

• CLINICAL RESEARCH •

CT and MR imaging for detecting neoplastic invasion of esophageal inlet

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Abstract

AIM: Direct neoplastic invasion of esophageal inlet is an uncommon but significant sequela of advanced head and neck carcinomas. The aim of this study was to seek an optimal CT or MRI criterion for determining the neoplastic esophageal inlet involvement in order to help tumor staging and surgical planning.

METHODS: CT and MRI of 78 head and neck tumor cases were investigated retrospectively. At the level of the esophageal inlet on axial CT and MRI scans, the distance between the posterior aspect of cricoid cartilage and the anterior aspect of vertebra (d-CV) was measured by two senior radiologists who were unaware of clinical findings. Then, according to pathologic evidence and follow-up findings, these patients were divided into patient group, including 32 cases with neoplastic invasion of esophageal inlet and control group, including 46 cases without neoplastic esophageal inlet involvement. The statistical difference based on d-CV between the two groups was determined. The optimal criterion of d-CV on CT or MRI was assessed and its accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were evaluated respectively.

RESULTS: In control group, d-CV at the esophageal inlet level was 0.94 ± 0.15 cm on axial CT and 0.91 ± 0.18 cm on axial MRI, whereas in patient group, d-CV was 1.24 ± 0.32 cm on CT and 1.31 ± 0.36 cm on MRI. There was a statistical significance in d-CV between the two groups on CT and MRI modalities ($P < 0.01$). d-CV greater than 1.0 cm was the typical feature of neoplastic invasion of the esophageal inlet with 73% sensitivity, 83% specificity, 79% accuracy, 76% PPV, 80% NPV on CT and 84% sensitivity, 77% specificity, 80% accuracy, 70% PPV, 88% NPV on MRI respectively.

CONCLUSION: Except for other CT and MR imaging features of neoplastic invasion of esophageal inlet, d-CV greater than 1.0 cm is an optimal adjunct criterion for esophageal inlet invasion by advanced head and neck carcinomas.

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Key words: Esophageal neoplasms; Esophageal inlet; CT; MRI; Neoplasm invasiveness

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INTRODUCTION

Esophageal inlet is the pharyngoesophageal junction, which is the portion between postcricoid region of the hypopharynx and cervical esophagus. It is located at the level of the lower border of the cricoid cartilage or approximately the level of the sixth cervical vertebra^[1,2]. Direct neoplastic invasion of esophageal inlet by advanced head and neck carcinomas is uncommon, but it is generally associated with upgrading primary tumor staging, increasing surgical complexity and a relatively low survival rate^[2,27]. CT and MRI assessments of the presence or absence of esophageal inlet invasion by tumors is clinically useful for pretherapeutic staging, surgical planning and prediction of prognosis. Although there have been some literatures describing CT and MRI findings in the normal esophagus, esophageal tumor and invasion by advanced head and neck neoplasms^[2-4,6,17,27], there are few articles on the role of CT or MRI for predicting esophageal inlet invasion by advanced head and neck carcinomas^[2-4]. Therefore, the aim of this study was to seek an optimal criterion for determining the neoplastic esophageal inlet involvement in order to help tumor staging and surgical planning for resection and reconstruction.

MATERIALS AND METHODS

Study design and study subjects

Seventy-eight head and neck tumor cases, aged 27-81 years (mean age, 57.9 years), including 57 men and 21 women, were obtained from our hospital between January 1990 and February 2004. CT and MRI of these patients were investigated retrospectively by two senior radiologists without the knowledge of clinical evidence of esophageal inlet invasion. At the level of esophageal inlet on axial CT and MRI scans, the distance between the posterior aspect of cricoid cartilage and the anterior aspect of vertebra (d-CV) was measured. Then, according to pathologic evidence and follow-up findings, these patients were divided into patient group, including 32 cases with neoplastic invasion of esophageal inlet and control group, including 46 cases without neoplastic esophageal inlet involvement.

