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INDEXING WORDS

magnetic resonance imaging; laryngeal carcinoma; histopathology

SYNOPSIS

Preoperative magnetic resonance imaging (MRI) of laryngeal carcinoma was performed on thirteen laryngeal cancer patients. We compared the images with histopathologic whole-organ sections after operation. Four normal male larynxes were also studied with MRI and two cadaver normal larynxes were sectioned in a horizontal plane as a whole organ for the control group. Correlation was made between these studies as well as with clinical history, physical examination, fiberoptic endoscopy, laryngeal tomography, and CT. In thirteen patients who underwent total laryngectomy or supraglottic partial laryngectomy, the spread of the tumor, cartilage invasion, intraorgan and extraorgan spread of the disease were compared. MRI was superior in definition of soft tissue and for determination of the extent of the disease. The use of axial and sagittal imaging with a surface coil on MRI allowed a clear

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visualization of the laryngeal structure and cartilage invasion which was important for advanced laryngeal carcinoma. We found a very close correlation between MRI and histologic sections in the advanced laryngeal carcinoma. However, MRI was unreliable for microscopic intralaryngeal invasion and at all levels when severe postradiation reactions were present.

INTRODUCTION

With the aid of innovative diagnostic tools such as computer tomography (CT) and fiberoptic endoscopy, the quality and quantity of preoperative information concerning the location and extent of laryngeal carcinoma have undoubtedly been increased. CT has replaced laryngography because of its ability to show the fascial plane and deep extentions of the disease in the soft tissue.[8)]

Although the information obtained from CT is very useful for determining advanced laryngeal carcinoma, it has some limitations in the case of tumor invasion into the cartilage (less than 6mm) and trying to provide coronal and sagittal dimensional representation of the pathologic tissue.[7)] There are also some hazards associated with CT scanning in the form of X-ray exposure and the use of intravenous contrast materials.[11)]

Thanks to the development of a new imaging modality with magnetic resonance (MR), it is suggested that an image resolution equal to CT can be obtained without exposure to X-rays and use of contrast materials.[11)] The MRI is able to produce high contrast images in any desired plane, which has great potential in displaying both normal and pathological laryngeal anatomy.[1)] MRI is an appealing modality for the study of laryngeal carcinoma because of both its high contrast resolution in the soft tissue and its multidimensional capability.[4,6)]

This study was designed to illustrate the benefit of the MRI in evaluating the location and extent of laryngeal carcinoma. For this purpose, a comparison was made among the findings obtained from the preoperative MRI, CT and the postoperative histopathological specimen by whole organ sectioning at the corresponding levels.

MATERIALS AND METHODS

Thirteen laryngeal cancer patients at different TNM stages (according to UICC, 1987) who were operated upon in our clinic, were selected for this study. The age range was from 52 to 71 years. Nine were male and four were female. Laryngeal carcinomas comprised five supraglottic, six glottic, one subglottic, and one pyriform sinus tumors. Nine had primary and four had recurrent disease after radiotherapy. Ten had total laryngectomy and three had supraglottic partial laryngectomy (Table 1).

TABLE 1. Summary of Clinical Findings

Case	Age (yr)	Sex	T-Primary Tumor, Location	Radiotherapy Before Surgery	Surgery
1	65	M	T_3-Glottic	-	TL
2	62	M	T_3-Glottic	-	TL
3	68	F	T_2-Supraglottic	-	SGL
4	66	M	T_3-Glottic	-	TL
5	63	F	T_1-Supraglottic	-	SGL
6	59	M	T_2-Sin.Pyriformis	-	PP+SGL
7	69	M	T_3-Supraglottic	+	TL
8	63	M	T_2-Subglottic	-	TL
9	56	M	T_3-Glottic	+	TL
10	62	F	T_2-Supraglottic	+	TL
11	52	F	T_2-Glottic	-	TL
12	62	M	T_2-Glottic	+	TL
13	71	M	T_3-Supraglottic	-	TL+PP+G

Abbrev.: - , negative for radiotherapy; +, positive for radiotherapy; TL, total laryngectomy; SGL, supraglottic laryngectomy; PP, partial pharyngectomy; G, glossectomy

Four normal larynxes of adult male patients were studied with MRI and two normal larynxes of 56 and 61 year-old male cadavers were sectioned in a horizontal plane as a whole organ for the control group.

