**Name of Journal:** *World Journal of Radiology*

**Manuscript NO:** 85238

**Manuscript Type:** MINIREVIEWS

**Progress of magnetic resonance imaging radiomics in preoperative lymph node diagnosis of esophageal cancer**

Xu YH *et al*. MRI radiomics in esophagus cancer

Yan-Han Xu, Peng Lu, Ming-Cheng Gao, Rui Wang, Yang-Yang Li, Jian-Xiang Song

**Yan-Han Xu, Ming-Cheng Gao, Rui Wang, Yang-Yang Li, Jian-Xiang Song,** Department of Thoracic Surgery, Yancheng Third People's Hospital, Sixth Affiliated Hospital of Nantong University, Yancheng 224000, Jiangsu Province, China

**Peng Lu,** Department of Imaging, Yancheng Third People's Hospital, The Sixth Affiliated Hospital of Nantong University, Yancheng 224000, Jiangsu Province, China

**Author contributions:** Xu YH contributed mainly to this work; Xu YH, Lu P, Gao MC, Wang R, Li YY, Song JX designed research; Xu YH, Lu P and Gao MC performed research; and Xu YH wrote the paper.

**Corresponding author: Jian-Xiang Song, PhD, Chief Doctor,** Department of Thoracic Surgery, Yancheng Third People's Hospital, Sixth Affiliated Hospital of Nantong University, No. 500 Yonghe Road, Gangzha District, Yancheng 224000, Jiangsu Province, China. jxsongycsy@163.com

**Received:** April 18, 2023

**Revised:** June 11, 2023

**Accepted:** June 30, 2023

**Published online:**

**Abstract**

Esophageal cancer, also referred to as esophagus cancer, is a prevalent disease in the cardiothoracic field and is a leading cause of cancer-related mortality in China. Accurately determining the status of lymph nodes is crucial for developing treatment plans, defining the scope of intraoperative lymph node dissection, and ascertaining the prognosis of patients with esophageal cancer. Recent advances in diffusion-weighted imaging and dynamic contrast-enhanced magnetic resonance imaging (MRI) have improved the effectiveness of MRI for assessing lymph node involvement, making it a beneficial tool for guiding personalized treatment plans for patients with esophageal cancer in a clinical setting. Radiomics is a recently developed imaging technique that transforms radiological image data from regions of interest into high-dimensional feature data that can be analyzed. The features, such as shape, texture, and waveform, are associated with the cancer phenotype and tumor microenvironment. When these features correlate with the clinical disease outcomes, they form the basis for specific and reliable clinical evidence. This study aimed to review the potential clinical applications of MRI-based radiomics in studying the lymph nodes affected by esophageal cancer. The combination of MRI and radiomics is a powerful tool for diagnosing and treating esophageal cancer, enabling a more personalized and effectual approach.

**Key Words:** Esophageal cancer; Diffusion-weighted imaging; Dynamic contrast-enhanced imaging; Radiomics; Lymph nodes

Xu YH, Lu P, Gao MC, Wang R, Li YY, Song JX. Progress of magnetic resonance imaging radiomics in preoperative lymph node diagnosis of esophageal cancer. *World J Radiol* 2023; In press

**Core Tip:** Precise TNM staging is crucial for developing effective treatment plans for esophageal cancer. Establishing whether esophageal cancer has lymph node metastasis before surgery remains a significant clinical challenge. However, with the continuous advancement of radiomics, high-quality clinical decision support systems have emerged, enabling more accurate determination of preoperative lymph node status in esophageal cancer. This breakthrough may lead to formulating treatment plans that adhere to individualized medical guidelines.

**INTRODUCTION**

According to statistical studies, esophageal cancer is a prevalent malignant tumor of the digestive system, ranking seventh in incidence and sixth in mortality worldwide[1,2]. Endoscopic therapy, chemotherapy, and surgical resection are the primary treatments for esophageal cancer, with surgery being the leading treatment method for early-stage esophageal cancer[3]. Lymph node metastasis is an important prognostic factor in surgically treatable esophageal cancer[4-6]. While lymphatic spread in esophageal cancer is highly variable, positive lymph nodes should be resected along with the tumor to improve long-term survival[7,8]. However, extended lymph node resection may increase postoperative complications and worsen the prognosis of patients with esophageal cancer. Therefore, accurate lymph node evaluation is essential for developing an appropriate treatment strategy.

Magnetic resonance imaging (MRI) is more definitive than other imaging modalities in detecting positive lymph nodes in cancer and has been increasingly used in studying esophageal squamous cell carcinoma at the T and N stages[9-13]. Additionally, radiomics has gained momentum in cancer research over recent years[14]. Radiomics can quantify inter- and intratumor heterogeneity, accurately determine the status of preoperative lymph nodes in esophageal cancer and provide a better basis for clinical decisions regarding treatment options for esophageal cancer[15]. This paper reviews the research and applications of MRI, radiomics, and combined imaging techniques to determine the status of lymph nodes in esophageal cancer.

**METASTATIC FEATURES OF ESOPHAGEAL CANCER LYMPH NODES AND THEIR IMPACT ON TREATMENT**

Esophageal cancer commonly metastasizes to the lower neck, upper mediastinum, and perigastric area[16,17]. The lymph node metastasis rate (LNMR) primarily depends on the location and depth of tumor infiltration[18]. Therefore, certain lymph node regions, such as the cervical segmental paraoesophageal LN, the laryngeal recurrent nerve LN, and the LN along the left gastric artery, have a high LNMR[16].

Since the prognosis of patients with esophageal cancer mainly depends on the extent of the primary tumor and the lymphatic spread of the disease, lymph node status is a crucial prognostic factor[19,20]. Thus, clarifying the extent of lymph node dissection during surgical treatment is important for the prognosis of esophageal cancer. Tong and Kim et al. have demonstrated that patients with esophageal cancer with lymph node metastasis have a lower 5-year survival rate[19,21-23]. The lymph node ratio (absolute number of lymph nodes removed compared to the number of lymph nodes involved) in postoperative patients was an independent predictor of overall survival. Similar studies have indicated that residual lymph node metastasis after treatment is a critical indicator for assessing survival[24]. Therefore, an accurate assessment of the extent of lymph node metastasis in esophageal cancer provides an objective basis for clinical treatment planning and a reference value for patient regression after treatment.

The treatment options for esophageal cancer primarily depend on the TNM stage of the patient. According to Mönig *et al*[17] endoscopic resection is the recommended treatment for early superficial submucosal invasive carcinoma without histologic risk factors such as lymphatic or vascular infiltration. However, the rate of lymph node metastasis in submucosal carcinoma increases with the depth of infiltration. Therefore, the current gold standard of treatment for esophageal cancer is transthoracic subtotal esophagectomy and double field lymph node dissection[25].