In patient group, 30 (93.8%) of the 32 cases received preoperative CT, whereas 19 (59.4%) underwent MR imaging. The presence of esophageal invasion was determined by pathologic evidence from surgical resection or biopsy. These cases included laryngeal squamous carcinoma ($n = 9$), postcricoid squamous carcinoma ($n = 7$), pyriform sinus squamous carcinoma ($n = 10$) and thyroid papillary or follicular carcinoma ($n = 6$).

In control group, 40 (87.0%) of the 46 cases underwent preoperative CT, whereas 30 (65.2%) received MR imaging. These 46 patients included laryngeal papilloma ($n = 4$), laryngeal

squamous cell carcinoma ($n = 17$), pyriform sinus squamous cell carcinoma ($n = 9$), postcricoid squamous carcinoma ($n = 2$), thyroid papillary or follicular carcinoma ($n = 9$) and thyroid adenoma ($n = 5$). All these cases were confirmed without esophageal inlet invasion by head and neck surgeons during preoperative or operative evaluation and follow-up examinations.

CT and MRI techniques

Computed tomography was performed with scanners including Toshiba 600S, Toshiba Xvision/GX (Toshiba Medical Systems, Tochigi, Japan) and SOMATOM Sensation 4 (Siemens, Erlangen, Germany). Axial slices of 3-mm thickness and 3-mm interspace were obtained from the base of the tongue to the thoracic inlet before and after intravenous administration of meglumine iothalamate (Telebrix, Guerbet, Aulnay-sous-Bois, France).

MR imaging was performed using a 1.0-T unit (Schimadzu SMT-100 type, Shimadzu Medical Systems, Tokyo, Japan) and a 1.5-T unit (Signa Performance Plus, GE Medical Systems, Milwaukee, WI) with anteroposterior volume neck coils. The MR imaging protocol consisted of axial T₁-weighted spin-echo and T₂-weighted spin-echo images. T₁-weighted images included 450/18 [TR/TE] at 1.0 T and 550/10 [TR/TE] at 1.5 T, whereas T₂-weighted images included 2 000/90 [TR/TE] at 1.0 T and 4 200/95 [TR/TE] at 1.5 T. After intravenous administration of gadolinium-diethylenetriamine pentaacetic acid (Magnevist, Schering, Berlin, Germany), axial, sagittal and coronal T₁-weighted spin-echo images were obtained. The slice thickness was 5 mm with no interslice gap.

Statistical analysis

At the level of the esophageal inlet on axial CT and MRI scans, d-CV was measured retrospectively. The results of d-CV between the two groups were analyzed by using Student's *t* group test with SPSS software (SPSS, Chicago, IL). For all tests, statistical significance was set at $P < 0.05$ level. Then, the optimal criterion of d-CV on CT or MRI was assessed by determining its accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) respectively.

RESULTS

CT and MRI findings in control group

Ovoid or concave normal esophageal inlet was found in 82.5% (33/40) of cases on CT and in 76.7% (23/30) of cases on MR imaging. The fat planes surrounding the well-defined margins of esophageal inlet and between the esophageal inlet and both lobes of the thyroid gland were visible in most CT or MRI scans. At the esophageal inlet level, d-CV was 0.94 ± 0.15 cm on CT and 0.91 ± 0.18 cm on MR imaging (Table 1).

