. Wu reports on one patient staged with a T1 lesion, which pathologically appeared to be a T2 lesion.[9] Carriero reports correct staging of all 17 patients with T1 and T2 carcinomas.[14]

Author	Study Design	MRI Strength (Tesla)	Other Imaging Reference	Direct Laryngoscopy
Wu[9]	P	3.0	CT/DW MRI	No
Allegra[10]	P	1.5	CT	No
Banko[11]	P	1.5	-	No
Kraft[12]	P	?	CT/endosonography	Yes
Hu[13]	P	1.5	sonography	No
Carriero[14]	P?	1.0	-	Yes
Zbaren[15]	P	1.5	CT	Yes

P = prospective.

Except for T staging of the initial tumor, no data concerning tumor infiltration depth or tumor volume could be evaluated in the included studies.

Diagnostic value of imaging according to anatomical subsites. The diagnostic accuracy of MRI to predict invasion of anatomical subsites, including the anterior commissure, paraglottic space, and cartilages was reported in several selected articles (ranging from three to six articles, depending on the subsite). However, since sensitivity, specificity, positive predictive value and negative predictive value could only be calculated for the whole study population, including T1-T4 tumors, no subanalysis could be done for T1 and T2 tumors only.

DISCUSSION

This systematic review evaluates the diagnostic value of MRI for pre-therapeutic staging of early glottic cancer (T1–T2). A standardized method that accurately measures tumor extent and depth, especially in case of more extensive T1 or T2 lesions, is needed to systematically compare endoscopic resections and radiotherapy with the best possible functional outcome. For example, invasion of the vocal muscle automatically leads to an ELS type III resection, whereas more superficial lesions can be resected with an ELS type I or II.

Using TNM classification, overall concordance calculated from five articles, between MRI and histopathology was 81% (52 out of 64 patients). In total, 6% (4 out of 64) of tumors were over-staged, 13% (8 out of 64) were under-staged.

According to these numbers, MRI more often underestimates than overestimates tumor extent in small laryngeal carcinomas. This is not in concordance with the idea that peritumoral inflammation on MRI, which amplifies the boundaries of abnormal tissues, can lead to overestimation. However, these numbers must be seen in perspective.

First, all over-staged tumors calculated in this review were described by Allegra et al., which was considered the most relevant study population. All understaged tumors were scored by other articles of which only a small part of the study population consisted of T1 and T2 laryngeal tumors. Second, we screened all full text articles on clinical T1 and T2 carcinomas. As a result, all under-staged and correctly staged tumors were included in this review. However, patients with cT3 and cT4 carcinomas, which were eventually down-staged to pT1 or pT2 on pathological examination could be left out. The number of over-staged tumors according to MRI can therefore be higher than calculated here. Patients with cT3 and cT4 of the included articles in this review were also not included, since our search did not screen on this population and numbers are not reliable.

We conducted a broad search in literature and included all laryngeal carcinomas and MRI as diagnostic imaging modality. We detected a high level of bias in reported articles. Also, our review showed that there is a very limited amount of studies in this field. Only two articles included glottic laryngeal carcinomas.[10,13] Second, none of the articles included T1 and T2 stages only, and no subanalysis was done for different T-stages. Third, studies are very heterogeneous. Only four studies describe completely excised tumors, of which histopathologic correlation for T1 and T2 stages is unclear in one of these studies.[13] Fourth, invasion of glottic subsites (eg, anterior commissure or sinus of Morgagni) that can be relevant for therapeutic approach and functional outcome of early glottic carcinomas were only scored in two articles and since numbers were not specified according to T stage, no subanalysis could be performed.

Fifth, scanning protocols varied widely or were not described at all.[12] Field strengths varied between 1 and 3 Tesla and was not reported in one study.[12] Imaging consisted mostly of T2 and T1W contrasts with scans in several directions. Contrast was not used routinely in the study by Hu et al.[13] Three studies used contrast before a second T1W scan was performed.[10,11,14] The in-plane resolution was not always clearly described and (when reported) varied between 0.5×0.5 mm^2 and 1×1 mm^2. Slice thickness was 3–4 mm in all included studies. For the depiction of anatomical (laryngeal) structures, a larger slice thickness has the benefit of strong signal to noise ratio (SNR). However, a slice thickness of 3–4 mm could give rise to large partial volume effects in case of smaller lesions. These partial volume effects may have been partly mitigated by scanning in axial, coronal, and sagittal direction. But for small laryngeal lesions, with a possible cranio-caudal diameter of 1–2 mm, a slice thickness of 3 mm or more may greatly reduce

PA Stage	Radiological Stage (MRI)			
	T0	T1a/b	T2	Total
T0	-	2/-	-	2
T1a/b	3	23	-	26
T2	1	1	31	33
T3	-	-	3	3
T4	-	-	-	-
Total	4	26	34	64

visibility of the tumor. Furthermore, the use of neck receive coils was not reported in some studies. Two articles report the use of an anterior neck coil.[10,15] One article describes the use of a dedicated neck coil.[14] In general, higher field strength and receive coils located close to the larynx, in combination with sufficiently high resolution results in a better depiction of smaller lesions.

