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Review Article

Imaging in Esophageal Cancer: A Comprehensive Review

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Abstract

Esophageal cancer is one of the common cancers. Risk factors are well recognized and lead most commonly to two distinct histological subtypes (squamous cell carcinoma and adenocarcinoma). The diagnosis is based on endoscopic evaluation. The most challenging aspect of management is accurate staging as it guides appropriate management. Endoscopic ultrasound, computed tomography (CT), positron emission tomography-CT, and magnetic resonance imaging are the imaging tests employed for the staging. Each imaging test has its own merits and demerits. Imaging is also critical to evaluate posttreatment complication and for response assessment. In this review article, we discuss in detail the risk factors, anatomical aspects, and role of imaging test in staging and evaluation of complications and response after treatment.

Keywords
- esophageal cancer
- CT
- endoscopic ultrasound
- imaging
- MRI

Introduction

Esophageal carcinoma is the 8th most common cancer and is the 6th highest cause of cancer-related mortality worldwide. It affects the elderly and is four times more common in males than females. Smoking and alcohol are the most important risk factors. Early diagnosis and staging are critical to appropriate management. Endoscopy and radiological imaging modalities have a complementary role in screening, diagnosis, staging, treatment, as well as follow-up of patients with esophageal carcinoma. Endoscopic ultrasound (EUS) and multidetector computed tomography (MDCT) are most effective in staging the disease. Positron emission tomography (PET)-CT is used in selected cases. Magnetic resonance imaging (MRI) is emerging as a useful radiological tool in staging of disease and also in assessing the response to treatment.

Risk Factors

Smoking

Smoking is one of the most important risk factors for the development of esophageal carcinoma. Smoking is an independent risk factor for developing Barrett's esophagus. The odds ratio for squamous cell carcinoma (SCC) is 4:1 and that for adenocarcinoma (AC) is 2:1.[1]

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Alcohol

Acetaldehyde, one of the major metabolites of alcohol, forms deoxyribonucleic acid adducts that lead to genetic mutation.[2] The odds ratio is significant for SCC and not for AC.

Diet

Starch-rich diet, inadequate intake of fruits and vegetables, exposure to nitrosamine, consumption of smoked fish, betel leaves chewing, and exposure to tannins and asbestos are some of the dietary risk factors associated with the development of esophageal cancer.[3]

Specific Risk Factors for SCC

The prevalence of esophageal carcinoma in achalasia cardia is 2 to 8%.[4] Carcinoma arises in the dilated rather than the narrowed segment. The dilated esophagus retains the food particles, leading to chronic esophagitis, dysplasia, metaplasia, and carcinoma in situ. Other specific risk factors include Plummer Vinson syndrome, radiation exposure, Howell-Evans syndrome, Zenker's diverticulum, and celiac disease.

Specific Risk Factors for AC

Barrett's esophagus is showing a rising trend in prevalence, especially in developed countries both due to increasing incidence of gastroesophageal reflux disease and due to incidental detection during upper gastrointestinal (GI) endoscopies. The risk of AC is 20 times higher with a background of Barrett's epithelium.[5]

Anatomy of the Esophagus

The esophagus is a 25-cm long hollow muscular tube divided into cervical, thoracic, and abdominal segments. The thoracic esophagus is further divided as upper, mid, and lower thoracic esophagus.[6] Three constrictions are identified at endoscopy, and correspondingly physiological narrowing may be seen at imaging. The first constriction is at the level of C5-C6 vertebrae at the cricopharyngeal junction. Second constriction is at the crossing of the arch of the aorta and left main bronchus at the T4-T5 vertebral level. The third constriction is at the T11 vertebral level at lower esophageal junction.[7]

Mesoesophagus

Just like mesentery, mesocolon, and mesorectum, the fetal esophagus is covered by a mesentery-like structure which later becomes unclear secondary to the compression of the esophagus against the aorta due to expanding lungs.[8] In 2015, Cuesta et al[9] reviewed their thoracoscopic esophagectomy videos and found that a bilayered fascia is seen extending along the left side of the descending thoracic esophagus in its infracarinal part. Further, Weijs et al[10] defined two distinct ligaments that were confirmed on histology as well as human cadaveric MRI. These were called aortoesophageal and aorto-pleural ligament. The aortoesophageal ligament was seen extending from the descending thoracic aorta to the left side of the esophagus. The aorto-pleural ligament extends from the aorta to the right-sided pleural reflection. These ligaments divide the posterior mediastinum into the anterior compartment and posterior compartment. The anterior compartment, called the periesophageal compartment, contains the esophagus, lymph nodes, and vagus nerve. The posterior compartment called the para-aortic compartment contains the azygos vein, thoracic duct, and a few lymph nodes (►**Fig. 1**). The concept of mesoesophagus is important as recent studies have shown better outcomes with total mesoesophageal excision.[11,12] These ligaments of the mesoesophagus can be visualized with clinical MRI.[10]

Pathology

Gross Features

Esophageal carcinoma can be infiltrative, polypoidal, ulcerative, or superficially spreading (varicoid) types. Among these, infiltrative lesions are the most common, causing irregular narrowing. Superficial spreading or varicoid type is the least common variety seen where the cancer spreads along the submucosal lymphatics.[13]

Microscopic Features

SCC and AC are esophageal carcinoma's two most common histological subtypes. Although, overall, SCC is more common than AC, the latter is increasing in incidence. AC is the most common type in the developed countries.[14]

Routes of Spread

Direct Spread

Esophagus lacks serosa. It is covered by a thin layer of loose connective tissue called adventitia. This promotes the early and rapid spread of primary carcinoma to the adjacent structures, including the descending thoracic aorta, left subclavian artery, azygos vein, trachea, left main bronchus, left atrium, and thoracic duct.[15] Additionally, carcinoma of the cervical esophagus spreads to the adjacent hypopharynx, and carcinoma of the lower thoracic esophagus invariably involves the gastroesophageal junction and further spreads into the adjacent cardia of the stomach.

Lymphatic Spread

Esophagus is rich in submucosal lymphatics. Three distinct lymphatic drainage pathways are identified—longitudinal, transverse, and perpendicular. The most common type is the longitudinal spread of tumor emboli. This allows the spread of esophageal carcinoma cranially up to the cervical lymph nodes and subdiaphragmatically up to the perigastric lymph nodes. The transverse spread includes spreading the disease to the adjacent periesophageal lymph nodes. Perpendicular spread being a rare variety, is the spread of the disease across the muscularis propria to the thoracic duct and into the internal jugular vein.[16] Thus, care should be taken to identify the involvement of longitudinal lymph nodal stations that may be distant from the primary tumor site.

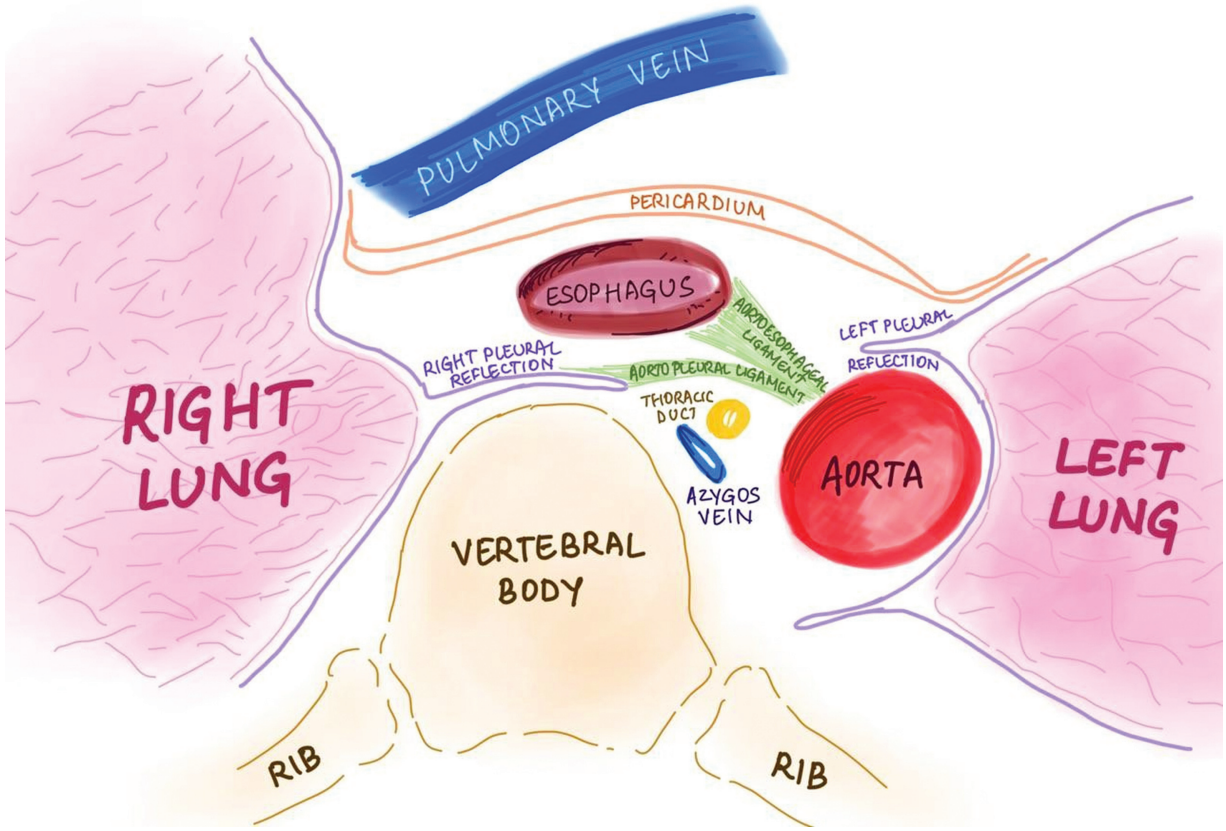

Fig. 1 Diagrammatic representation of axial section of thorax demonstrating aortoesophageal and aorto-pleural ligaments.