Table 1 Comparison of d-CV between control and patient groups on CT and MR imaging (mean \pm SD)

	CT		MRI	
	Control group	Patient group	Control group	Patient group
<i>n</i>	40	30	30	19
mean \pm SD (cm)	0.94 ± 0.15	1.24 ± 0.32	0.91 ± 0.18	1.31 ± 0.36
<i>t</i>	4.806		4.544	
<i>P</i>	<0.01		<0.01	

CT and MRI findings in patient group

Postcricoid carcinoma with esophageal inlet invasion All the 7 cases of postcricoid tumor invading the esophageal inlet on CT and MRI scans were histologically documented squamous

cell carcinoma, 85.7% (6/7) of the cases underwent preoperative CT scanning, whereas 57.1% (4/7) of the cases underwent MR imaging. On axial CT or MR images, all the cases had a large tumor mass arising from the postcricoid region resulting in asymmetric thickening of the pharyngeal wall and obliteration of surrounding fat plane (Figure 1), while 57.1% (4/7) of the cases presented with arytenoid cartilage destruction. On MR imaging, the sagittal, contrast-enhanced T₁-weighted spin-echo (SE) image showed postcricoid tumor spreading circumferentially and towards the esophageal inlet and cervical esophagus. At the esophageal inlet level, d-CV was 1.25 ± 0.31 cm on CT and 1.28 ± 0.45 cm on MR imaging (Table 2).

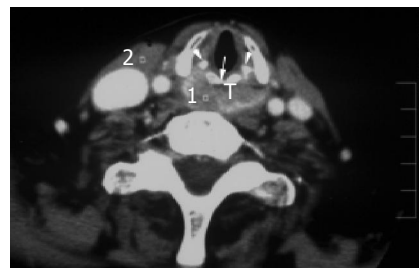


Figure 1 Axial contrast-enhanced CT scan at the subglottic level of a 56-year-old man with postcricoid carcinoma (T) invading the esophageal inlet. Arrowheads point to the arytenoid cartilage and the arrow points to the cricoid cartilage.

Pyriform sinus carcinoma with esophageal inlet invasion All the 10 cases of pyriform sinus tumor invading the esophageal inlet were histologically confirmed squamous cell carcinoma. Of the 10 cases, 5 (50%) involved the apex of pyriform sinus, 8 (80%) invaded submucosally to the postcricoid region. 3 (30%) spread extensively to the aryepiglottic fold and epiglottis, 2 (20%) displayed thyroid cartilage erosion, 4 (40%) presented with arytenoid cartilage destruction. All the 10 cases showed a tumor mass as asymmetric thickening of the posterior wall. On MR imaging, all the 5 cases also revealed the tumor mass with poorly defined margins circumferentially around the esophageal inlet (Figure 2). At the esophageal inlet level, d-CV was 1.14 ± 0.25 cm on CT and 1.11 ± 0.24 cm on MR imaging (Table 2).

Laryngeal carcinoma with esophageal inlet invasion All the 9 cases of laryngeal carcinoma invading esophageal inlet were histologically documented squamous cell carcinoma. On MR imaging, 71.4% (5/7) of the cases showed a large tumor mass involving the whole larynx, obstructing the tracheal cavity and spreading posterolaterally to the esophageal inlet. The margin between tumor and esophageal inlet was poorly defined. On CT scanning, 25% (2/8) of cases indicated arytenoid cartilage erosion, whereas 37.5% (3/8) of cases revealed thyroid cartilage destruction (Figure 3). At the esophageal inlet level, d-CV was 1.18 ± 0.33 cm on CT and 1.30 ± 0.30 cm on MRI (Table 2).

Table 2 d-CV in different types of head and neck tumor with esophageal inlet involvement on CT and MR imaging (mean \pm SD)

Tumors	CT	MRI
Postcricoid carcinoma (<i>n</i> =7)	1.25 ± 0.31 cm (<i>n</i> =6)	1.28 ± 0.45 cm (<i>n</i> =4)
Pyriform sinus carcinoma (<i>n</i> =10)	1.14 ± 0.25 cm (<i>n</i> =10)	1.11 ± 0.24 cm (<i>n</i> =5)
Laryngeal carcinoma (<i>n</i> =9)	1.18 ± 0.33 cm (<i>n</i> =8)	1.30 ± 0.30 cm (<i>n</i> =7)
Thyroid carcinoma (<i>n</i> =6)	1.46 ± 0.38 cm (<i>n</i> =6)	1.72 ± 0.39 cm (<i>n</i> =3)

