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Application and Evaluation of Common Clinical Imaging Techniques in Cancer Diagnosis

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Abstract: With the reform and opening up entering a new era, China's modern civilization and technology are "rolling forward". In the medical field, innovative changes in radiology imaging technology have presented unprecedented value opportunities in tumor diagnosis. Therefore, this article explores the classification of radiological imaging techniques, specifically including X-ray imaging, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and ultrasound imaging. Furthermore, it analyzes the practical application of these key technologies in tumor diagnosis and propose new ideas. In the end, the advantages and characteristics of radiology imaging technology are evaluated, and two limitations are also pointed out, which deserves profound reflection.

Keywords: Radiology; Imaging technology; Tumor diagnosis; Application; Evaluate

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1. Introduction

In the past, tumors posed a serious threat to human life and health, and if left untreated in the early stages, the survival rate was extremely low. But with radiological imaging technology, it can provide certain technical guidance to make judgments on the location, size, shape, and surrounding tissues of tumors, assisting doctors in diagnosis and treatment. Especially in recent years, with the rapid development of technology, radiological imaging technology can provide more and more important information related to diseases, which is of great medical research value. Therefore, a deep understanding of the application characteristics and value of various radiological imaging techniques in tumor diagnosis is of great practical significance for optimizing the tumor diagnosis process and improving diagnostic accuracy.

2. The application direction of radiological imaging technology in tumor diagnosis

2.1. X-ray imaging

X-ray imaging uses X-rays to penetrate the human body, presenting black and white contrast images of different density tissues on film or detectors. In the diagnosis of bone tumors, X-ray plain films can clearly display the morphological and structural changes of bones, and can detect typical manifestations of bone tumors such as bone destruction, periosteal reactions, and soft tissue masses. This is of great significance for the preliminary diagnosis of common bone tumors such as osteosarcoma and giant cell tumor of bone [1]. In terms of lung tumor screening, chest X-ray can detect larger lung space-occupying lesions, which is one of the commonly used methods for preliminary screening of lung cancer. However, X-ray imaging also has significant limitations. Due to its two-dimensional imaging, tissue overlap can affect the observation of lesion details and easily miss small lesions. For nodules with a diameter less than 1cm in some diseases, the detection rate of X-rays is low, which can easily lead to missed diagnosis. Moreover, X-ray imaging has low resolution for soft tissue, making it difficult to distinguish subtle differences between tumors and surrounding soft tissue, and accurately determine the boundaries and extent of tumor infiltration [2, 3].

2.2. CT scan

CT imaging uses X-rays to perform cross-sectional scans of the human body. The detector can receive X-ray attenuation signals from different angles and generate cross-sectional images of the human body through computer reconstruction algorithms. In the diagnosis of lung cancer, CT technology can accurately display detailed information such as the size, shape, edge features, and internal density of lung nodules, which plays a crucial role in evaluating the benign and malignant nature of nodules. Specifically, CT manifestations such as lobulation sign, spiculation sign, and vacuolar sign often indicate that the nodule is a malignant tumor [4]. Enhanced CT scanning, by injecting contrast agents, can further observe the blood supply of tumors, help identify the nature of tumors, and also detect lymph node metastasis in the hilum and mediastinum, accurately determine tumor staging, and provide key basis for developing treatment plans. CT also has a positive significance in displaying tumors in various organs of the abdomen, with a particularly high detection rate for liver cancer. Plain scan can detect low-density occupying lesions inside the liver, and enhanced CT scan shows significant enhancement of arterial phase tumors, presenting a typical manifestation of “fast in and fast out”.

2.3. MRI

MRI imaging technology, as shown in **Figure 1**, relies on the principle of nuclear magnetic resonance, which applies radio frequency pulses to hydrogen nuclei in a strong magnetic field to excite them and generate resonance signals, thereby achieving imaging.

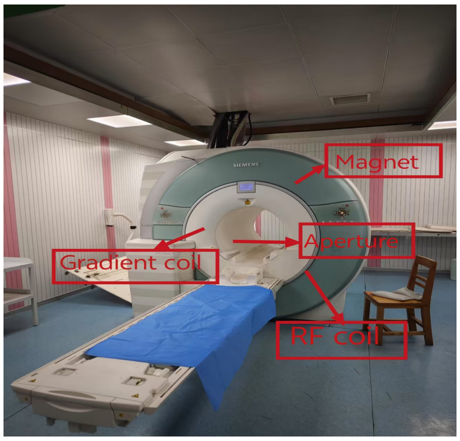

Figure 1. A photo of a certain brand of MRI equipment in clinical practice

Unlike the two aforementioned techniques, MRI has extremely high resolution for soft tissue and also has unique advantages in tumor diagnosis. In the diagnosis of brain tumors, MRI can clearly display the location, size, shape, boundary, and relationship with surrounding brain tissue of tumors, which is of great value for the diagnosis and differential diagnosis of common brain tumors such as gliomas, meningiomas, and pituitary tumors. MRI imaging of different sequences (such as T1WI, T2WI, FLAIR, etc.) can provide rich tissue information and help determine the nature of tumors. MRI also plays a similar role in the diagnosis of breast tumors, pelvic tumors (such as cervical cancer, endometrial cancer), spinal cord tumors, etc., but the examination time is relatively long, the patient's cooperation requirements are high, and the cost is also high, which limits its application in some underdeveloped areas and is also an important aspect of future research and practice [5–8].