Distant Spread

Distant spread is seen in the liver, lung, bone, adrenal, pleura, peritoneum, and brain.

Clinical Presentation

Dysphagia is the most common symptom.[17] Other common symptoms are odynophagia, anorexia, and weight loss. Symptoms due to the involvement of adjacent structures involve dyspnea and hoarseness of voice. Acute presentations may be due to esophagopleural, tracheoesophageal, esophagobronchial,[18] esophagopericardial,[19] and aortoesophageal fistula.[20]

Imaging Modalities

Barium Study

Double-contrast barium swallow was the traditional imaging modality employed for diagnosing carcinoma esophagus. However, owing to its low sensitivity and specificity, it is not recommended for diagnosis, staging, or assessment of treatment response.

Endoscopic Ultrasound

EUS allows precise T-staging. Using EUS has made a paradigm shift in the staging, management, and prognosis. The radial echoendoscope, by its 360-degree view, provides circumferential evaluation of the esophageal wall. The linear endoscope has a 120-degree view and helps in EUS-guided interventions.[21] Miniprobe-based endoscopes are useful in navigating through stenotic lesions.[22]

Tumor (T) Staging

Five distinct layers are visualized (►**Fig. 2**). These are alternate layers of hyper- and hypoechogenicity. From the inner outwards, the first layer is hyperechoic—representing the interface between the balloon and the epithelial layer. Followed by a hypoechoic layer—comprising lamina propria and muscularis mucosae. Submucosa forms the third layer and appears hyperechoic. The fourth layer is hypoechoic—representing muscularis propria. The last layer is hyperechoic, representing adventitia.[23] High-frequency EUS can even delineate the inner circular and outer longitudinal muscle layers. Puli et al reported that the sensitivity and specificity of EUS are 81.6 and 99.4% in T1, 81.4 and 96.3% in T2, 91.4 and 94.4% in T3, and 92.4 and 97.4% in T4, respectively.[24] Thosani et al performed a meta-analysis on 19 studies comprising early esophageal cancer and reported that the sensitivity and specificity were 85 and 87% in T1a. The sensitivity and specificity were 86 and 86% for T1b.[25] T1b lesions can be further categorized into submucosa (SM) 1, SM2, and SM3 depending on the depth of the lesion aiding in choosing the appropriate modality of treatment.[21]

Nodal (N) Staging

EUS has a sensitivity ranging from 59.5 to 97.2% for N staging and a specificity ranging from 40 to 100%.[26] The presence of

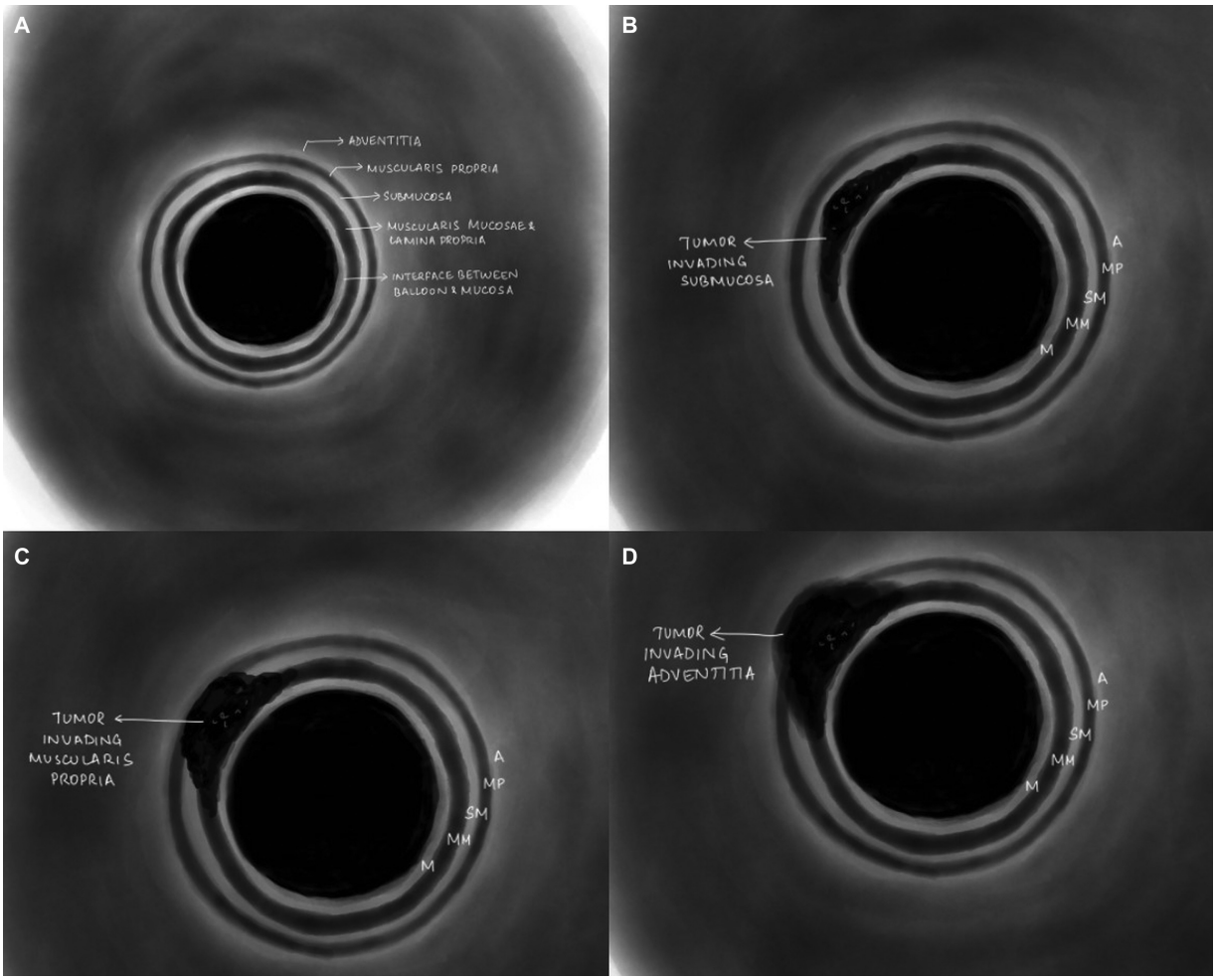

Fig. 2 Endoscopic ultrasound (EUS) schematic diagram. (**A** - normal; **B** - T1; **C** - T2; **D** - T3 stages).

hypoechoic appearance, size more than 10 mm, absence of central intranodal vessels, and sharp border predicts the malignant lymph nodes with an accuracy of 80%.[21] Puli et al reported that EUS-guided fine-needle aspiration was more sensitive (96.7% vs. 84.7%) and specific (95.5% vs. 84.6%) than EUS alone for staging. Potential metastatic sites like liver, pancreas, adrenals, celiac, periportal, and peripancreatic lymph nodal stations can also be screened with EUS.[27]

Limitations

EUS is operator-dependent. Visualization of the primary lesion and lymph nodes may be challenging in the background of near-complete/complete stenosis and post-radiotherapy fibrosis. Due to its invasive nature, there is a potential risk of complications, including perforation.[21]

Multidetector CT

MDCT is the most common imaging modality utilized in tertiary care centers to evaluate patients with esophageal carcinoma. Normal esophagus is a collapsed structure in the posterior mediastinum placed anteriorly and to the right of descending thoracic aorta. When distended with oral contrast, it is an oval tubular structure with mural thickness less than 2 mm. The fat planes around the esophagus are well defined. The appearance of esophageal cancer on CT is similar to the gross pathological appearance and appears as infiltrative, polypoidal, ulcerative, or superficially spreading. The protocol for imaging of carcinoma esophagus is single-phase contrast-enhanced (CE) CT of the neck, chest, and abdomen with the administration of oral on table bolus of diluted positive contrast to achieve adequate distension of esophagus for reduction of false positive esophageal thickening in its collapsed status. Dilution of contrast should be done to mitigate beam hardening artifacts. If there is a high risk of aspiration, oral plain water bolus can be given.