Another remark is the adjustment of the TNM staging in 2002. Imaging studies of glottic carcinoma before 2002 suggested that a tumor adjacent to the thyroid cartilage (adjacent sign) had an increased risk of local failure after definitive RT. In the sixth edition of the TNM staging system, proposed in 2002, paraglottic space invasion or minor thyroid cartilage erosion was upstaged to a T3, in addition to the vocal cord fixation in the fifth edition. As both studies of Zbaren and Carriero were published before 2002, this could have influenced their diagnostic T staging as presented in Table I.

MRI is generally used to supplement microlaryngoscopy under general anesthesia in the staging of glottic cancer. Ideally, additional imaging would detect exact tumor size and extension, submucosal spread, invasion of the vocal muscle or paraglottic space, possible spread to the anterior commissure or crossing of the midline (with the risk of tumor spread to the thyroid and subglottic area).

Although MRI evaluation does appear to be a helpful diagnostic method in the scarce literature that can be found, combined accuracy of MRI and clinical staging remains higher than MRI staging alone. According to Zbaren et al., the accuracy of clinical/endoscopic staging was 55%.[15] The accuracy of combined clinical and MR imaging staging was 87.5%. However, it must be taken into account that in this study, all T stages were included.

Champsaur et al. studied the MRI radio-anatomy of the larynx based on correlations between MRI and histologic sections on non-oncologic cadaver specimens in vitro.[16] They identified the conus elasticus, paraglottic space, and the vocal processes of the arytenoid cartilages. It was impossible to delineate the thyroarytenoid muscle or the vocal muscle on MRI. The two muscles seem continuous. They emphasize that hyaline cartilages (cricoid, thyroid, arytenoids) are the site of endochondral ossification, which is very variable. Cartilaginous ossification, resulting from cartilaginous angiogenesis, may be misinterpreted as a tumoral invasion. The fibrocartilages (epiglottis, vocal process of the arytenoid) ossify only very rarely. Their signal intensity therefore remains constant irrespective of age. Both fibrocartilages displayed a low signal intensity, in the sagittal plane. Identification of the vocal process may allow a more precise assessment of cancers of the glottic plane.

Besides MRI, the introduction of new endoscopic devices has proven to be of additional value for defining tumor extension and delineating its resection margins. Narrow band imaging (NBI) is an especially promising tool. Filtered wavelengths enhance the microvascular abnormalities associated with preneoplastic changes of the mucosal lining. Routine intra-operative use would decrease the rate of positive superficial margins from 23.7% to 3.6% during transoral laser microsurgery for early glottic cancer.[17] Although NBI can detect subtle mucosal extension, the filtered wavelengths only penetrate the superficial layers of mucosa, enhancing the mucosal and submucosal microvascular networks only. And it has therefore no role in the evaluation of deep extension of neoplastic lesions and does not affect the incidence of deep positive margins.

With technological advancement, image quality of MRI is still increasing. The integration of DWI into the magnetic resonance protocol has the potential to increase the specificity.[18] Furthermore, developments in higher field strength are of potential benefit. Of the studies reviewed here, only two used a 3 Tesla MRI unit. All other patients were scanned at 1.5 Tesla. Nowadays, 3 Tesla units are more readily available and even 7 Tesla scanners can be used for clinical scanning. The implementation of 7 Tesla MRI for human use has the potential to further advance spatial resolution beyond that of 1.5T and 3T. 7 Tesla has already been used to produce high-definition images of various anatomical areas, including the brain and inner ear.[19,20] Challenges encountered are that higher field strengths are more prone to image artifacts and longer acquisition times. Hopefully, future studies can further address these developments.

CONCLUSION

This systematic review evaluates the diagnostic value of MRI for pre-therapeutic staging of early glottic cancer (T1-T2). A standardized method that accurately measures tumor extent and depth, especially in case of more extensive T1 or T2 lesions, is needed to systematically compare endoscopic resections and radiotherapy with the best possible functional outcome. Overall concordance between MRI and histopathology was 81% (52 out of 64 patients). In total, 6% (4 out of 64) of tumors were over-staged, 13% (8 out of 64) were under-staged. However, available data for MRI and T1 and T2 glottic carcinomas are very limited and numbers can be influenced by the necessity of subanalysis-based numbers based on a small amount of patients. Since no articles solely include the defined subgroup (cT1 and cT2 glottic carcinomas), no diagnostic values (sensitivity, specificity, PPV, and NPV) could be calculated. Furthermore, neoplastic invasion of glottic subsites in cT1 and cT2 carcinomas cannot be reliably assessed. MRI protocols were heterogenous and included slice thickness of 3–4 mm, which may be suboptimal for small glottic lesions. More studies are needed to evaluate the additional diagnostic value of MRI compared to clinical evaluation alone. Moreover, with technological advancement, image quality of MRI is still increasing, with the potential of more detailed cross-sectional imaging. Detection of subtle in-depth infiltration may be a step forward in treatment planning and patient counseling in the pre-operative stage.