MRI were obtained with a 0.15 Tesla resistive model (Picker International 1100) using a solenoid surface coil placed around the anterior aspect of the neck to generate a localized, relatively high intensity radio frequency signal. Mostly SE (spin-echo), and a few IR (inversion recovery) pulsus were used to obtaine all images. In all three directions (axial, coronal, sagittal) a T1-weighted technique which is optimal in revealing anatomical details, was carried out using a repetition time (TR) of 500 msec and echo time (TE) of 40 msec. In the axial plane we also generated images at each level using a TR of 2000 msec and a TE of 80 msec (T2-weighted image). 10 mm thick sections were acquired axially. Gradient zooming was used to keep the field of view as small as possible (Table 2).

All patients had preoperative CT carried out on a General Electric 8800 total body scanner using 9.6 second scan time at 120 kVp and 200-300 mA. Axial scans of 5 mm thickness were obtained at 5 mm intervals from the level of the first tracheal ring to the base of the tongue. Scanning was done with the patient in quiet respiration and then Iohexole 100 ml was infused.

Thirteen surgical specimens from patients with laryngeal cancer and two normal larynxes from cadavers were fixed in 10% buffered formalin solution. Laryngeal specimens were serially sectioned (5-6 mm thick) as a whole organ in a horizontal plane. The specimens were washed and then decalcified with K-CX solution, embedded in paraffin blocks and sectioned (4 micrometer) with microtome. Serial sections were made until slides corresponding to the MRI sections were obtained. Histologic slices were then prepared by a routine hematoxyline-eosin staining technique. After staining, all the histologic slices were photographed macroscopically for comparison to axial MRI. Complementary microscopic examination was carried out to evaluate the MRI of the laryngeal structure.

TABLE 2. Imaging Sequences for Thirteen Patients

CASE	PULSE SEQUENCE	TI	TE	TR	IMAGING	SCAN NUMBER
1	SE		80	2000	Sagittal	128
	SE		40	500	Coronal	256
	SE		40	800	Axial	128
2	SE		40	600	Axial	128
	SE		40	2000	Sagittal	128
	SE		40	600	Coronal	128
3	SE		40	500	Axial	256
	SE		80	2000	Axial	128
	IR	500		2100	AXial	128
	SE		40	500	Coronal	256
4	SE		40	500	Axial	256
	SE		80	2000	Axial	256
	SE		40	500	Coronal	256
5	SE		40	500	Axial	256
	SE		80	2000	Axial	256
	IR	500		2100	Axial	128
6	SE		40	500	Axial	256
	SE		80	2000	Axial	256
	SE		26-256	1000	Axial	128
	IR	500		2100	Axial	128
	SE		40	500	Coronal	256
7	SE		40	600	Axial	256
	SE		80	2000	Axial	128
	SE		40	500	Coronal	256
8	SE		40	500	Axial	256
	SE		80	1500	Axial	256
	SE		40	500	Coronal	256
9	SE		40	500	Axial	256
	SE		80	2000	Axial	256
	SE		40	500	Coronal	256
10	SE		40	500	Axial	256
	SE		80	2000	Axial	256
	SE		40	500	Coronal	256
11	SE		80	2000	Axial	128
	SE		40	500	Axial	256
	SE		40	500	Coronal	256
12	SE		80	2000	Axial	128
	SE		40	500	Axial	256
	SE		40	500	Coronal	256
13	SE		80	2000	Axial	128
	SE		40	600	Axial	256
	SE		40	500	Sagittal	256

SE: Spin-echo TI: Inversion delay(in msec)
TE: Echo time (in msec) IR: Inversion recovery
TR: Pulse repetition time (in msec)

RESULTS

Supraglottic level

The arytenoid cartilages and preepiglottic space were easily identified on the MRI. In a patient with a large tumor of the supraglottic region, MRI revealed a mass in the preepiglottic space with a slightly higher signal intensity than the signal intensity of the preepiglottic fatty tissue (Fig. 1). The masses with high signal intensity in the preepiglottic space and base of the tongue were also identified on the sagittal MRI (Fig. 1-A). The macroscopic section at the corresponding level showed good correlation with MRI (Fig. 1-C).

The non-ossified epiglottic cartilage could not be identified within the tumor. Axial MRI at the supraglottic level revealed the involvement of the epiglottis as an irregular shape and thickened soft tissue mass with intermediate high signal intensity (Fig. 2-A,D).