T Staging

Differentiation between T1 and T2 disease cannot be achieved with MDCT. Periesophageal fat infiltration in MDCT is 75% sensitive and 78% specific for T3 disease. Loss of fat planes between the tumor and adjacent mediastinal structure suggests T4 disease with 75% sensitivity and 86% specificity.[28] The study by Picus et al in 1893 was the earliest to predict the invasion of the aorta using the angle of contact

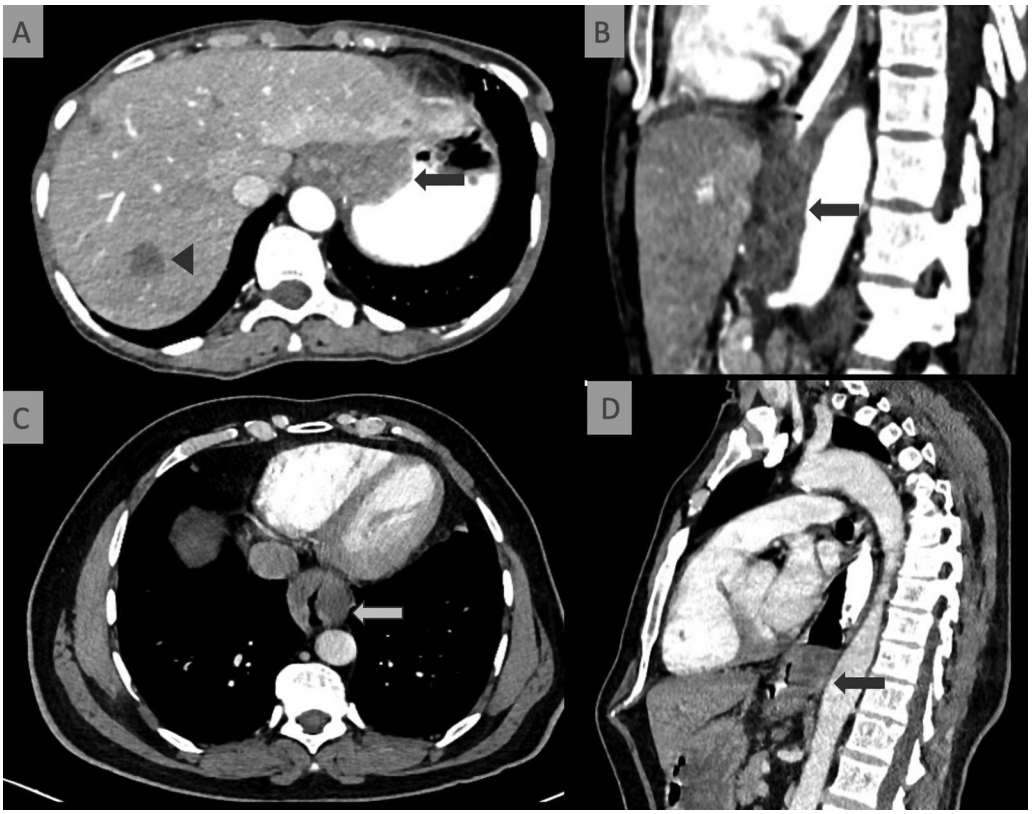

Fig. 3 Locally advanced esophageal cancer on computed tomography (CT). (**A** and **B**) Axial and sagittal contrast-enhanced CT scan shows asymmetrical circumferential mural thickening involving the distal thoracic and abdominal esophagus with ill-defined fat planes with left lobe of the liver anteriorly. Angle of contact with aorta > 90 (arrows). Multiple hypodense lesions in the right lobe of the liver suggestive of metastasis (arrowhead). (**C** and **D**) Axial and sagittal contrast-enhanced CT scan shows polypoidal lesion with ulcerated margins projecting within the lumen of mid and distal thoracic esophagus causing luminal narrowing (arrows).

of the esophageal lesion with the aorta.[29] The angle of contact with the aorta of more than 90 degrees is 88% sensitive and 96% specific in predicting the invasion of the aorta (►**Figs. 3** and **4**).[30] There may be skip lesions. MDCT allows accurate identification of complications arising due to advanced stages such as tracheoesophageal, esophagobronchial, esophagopleural, esophagopericardial fistula, and aortoesophageal fistula (►**Figs. 5** and **6**).[31]

N and M Staging

MDCT has an overall sensitivity of 30 to 60% and specificity of 60 to 80% for the lymph node involvement.[32] The false negative rates are mainly due to fixed size criteria (10 mm) and micrometastasis. Low specificity may be attributed to benign enlargement of lymph nodes due to infection or inflammatory pathologies. MDCT also allows the identification of distant metastasis (►**Figs. 7**–**9**).

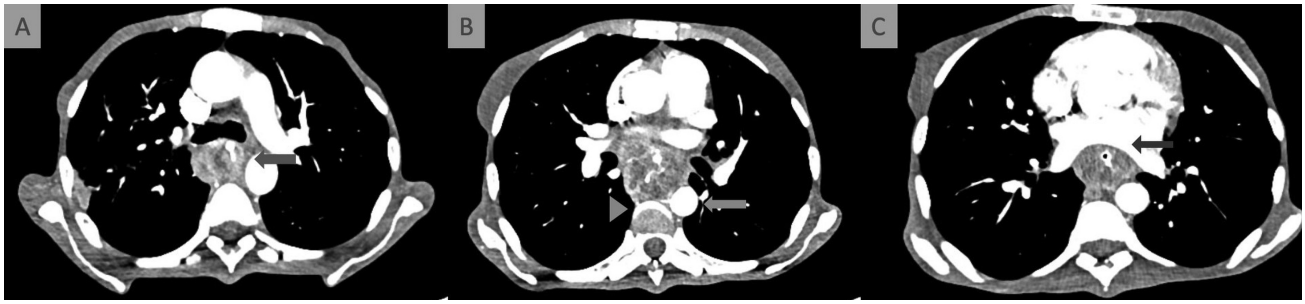

Fig. 4 Locally advanced esophageal cancer on computed tomography (CT). (**A**) Axial contrast-enhanced CT shows asymmetrical circumferential mural thickening involving the mid thoracic esophagus with loss of fat planes with carina and right and left main bronchi (arrow). (**B**) Asymmetrical circumferential mural thickening involving the mid thoracic esophagus with angle of contact with aorta > 90 (arrow) and loss of triangular prevertebral fat plane suggestive of prevertebral space invasion (arrowhead). (**C**) Asymmetrical circumferential mural thickening involving the mid thoracic esophagus causing left atrial bulge and loss of fat plane with bilateral pulmonary veins (arrows).

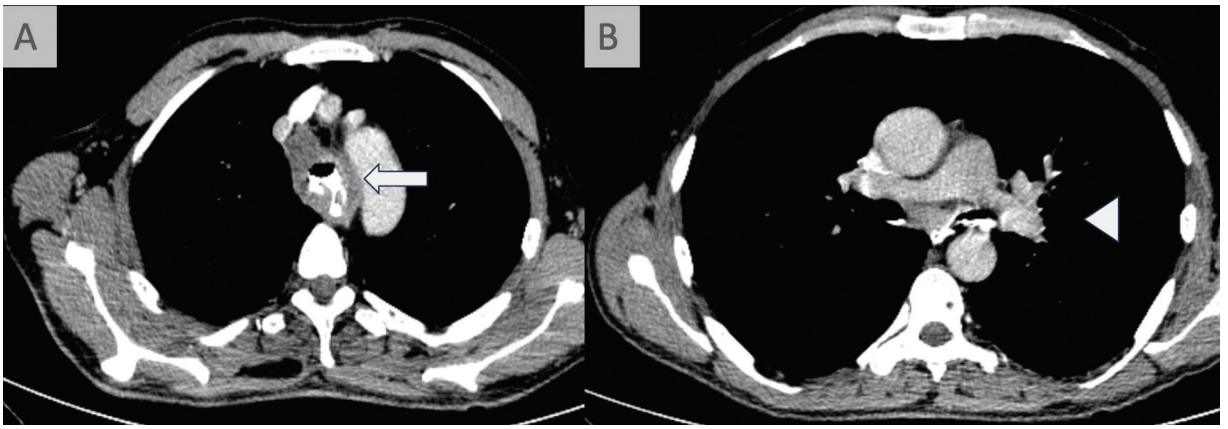

Fig. 5 Esophagobronchial fistula in esophageal cancer. (**A** and **B**) Axial and coronal contrast-enhanced computed tomography (CT) scan show extravasation of contrast into the trachea (arrows) and left main bronchus (arrowhead) suggestive of tracheoesophageal and esophagobronchial fistula.

