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CASE REPORT

# Positron emission tomography and magnetic resonance imaging combined with computed tomography in tumor volume delineation: A case report

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## Abstract

*BACKGROUND*

Accurate delineation of the target area for patients with hypopharyngeal cancer is the key to achieving an ideal radiotherapy effect. Since computed tomography (CT) alone can no longer meet the treatment needs, fusing CT images with magnetic resonance imaging (MRI) or positron emission tomography (PET) images can overcome the disadvantages of CT. Herein, we present a clinical case of hypopharyngeal cancer to delineate the tumor volume using combined MRI-CT and PET-CT fusion images to examine if they could accurately cover the tumor volume.

*CASE SUMMARY*

A 67-year-old male patient with hypopharyngeal carcinoma could not tolerate chemotherapy and surgery due to complicated health issues such as diabetic nephropathy and other underlying diseases. After multidisciplinary consultations, clinicians eventually agreed to undergo radiotherapy to control the progression of his tumor. He was examined by CT, MRI, and 18-fluorodeoxy-glucose-PET for treatment planning, and CT images were fused with PET and MRI images while delineating tumor volume.

*CONCLUSION*

The image fusion of MRI-CT and PET-CT has both advantages and disadvantages. Compared with CT images alone, the combination of MRI-CT and PET-CT fusion images can precisely cover the gross tumor volume in hypopharyngeal carcinoma and avoid overestimation or incomplete coverage of tumor volume.

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**Core Tip:** Magnetic resonance imaging (MRI) and computed tomography (CT) image fusion or positron emission tomography (PET) and CT image fusion is often used to delineate the target areas of hypopharyngeal cancer. Both have their advantages and disadvantages. We report an elderly patient with hypopharyngeal cancer who needed radiotherapy. By combining MRI-CT and PET-CT fusion images to delineate the gross tumor volume, the radiation dose can be maximized, the coverage range is more accurate, and the surrounding normal organs and tissues can be effectively spared.

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## INTRODUCTION

Hypopharyngeal carcinoma is one of the malignant tumors that occur in the head and neck, accounting for 0.15%-0.24% of the total malignant tumors. The anatomical structure is complex, the early symptoms are often unclear, and lymph node metastasis is easy to develop; thus, all three factors contribute to the poor prognosis of hypopharyngeal carcinoma, and the 5-year survival rate is only about 51.3%[1]. Therefore, it is of great significance to make an early diagnosis and plan the treatment accordingly. The main treatments for hypopharyngeal cancer are surgery and radiotherapy.

Currently, patients with previously untreated and newly diagnosed hypopharyngeal cancer have options for surgery to remove the primary tumor and lymph node metastasis, radiotherapy, systemic medical treatment, including traditional chemotherapy and immunotherapy. Radiotherapy can treat hypopharyngeal carcinoma in patients who are not suitable for surgery of the primary tumor. Besides, a small number of patients use radiotherapy as a palliative approach[2]. Intensity-modulated radiation therapy (IMRT) is the mainstream of modern radiotherapy technology and is an effective treatment method for head and neck cancer patients. IMRT can precisely deliver a high radiation dose to the tumor while maintaining a low dose target area for essential tissues and organs around the tumor. The proper delineation of gross tumor volume (GTV, including the gross tumor volume of hypopharyngeal tumor and the involved lymph node) is the key to realizing the overall radiotherapy effect of hypopharyngeal cancer. However, the wrong target volume affects the treatment and damages normal tissues and organs, mainly when critical anatomical structures frequently surround the head and neck tumor. The accurate delineation of GTV is essential for optimal radiation treatment of any tumor, as it can maximize radiation dose to the tumor and minimize that to nontumor tissue [3]. Before outlining GTV, most radiotherapy plans are based on computed tomography (CT) positioning images, which can be used directly in the calculation of radiotherapy dose because of the fast speed of spiral CT scanning, small image distortion, little influence by organs movement, and the linear relationship between CT value and human body density. However, the disadvantage of CT lies in its poor resolution of the boundary of human soft tissue and its inability to define the tumor area accurately. Therefore, only relying on CT images can no longer meet the needs of treatment. Besides, positron emission tomography (PET) and magnetic resonance imaging (MRI) have advantages in accurately diagnosing tumors. PET is an imaging technique that reflects the gene, molecule, metabolism, and functional state of lesions. It uses positron nuclide labeled glucose as an imaging agent to reflect the metabolic changes of lesions through the uptake of imaging agents and to provide clinical biometabolic information of diseases. As cancer cells multiply rapidly and metabolize profusely, only radionuclide-containing imaging agents can be used to contrast them. The advantage of MRI is that it has superior soft tissue contrast and fewer dental artifacts, which can clearly distinguish tumors from surrounding soft tissues[4]. Previous studies[5,6] have shown that it is challenging to delineate GTV based CT images alone; however, an accurate delineation can significantly improve while image fusion occurs between CT and PET or CT and MRI. So far, no relevant studies have combined the fusion images of PET-CT and MRI-CT to provide full play and combine their respective strengths to bring the images closer to the actual volume of tumor. Therefore, we would like to present a clinical case to emphasize the awareness of this condition and show that the combination can play a significant role in delineating tumor volume.

## CASE PRESENTATION

### Chief complaints

A 67-year-old male patient had pharyngalgia and dysphagia without an obvious cause. The symptoms gradually worsened, and he had later developed dyspnea. After completing relevant examinations, he was diagnosed with hypopharyngeal carcinoma.