An axial Tl-weighted image (SE 500/40) showed an intermediate high signal intensity thickening at the level of the false vocal folds and showed slightly low signal intensity mass in the preepiglottic space (Fig. 3-A). Correlations with the macroscopic pathologic specimen were not found at this level (Fig. 3-B). Microscopic examination identified preepiglottic invasion at this level.

Glottic level

Coronal MRI at the midlevel of the true vocal cords clearly showed the transglottic nature of the glottic cancers as in the supraglottic level (Fig. 4-A). Ossified cartilage was shown as a central high signal intensity area surrounded by a low signal intensity rim (Fig. 4-B).

An axial MRI at the level of the true vocal cords clearly demonstrated thickening of the left vocal cord with intact thyroid cartilage (Fig. 5-A). A section of the postoperative specimen at the corresponding level showed that the contour of the tumor corresponded to the lesion as outlined by MRI (Fig. 5-B).

An axial image at the level of the true vocal cords demonstrated the left anterior part of the thyroid cartilage invasion (Fig. 7-A). The corresponding level of the pathologic specimen showed non-ossified thyroid cartilage in the left anterior part (Fig. 7-B). Microscopic examination showed no invasion of the cartilage but diffuse infiltration by the tumor cells at the anterior commissure ligament. An axial MRI at the level of the true vocal cords showed invasion of the right part of the thyroid cartilage (Fig. 6-B). The macroscopic section at the corresponding level showed close correlations with MRI (Fig. 6-C). We did not find correlations with the CT scan at the same level (Fig. 6-D). MRI failed to detect cartilage invasion in some cases. There were no false negatives, but three false positive MRI readings at the glottic level (Table 3).

TABLE 3. Summary of MRI with Pathologic Specimen Correlation

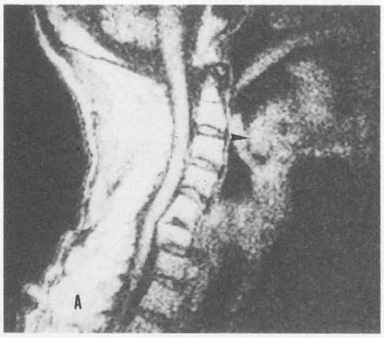
CASE	MRI Abnormalities in the Study Group: Cartilage Invasion	Intraorgan Spread	Extraorgan Spread	Microscopic Examination: Cartilage Invasion	Intraorgan Spread	Extraorgan Spread	Macroscopic Specimen, Correlation with MRI
1	+	+	-	-	+	-	Good
2	+	+	-	-	+	-	Good
3	+	-	-	-	-	-	Good
4	+	+	-	+	+	-	Good
5	+	-	-	-	-	-	Good
6 ...	No abnormalities			-	-	-	Good
7	+	+	+	-	+	-	Not good
8	+	+	+	+	+	+	Good
9	-	-	-	-	+	-	Good
10	-	-	+	-	+	+	Good
11 ..	No abnormalities			-	-	-	Good
12	+	+	+	-	+	-	Good
13	+	+	+	-	+	+	Good

Abbrev. : -, negative for involvement; +, positive for involvement.

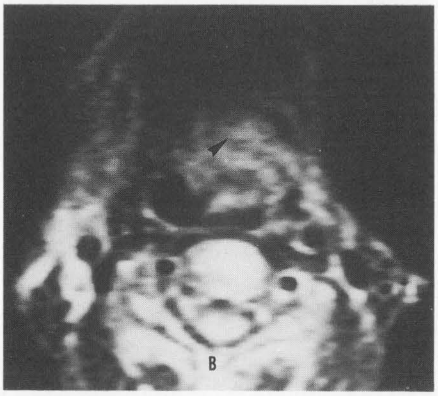
Subglottic level

Axial MRI at the level of the cricoid cartilage and the first tracheal ring showed a bulky intermediate signal and invasion into the tracheal ring on the right side but no invasion into the cricoid cartilage (Fig. 8-B,D). Macroscopic section at the tracheal level demonstrated no invasion into the tracheal cartilage (Fig. 8-E). Microscopy showed no invasion into the tracheal and cricoid cartilage. MRI failed to detect cartilage invasion due to non-ossified cartilage at the tracheal cartilage level.