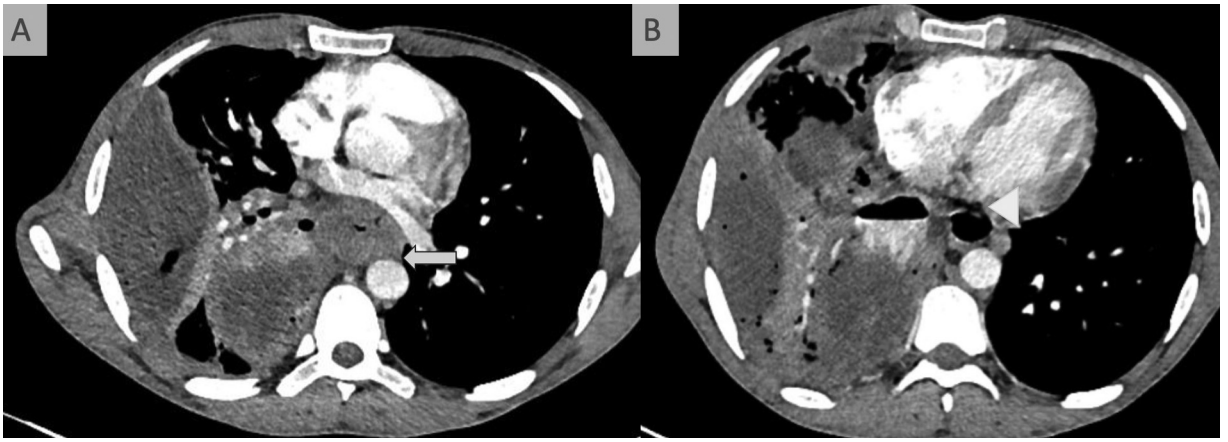

Fig. 6 Esophagopleural fistula in esophageal cancer. (**A** and **B**) Axial contrast-enhanced computed tomography (CT) scan shows asymmetric circumferential mural thickening involving the mid thoracic esophagus (arrows). An irregular, thick-walled collection with air fluid level showing contrast extravasation in the right pleural cavity. Multiple air foci are seen within. There is passive collapse of the underlying lung segments (arrowhead).

Limitations

Drawbacks of MDCT include low sensitivity for early-stage disease, need for adequate distension of esophageal lumen, no definite criteria for lymph nodal metastasis, requirement of whole-body scan for M staging of the disease, and poor post-neoadjuvant chemoradiotherapy (CRT) assessment.

PET-CT

In comparison to MDCT, PET-CT is more sensitive in identifying primary tumors, lymph nodal spread, and distant metastasis (►**Fig. 10**). Furthermore, the maximal standard uptake value, or SUVmax, is an analogous marker for tumor metabolic status. The metabolic tumor volume is a reliable prognostic indicator for esophageal cancer.[33]

T Staging

Although most of the lesions are fluorodeoxyglucose (FDG)-avid on PET-CT, the poor spatial and contrast resolution leads to lower confidence in assessing the length and depth of the disease.[34]

N Staging

According to Shi et al, the pooled sensitivity and specificity for detecting lymph nodal metastasis were 62 and 96%, respectively.[35] The limited spatial resolution of PET-CT leads to poor identification of periesophageal lymph nodes that are adjacent to primary tumors. FDG avidity cannot be observed in micrometastasis. Background benign pathologies like infection and inflammatory disorders lead to false positive rates.[36]

M Staging

PET-CT has the best performance for the detection of metastasis. PET-CT detection of metastasis prevents unnecessary surgeries in the higher stages of the disease. Overall sensitivity and specificity for distant metastasis are 71 and 93%, respectively.[37]

Limitations

Higher cost, nonavailability in resource-poor settings, poor spatial resolution (leading to reduced sensitivity for T and N staging), failure in the identification of FDG nonavid lesions,

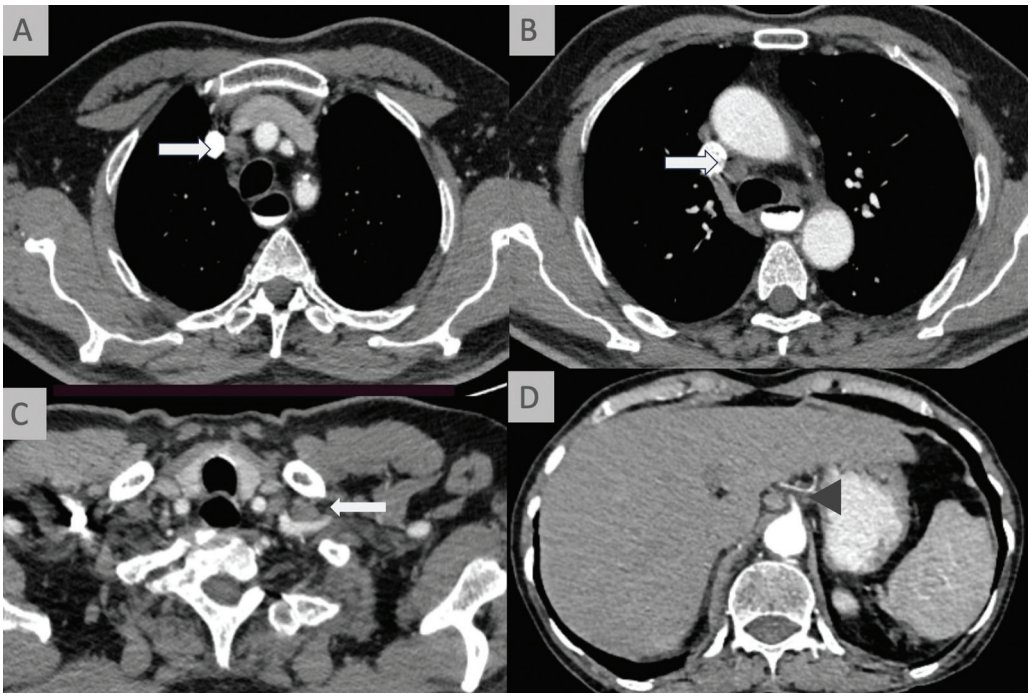

Fig. 7 Lymph node metastases in esophageal cancer. (**A** and **B**) Axial contrast-enhanced computed tomography (CT) scan shows right upper paratracheal lymph nodal enlargement (arrows). (**C** and **D**) Axial contrast-enhanced CT scan shows enlarged left supraclavicular lymph node (arrows, **C**) and gastrohepatic lymph node (arrowhead, **D**).

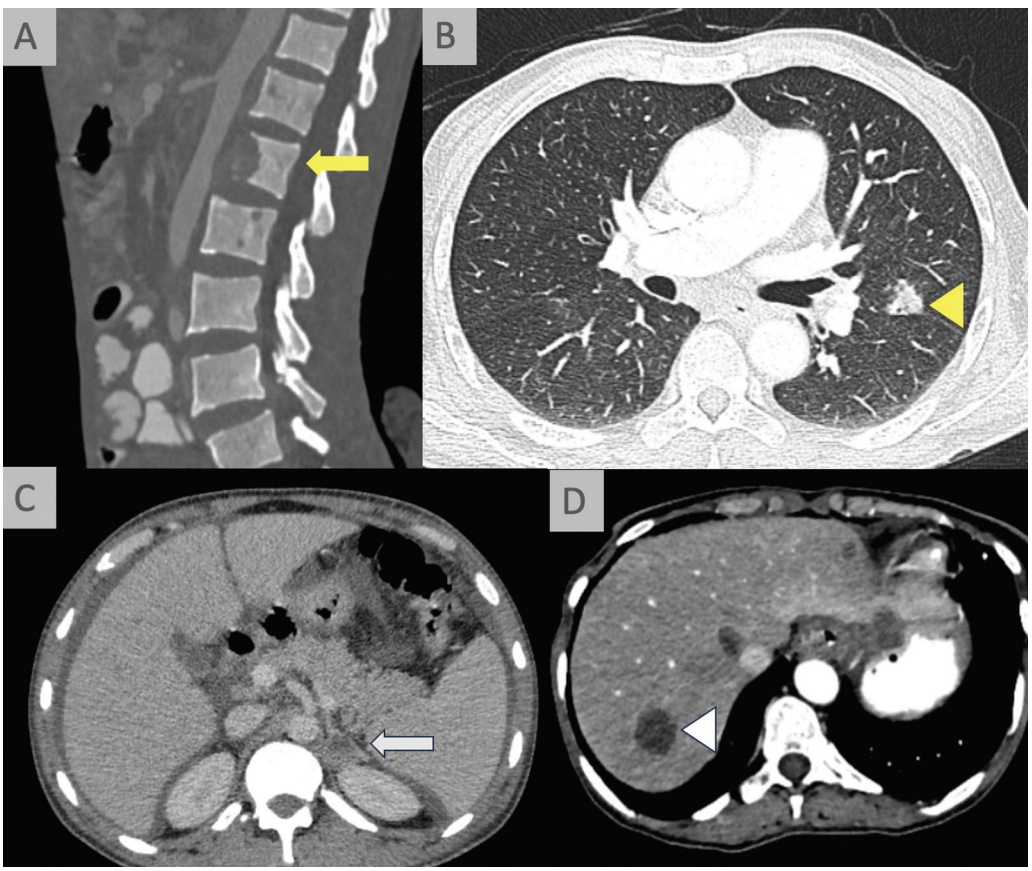

Fig. 8 Distant metastases in esophageal cancer. Sagittal (**A**) and axial (**B**–**D**) contrast-enhanced computed tomography (CT) shows multiple lytic lesions in the bodies of distal thoracic vertebrae (yellow arrow, **A**), a random nodule with indistinct margins in the left lung (yellow arrowhead, **B**), hypodense lesion in the left adrenal gland (white arrow, **C**), and multiple hypodense lesions in the liver (white arrowhead, **D**).