### History of present illness

A pharyngeal mass biopsy revealed that the dimension of the tumor was 6.0 cm × 4.5 cm × 12.5 cm. The postoperative pathological diagnosis showed squamous cell carcinoma with small focal high-grade neuroendocrine carcinoma. The clinical stage was confirmed as T4N3Mx based on the results of MRI.

### History of past illness

No data were available.

### Personal and family history

The patient claimed to have been an alcoholic for more than 20 years and did not have a history of smoking or a notable family medical history.

### Physical examination

The patient was emaciated and anemic, and had multiple enlarged lymph nodes on both sides of his neck.

### Laboratory examinations

No data were available.

### Imaging examinations

MRI of the nasopharynx and neck showed thickened left piriform fossa wall with a soft tissue mass, filling of the laryngopharynx oropharynx cavity, and involving the right piriform fossa, consistent with hypopharyngeal carcinoma. There were multiple lymph nodes in the bilateral neck, of which the larger one was located in bilateral neck areas II-III, suggesting lymph node metastasis.

## FINAL DIAGNOSIS

Hypopharyngeal carcinoma.

## TREATMENT

Neither surgery nor chemotherapy was applied to the patient due to multiple associated diseases, such as diabetic nephropathy, renal insufficiency, and emphysema. Besides, surgery could not achieve a radical cure. Hence, radiotherapy was the only option to control tumor progression after a multi-department consultation in our hospital. He was examined by CT, MRI, and 18-fluorodeoxy-glucose ($^{18}$FDG)-PET for his treatment plan, including CT fused with PET and MRI to delineate the tumor volume (Figure 1).

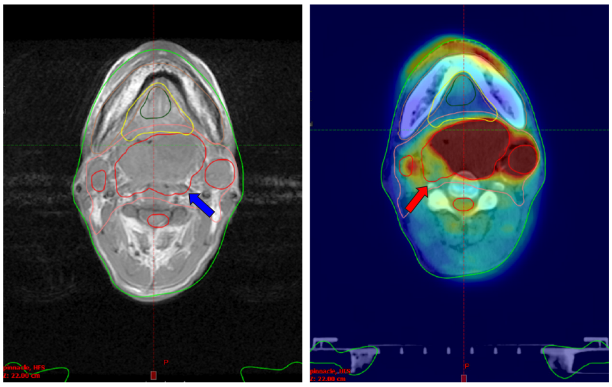

**Figure 1 Scan of the patient's skull base and the site of tumor invasion (red circle).** The magnetic resonance imaging-computed tomography (CT) fusion image has a high resolution of soft tissue, including the tumor boundary and lymph nodes. However, compared with the positron emission tomography (PET)-CT fusion image, the bone invasion site is not shown (blue arrow). The PET-CT fusion image shows the tumor and its invasion by hypermetabolism with a high sensitivity for tumor recognition. However, the decreased glucose uptake of tumor necrotic tissues did not develop (red arrow), causing false-negative results.

## OUTCOME AND FOLLOW-UP

Fortunately, the patient recovered and was discharged after radiotherapy. The patient was reexamined by MRI scans 3 mo later and showed no signs of tumor recurrence.

## DISCUSSION

MRI permits multi-sequencing and multi-parametric imaging with higher soft tissue resolution than CT, making the actual boundary between tumor and soft tissue more precise, and causes no radiation damage[7]. MRI-CT image fusion can avoid overestimation of clinical tumor volume by CT images only. Tzikas *et al*[8] compared fused MRI-CT with only CT images in radiotherapy plan, and found that the dose distribution generated by fused MRI-CT image could achieve better treatment results, leading to a lower complication rate of principal organs at risk than that of CT images. Although MRI complements the lack of soft tissue resolution of CT images, both have a limited sensitivity and specificity concerning the presence or extent of nodal involvement, because they mainly rely on the size criterion. Thus, MRI-CT fusion images cannot reveal nodal disease in normal-size lymph nodes. Besides, accuracy is lacking in defining the dimension of malignant bone infiltration *vs* concomitant infectious bone reactions[9]. Our research also showed that MRI-CT fusion images failed to show the bone invasion site.

In PET, 18F-labeled FDG ($^{18}$F-FDG fluorinated deoxyglucose) is used as the tracer. The level of glucose utilization can determine the tumor and invasion site, and metabolic imaging is one of the most sensitive methods for the early diagnosis of malignant tumors. PET can reflect the differences in the metabolic status and biochemical changes of tumor tissues at the molecular level by providing living biological information while determining the clinical tumor volume, making up for the shortcoming of CT to provide information of the vitality of tumors. PET-CT image fusion can simultaneously show metabolic activity and anatomical location to achieve a more accurate delineation of GTV and provide more effective protection for the surrounding normal organs and tissues. However, the distribution of 18F-FDG is not limited to malignant tissues; thus, PET-CT fusion images can also lead to false negative and false positive results in tumor diagnosis[7]. False-positive results in PET-CT may occur due to inflammation, limited spatial resolution, and lack of a standard method for segmentation[4]. However, false-negative results may occur in some slow-growing or low-malignant tumor cells or in necrotic tumor tissues, where glucose metabolism is reduced.

## CONCLUSION

The image fusion of MRI-CT and PET-CT has both advantages and disadvantages. Hence, combining the two can cover the GTV of hypopharyngeal cancer more accurately than CT images alone, which is more likely to improve the radiotherapy effect and reduce the risk of recurrence and is worthy of further development in clinical practice.

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