1A



1B



1C

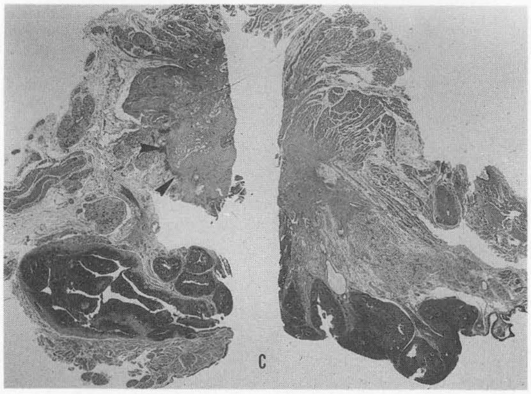
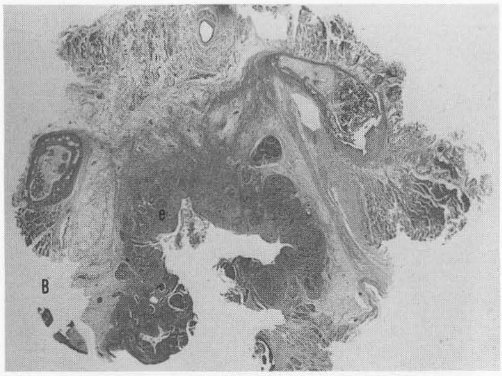


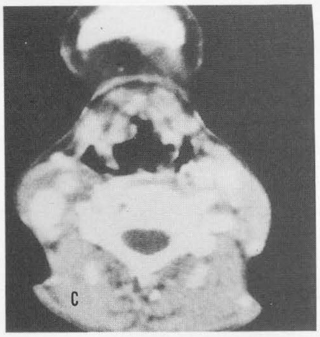
Fig. 1 A; Tumor mass in the preepiglottic space is identifing with high signal intensity (arrow head).
B; Tumor mass demonstrates slightly higher signal intensity than the signal intensity of the preepiglottic fatty tissue (arrow head).
C; Histologic section at the level of the base of tongue shows extension of tumor mass to the base of tongue similar with sagittal MRI (arrow heads).

2A

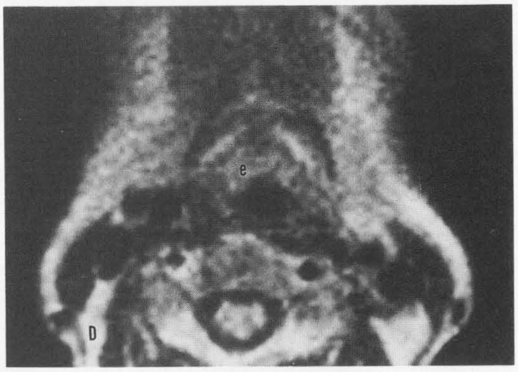
2B



2C



2D



2E

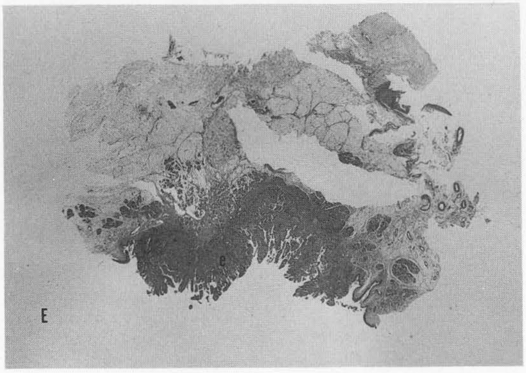


Fig. 2
A, D; At the supraglottic level axial MRI demonstrates thickened and irregular shape of epiglottis (e) as the high signal intensity.
B, E; Histologic sections at the corresponding level show the same landmarks with MRI.
C; CT at this level the epiglottis is not visible.

3A

3B

Fig. 3 A; Axial MRI at the supraglottic level demonstrates a low signal intensity mass in the preepiglottic space (arrow).

B; Correlation with histologic section were not found.