The extent of lymph node dissection in esophageal cancer remains controversial[26]. A randomized study found no significant improvement in long-term survival with expanded transthoracic surgery in esophageal adenocarcinoma[27,28]. Meanwhile, Lordick *et al*[29] concluded in their discussion of early management of esophageal cancer that surgery is considered standard of care for disease without suspected lymph node involvement (T1-2 N0 M0), and if lymph node involvement of disease is suspected (T1-2 N1-3 M0), patients are recommended to undergo preoperative treatment. Only after evaluation without involvement of lymph nodes should surgery be considered. Therefore, accurately diagnosing preoperative lymph nodes remains a challenge to be addressed.

**RESEARCH PROGRESS OF MRI IN LYMPH NODES OF ESOPHAGEAL CANCER**

After the diagnosis of esophageal cancer is confirmed by endoscopy and biopsy, staging is crucial for treatment and prognosis. Traditional examination methods, including endoscopic ultrasound (EUS) and CT, play an important role in determining T stage, invasiveness of surrounding structures, and detecting distant metastases[30,31]. Recent studies have shown that 18F-fluoro-2-deoxyglucose positron emission tomography (FDG-PET/CT) examination is also valuable in detecting distant metastases[32]. However, EUS, CT, and FDG-PET(/CT) have limitations in detecting lymph node involvement, which is an important independent predictor of long-term survival in patients[33].

CT scans are commonly used as a non-invasive method to assess metastatic infiltration of esophageal cancer lymph nodes. In CT diagnosis, intra-thoracic lymph nodes with a short diameter greater than 10 mm are considered metastatic lymph nodes. However, some studies have shown that only a small percentage of metastatic lymph nodes in esophageal cancer have a short diameter greater than 10 mm[33,34].

Furthermore, a related study found that although the sensitivity of CT was 59% in detecting lymph nodes larger than 10 mm in the conventional lymph node region of esophageal cancer, the diagnostic value of lymph nodes with metastasis was still insufficient[35]. Measuring the long and short axis diameters of lymph nodes in each region of esophageal cancer in CT images and calculating the axis ratio could improve the sensitivity of CT detection of lymph node metastasis in esophageal cancer. However, the sensitivity, specificity, and accuracy of this approach are still insufficient to provide high-quality clinical decision support systems[36].

MRI is superior to CT in terms of soft tissue resolution and can accurately detect differences in water content in tissues. Its images are unique in their ability to discriminate between masses, lymph nodes, and vascular structures from each other. MRI has multi-sequence imaging and multiple image types, and can generate images from multiple levels (cross-sectional, sagittal, coronal, and various oblique views) at will, reducing the artifacts of soft tissue boundaries in the images and providing richer imaging information to clarify the nature of the lesion. Although MR imaging modalities primarily focus on morphologic changes and provide less functional information about the tumor and are not the preferred method for staging, recent studies have shown that with the technical development of diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE)-MRI, and IVIM, MR is progressively more accurate than CT in determining resectability, mediastinal invasion, and especially lymph node involvement[37].

DWI can provide information on tissue structure and cell density by reflecting the measured apparent diffusion coefficient (ADC) of water molecule mobility, and this quantitative metric is considered a meaningful imaging biomarker in esophageal studies[38]. Since its introduction into clinical practice, DWI has been widely used to detect lymph node metastasis in various primary malignancies and is a successful method[39]. In a prognostic study of esophageal cancer treatment, Giganti *et al*[38] found that pathological ADC could be considered a prognostic factor in esophageal cancer, and DWI may become a promising and reliable diagnostic technique for esophageal cancer. Sakurada et al. also found that the DWI-MRI imaging technique is important in determining the lymph node status of patients with esophageal cancer by visualizing lymph nodes and performing ADC value measurement[40]. In a quantitative analysis study by Alper *et al*[34] it was found that the STIR sequence improved the detection of metastatic lymph nodes with a sensitivity of 81.3% and a specificity of 98.3%, which is consistent with the findings of the group. While the diagnostic performance of DWI and PET for lymph nodes is controversial, the study by Shuto *et al*[39] concluded that DWI showed a higher sensitivity than PET in terms of diagnostic performance of lymph nodes. Given the association between lymph node status and prognosis in esophageal cancer, we believe that DWI is a predictive modality for survival after surgery in patients with esophageal cancer.

DCE-MRI has proven useful as a functional MRI modality in assessing vascular perfusion for monitoring and predicting response to radiotherapy. The histogram analysis established in DCE-MRI is a means of extracting heterogeneous parameters from significant regions (ROI) and whole-tumor analysis of samples from the entire tumor parenchyma and interstitium that can provide a more accurate quantitative assessment of tumor biology[41]. This technique has improved the diagnostic capability of MRI. In the study by Sun *et al*[42] on radiotherapy for esophageal cancer, the results of different histogram parameters (median, mean, standard deviation, mode, skewness, kurtosis, minimum, maximum, percentile, and entropy) derived from DCE-MRI were compared and found to be useful for the assessment of tumor heterogeneity and monitoring the response to radiotherapy for esophageal cancer. Regarding lymph node status analysis, the findings of Chen *et al*[41] suggest that whole-tumor cumulative histogram analysis obtained from DCE-MRI with pharmacokinetics as a parameter may be useful for T-staging and regional lymph node status determination in esophageal squamous cell carcinoma. Although the study of lymph node status in esophageal cancer by DCE-MRI is still in its infancy, the available data and results show that DCE-MRI has a high accuracy in determining lymph node status, which is important for developing individualized treatment plans for esophageal cancer.

Recently, the StarVIBE sequence on MRI has been utilized in cases where patients are unable to hold their breath and has gradually been incorporated into studies on esophageal cancer[12,43]. Qu *et al*[44] conducted a study where MRI was shown to better predict lymph node status in patients with preoperative esophageal cancer by extracting the ROI of esophageal cancer lesions. This method demonstrated significantly improved diagnostic accuracy over CT and could facilitate better treatment planning for esophageal cancer. Therefore, MRI shows promise in aiding lymph node assessment in esophageal cancer patients, particularly when CT scans yield inconclusive results. Nevertheless, further research is required to confirm its effectiveness in clinical practice.

While the clinical value of MRI in lymph node diagnosis, treatment evaluation, and prognosis prediction has been gradually recognized, false-positive lymph nodes can also occur on MRI due to interference from cardiac motion and gastric peristaltic artifacts. Moreover, false-negative lymph nodes can also be observed in smokers and patients with pneumoconiosis or silicosis with esophageal cancer[45]. Despite advancements in radiological examination methods, further improvement in the sensitivity of lymph node metastasis determination may still be possible. For instance, the development of new imaging techniques or the integration of multiple imaging modalities could potentially improve the accuracy of lymph node metastasis detection in esophageal cancer patients. Additionally, further studies focusing on the optimization of imaging protocols and the standardization of image interpretation criteria may lead to more accurate and reliable diagnosis of lymph node metastasis.