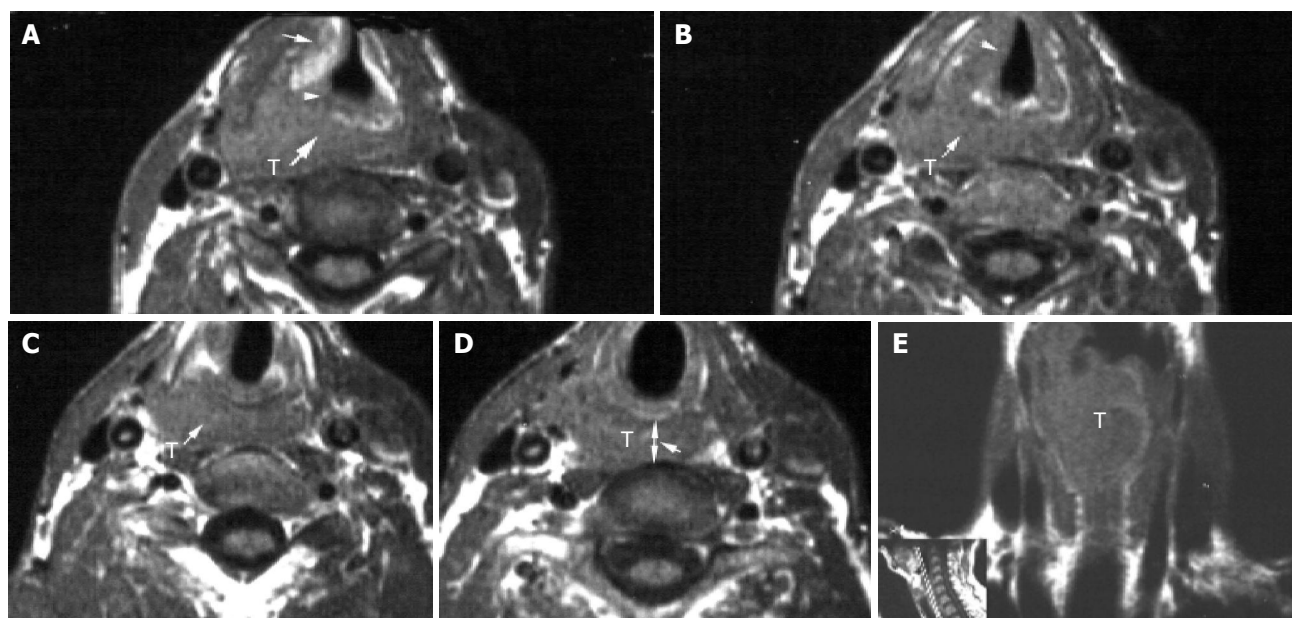


Figure 2 T₁-weighted image of a 72 year-old man with pyriform sinus carcinoma invading the esophageal inlet. A: Axial T₁-weighted image of a right-sided pyriform sinus tumor mass (T) invading the right false cord, the laryngeal ventricle, the right paraglottic space (arrow), the right aryepiglottic fold (arrowhead) and the postcricoid region (heavy arrow); B: Axial T₁-weighted image of the tumor mass (T) involving the right true vocal cord (arrowhead) and extending to the postcricoid region (arrow); C: Axial T₁-weighted image 5 mm above the esophageal inlet level of a pyriform sinus tumor mass (T) invading the postcricoid region (arrow); D: Axial T₁-weighted image of the neoplastic esophageal inlet involvement (arrow). T = tumor mass, arrowhead points to the distance between the posterior aspect of the cricoid cartilage and the anterior aspect of the vertebra (d-CV=1.32); E: Coronal T₁-weighted image of a tumor mass (T) arising from the right piriform sinus with extension to the postcricoid region and the anteriorlateral wall of the esophagus, including esophageal inlet and cervical esophagus.