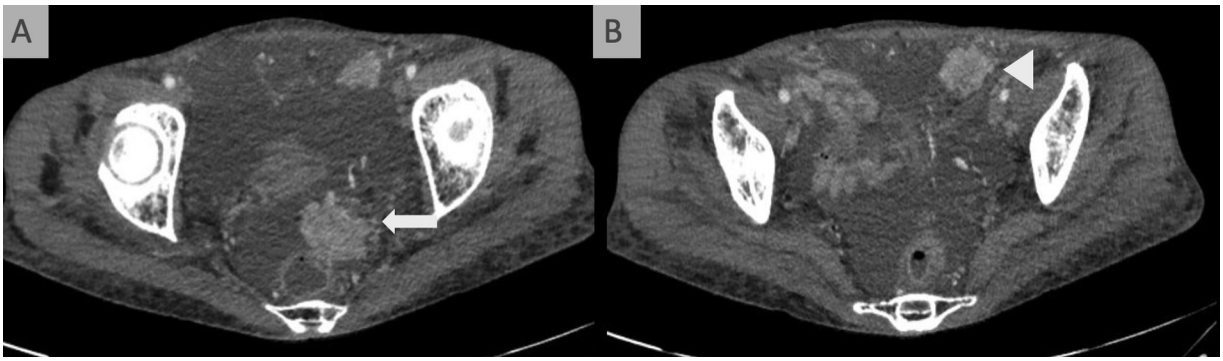

Fig. 9 Peritoneal carcinomatosis in esophageal cancer. (**A** and **B**) Axial contrast-enhanced computed tomography (CT) scan shows heterogeneously enhancing mass in the pouch of Douglas (arrows) and left iliac fossa (arrowhead) with ascites.

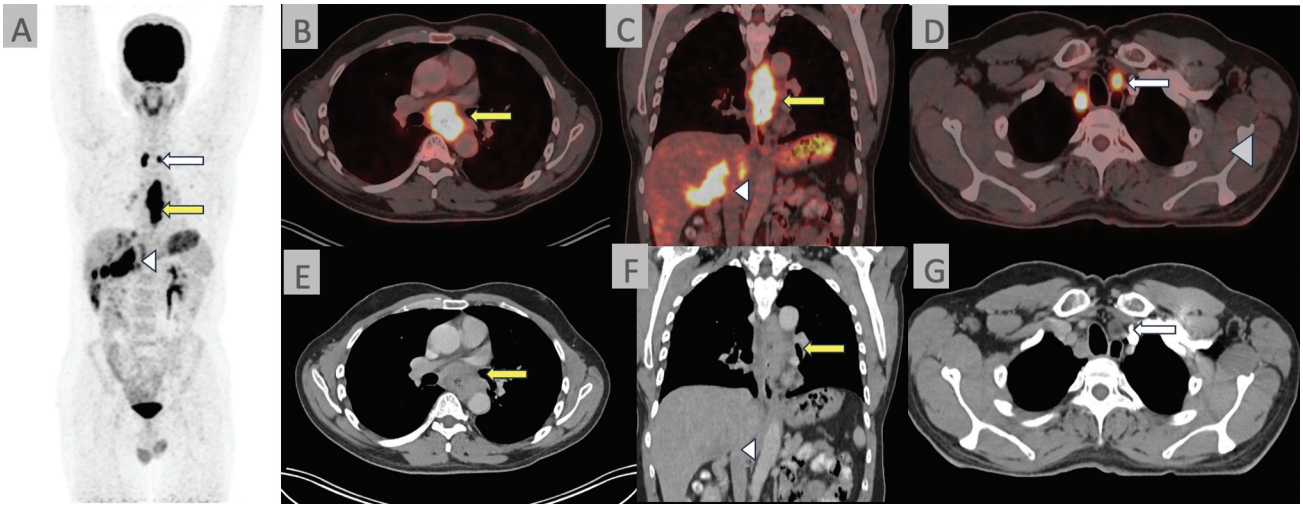

Fig. 10 F18-fluorodeoxyglucose (FDG)-positron emission tomography (PET) computed tomography (CT) in esophageal cancer. PET (**A**), coregistered PET-CT (**B**–**D**), and CT scan (**E**–**G**) show FDG-avid lesion in the mid thoracic esophagus (yellow arrows) with FDG-avid paratracheal lymph node (white arrows) and FDG-avid lesion in the liver (arrowhead) suggestive of metastasis.

and poor response assessment after neoadjuvant CRT are important limitations of PET-CT.

Magnetic Resonance Imaging

MRI does not involve exposure to ionizing radiation. Thus, it offers an advantage over CT and PET-CT. Additionally, unlike EUS, it is noninvasive. It provides unmatched soft tissue contrast; in addition, functional imaging is possible (►**Figs. 11** and **12**).[38,39]

T Staging

Many in vitro and in vivo studies have reported high accuracy of MRI for assessing the depth of invasion.[40–46] These studies utilized high-resolution T2-weighted (T2W) and diffusion-weighted imaging (DWI) sequences. In vitro studies identified eight individual layers of the esophagus seen as alternating hypointense and hyperintense lines. The layers from inner outwards are—hypointense epithelium, hyperintense lamina propria, hypointense muscularis mucosa, hyperintense submucosa, hypointense inner circular muscle layer, hyperintense intermuscular connective tissue, hypointense outer longitudinal muscle layer, and hyperintense adventitia.[40–42]

High-field (7-Tesla) strength MRI can accurately depict the layers of the esophagus, similar to EUS or histopathological images.

It was found to have high sensitivity and specificity for esophageal cancer detection.[40] Differentiation between superficial T1 and deep T1 and T2 lesions was also possible.[46,47] Wei et al showed that T2 mapping of the esophageal wall can accurately depict the precise histopathological layers and help assess the depth of esophageal cancer.[45] For early esophageal cancer, CE radial volumetric interpolated breath-hold examination (VIBE) sequence in free breathing was more accurate than breath-hold Cartesian VIBE for T staging.[48] MR esophagography was found to be better at localizing and assessing the longitudinal extent of the tumor.[49] $T2^*$ values of the tumor were found to correspond with the stage of disease. Higher T stage is associated with greater neoangiogenesis and blood supply. This increases the $T2^*$ values.[50]

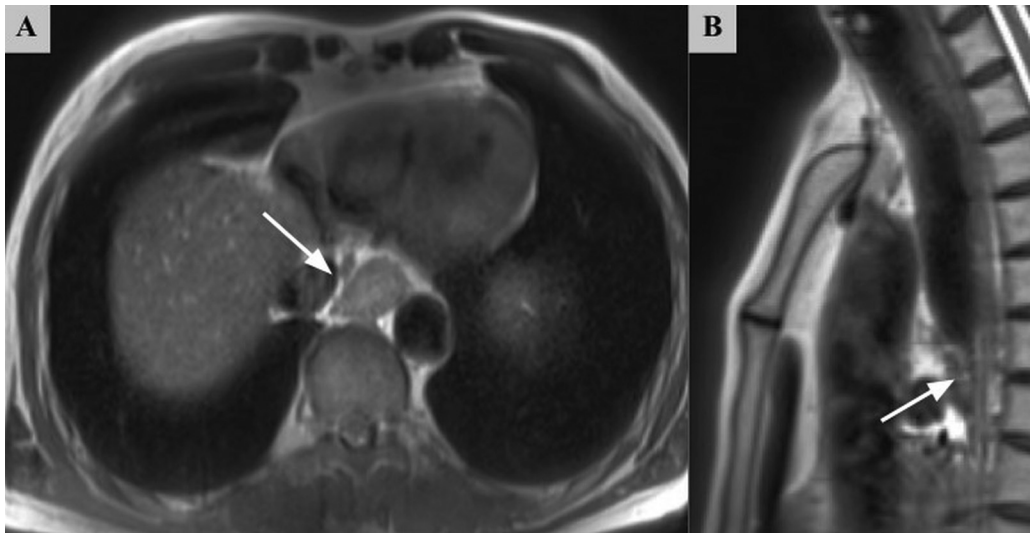

Fig. 11 Magnetic resonance imaging (MRI) in esophageal cancer. (**A** and **B**) Axial and sagittal T2-weighted images shows heterogeneous intermediate signal intensity circumferential mural thickening involving the distal end of the esophagus (arrows).