***Process steps of radiomics***

Radiomics is the application of computerized mathematical tools to image processing, transforming image data from ROI in radiological images into mineable high-dimensional feature data. The radiological features (*e.g.,* shape, texture, or waveform) extracted from them can provide information about the cancer phenotype as well as the tumor microenvironment[14]. This information is distinct and complementary to other disease-related information, including clinical features, treatment-related decision information, or genomic data[46]. When radiomics-derived data are combined with other relevant data and correlated or extrapolated to clinical disease outcomes, they can produce accurate and reliable clinical decision support systems (CDSS). These CDSS can assist clinicians in making more informed decisions regarding diagnosis, treatment planning, and prognosis prediction for patients with esophageal cancer (Figure 1).

Radiomics refers to the quantitative mapping of medical images, involving the extraction and analysis of numerous image features that are relevant to the study objectives, including clinical treatment decisions and genomic features. Radiomics studies typically encompass five phases, namely data selection, medical imaging, feature extraction, exploratory analysis, and modeling. The analysis of radiomics can be localized in the primary tumor foci, metastatic lesions, or normal tissues or can be applied to any image generated in the clinical setting. Radiomics analysis can provide valuable insights into tumor heterogeneity and microenvironment, which can aid in identifying potential biomarkers for prognosis and treatment response prediction in patients with esophageal cancer. However, further research is necessary to validate the clinical utility of radiomics in esophageal cancer and to establish standardized protocols for radiomics analysis.

Regarding image feature extraction in radiomics, it involves extracting quantitative features from images that represent the volume of interest (VOI), which are eigenvalues of an image that depend on factors such as image preprocessing (*e.g.*, filtering or intensity discretization) and reconstruction (*e.g.*, filtered backprojection or iterative reconstruction)[14]. Delineating the ROI or VOI is a critical first step in any radiomics method. However, manual, and semi-automatic segmentation methods often introduce observer bias and can be time-consuming. Additionally, inter-, and intra-observer variation in ROI/VOI delineation can affect the reproducibility and stability of radiomics features. Therefore, studies using manual or semi-automatic segmentation with manual correction should evaluate the internal and external reproducibility of derived radiomics features. To ensure result reproducibility, it is advisable to exclude irreproducible features from further analysis. Automating the segmentation process using deep learning techniques has also shown promise in improving the reproducibility and efficiency of ROI/VOI delineation in radiomics studies.

The second step in image processing is a crucial intermediary between image segmentation and feature extraction. Its objective is to standardize the images for radiomics feature extraction, including pixel spacing, grayscale intensities, and gray histogram binning, among other factors. The reliability of test-retest of extracted radiomics features depends on the image processing settings used in this step. Therefore, it is critical to carefully select and optimize the image processing settings to ensure the robustness and reproducibility of radiomics features. The pyRadiomics package, which is one of the most widely used packages for radiomics analysis, allows various image processing steps to be defined through a parameter file in YAML or JSON structured text format. This file can then be loaded into 3D Slicer or integrated into a Python framework to facilitate feature calculation.

After image segmentation and processing, the third step of radiomics feature extraction can be performed. Feature extraction involves calculating feature descriptors to quantify the gray-level features within the ROI/VOI. As there are many ways and formulas to calculate these features, it is recommended to follow the Image Biomarker Standardization Initiative (IBSI) guidelines[47].

The IBSI guidelines provide a consensus for standardized feature calculations from a matrix of all radiomics features. Different types of radiomics features exist, including intensity-based (histogram) features, shape features, texture features, transform-based features, and radial features, with different types of filters (*e.g.,* wavelet or Gaussian filters) usually applied in the feature extraction step. After feature selection/deviation is performed, subsequent statistical analysis and machine learning will be used to identify the important features that support image analysis. Dimensionality reduction is a multi-step process to exclude irreducible, redundant, and irrelevant features from the dataset.

The first step involves excluding non-replicated features, as a feature that has high intra- or inter-observer variability may be less likely to be useful. The second step is to select the most relevant variables for the corresponding task. Various methods that often rely on machine learning techniques can be used for this initial feature selection step, such as elimination filters, recursive feature elimination methods, or random forest algorithms. As these algorithms often cannot account for covariance and correlation in the data, constructing correlation clusters is the logical next step in the dimensionality reduction workflow. In some cases, this step may be combined with the previous (second) step, as few machine learning techniques can handle correlations in the data. Correlation clustering allows the visualization of highly correlated features in the data and the selection of only one representative feature per correlation cluster.

Selecting the variable with the highest bio-clinical variability in the dataset is crucial as it is likely to be the most representative of the variation within a given patient population. Once the dimensionality of the data has been reduced, the importance of the data visualization step increases. Therefore, reducing the number of features used to build statistical and machine learning models through a step called feature selection or dimensionality reduction is critical to generating valid and generalizable results. The remaining uncorrelated and highly correlated features can be used to train models for the corresponding classification tasks, and the constructed radiomics models are evaluated according to the radiomics quality score. These key steps form the basis for ensuring that the imaging histology produces high-quality CDSS.

***Progress of CT radiomics in esophageal cancer lymph nodes***

When radiomics is involved in tumor exploration, it provides a new approach in the study of cancer patients by developing and validating an imaging-based radiomic columnar map that combines radiomic features and clinical factors in the development of cancer patients. In the esophageal cancer study discussed in this article, there have been many researchers, in recent years, who have applied radiomics to the study of esophageal cancer, thus showing that radiomics is not a novel technique.

Li *et al*[48] extracted radiomic features from FDG-PET images of 152 patients with esophageal cancer and successfully predicted those patients who would not benefit from preoperative radiotherapy. Qiu *et al*[49] developed and validated a CT-based radiomic columnar map that combined radiomic features and clinical factors to predict the risk of recurrence in patients who underwent surgery after neoadjuvant chemotherapy and achieved a pathologic complete response in patients with esophageal cancer at risk of recurrence. Meanwhile, in terms of lymph nodes, which are the focus of this article, Gu et al. studied 129 sets of lymph nodes from 77 patients in the cohort (trial cohort: 102 lymph nodes from 59 patients; validation cohort: 27 lymph nodes from 18 patients) based on the radiomic features of CT to predict the treatment response and the ability of local control of locally recurrent lymph nodes after radiotherapy esophagectomy[50]. A scoring model based on the location and length of the cancer focus and the size and status of the corresponding lymph node region as revealed by CT allowed for accurate assessment of the status of the lymph nodes, which helped in the development of the surgical approach and accurate intraoperative clearance of the corresponding lymph nodes. Meanwhile, in a case-control study of esophageal cancer, Qu *et al*[44] extracted radiomic features from CT data of 152 patients with esophageal cancer without lymph node metastases and 182 patients with lymph node metastases and found that CT radiologic features could help predict the lymph node status of patients with advanced esophageal cancer and effectively distinguish whether there were regional lymph node metastases in esophageal cancer. Moreover, Tan et al. retrospectively analyzed 230 patients with esophageal cancer who had CT examinations and found that radiomics could help reveal intra-tumor heterogeneity and could be used as a new biomarker to determine LN status in patients with resectable esophageal cancer by using a radiomic column line graph containing 5 features in combination with CT-reported LN status (*i.e.*, size criteria)[51]. This shows that the CT radiomics model can be applied clinically to assess the lymph node status in patients with esophageal cancer prior to treatment.