2.4. PET

PET imaging (as shown in **Figure 2**) belongs to nuclear medicine imaging technology and is generally combined in series with CT in clinical practice as a PET/CT scanner. PET utilizes the high uptake of glucose and other metabolites by tumor cells through injection of radioactive tracers, displaying the metabolic activity of tumor cells and functionally imaging each cell. In terms of early diagnosis of tumors, PET can detect metabolic abnormalities in tumor cells before morphological changes occur, which helps to detect early small tumor lesions. Early cancer cell concentration, on the other hand, has a slightly better therapeutic effect. For MRI and CT that use anatomical imaging principles, cancer is detected relatively late, and the choice of treatment methods for advanced cancer is often limited, and most treatment outcomes are also poor. It is of great significance for the early screening and diagnosis of lung cancer, breast cancer, colorectal cancer, and other common tumors.

Figure 2. Photo of the internal scanning ring of a certain brand PET/CT in clinical practice

For tumor staging, PET can comprehensively evaluate the distribution of tumors throughout the body, accurately detect distant metastases, avoid errors in tumor staging due to missed metastases, and provide a reliable basis for developing reasonable treatment plans [9]. In terms of follow-up treatment evaluation, PET can timely and accurately determine the treatment effect by observing the changes in tumor cell metabolic activity before and after treatment, which helps to adjust the treatment plan. However, PET examination is expensive and radioactive tracers have a certain level of radioactivity, which poses potential radiation hazards to patients and operators and requires strict protection.

2.5. Ultrasonic imaging

Ultrasonic imaging technology constructs detailed images of internal organs and tissues of the human body by utilizing physical phenomena such as reflection, refraction, and scattering generated when ultrasound propagates through human tissues. For example, in the diagnosis of thyroid tumors, ultrasound examination has become the preferred diagnostic method due to its ability to clearly display key features such as the size, shape, edges, internal echoes, and blood flow status of thyroid nodules. Including but not limited to low echo, unclear boundaries, irregular morphology, aspect ratio greater than 1, microcalcifications, and rich blood flow signals, ultrasound findings often indicate that the nodule is a malignant tumor. However, the accuracy of ultrasound imaging largely depends on the skill level and experience of the operator, and the examination results of different doctors may vary [10]. The quality of ultrasound images is easily affected by elements such as gases and bones. For gas-containing organs such as the lungs and gastrointestinal tract, as well as tumors located behind the bones, the display effect of ultrasound examination is often unsatisfactory, and its diagnostic value is relatively limited.

3. Application of radiology imaging technology in cancer treatment

3.1. Image-guided radiotherapy

Image-guided radiotherapy (IGRT) can be regarded as a major breakthrough in modern radiotherapy technology. This technology utilizes advanced imaging equipment to provide real-time or near real-time imaging monitoring of patients before, during, and after radiotherapy. Before radiotherapy, high-precision CT scans are used to obtain detailed three-dimensional anatomical information of the patient's tumor and surrounding tissues. Based on imaging information, doctors can develop personalized radiotherapy plans, accurately planning parameters such as the direction of radiation, dose distribution, and irradiation time, to ensure that the radiation can cover the tumor target area to the maximum extent possible while minimizing exposure to surrounding normal tissues [11, 12].

In the subsequent radiotherapy process, this technology can also play a real-time monitoring role. Taking lung cancer radiotherapy as an example, the impact of respiratory movement on the location of lung tumors is extremely significant. At this point, 4D-CT imaging technology synchronously records the patient's respiratory signals during CT scanning, divides the respiratory cycle into multiple phases, and obtains the dynamic motion trajectory of the tumor throughout the entire respiratory cycle, allowing doctors to make real-time adjustments to the entire radiotherapy plan. By using respiratory gating technology, the radiotherapy equipment will only emit radiation when the tumor moves to a predetermined safe position, ensuring that the radiotherapy radiation always accurately hits the tumor and avoiding irradiation deviation caused by tumor position movement. This significantly reduces the incidence of radiation therapy complications and greatly improves the quality of life of patients.