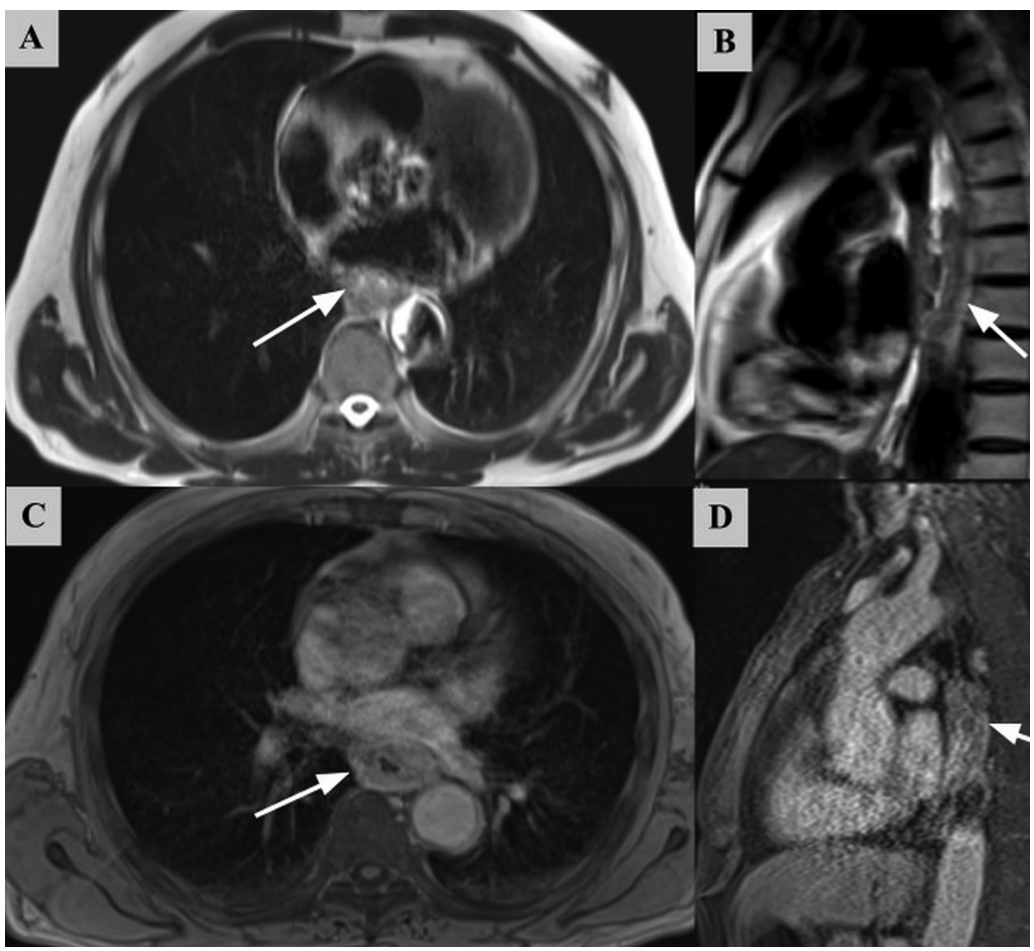

Fig. 12 Magnetic resonance imaging (MRI) in esophageal cancer. Axial and sagittal precontrast T2-weighted and postcontrast T1-weighted images shows heterogeneous circumferential mural thickening of the middle thoracic esophagus (arrows, **A** and **B**) which shows heterogeneous enhancement on postcontrast images (arrows, **C** and **D**).

Table 1 MRI protocol for carcinoma esophagus

Sequence parameter	T2 single-shot FSE	Steady states	Diffusion (EPI)	T1W pre- and postcontrast
Plane	Axial, coronal	Oblique	Axial	Axial, coronal
TE/TR	93/100	1.71/433	80/7900	2.19/4.85
Flip angle	150	60	90	10
FOV (mm)	450 × 450	360 × 360	420 × 380	380 × 308
Matrix size	384 × 269	256 × 256	200 × 200	320 × 240
Slice thickness	6	10	7	2
Voxel size	1.2 × 1.2 × 6	0.7 × 0.7 × 10	1.1 × 1.1 × 7	1.2 × 1.2 × 2
Number of slices	23	1	40	80
Interslices gap	30	NA	20	20

Abbreviations: EPI, echo-planar imaging; FOV, field of view; FSE, fast spin echo; MRI, magnetic resonance imaging; TE, echo time; TR, repetition time; T1W, T1-weighted.
Note: Modified from Pellat et al.[38]

Table 2 MRI staging of carcinoma esophagus

T stage	MRI features
T1	No discernable tumor on MRI
T2	Intermediate signal intensity tumor seen involving the submucosa and muscularis propria. Outer margin of muscularis propria well defined and intact
T3	Intermediate signal intensity tumor involving the submucosa, entire thickness of muscularis propria with extension to periesophageal tissue
T4	Intermediate signal intensity tumor extending to adjacent structures with loss of intervening high signal intensity fat plane
N stage	MRI features
N0	Periesophageal tissue shows uniform high signal intensity
N1	Intermediate signal intensity nodules > 2 mm are seen in periesophageal tissue

Abbreviation: MRI, magnetic resonance imaging.
Note: Modified from Weijs et al.[10]

A typical MRI protocol for evaluating esophageal cancer is shown in ►**Table 1**. ►**Table 2** shows the MRI criteria for T and N staging of esophageal cancer.

For lower T stages, MRI shows good sensitivity and specificity for higher T stages.[38] For the differentiation between T0 and T1 or higher stage tumors, the sensitivity of MRI was 92%, and specificity was 67%, which was higher than CT, PET-CT, and comparable to EUS. There was no difference in the diagnostic performance between pre- and post-neoadjuvant therapy groups.[51] The sensitivity (86%) and specificity (86%) of MRI for differentiating T2 or lower stage disease from T3 or higher stage was comparable to EUS, CT, and PET-CT.[51]

N Staging

Metastatic lymph nodes appear as intermediate signal intensity enhancing lesions with blurred margins on T2W images and appear hyperintense on short-tau inversion recovery images and high b-value DWI. Some studies have shown that DWI is more sensitive than FDG-PET in detecting metastatic lymph nodes.[52] Superparamagnetic iron oxide (SPIO) and ultrasmall SPIO are negative contrast agents. These particles are normally taken up by macrophages, and hence normal lymph nodes appear hypointense on post-SPIO T2W. In metastatic lymph nodes, there is a paucity of macrophages. Thus, there is little or no uptake of SPIO. Hence, metastatic nodes appear hyperintense on post-SPIO T2W.[53,54] The sensitivity and specificity of MRI for N staging have been reported to be 59 to 100% and 57 to 92%, respectively.

M Staging

Whole-body MRI was found to have similar accuracy as PET-CT for the exclusion of distant metastasis.[55] However, additional studies are warranted to determine its role as a diagnostic alternative to PET-CT.