Although most current radiomic studies of ESCC are based on CT and PET, preoperative MRI radiologic features are more valuable because MRI is noninvasive and has higher tissue resolution. Qu *et al*[44] 50 of 181 patients with pathologically confirmed esophageal cancer with lymph node metastases, based on T2-TSE-BLADE and StarVIBE enhancement sequences in MRI images. Nine radiographic features were selected to create radiographic features significantly associated with LN metastasis, and the model was found to distinguish well between metastatic and non-metastatic lymph nodes.

***Development of MRI radiomics in tumor research***

Although most of the current radiomic studies of ESCC are based on CT and PET, with the advancement of MRI techniques such as DWI, DCE-MRI, and IVIM, and the availability of high-quality imaging sequences such as the related StarVIBE and T2\_BLADE, MRI has excellent soft-tissue resolution and is more conducive to the mutual discrimination between lesions, lymph nodes, and vascular structures. MRI findings such as the size, morphology, and shape of cancer foci are important for their identification in the study of tumor subtypes[52,53]. In some studies, it has been found that some specific MRI sequences can better detect lesions and aid in treatment selection[53]. The ROI generated from MRI images can be analyzed by imaging histology to extract superior imaging features. These features can be combined with clinically relevant patient information to generate high-quality CDSS to guide treatment planning.

ROI analysis of the primary tumor lesion not only yields key information about the relevant pathology but also has value for the prognostic analysis of patient survival. Shin et al. applied an MRI radiomic model to assess the pathological remission response in rectal cancer patients receiving neoadjuvant radiotherapy and found that the diagnostic value was superior to visual assessment by an experienced radiologist[54]. Meanwhile, Li *et al*[48] extracted radiomic features from T2-weighted MRI images and combined them with clinical data for deep machine learning, which stably predicted the survival of glioma patients and helped to preoperatively assess the extent of macrophage infiltration in glioma tumors[55].

Although there is increasing interest in MRI radiomics in various areas of oncology across studies, most of the studies have focused almost exclusively on the histological and radiomic features associated with the primary tumor. It is well-known that histopathological data of the primary tumor, such as lymph-vascular invasion, histological grading, and tumor markers, are important factors used to guide or determine clinical treatment decisions. Meanwhile, when MRI radiomics is focused on the diagnosis of preoperative lymph node status, its high-quality diagnostic results can further guide treatment decisions in the clinical setting. In a study by Domiziana et al., they found 3T MRI radiomics combined with histological data could predict preoperative lymph node metastasis in breast cancer patients and guide treatment planning. The results suggest that accurate prediction of lymph node status can avoid invasive surgery, such as lymph node dissection or biopsy[56]. Similar conclusions were reached in studies on the prediction of preoperative lymph node status in breast cancer, suggesting that the influential features of MRI radiomics are important for the determination of lymph node status[57-59].

It is worth noting that while the image features derived solely from the ROI of cancer foci can be used to analyze the status of lymph nodes, the CDSS obtained from both the ROI of lymph nodes and cancer foci is more clinically valuable when combined for imaging histological analysis. In Li et al.'s study, they combined the ROIs of both primary colon cancer lesions and lymph node lesions for imaging histological analysis, and their findings were even more convincing because they required the analysis of both cancer lesion features and lymph node features in their derived nomogram features[60].

While various high-quality MRI sequences have been studied, the analysis of optimal imaging sequences is still rare. Qu *et al*[44] selected 9 radiographic features based on the T2-TSE-BLADE and Star-VIBE enhancement sequences in MRI images to create radiographic features that are significantly associated with LN metastasis in 181 patients with pathologically confirmed lymph node metastasis. They found that the model based on this sequence effectively distinguished between metastatic and non-metastatic lymph nodes[44].

It is important to note that MRI examinations typically have a long examination time, and tumors that originate in the chest may be affected by the patient's respiratory movements, making artifacts unavoidable. While imaging histology can help reduce the impact of artifacts, it may also be beneficial to minimize examination time and extract established imaging histological features from optimal sequences to improve CDSS quality.

In oncology patients, accurately diagnosing lymph node status is critical for determining appropriate treatment options. While existing MRI radiomics studies have demonstrated its effectiveness in determining lymph node status, studies targeting focal radiomic features that link tumor features with lymph node status remain relatively uncommon. Analyzing various MRI sequences to identify sequences that yield high-quality imaging histological features may be an important area for future research.

Radiomics has garnered significant attention from researchers worldwide for its non-invasive, quantitative, and low-cost approach in diagnosing tissue characteristics, tumor staging, and treatment response. The current focus of radiomics research for esophageal cancer is on evaluating patient response and survival prognosis after different treatments. While predicting preoperative lymph node status using radiomics remains relatively rare, the numerous studies exploring various aspects of radiomics in esophageal cancer offer optimism for future research into using radiomics more widely to evaluate lymph nodes.

**CONCLUSION**

Although MRI has shown a trend toward superiority over other imaging methods for determining the lymph node status of esophageal cancer, the interference of respiratory motion and heartbeat specific to the chest and the presence of artifacts in imaging can affect the diagnosis of the lymph node status of esophageal cancer. Radiomics techniques use a combined medical-mathematical tool approach to convert conventional images into digital quantitative features, which have the potential to tap into the underlying biological features and heterogeneity of tumor images and have been widely used for diagnosis, differential diagnosis, and disease assessment. Radiomics can significantly improve the diagnostic specificity of lymph nodes.

However, MRI-based radiomics has not been extensively studied in esophageal cancer lymph nodes. Although some studies have found that MRI-based radiomic features are associated with lymph node metastasis, most were relatively small-sample and single-center studies, and the applicability and generalizability of the findings require further validation. The specificity of various MRI sequences and techniques for diagnosing lymph node status in esophageal cancer needs to be compared, and the quality of the images formed by the selected MRI sequences needs to be validated against histological data. Furthermore, a multicenter study should be conducted to increase the sample size and validate our findings. Successful completion of these essential steps can lead to the development of a valuable clinical decision support systems (CDSS) for esophageal cancer.

It is important to note that while radiomics analysis can be performed on medical images from different modalities, integrating cross-modality approaches using the potential information extracted from MRI, computed tomography, and PET can provide added value compared to evaluating each modality separately. However, the level of research sophistication still has low stability and generalizability, and specific study conditions and author selection can strongly influence the results.

In addition, most radiomic studies are based on retrospective data, resulting in a low evidence level. Therefore, prospective studies for validation in external cohorts or confirmatory studies, besides larger patient cohorts, are necessary to provide more reliable and generalizable results. Future studies should focus on developing standardized radiomics protocols and establishing open-access radiomics databases to promote the reproducibility and transparency of radiomics research. Radiomics has great overall potential for aiding clinical decision-making and improving patient outcomes; however, further validation and standardization are needed to ensure clinical utility.