4A

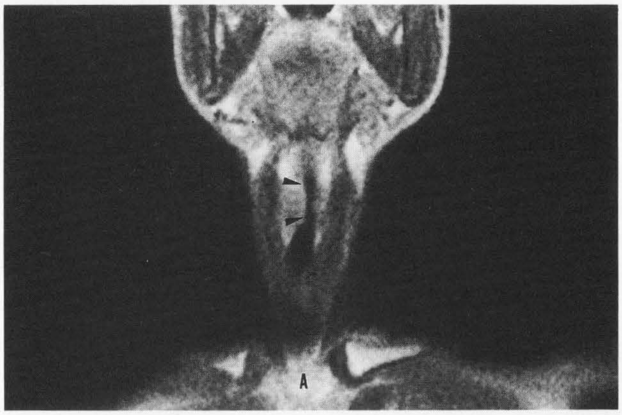
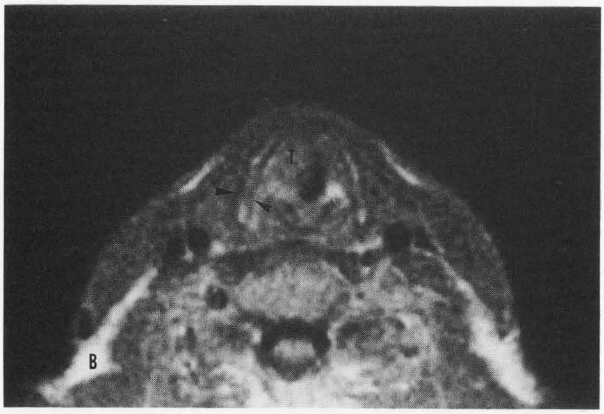


Fig. 4 A; Coronal MRI shows transglottic nature of glottic carcinoma (arrow heads).

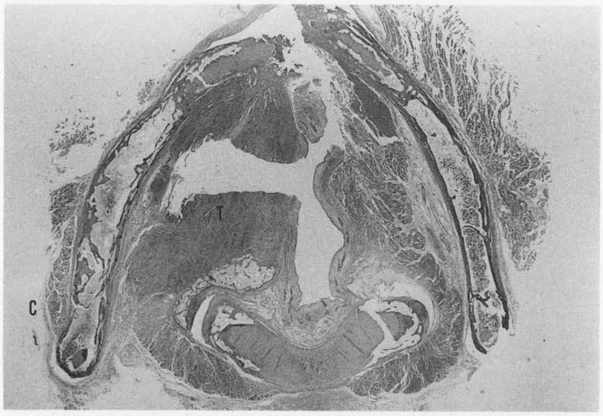
B; Thyroid cartilage can be identify as a central high signal intensity area surrounded by a low intensity rim (arrow heads). Tumor (T) shows higher signal intensity than normal true vocal cord.

C; Histologic section shows same landmarks with MRI.

4B



4C



5A

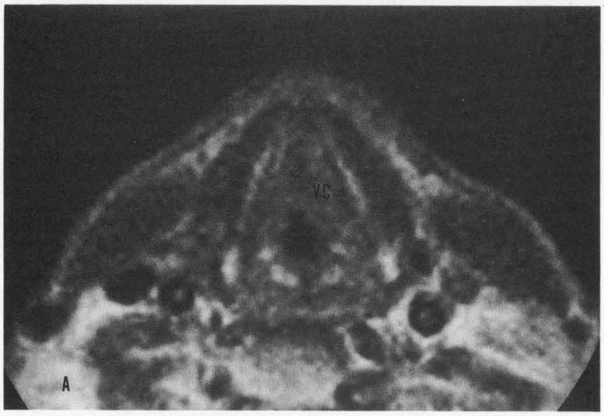
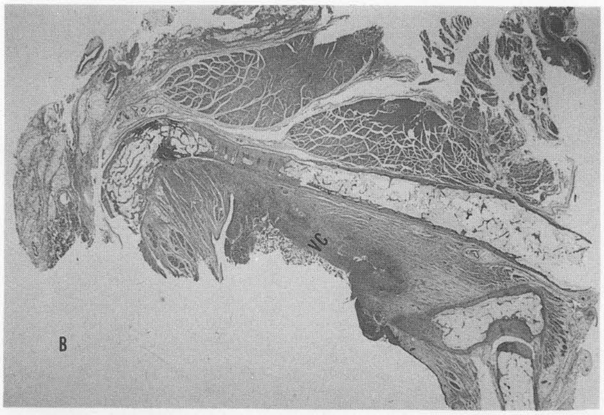
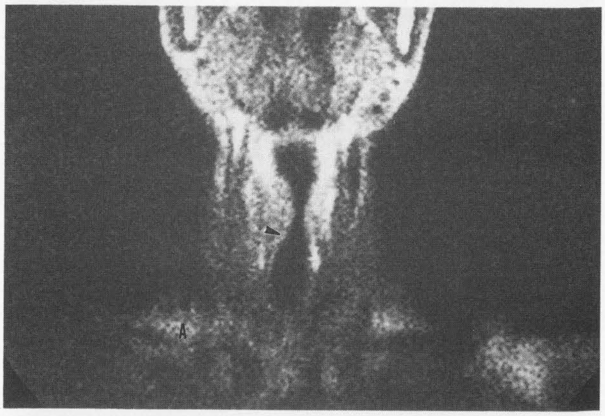


Fig. 5 A; Axial image demonstrates a left-sided tumor with thickening of the left true vocal cord (VC).
B; Histologic section demonstrate also tumor extension all along the left vocal cord (VC).