PET-MRI

It combines anatomic information with functional imaging. It provides metabolic information about the tumor, SUV from PET, and apparent diffusion coefficient (ADC) values from DWI. PET-MRI was found to have accuracy similar to EUS

Table 3 TNM classification

T stage	Criteria
Tx	Tumors cannot be assessed
T0	No evidence of primary
Tis	High-grade dysplasia, carcinoma in situ
T1–T1a	Invasion into lamina propria or muscularis mucosae
T1b	Invasion into submucosa
T2	Invasion into the muscularis propria
T3	Invasion into the adventitia
T4–T4a	Invasion into the pleura, pericardium, azygos vein, diaphragm, or peritoneum
T4b	Invasion into the adjacent structures such as aorta, vertebral body, or trachea
N category	Criteria
Nx	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	Metastasis in 1–2 regional lymph nodes
N2	Metastasis in 3–6 regional lymph nodes
N3	Metastasis in 7 or more regional lymph nodes
M category	Criteria
M0	No metastasis
M1	Distant metastasis

Note: Modified from Giuliano et al.[67]

for T staging and higher accuracy than PET-CT and EUS for N staging.[56]

Limitations

MRI is not routinely used in clinical practice. Its availability is limited. The acquisition time is longer than other imaging modalities. The cost is also higher. Motion artifacts due to breathing and cardiac pulsations impair the image quality.[38,39]

Other Uncommon Esophageal Neoplasms

Spindle cell squamous carcinoma is seen as a hypodense intraluminal mass without a proximal dilatation or localized wall thickening on CT. This imaging features closely mimics primary melanoma of esophagus. Neuroendocrine carcinoma causes diffuse esophageal thickening giving a striking hyperenhancement on arterial phase of CT. Leiomyosarcoma is the most common esophageal sarcomas. Imaging features include a heterogeneous exophytic intraluminal lesion with areas of necrosis, air, and contrast tracking within the tumor. GI stromal tumor is commonly seen in the lower third of the esophagus either as a small intramural mass or a large exophytic tumor with homogenous contrast enhancement. Necrosis and calcification can lead to a heterogeneous appearance. Lymphoma causes irregular narrowing of the distal esophagus with concentric/asymmetric mural thickening and adjacent lymphadenopathy. Involvement of esophagus by metastasis is most commonly by direct extension. Hematogenous spread results in submucosal lesions with circumferential short segment strictures.[57]

Management of Carcinoma Esophagus

Upper GI endoscopy is the first-line imaging modality for patients suspected of esophageal malignancy. Suspicious lesions identified on endoscopy should be biopsied and subjected to histopathological assessment. At least six cores are to be taken to ensure adequate representation and sufficient samples for molecular analysis.[58] A multidisciplinary approach is mandated for the assessment and planning of treatment. The treatment choice depends on the TNM stage (►**Table 3**), histological subtype, location of the tumor, and the predicted treatment tolerance. The European Society for Medical Oncology guidelines propose an algorithm for the treatment of esophageal cancer as shown in ►**Fig. 13**.[59] National Comprehensive Cancer Network guidelines are shown in ►**Fig. 14**.[68]

Early Disease (cT1 N0 M0)

Early esophageal lesions are treated by endoscopic mucosal resection or endoscopic submucosal dissection.[59,60] It is the definitive treatment unless deeper margins are involved or risk factors for lymph nodal metastasis are present. In such cases, surgery with lymphadenectomy is offered.

Locally Advanced Resectable Disease (cT2-T4 or cN1–3 M0)

Surgery is the definitive treatment for resectable locally advanced esophageal cancer. Definitive CRT with surveillance and salvage esophagectomy are done in unresectable

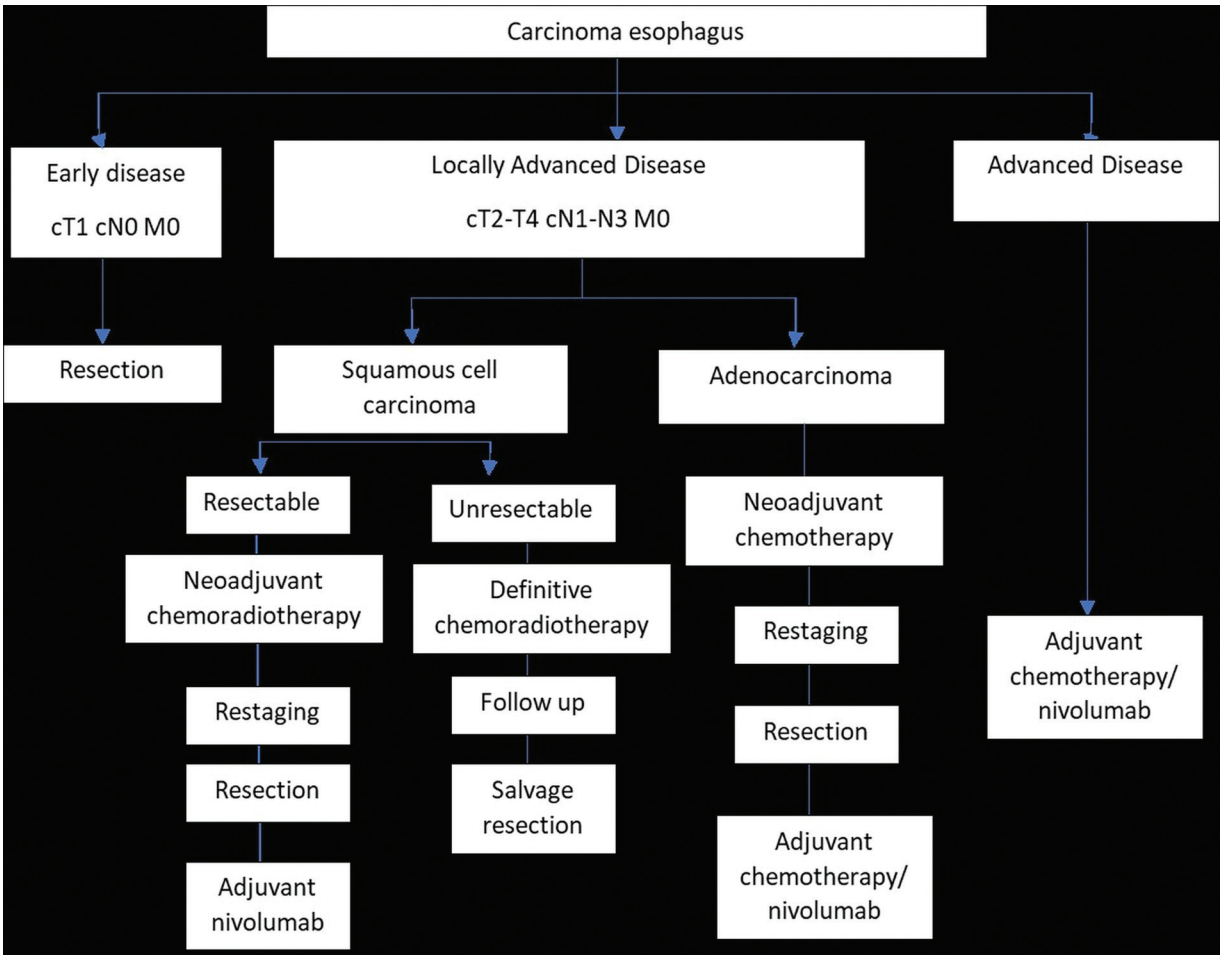

Fig. 13 Stage-based management of carcinoma esophagus. Adapted from Obermannova et al.[59]

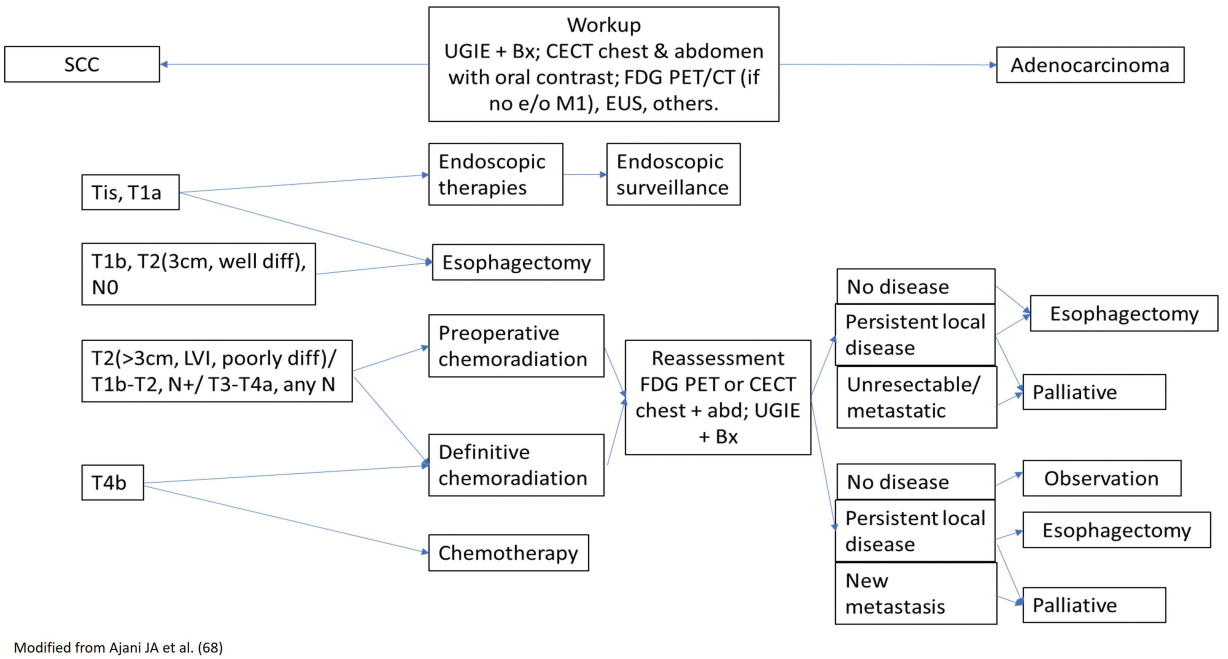

Fig. 14 National Comprehensive Cancer Network (NCCN) guidelines for management of carcinoma esophagus.