It is essential to ensure that the imaging histology study is of high quality, addresses actual clinical needs, and can be implemented clinically to increase the likelihood of clinically relevant and valuable radiomics studies. Obtaining all relevant non-imaging data, such as demographics and bioinformatics, is critical. Standardizing the acquired images before performing radiomics analysis is essential to minimize the impact of different settings on the modeling. Implementing these key steps can lead to the formation of a valuable CDSS.

Furthermore, we believe that combining various MRI techniques and radiomics studies on esophageal cancer lymph nodes can introduce new quantitative imaging markers for medical imaging. With the precise determination of lymph node status using different MRI techniques and high-quality CDSS provided by radiomics findings, this approach may lead to significant breakthroughs in clinical studies. Preoperative personalized clinical characterization and precise treatment planning for esophageal cancer are possible with the introduction of new quantitative imaging markers.

**REFERENCES**

1 **Bray F**, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2018; **68**: 394-424 [PMID: 30207593 DOI: 10.3322/caac.21492]

2 **Chen W**, Zheng R, Baade PD, Zhang S, Zeng H, Bray F, Jemal A, Yu XQ, He J. Cancer statistics in China, 2015. *CA Cancer J Clin* 2016; **66**: 115-132 [PMID: 26808342 DOI: 10.3322/caac.21338]

3 **Ishihara R**. Endoscopic Diagnosis and Treatment of Superficial Esophageal Squamous Cell Cancer: Present Status and Future Perspectives. *Curr Oncol* 2022; **29**: 534-543 [PMID: 35200548 DOI: 10.3390/curroncol29020048]

4 **Hofstetter W**, Correa AM, Bekele N, Ajani JA, Phan A, Komaki RR, Liao Z, Maru D, Wu TT, Mehran RJ, Rice DC, Roth JA, Vaporciyan AA, Walsh GL, Francis A, Blackmon S, Swisher SG. Proposed modification of nodal status in AJCC esophageal cancer staging system. *Ann Thorac Surg* 2007; **84**: 365-73; discussion 374-5 [PMID: 17643602 DOI: 10.1016/j.athoracsur.2007.01.067]

5 **Mariette C**, Piessen G, Briez N, Triboulet JP. The number of metastatic lymph nodes and the ratio between metastatic and examined lymph nodes are independent prognostic factors in esophageal cancer regardless of neoadjuvant chemoradiation or lymphadenectomy extent. *Ann Surg* 2008; **247**: 365-371 [PMID: 18216546 DOI: 10.1097/SLA.0b013e31815aaadf]

6 **Rice TW**, Lerut TE, Orringer MB, Chen LQ, Hofstetter WL, Smithers BM, Rusch VW, van Lanschot J, Chen KN, Davies AR, D'Journo XB, Kesler KA, Luketich JD, Ferguson MK, Räsänen JV, van Hillegersberg R, Fang W, Durand L, Allum WH, Cecconello I, Cerfolio RJ, Pera M, Griffin SM, Burger R, Liu JF, Allen MS, Law S, Watson TJ, Darling GE, Scott WJ, Duranceau A, Denlinger CE, Schipper PH, Ishwaran H, Apperson-Hansen C, DiPaola LM, Semple ME, Blackstone EH. Worldwide Esophageal Cancer Collaboration: neoadjuvant pathologic staging data. *Dis Esophagus* 2016; **29**: 715-723 [PMID: 27731548 DOI: 10.1111/dote.12513]

7 **Hosch SB**, Stoecklein NH, Pichlmeier U, Rehders A, Scheunemann P, Niendorf A, Knoefel WT, Izbicki JR. Esophageal cancer: the mode of lymphatic tumor cell spread and its prognostic significance. *J Clin Oncol* 2001; **19**: 1970-1975 [PMID: 11283129 DOI: 10.1200/JCO.2001.19.7.1970]

8 **Visser E**, van Rossum PSN, Ruurda JP, van Hillegersberg R. Impact of Lymph Node Yield on Overall Survival in Patients Treated With Neoadjuvant Chemoradiotherapy Followed by Esophagectomy for Cancer: A Population-based Cohort Study in the Netherlands. *Ann Surg* 2017; **266**: 863-869 [PMID: 28742691 DOI: 10.1097/SLA.0000000000002389]

9 **Dappa E**, Elger T, Hasenburg A, Düber C, Battista MJ, Hötker AM. The value of advanced MRI techniques in the assessment of cervical cancer: a review. *Insights Imaging* 2017; **8**: 471-481 [PMID: 28828723 DOI: 10.1007/s13244-017-0567-0]

10 **Moreno CC**, Sullivan PS, Mittal PK. MRI Evaluation of Rectal Cancer: Staging and Restaging. *Curr Probl Diagn Radiol* 2017; **46**: 234-241 [PMID: 28089690 DOI: 10.1067/j.cpradiol.2016.11.011]

11 **Qiu Y**, Zhang X, Wu Z, Wu S, Yang Z, Wang D, Le H, Mao J, Dai G, Tian X, Zhou R, Huang J, Hu L, Shen J. MRI-Based Radiomics Nomogram: Prediction of Axillary Non-Sentinel Lymph Node Metastasis in Patients With Sentinel Lymph Node-Positive Breast Cancer. *Front Oncol* 2022; **12**: 811347 [PMID: 35296027 DOI: 10.3389/fonc.2022.811347]

12 **Qu J**, Zhang H, Wang Z, Zhang F, Liu H, Ding Z, Li Y, Ma J, Zhang Z, Zhang S, Dong Y, Jiang L, Zhang W, Grimm R, Kiefer B, Kamel IR, Qin J, Li H. Comparison between free-breathing radial VIBE on 3-T MRI and endoscopic ultrasound for preoperative T staging of resectable oesophageal cancer, with histopathological correlation. *Eur Radiol* 2018; **28**: 780-787 [PMID: 28799124 DOI: 10.1007/s00330-017-4963-0]

13 **Giganti F**, Ambrosi A, Petrone MC, Canevari C, Chiari D, Salerno A, Arcidiacono PG, Nicoletti R, Albarello L, Mazza E, Gallivanone F, Gianolli L, Orsenigo E, Esposito A, Staudacher C, Del Maschio A, De Cobelli F. Prospective comparison of MR with diffusion-weighted imaging, endoscopic ultrasound, MDCT and positron emission tomography-CT in the pre-operative staging of oesophageal cancer: results from a pilot study. *Br J Radiol* 2016; **89**: 20160087 [PMID: 27767330 DOI: 10.1259/bjr.20160087]

14 **Lambin P**, Leijenaar RTH, Deist TM, Peerlings J, de Jong EEC, van Timmeren J, Sanduleanu S, Larue RTHM, Even AJG, Jochems A, van Wijk Y, Woodruff H, van Soest J, Lustberg T, Roelofs E, van Elmpt W, Dekker A, Mottaghy FM, Wildberger JE, Walsh S. Radiomics: the bridge between medical imaging and personalized medicine. *Nat Rev Clin Oncol* 2017; **14**: 749-762 [PMID: 28975929 DOI: 10.1038/nrclinonc.2017.141]