5B



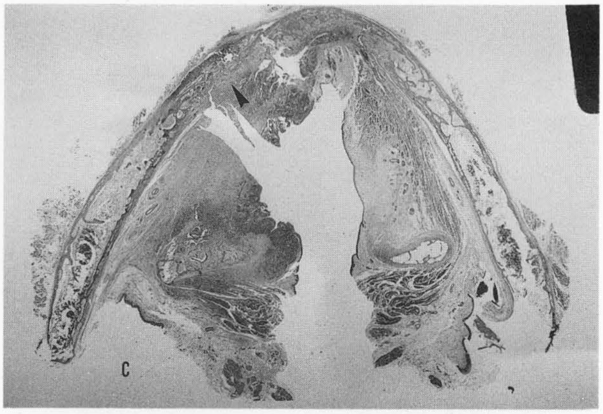
6A



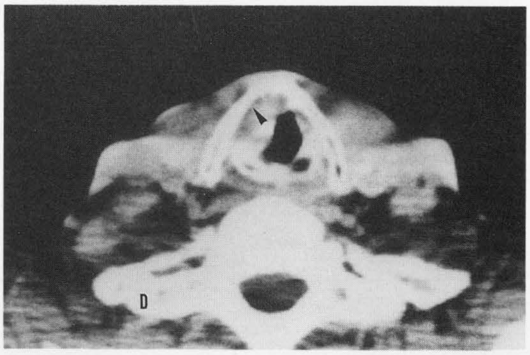
6B

Fig. 6 A; Transglottic nature of glottic cancer on coronal MRI (arrow head).
B; Axial MRI demonstrates thyroid cartilage invasion at the right side (arow head).
C; Histologic section shows close findings.
D; CT, at the level of the true vocal cords failed to detect of cartilage invasion.

6C



6D



7A

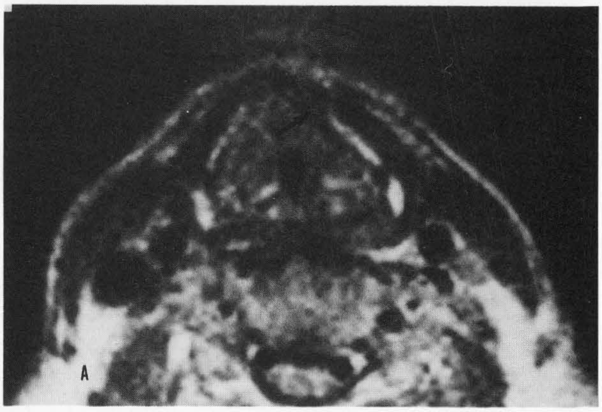
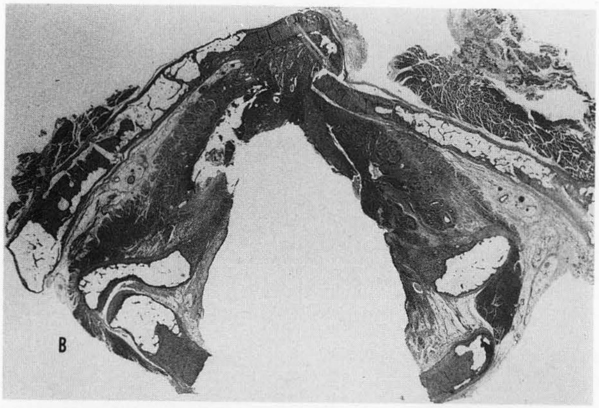


Fig. 7 A; False positive findings due to nonossified thyroid cartilage (arrow).