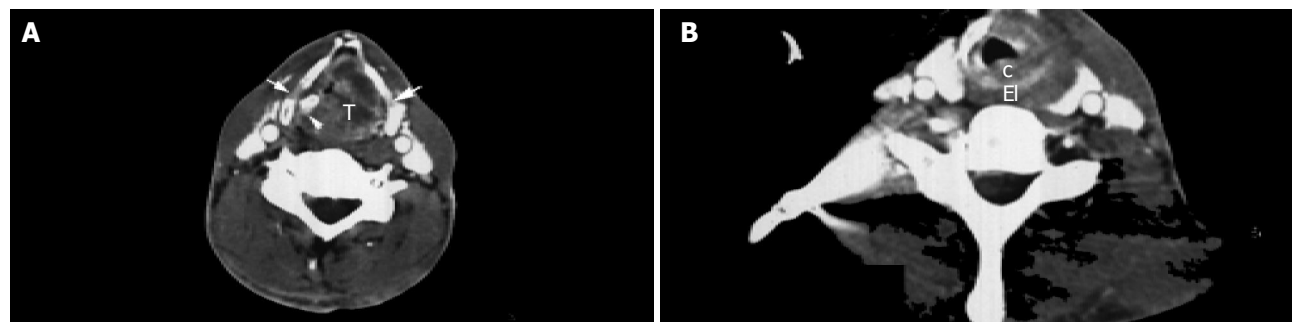


Figure 3 Axial contrast-enhanced CT of a 67-year-old man with direct esophageal inlet involvement by laryngeal carcinoma. A: Axial contrast-enhanced CT at the supraglottic level of a left-sided laryngeal tumor mass (T) invading both aryepiglottic folds, both false cords, laryngeal ventricles and paraglottic spaces. Arrows point to the destruction of thyroid cartilages. Arrowhead points to the intact arytenoid cartilage; B: Axial contrast-enhanced CT at the esophageal inlet level of a tumor mass extending to the subglottic region, eroding the cricoid cartilage (C) and invading the esophageal inlet (EI).

Thyroid carcinoma with esophageal inlet invasion All the 6 thyroid carcinoma cases 'were preoperatively performed' CT scanning, whereas 50% (3/6) of the cases underwent MR imaging. These 6 cases included 4 papillary carcinomas and 2 follicular carcinomas and were pathologically verified to have esophageal inlet involvement. Three (50%) of the 6 cases also indicated cervical esophageal invasion. On CT scans, the 6 cases showed a large tumor mass arising from the thyroid gland and invading the esophageal inlet (Figure 4). Of the 6 cases, 4 (66.7%) presented with contralateral displacement of the trachea, 2 (33.3%) revealed aortic invasion with concomitant luminal narrowing and effaceable flat plane between tumor and the aorta, 5 (83.3%) showed esophageal inlet involvement by a circumferential tumor mass greater than 120°, whereas 2 (33.3%) represented esophageal inlet invasion by a circumferential mass more than 180°. The margin between the esophagus inlet and thyroid mass was poorly defined. Two (33.3%) of the 6 cases

presented with arytenoid cartilage erosion, whereas 1 (16.6%) of the 6 cases revealed thyroid cartilage destruction. On MR imaging, the extensive tumor mass displayed an intermediate, slightly lower or higher signal intensity on T₁-weighted MR images and a high and heterogeneous signal intensity on T₂-weighted MR images. At the esophageal inlet level, d-CV was 1.46±0.38 cm on CT and 1.72±0.39 cm on MR imaging (Table 2).