15 **Gillies RJ**, Kinahan PE, Hricak H. Radiomics: Images Are More than Pictures, They Are Data. *Radiology* 2016; **278**: 563-577 [PMID: 26579733 DOI: 10.1148/radiol.2015151169]

16 **Wang Y**, Zhu L, Xia W, Wang F. Anatomy of lymphatic drainage of the esophagus and lymph node metastasis of thoracic esophageal cancer. *Cancer Manag Res* 2018; **10**: 6295-6303 [PMID: 30568491 DOI: 10.2147/CMAR.S182436]

17 **Mönig S**, Chevallay M, Niclauss N, Zilli T, Fang W, Bansal A, Hoeppner J. Early esophageal cancer: the significance of surgery, endoscopy, and chemoradiation. *Ann N Y Acad Sci* 2018; **1434**: 115-123 [PMID: 30138532 DOI: 10.1111/nyas.13955]

18 **Nishimori H**, Hayashi S, Naito M, Murakami G, Fujita M, Hosokawa M. Mucosal lymphatic vessels of the esophagus distant from the cancer margin: morphometrical analysis using 27 surgically removed specimens of squamous cell carcinoma located in the upper or middle thoracic esophagus. *Okajimas Folia Anat Jpn* 2011; **88**: 43-47 [PMID: 22184865 DOI: 10.2535/ofaj.88.43]

19 **Markar S**, Gronnier C, Duhamel A, Pasquer A, Théreaux J, du Rieu MC, Lefevre JH, Turner K, Luc G, Mariette C. Salvage Surgery After Chemoradiotherapy in the Management of Esophageal Cancer: Is It a Viable Therapeutic Option? *J Clin Oncol* 2015; **33**: 3866-3873 [PMID: 26195702 DOI: 10.1200/JCO.2014.59.9092]

20 **Merkow RP**, Bilimoria KY, Keswani RN, Chung J, Sherman KL, Knab LM, Posner MC, Bentrem DJ. Treatment trends, risk of lymph node metastasis, and outcomes for localized esophageal cancer. *J Natl Cancer Inst* 2014; **106** [PMID: 25031273 DOI: 10.1093/jnci/dju133]

21 **Tong DK**, Law S, Kwong DL, Chan KW, Lam AK, Wong KH. Histological regression of squamous esophageal carcinoma assessed by percentage of residual viable cells after neoadjuvant chemoradiation is an important prognostic factor. *Ann Surg Oncol* 2010; **17**: 2184-2192 [PMID: 20217248 DOI: 10.1245/s10434-010-0995-2]

22 **Kim MP**, Correa AM, Lee J, Rice DC, Roth JA, Mehran RJ, Walsh GL, Ajani JA, Maru DM, Chang JY, Marom EM, Macapinlac HA, Lee JH, Vaporciyan AA, Rice T, Swisher SG, Hofstetter WL. Pathologic T0N1 esophageal cancer after neoadjuvant therapy and surgery: an orphan status. *Ann Thorac Surg* 2010; **90**: 884-90; discussion 890-1 [PMID: 20732513 DOI: 10.1016/j.athoracsur.2010.03.116]

23 **Sisic L**, Blank S, Weichert W, Jäger D, Springfeld C, Hochreiter M, Büchler M, Ott K. Prognostic impact of lymph node involvement and the extent of lymphadenectomy (LAD) in adenocarcinoma of the esophagogastric junction (AEG). *Langenbecks Arch Surg* 2013; **398**: 973-981 [PMID: 23887283 DOI: 10.1007/s00423-013-1101-6]

24 **Wang Q**, Yu S, Xiao Z, Liu X, Zhang W, Zhang X, He J, Sun K, Xu T, Feng Q, Zhou Z, Wang L, Yin W. Residual lymph node status is an independent prognostic factor in esophageal squamous cell Carcinoma with pathologic T0 after preoperative radiotherapy. *Radiat Oncol* 2015; **10**: 142 [PMID: 26159510 DOI: 10.1186/s13014-015-0450-4]

25 **Hölscher AH**, Bollschweiler E, Schröder W, Metzger R, Gutschow C, Drebber U. Prognostic impact of upper, middle, and lower third mucosal or submucosal infiltration in early esophageal cancer. *Ann Surg* 2011; **254**: 802-7; discussion 807-8 [PMID: 22042472 DOI: 10.1097/SLA.0b013e3182369128]

26 **van der Sluis PC**, Ruurda JP, Verhage RJ, van der Horst S, Haverkamp L, Siersema PD, Borel Rinkes IH, Ten Kate FJ, van Hillegersberg R. Oncologic Long-Term Results of Robot-Assisted Minimally Invasive Thoraco-Laparoscopic Esophagectomy with Two-Field Lymphadenectomy for Esophageal Cancer. *Ann Surg Oncol* 2015; **22** Suppl 3: S1350-S1356 [PMID: 26023036 DOI: 10.1245/s10434-015-4544-x]

27 **Omloo JM**, Lagarde SM, Hulscher JB, Reitsma JB, Fockens P, van Dekken H, Ten Kate FJ, Obertop H, Tilanus HW, van Lanschot JJ. Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the mid/distal esophagus: five-year survival of a randomized clinical trial. *Ann Surg* 2007; **246**: 992-1000; discussion 1000-1 [PMID: 18043101 DOI: 10.1097/sla.0b013e31815c4037]

28 **Hulscher JB**, van Sandick JW, de Boer AG, Wijnhoven BP, Tijssen JG, Fockens P, Stalmeier PF, ten Kate FJ, van Dekken H, Obertop H, Tilanus HW, van Lanschot JJ. Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the esophagus. *N Engl J Med* 2002; **347**: 1662-1669 [PMID: 12444180 DOI: 10.1056/nejmoa022343]

29 **Lordick F**, Mariette C, Haustermans K, Obermannová R, Arnold D; ESMO Guidelines Committee. Oesophageal cancer: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol* 2016; **27**: v50-v57 [PMID: 27664261 DOI: 10.1093/annonc/mdw329]

30 **DeMeester SR**. Adenocarcinoma of the esophagus and cardia: a review of the disease and its treatment. *Ann Surg Oncol* 2006; **13**: 12-30 [PMID: 16378161 DOI: 10.1245/aso.2005.12.025]

31 **Kelly S**, Harris KM, Berry E, Hutton J, Roderick P, Cullingworth J, Gathercole L, Smith MA. A systematic review of the staging performance of endoscopic ultrasound in gastro-oesophageal carcinoma. *Gut* 2001; **49**: 534-539 [PMID: 11559651 DOI: 10.1136/gut.49.4.534]

32 **Bruzzi JF**, Munden RF, Truong MT, Marom EM, Sabloff BS, Gladish GW, Iyer RB, Pan TS, Macapinlac HA, Erasmus JJ. PET/CT of esophageal cancer: its role in clinical management. *Radiographics* 2007; **27**: 1635-1652 [PMID: 18025508 DOI: 10.1148/rg.276065742]