7B



8A

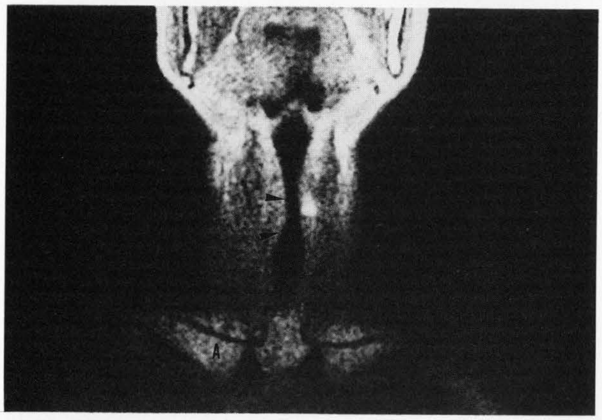
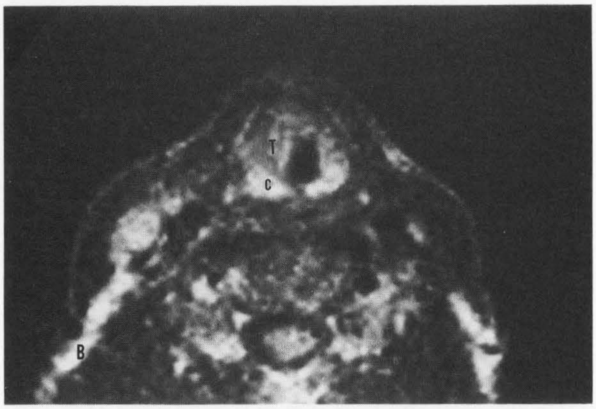


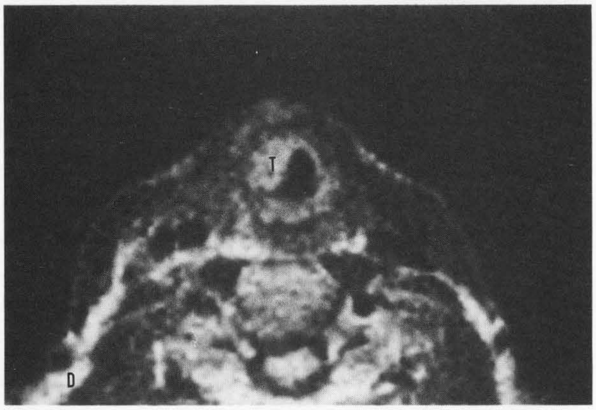
Fig. 8 A; Transglottic character of subglottic tumor on coronal MRI (arrow heads).
B; Axial image demonstrates tumor (T) no invasion to the cricoid cartilage (c).
C; Histologic section shows same contour of tumor (T).
D; Axial image at the level of the tracheal cartilage shows bulky tumor mass (T). Both structures tumor and tracheal cartilage are seen with similar signal intensity.
E; Histologic section at the first tracheal ring demonstrates in contact with tumor (T) and tracheal cartilage (t).

8B

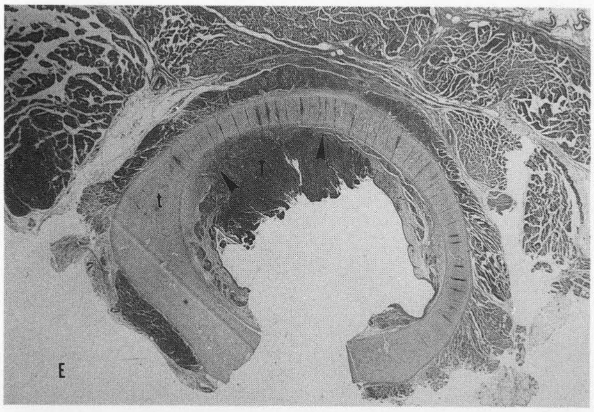


8C

8D



8E



9A

9B

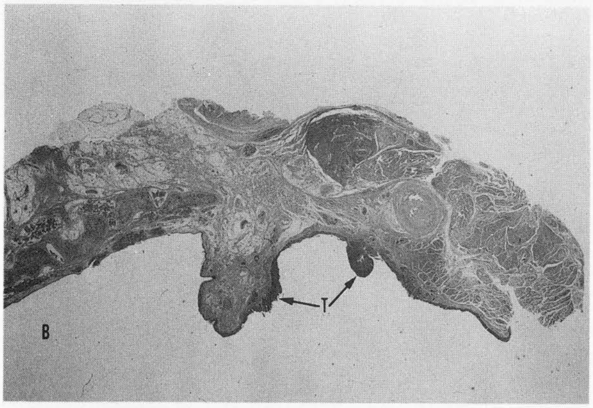
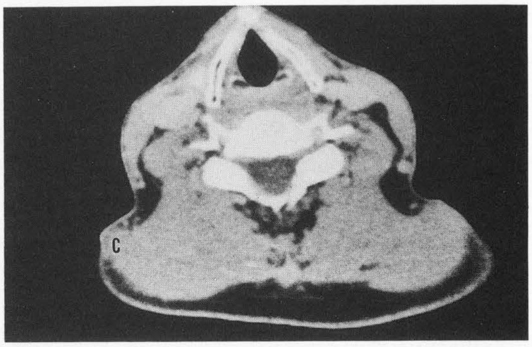


Fig. 9 A, C; No significant findings not only on MRI but also on CT.
B; Histologic section shows small size tumor (T) in the pyriform sinus (arrows).