In the present work, we found that at the esophageal inlet level, d-CV was 0.94±0.15 cm on axial CT and 0.91±0.18 cm on axial MR imaging in control group, whereas d-CV was 1.24±0.32 cm on CT and 1.31±0.36 cm on MR imaging in patient group. There was a statistical significance in d-CV between these two groups (Table 1). d-CV greater than 1.0 cm was an optimal adjunct criterion of neoplastic invasion of the esophageal inlet with 73% sensitivity, 83% specificity, 79% accuracy, 76% PPV, 80% NPV on CT and 84% sensitivity, 77% specificity, 80% accuracy, 70% PPV, 88% NPV on MRI respectively (Table 3).

Table 3 Diagnostic statistics of d-CV criterion on CT and MRI for predicting neoplastic esophageal inlet involvement

	Sensitivity (%)	Specificity (%)	Accuracy (%)	Positive predictive value (%)	Negative predictive value (%)
d-CV>1.0 cm on CT	73 (22 of 30)	83 (33 of 40)	79 (55 of 70)	76 (22 of 29)	80 (33 of 41)
d-CV>1.0 cm on MRI	84 (16 of 19)	77 (23 of 30)	80 (39 of 49)	70 (16 of 23)	88 (23 of 26)

**Figure 4** Axial contrast-enhanced CT of a 49-year-old woman with thyroid carcinoma invading the esophageal inlet. Arrowhead points to the distance between the posterior aspect of the cricoid cartilage and the anterior aspect of the vertebra (d-CV = 1.12).

DISCUSSION

Esophageal inlet is the cricopharyngeal ring extending from the postcricoid region of hypopharynx to the cervical esophagus. It is defined as the pharyngo-esophageal junction which is delineated by the cricopharyngeus muscle^[1]. Saleh *et al*^[2] have further defined the esophageal inlet in their study to the point where the lower fibers of the inferior constrictor (cricopharyngeus) muscle are last seen attached to the posterolateral aspects of the laryngeal skeleton. They defined that the esophageal inlet was the portion of the postcricoid hypopharynx 3-mm or less above the lower margin of the cricoid cartilage. At this level, the emerging muscular wall of the esophagus merges with the lowermost fibers of the inferior constrictor (cricopharyngeus) muscle, whereas the flattened ellipsoid shape of the postcricoid hypopharynx gives way to a much more round ellipsoid shape of the esophageal inlet^[1-4]. According to these previous literatures, we measured d-CV on axial CT and MRI sections at that level. In control group, d-CV of the normal esophageal inlet was 0.94 ± 0.15 cm on axial CT and 0.91 ± 0.18 cm on axial MRI.

Esophageal inlet invasion is a significant sequela of advanced head and neck carcinomas. In our study, malignancies associated with esophageal inlet included hypopharyngeal carcinoma, laryngeal carcinoma and thyroid carcinoma. Hypopharyngeal carcinomas, such as postcricoid carcinoma and pyriform sinus carcinoma, do have a propensity to infiltrate submucosally, either circumferentially or towards the esophageal inlet^[2-5]. Laryngeal carcinoma could also spread extensively to hypopharynx and even to esophageal inlet^[5]. Thyroid carcinoma could often invade the esophageal inlet by extrathyroidal growth rather than by nodal metastasis^[6]. Nevertheless, esophageal involvement, including neoplastic invasion of esophageal inlet and cervical esophagus, is more often from extension of thyroid carcinoma than from spread of pharyngeal or laryngeal tumor^[7]. Because of these characteristic spread patterns of advanced head and neck carcinomas to the esophageal inlet, the true extent only becomes apparent on axial CT and axial, coronal or sagittal MR images.