33 **Schröder W**, Baldus SE, Mönig SP, Beckurts TK, Dienes HP, Hölscher AH. Lymph node staging of esophageal squamous cell carcinoma in patients with and without neoadjuvant radiochemotherapy: histomorphologic analysis. *World J Surg* 2002; **26**: 584-587 [PMID: 12098049 DOI: 10.1007/s00268-001-0271-5]

34 **Alper F**, Turkyilmaz A, Kurtcan S, Aydin Y, Onbas O, Acemoglu H, Eroglu A. Effectiveness of the STIR turbo spin-echo sequence MR imaging in evaluation of lymphadenopathy in esophageal cancer. *Eur J Radiol* 2011; **80**: 625-628 [PMID: 20800403 DOI: 10.1016/j.ejrad.2010.08.003]

35 **Sgourakis G**, Gockel I, Lyros O, Hansen T, Mildenberger P, Lang H. Detection of lymph node metastases in esophageal cancer. *Expert Rev Anticancer Ther* 2011; **11**: 601-612 [PMID: 21504265 DOI: 10.1586/era.10.150]

36 **Liu J**, Wang Z, Shao H, Qu D, Liu J, Yao L. Improving CT detection sensitivity for nodal metastases in oesophageal cancer with combination of smaller size and lymph node axial ratio. *Eur Radiol* 2018; **28**: 188-195 [PMID: 28677059 DOI: 10.1007/s00330-017-4935-4]

37 **Xu XQ**, Hu H, Su GY, Liu H, Hong XN, Shi HB, Wu FY. Utility of histogram analysis of ADC maps for differentiating orbital tumors. *Diagn Interv Radiol* 2016; **22**: 161-167 [PMID: 26829400 DOI: 10.5152/dir.2015.15202]

38 **Giganti F**, Salerno A, Ambrosi A, Chiari D, Orsenigo E, Esposito A, Albarello L, Mazza E, Staudacher C, Del Maschio A, De Cobelli F. Prognostic utility of diffusion-weighted MRI in oesophageal cancer: is apparent diffusion coefficient a potential marker of tumour aggressiveness? *Radiol Med* 2016; **121**: 173-180 [PMID: 26392393 DOI: 10.1007/s11547-015-0585-2]

39 **Shuto K**, Kono T, Shiratori T, Akutsu Y, Uesato M, Mori M, Narushima K, Imanishi S, Nabeya Y, Yanagawa N, Okazumi S, Koda K, Matsubara H. Diagnostic performance of diffusion-weighted magnetic resonance imaging in assessing lymph node metastasis of esophageal cancer compared with PET. *Esophagus* 2020; **17**: 239-249 [PMID: 31820208 DOI: 10.1007/s10388-019-00704-w]

40 **Sakurada A**, Takahara T, Kwee TC, Yamashita T, Nasu S, Horie T, Van Cauteren M, Imai Y. Diagnostic performance of diffusion-weighted magnetic resonance imaging in esophageal cancer. *Eur Radiol* 2009; **19**: 1461-1469 [PMID: 19172278 DOI: 10.1007/s00330-008-1291-4]

41 **Chen YL**, Li R, Chen TW, Ou J, Zhang XM, Chen F, Wu L, Jiang Y, Laws M, Shah K, Joseph B, Hu J. Whole-tumour histogram analysis of pharmacokinetic parameters from dynamic contrast-enhanced MRI in resectable oesophageal squamous cell carcinoma can predict T-stage and regional lymph node metastasis. *Eur J Radiol* 2019; **112**: 112-120 [PMID: 30777199 DOI: 10.1016/j.ejrad.2019.01.012]

42 **Sun NN**, Ge XL, Liu XS, Xu LL. Histogram analysis of DCE-MRI for chemoradiotherapy response evaluation in locally advanced esophageal squamous cell carcinoma. *Radiol Med* 2020; **125**: 165-176 [PMID: 31605354 DOI: 10.1007/s11547-019-01081-1]

43 **Azevedo RM**, de Campos RO, Ramalho M, Herédia V, Dale BM, Semelka RC. Free-breathing 3D T1-weighted gradient-echo sequence with radial data sampling in abdominal MRI: preliminary observations. *AJR Am J Roentgenol* 2011; **197**: 650-657 [PMID: 21862807 DOI: 10.2214/AJR.10.5881]

44 **Qu J**, Shen C, Qin J, Wang Z, Liu Z, Guo J, Zhang H, Gao P, Bei T, Wang Y, Liu H, Kamel IR, Tian J, Li H. The MR radiomic signature can predict preoperative lymph node metastasis in patients with esophageal cancer. *Eur Radiol* 2019; **29**: 906-914 [PMID: 30039220 DOI: 10.1007/s00330-018-5583-z]

45 **Tatsumi Y**, Tanigawa N, Nishimura H, Nomura E, Mabuchi H, Matsuki M, Narabayashi I. Preoperative diagnosis of lymph node metastases in gastric cancer by magnetic resonance imaging with ferumoxtran-10. *Gastric Cancer* 2006; **9**: 120-128 [PMID: 16767368 DOI: 10.1007/s10120-006-0365-8]

46 **Gatenby RA**, Grove O, Gillies RJ. Quantitative imaging in cancer evolution and ecology. *Radiology* 2013; **269**: 8-15 [PMID: 24062559 DOI: 10.1148/radiol.13122697]

47 **Zwanenburg A**, Vallières M, Abdalah MA, Aerts HJWL, Andrearczyk V, Apte A, Ashrafinia S, Bakas S, Beukinga RJ, Boellaard R, Bogowicz M, Boldrini L, Buvat I, Cook GJR, Davatzikos C, Depeursinge A, Desseroit MC, Dinapoli N, Dinh CV, Echegaray S, El Naqa I, Fedorov AY, Gatta R, Gillies RJ, Goh V, Götz M, Guckenberger M, Ha SM, Hatt M, Isensee F, Lambin P, Leger S, Leijenaar RTH, Lenkowicz J, Lippert F, Losnegård A, Maier-Hein KH, Morin O, Müller H, Napel S, Nioche C, Orlhac F, Pati S, Pfaehler EAG, Rahmim A, Rao AUK, Scherer J, Siddique MM, Sijtsema NM, Socarras Fernandez J, Spezi E, Steenbakkers RJHM, Tanadini-Lang S, Thorwarth D, Troost EGC, Upadhaya T, Valentini V, van Dijk LV, van Griethuysen J, van Velden FHP, Whybra P, Richter C, Löck S. The Image Biomarker Standardization Initiative: Standardized Quantitative Radiomics for High-Throughput Image-based Phenotyping. *Radiology* 2020; **295**: 328-338 [PMID: 32154773 DOI: 10.1148/radiol.2020191145]