BIBLIOGRAPHY

1. O'Hara J, Markey A, Homer JJ. Transoral laser surgery versus radiotherapy for the tumour stage 1a or 1b glottic squamous cell carcinoma: systematic review of local control outcomes. *J Laryngol Otol* 2013;127(8): 732–738.
2. Van Loon Y, Sjogren E, Langeveld T, et al. Functional outcomes after radiotherapy or laser surgery in early glottic carcinoma: A systematic review. *Head Neck* 2012;34(8):1179–1189.
3. Abdurehim Y, Hua Z, Yasin Y, Xukurhan A, Imam I, Yuqin F. Transoral laser surgery versus radiotherapy: systematic review and meta-analysis for treatment options of T1a glottic cancer. *Head Neck* 2012;34(1):23–33.
4. Barbosa MM, Araújo VJ Jr, Boasquevisque E, et al. Anterior vocal commissure invasion in laryngeal carcinoma diagnosis. *Laryngoscope* 2005;115:724–730.
5. Naiboglu B, Kinis V, Toros SZ, et al. Diagnosis of anterior commissure invasion in laryngeal cancer. *Eur Arch Otorhinolaryngol* 2010;267(4): 551–555.
6. Becker M, Zbaren P, Laeng H, Stoupis C, Porcellini B, Vonck P. Neoplastic invasion of the laryngeal cartilage: comparison of MR imaging and CT with histopathologic correlation. *Radiology* 1995:194(3):661–669.
7. Huang BY, Solle M, Weissler MC. Larynx: anatomic imaging for diagnosis and management. *Otolaryngol Clin North Am* 2012;45(6):1325–1361.
8. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med* 2009;6(6):e1000097.
9. Wu JH, Zhao J, Li ZH, et al. Comparison of CT and MRI in diagnosis of laryngeal carcinoma with anterior vocal commissure involvement. *Sci Rep* 2016;6:30353.
10. Allegra E, Ferrise P, Trapasso S, et al. Early glottic cancer: role of MRI in the preoperative staging. *Biomed Res Int* 2014;2014:890385.
11. Banko B, Djuvic V, Milovanovic J, Kovac J, Novakovic Z, Mksimovic R. MRI in evaluation of neoplastic invasion into preepiglottic and paraglottic space. *Auris Nasus Larynx* 2014;41(5):471–474.
12. Kraft M, Bruns N, Hugens-Penzel M, Arens C. Clinical value of endosonography in the assessment of laryngeal cancer. *Head Neck* 2013;35(2):195–200.
13. Hu Q, Zhu SY, Zhang Z, Luo F, Mao YP, Guan XH. Assessment of glottic squamous cell carcinoma: comparison of sonography and non-contrast enhanced magnetic resonance imaging. *J Ultrasound Med* 2011;30(11): 1467–1474.
14. Carriero A, Scarabino T, Vallone A, Cammisa M, Salvolini U, Bonomo L. MRI T-staging of laryngeal tumours: role of contrast medium. *Neuroradiology* 2000;42(1):66–71.
15. Zbaren P, Becker M, Läng H. Pretherapeutic staging of laryngeal carcinoma; clinical findings, computed tomography, and magnetic resonance imaging compares with histopathology. *Cancer* 1996;77(7):1263–1273.
16. Champsaur P, Parlier-Cuau C, Brunet C, et al. Serial anatomy of the larynx in MRI: MRI-histologic correlations. *Surg Radiol Anat* 2000;22(1):5–11.
17. Garofolo S, Piazza C, Del Bon F, et al. Intraoperative narrow band imaging better delineates superficial resection margins during transoral laser microsurgery for early glottic cancer. *Ann Otol Rhinol Laryngol* 2015; 12(4):294–298.
18. Becker M, Zbaren P, Casselman JW, Kohler R, Dulguerov P, Becker CD. Neoplastic invasion of the laryngeal cartilage: reassessment of criteria for diagnosis at MR imaging. *Radiology* 2008;249(2):551–559.
19. Zwanenburg JJ, Hendrikse J, Visser F, Takahara T, Luijten PR. Fluid attenuated inversion recovery (FLAIR) MRI at 7.0 Tesla: comparison with 1.5 and 3.0 Tesla. *Eur Radiol.* 2010;20(4):915–922.
20. Van Egmond SL, Visser F, Pameijer FA, Grolman W. Ex vivo and in vivo imaging of the inner ear at 7 Tesla MRI. *Otol Neurotol* 2014;35(4):725–729.