9C



DISCUSSION

The structure of the larynx is based on its cartilaginous skeleton. The thyroid, cricoid cartilages and the lower parts of arytenoids are subject to ossification like all hyaline cartilages. The other laryngeal cartilages consist of yellow fibrocartilage; this type of cartilage does not ossify. Hyoid bone ossifies at an early age.[9)]

As in other areas of the head and neck the primary role of MRI, in imaging the larynx, is to define the extent of the disease. Indirect and direct laryngoscopy can show mucosal surfaces, masses involving the lumen and fixation of the vocal cords, but deep extensions are difficult to detect from clinical examination alone. Ultrasound and CT are the diagnostic tools available for preoperative evaluation of the larynx.

However, CT requires the administration of intravenous contrast material to allow identification of vessels, and the image quality is often down graded by motion-related streak artifacts. MRI offers excellent soft tissue contrast without the need for intravenous contrast materials and is resistent to motion-related artifacts.[10)]

Wortham et al. compared the MRI of the larynx of fresh cadavers, as an in vitro experiment with the corresponding histologic sections.[11)] However, MRI is different in vivo and in vitro depending upon the vitality and proton relaxation characteristics of the tissues.

Lufkin et al. studied the MRI of the larynx and hypopharynx application with surface coils.[6)] In this report, there is not enough data on the comparison of the MRI findings with the pathologic specimens of the laryngeal cancer cases.

Castelijins et al. compared the MRI of laryngeal cancer,[2] and normal or cancerous laryngeal cartilages[3] with the histopathologic findings. Among the analyses of forty-four laryngeal carcinomas, correlation was made not only with the histopathologic sections but also, in most cases with the laryngoscopic finding.[2] Castelijins et al. showed that the detection of cartilage invasion in the laryngeal cancer cases by MRI corresponded closely with the histopathologic findings in twelve cases of laryngeal carcinoma.[3]

Three-dimensional T1-weighted (SE 500/40) MRI permits calculation of the volume of the tumor mass.[2]

The visibility of a tumor on MRI depends on the combination of an alteration in normal anatomy with a signal intensity difference between the tumor mass and the surrounding tissues.

In T1-weighted images, the intralaryngeal soft tissue structures were revealed with intermediate signal intensity whereas in T2-weighted (SE 2000/80) images, they were seen with high signal intensity.[3] The T2-weighted images appear to be unsatisfactory in showing primary tumors, as tumor tissue is revealed less homogeneously and the signal-to-noise ratio of the image is decreased.[6] Tissue contrast between non-ossified cartilage and malignant tissue is minimal in T1-weighted images but is enhanced remarkably in balanced images as the signal intensity of the malignant tissue increases strongly. In the T1-weighted image, ossified cartilage has a typical three-layered appearance. The epiglottic cartilage and vocal process of the arytenoids are composed of yellow fibrocartilage, which usually does not ossify. In both types of images, contrast between tumor and cartilage is minimal (Fig. 2-A,D).

The differences in signal intensity between the same structures of the two sides of the larynx may occur normally and randomly. This fact may make it difficult to be certain that a tumor is present if the other tumor indicators, such as thickening of the tissues and distortion of the configuration, are not present.

In one case of pyriform sinus tumor, correlation with MRI and the specimen was less evident, due to the small size of the tumor (Fig. 9).

In this study MRI accurately assesed the extension to the preepiglottic space, intralaryngeal region and laryngeal cartilages of primary laryngeal cancer. The detection of the spread of the tumor to the other areas can markedly affect management. In the case of the spread of a supraglottic tumor involving the tongue base a glossectomy may have to performed in addition to primary surgery (Fig. 1). Site extension, and the contour of the tumor mass as shown by axial MRI corresponded to the actual configuration of the lesion seen on specimens. MRI was able to separate the tumor from neighboring tissue at all levels.

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