48 **Li Y**, Beck M, Päßler T, Lili C, Hua W, Mai HD, Amthauer H, Biebl M, Thuss-Patience PC, Berger J, Stromberger C, Tinhofer I, Kruppa J, Budach V, Hofheinz F, Lin Q, Zschaeck S. A FDG-PET radiomics signature detects esophageal squamous cell carcinoma patients who do not benefit from chemoradiation. *Sci Rep* 2020; **10**: 17671 [PMID: 33077841 DOI: 10.1038/s41598-020-74701-w]

49 **Qiu Q**, Duan J, Deng H, Han Z, Gu J, Yue NJ, Yin Y. Development and Validation of a Radiomics Nomogram Model for Predicting Postoperative Recurrence in Patients With Esophageal Squamous Cell Cancer Who Achieved pCR After Neoadjuvant Chemoradiotherapy Followed by Surgery. *Front Oncol* 2020; **10**: 1398 [PMID: 32850451 DOI: 10.3389/fonc.2020.01398]

50 **Gu L**, Liu Y, Guo X, Tian Y, Ye H, Zhou S, Gao F. Computed tomography-based radiomic analysis for prediction of treatment response to salvage chemoradiotherapy for locoregional lymph node recurrence after curative esophagectomy. *J Appl Clin Med Phys* 2021; **22**: 71-79 [PMID: 34614265 DOI: 10.1002/acm2.13434]

51 **Tan X**, Ma Z, Yan L, Ye W, Liu Z, Liang C. Radiomics nomogram outperforms size criteria in discriminating lymph node metastasis in resectable esophageal squamous cell carcinoma. *Eur Radiol* 2019; **29**: 392-400 [PMID: 29922924 DOI: 10.1007/s00330-018-5581-1]

52 **Kim JY**, Seo HB, Park S, Moon JI, Lee JW, Lee NK, Lee SW, Bae YT. Early-stage invasive ductal carcinoma: Association of tumor apparent diffusion coefficient values with axillary lymph node metastasis. *Eur J Radiol* 2015; **84**: 2137-2143 [PMID: 26318821 DOI: 10.1016/j.ejrad.2015.08.009]

53 **Liu C**, Ding J, Spuhler K, Gao Y, Serrano Sosa M, Moriarty M, Hussain S, He X, Liang C, Huang C. Preoperative prediction of sentinel lymph node metastasis in breast cancer by radiomic signatures from dynamic contrast-enhanced MRI. *J Magn Reson Imaging* 2019; **49**: 131-140 [PMID: 30171822 DOI: 10.1002/jmri.26224]

54 **Shin J**, Seo N, Baek SE, Son NH, Lim JS, Kim NK, Koom WS, Kim S. MRI Radiomics Model Predicts Pathologic Complete Response of Rectal Cancer Following Chemoradiotherapy. *Radiology* 2022; **303**: 351-358 [PMID: 35133200 DOI: 10.1148/radiol.211986]

55 **Wang Q**, Xiang L, Liu J. Re: Feng G, Hong Y, Li L, et al. Anterior decompression and nonstructural bone grafting and posterior fixation for cervical facet dislocation with traumatic disc herniation. Spine (Phila Pa 1976). 2012;37:2082–8. *Spine (Phila Pa 1976)* 2013; **38**: 967 [PMID: 23660805 DOI: 10.1097/BRS.0b013e31828fc937]

56 **Santucci D**, Faiella E, Cordelli E, Sicilia R, de Felice C, Zobel BB, Iannello G, Soda P. 3T MRI-Radiomic Approach to Predict for Lymph Node Status in Breast Cancer Patients. *Cancers (Basel)* 2021; **13** [PMID: 34066451 DOI: 10.3390/cancers13092228]

57 **Han L**, Zhu Y, Liu Z, Yu T, He C, Jiang W, Kan Y, Dong D, Tian J, Luo Y. Radiomic nomogram for prediction of axillary lymph node metastasis in breast cancer. *Eur Radiol* 2019; **29**: 3820-3829 [PMID: 30701328 DOI: 10.1007/s00330-018-5981-2]

58 **Dong Y**, Feng Q, Yang W, Lu Z, Deng C, Zhang L, Lian Z, Liu J, Luo X, Pei S, Mo X, Huang W, Liang C, Zhang B, Zhang S. Preoperative prediction of sentinel lymph node metastasis in breast cancer based on radiomics of T2-weighted fat-suppression and diffusion-weighted MRI. *Eur Radiol* 2018; **28**: 582-591 [PMID: 28828635 DOI: 10.1007/s00330-017-5005-7]

59 **Liu J**, Sun D, Chen L, Fang Z, Song W, Guo D, Ni T, Liu C, Feng L, Xia Y, Zhang X, Li C. Radiomics Analysis of Dynamic Contrast-Enhanced Magnetic Resonance Imaging for the Prediction of Sentinel Lymph Node Metastasis in Breast Cancer. *Front Oncol* 2019; **9**: 980 [PMID: 31632912 DOI: 10.3389/fonc.2019.00980]

60 **Li M**, Zhang J, Dan Y, Yao Y, Dai W, Cai G, Yang G, Tong T. A clinical-radiomics nomogram for the preoperative prediction of lymph node metastasis in colorectal cancer. *J Transl Med* 2020; **18**: 46 [PMID: 32000813 DOI: 10.1186/s12967-020-02215-0]

**Footnotes**

**Conflict-of-interest statement:** The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: https://creativecommons.org/Licenses/by-nc/4.0/

**Provenance and peer review:** Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** April 18, 2023

**First decision:** June 1, 2023

**Article in press:**

**Specialty type:** Radiology, nuclear medicine and medical imaging

**Country/Territory of origin:** China

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): 0

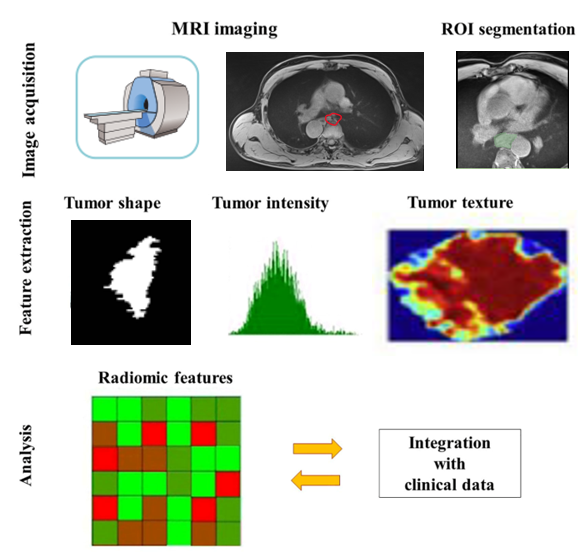
Grade C (Good): C, C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Jeong KY, South Korea; Singh G **S-Editor:** Ma YJ **L-Editor:** A **P-Editor:**

**Figure Legends**



**Figure 1 Research flow chart of radiomics based on magnetic resonance imaging in esophageal cancer.** MRI: magnetic resonance imaging; ROI: Regions of interest.