In recent years, the application of new diagnostic modalities such as endoscopic ultrasonography (EUS) and positron emission tomography (PET) on primary esophageal carcinoma

has been widely investigated^[8-16]. CT and MR imaging, however, still play a crucial role in the evaluation of primary esophageal tumors^[4,17-20] and neoplastic invasion of esophagus by advanced head and neck carcinomas^[2,7,21-23]. Roychowdhury *et al*^[7] have reported that a circumferential mass or focal T₂ signal abnormality on the esophageal wall on MR imaging suggests the presence of esophageal invasion by advanced head and neck carcinomas, whereas an intact fat plane, absence of wall thickening and no T₂ wall signal abnormalities imply that the esophagus is not invaded. Wang *et al*^[21] indicate that outer layer invasion and poorly defined margins are the significant factors of esophageal involvement due to thyroid carcinomas. They suggest that a MRI finding of outer layer invasion is optimal for diagnosing esophageal invasion by thyroid carcinoma. Nevertheless, there are a few studies on the role of CT or MRI in predicting esophageal inlet invasion by advanced head and neck carcinomas^[2-4]. The accurate evaluation of patients at risk for esophageal inlet involvement requires specific criteria for determining tumor invasion at that level. Zhuang *et al*^[24,25] have proposed that the distance between aryteoid cartilage and vertebra (d-AV) greater than 1.0 cm and the distance between crocoid cartilage and vertebra (d-CV) greater than 1.0 cm are the available criteria of neoplastic invasion of the retrocricoid region and esophageal inlet on CT and MRI modalities. However, the authors did not further describe these criteria in detail. In the present work, we found that except for other CT and MR imaging features of esophageal inlet involvement, such as circumscribed tumor mass adjacent to the esophageal inlet, poorly defined margins between the tumor and esophageal inlet and obliteration of the fat plane between the mass and esophageal inlet, d-CV at the esophageal inlet level might be another criterion, which was 1.24 ± 0.32 cm on CT and 1.31 ± 0.36 cm on MR imaging in patient group. There was statistical significance in d-CV between control group and patient group (Table 1). Therefore, we suggest that d-CV greater than 1.0 cm is a typical feature of neoplastic invasion of the esophageal inlet.

Predicting esophageal inlet invasion is important for determining primary tumor staging, predicting the prognosis and developing surgical strategy for advanced head and neck carcinomas. In patients with extensive head and neck tumors, esophageal inlet invasion would automatically upgrade primary tumor staging to a T₄ classification^[26]. Azurin *et al*^[27] indicate that the overall 5-year survival for patients with stage IV squamous cell carcinoma is 24-27%. Kowalski *et al*^[28] and McCaffrey *et al*^[29] have reported that well-differentiated thyroid carcinoma usually has an excellent prognosis. However, when invasion of the upper aerodigestive tract occurs, it would be a source of significant morbidity as well as mortality for the patient. Thyroid carcinoma with minimal esophageal invasion could be treated by shave resection, whereas tumors with full-thickness and even intraluminal esophageal involvement could be treated by complete resection. Similar survival results after complete or shave resection and a poor survival after incomplete resection have been reported^[28-30]. When the tumor just invades the full-thickness of cervical esophagus, pharyngo-esophagectomy is suggested with gastric transposition, and the larynx could be preserved. When the tumor invades the full-thickness of cervical esophagus, esophageal inlet and even hypopharynx, pharyngo-laryngo-esophagectomy are needed

with gastric pull-up for reconstruction^[28-30]. Furthermore, patients with advanced pharyngeal or laryngeal squamous cell carcinoma invading esophageal inlet might also benefit from surgical resection of the tumor for palliative maintenance of oral alimentation and prevention of airway compromise^[27]. When the tumor just involves the esophageal inlet, limited esophagectomy is usually suggested and myocutaneous flap or jejunal interpositioning is usually required for closure. When the tumor extended to the cervical esophagus, esophagectomy is needed with gastric transposition or jejunal interposition used for reconstruction^[2,27,31-35].

In conclusion, except for other CT and MR imaging features of neoplastic invasion of esophageal inlet, d-CV greater than 1.0 cm could be an optimal adjunct criterion to the esophageal inlet involvement by advanced head and neck carcinomas. It may exert a strong impact on the treatment recommendations for patients with esophageal inlet invasion by advanced head and neck carcinomas.

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