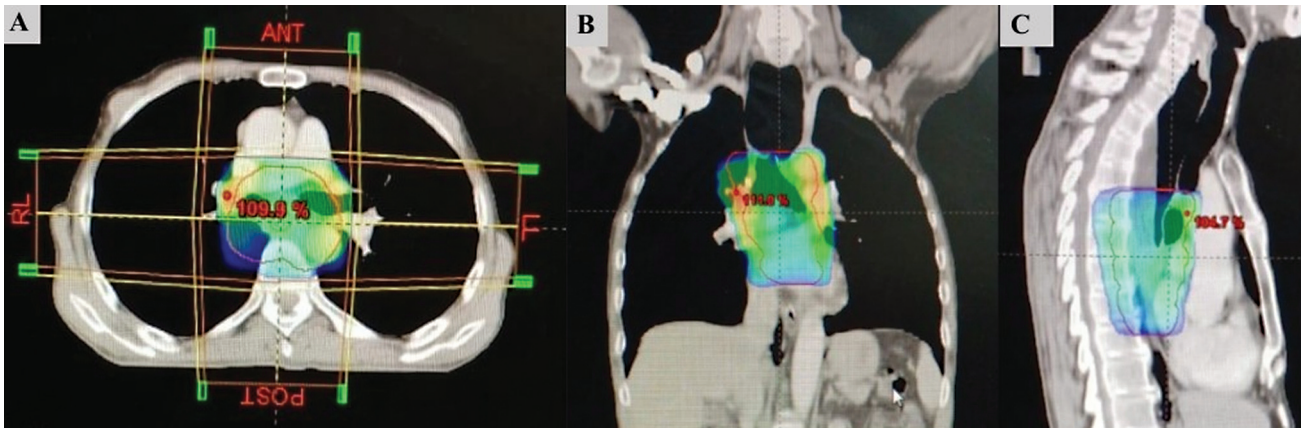

Fig. 15 Radiotherapy planning in esophageal cancer. Computed tomography (CT) images show planning strategy for three-dimensional conformal radiotherapy.

or surgically unfit cases. Radical transthoracic esophagectomy with en bloc two-field lymphadenectomy is the surgery of choice. Ivor Lewis and McKeown's procedures are done for distal and upper/mid esophageal tumors, respectively. In recent years, there has been increased implementation of minimally invasive esophagectomy in clinical practice. It is associated with lesser morbidity, faster recovery, and better quality of life up to 1 year following surgery.[61–64]

Pre- and Perioperative Treatment

Chemotherapy and CRT were found to increase rates of R0 resection and the chances of survival in patients with locally advanced resectable esophageal cancer, and all these patients must be considered for the same. For T2N0 disease, there are no strong recommendations to support the use of neoadjuvant chemotherapy. It was shown to improve complete resection rates but decreased postoperative survival rates.[65] Preoperative CRT is recommended for locally advanced esophageal SCC and AC.[59] Even after the complete clinical response of resectable esophageal AC to neoadjuvant therapy, patients should undergo surgery. Post-neoadjuvant therapy, patients found to have residual disease in the surgical pathological specimens are to be given adjuvant nivolumab weekly for a year.[59] Definitive CRT is the treatment of choice for unresectable esophageal SCC.[59] Three-dimensional conformal radiotherapy is preferred (►**Fig. 15**). Intensity-modulated radiation therapy or volumetric arc therapy can limit the radiation exposure to adjacent vital normal tissues.[59]

Management of Advanced/Metastatic Disease

Adjuvant immunotherapy like pembrolizumab and nivolumab are advocated for advanced, metastatic SCC of the esophagus.[59]

Radiologist must also be aware of the Siewert classification of gastroesophageal junction neoplasms. Siewert tumor type should be assessed in all patients with ACs involving the gastroesophageal junction. Siewert type I and II (located within 5 cm above and 2 cm below the gastroesophageal junction) are managed as esophageal cancer; whereas Siewert type III (located 2 cm below the gastroesophageal junction) as gastric cancer.[66]

Evaluation of Postsurgical Complications

Postoperative cases of esophageal cancer can be evaluated by CT and fluoroscopy. Complications that can occur during surgery are injury to the tracheobronchial tree and ischemia to the stomach. Early postoperative complications are anastomotic leak, operative site infection leading to abscess formation, and mediastinitis. Late complications include fistula formation, chylothorax, delayed emptying, anastomotic strictures, and internal hernia. Patients with neoesophagotracheal or bronchial fistula are prone to develop recurrent pneumonia, atelectasis, empyema, and pleural effusions.[39]

Assessment of Treatment Response

Following neoadjuvant therapy, CT or PET-CT is performed after 4 to 6 weeks. PET-CT has the advantage of being able to predict pathologic response and prognosis in patients and can identify those responding to treatment. It helps quantify metabolic response, which may precede pathologic response. A 35% or more decrease in SUVmax from baseline is associated with improved prognosis in esophageal cancer. A decrease in total lesion glycolysis by less than 26% was associated with poor pathologic response. Early metabolic response after induction chemotherapy was associated with favorable prognosis.[39] EUS, CT, and PET-CT are inaccurate for differentiation between residual disease and inflammation post-neoadjuvant therapy[38] (►**Fig. 16**). DWI and ADC were found to be useful markers to predict response to CRT and survival of patients. The relative change in tumor ADC following the first 2 weeks of neoadjuvant therapy was found to be highly predictive of pathologic complete response in esophageal cancer patients. Dynamic CE-MRI can also be used to predict response to treatment. High-field MRI has the potential to differentiate between fibrosis and residual

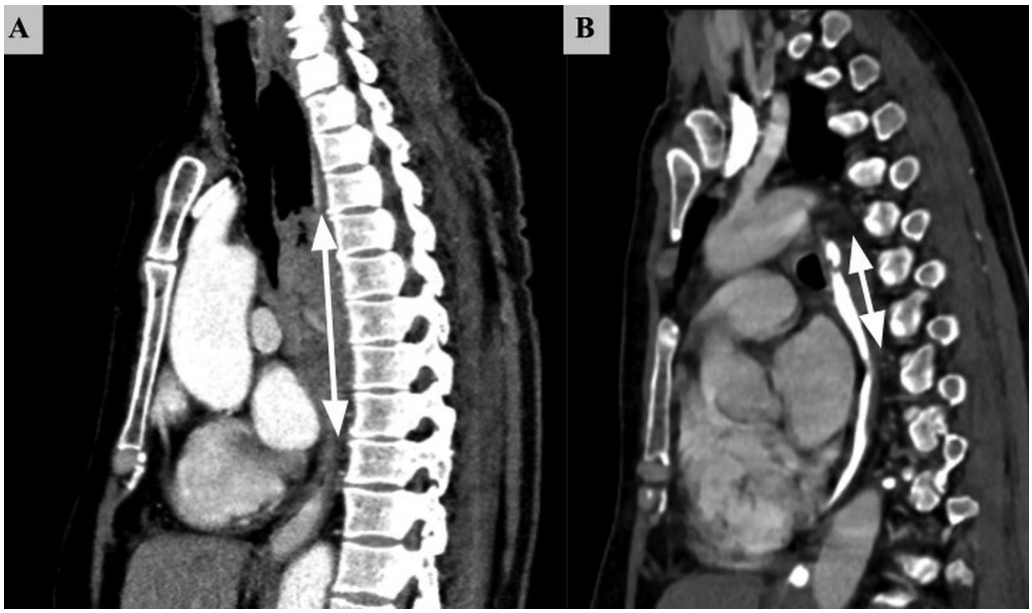

Fig. 16 Post-neoadjuvant chemoradiotherapy (NACRT) response assessment with computed tomography (CT). Contrast-enhanced CT (CECT) thorax in sagittal view showing esophageal tumor in the middle and lower thoracic esophagus. Post-NACRT, there is decrease in the longitudinal tumor extent.

neoplastic tissue, making it a promising candidate for assessment of response to neoadjuvant therapy.[38]

Follow-Up

Posttreatment, the patients are kept on follow-up. The frequency of visits is weekly for 1 month, three monthly for 2 years, then six monthly for the following 3 years, and thereafter annually. In every visit, clinical examination and blood investigations are done. Imaging is done annually, which is CECT neck, chest, and abdomen. Anytime during this period, if the patient develops symptoms of dysphagia or regurgitation, the patient undergoes upper GI endoscopy along with CECT neck, chest, and abdomen to look for disease recurrence or complications.

Conflict of Interest
None declared.

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