3.2. Interventional radiotherapy

Interventional radiation therapy is an advanced treatment method that uses minimally invasive techniques such as puncture and intubation, guided by imaging equipment, to directly deliver treatment instruments or drugs to the lesion site, achieving targeted treatment. Using transarterial chemoembolization (TACE) and real-time clear guidance from digital subtraction angiography (DSA) equipment, doctors puncture the patient's femoral artery and gradually insert a thin catheter along the vascular path into the hepatic artery branch that supplies blood to the tumor [13]. Injecting high concentrations of chemotherapy drugs through a catheter can instantly reach extremely high drug concentrations in the tumor tissue, directly exerting a powerful killing effect on tumor cells. Subsequently, embolic agents are injected to completely block the tumor's blood supply artery, cutting off the tumor's blood supply and causing tumor cells to gradually die due to ischemia and hypoxia. Clinical practice has shown that for patients with advanced liver cancer who cannot be surgically removed, after standardized TACE treatment, the tumor volume of some patients can be significantly reduced, tumor marker levels can be significantly decreased, and survival can be effectively prolonged.

In addition to TACE technology, thermal ablation technology in interventional radiation therapy has also demonstrated significant advantages in early cancer treatment. Taking early small liver cancer as an example, under the precise guidance of ultrasound or CT, doctors will percutaneous puncture the ablation needle into the tumor. Radiofrequency ablation technology utilizes the resistance heat generated by radiofrequency current in tumor tissue to rapidly raise the temperature of the tumor tissue to 60 °C–100 °C, leading to protein denaturation and membrane rupture of tumor cells, ultimately resulting in coagulative necrosis. Compared with traditional surgical resection, the hospitalization time of patients treated with thermal ablation is significantly shortened. Generally, patients can be discharged within 1–2 days after surgery, and the impact on the function of organs such as the liver is relatively small. Patients can recover their normal life and work faster [14]. For some early cancer patients who cannot tolerate surgical resection due to their advanced age and poor physical condition, this technology also provides them with safer and more effective treatment options.

3.3. Image-guided surgery

The emergence of image-guided surgery has brought unprecedented opportunities for transformation in cancer surgical treatment, making surgical treatment more precise and safe. In traditional cancer surgery, doctors mainly rely on preoperative imaging data and their own clinical experience to determine the location, extent, and relationship with surrounding tissues of the tumor. During the surgical process, due to factors such as changes in patient position, tissue tension, and bleeding, the actual anatomical structure often undergoes certain changes, resulting in deviations between preoperative images and intraoperative conditions, undoubtedly increasing the difficulty and risk of the surgery.

Intraoperative magnetic resonance imaging (iMRI) technology plays a significant role in neurosurgery, especially in brain tumor resection surgery. Due to its unique location, brain tumors are surrounded by complex neural and vascular structures, and even a slight carelessness during surgery can lead to severe neurological dysfunction. IMRI equipment can obtain high-resolution brain images in real-time during surgery, clearly displaying the boundaries, internal structures, and adjacent relationships with surrounding nerves and blood vessels of tumors. For example, when removing gliomas located near functional areas of the brain, with the help of iMRI technology, doctors can observe the real-time removal of the tumor during the surgery. When residual tumor boundaries are found, surgical operations can be adjusted in a timely manner to further remove residual tumor tissue, while avoiding damage to important nerve functional areas around the patient, maximizing the protection of the patient's nerve function, and reducing the incidence of postoperative complications [15]. Clinical studies have shown that using iMRI-guided brain tumor resection surgery can increase the total tumor resection rate by 15–20%, while reducing the incidence of postoperative neurological dysfunction by 10–15%.

4. Evaluation of the application of radiology imaging technology in tumor diagnosis

4.1. Advantages

X-ray imaging has multiple advantages, such as simple equipment and facilities, fast examination speed, etc., and is very common in current clinical work. CT has high spatial resolution and unique advantages, playing a key role in tumor localization and staging. MRT has high contrast and can clearly distinguish soft tissues, providing diverse information even without the use of ionizing radiation. It also plays an important role in tumor localization, staging, and differential diagnosis, and is one of the important technologies for testing and treatment. PET can reflect the metabolic activity of tissues and is an important technology for tumor detection and diagnosis, but it can also be used for efficacy evaluation. Finally, let's take a look at ultrasound imaging, which has the advantage of no radiation and real-time imaging. It has a positive effect on tumor screening in the thyroid, breast, liver, and other areas, and is worth exploring and practicing in depth.

4.2. Limitations

4.2.1. False positives and false negatives

Some radiology imaging techniques have false-positive and false-negative results. For example, in lung cancer screening, about 20–30% of small lung nodules detected by low-dose spiral CT are false positives, indicating that the nodules are not malignant tumors but require further examination and follow-up to confirm the diagnosis. This may lead to unnecessary anxiety and a waste of medical resources for patients. For some early-stage small tumors or special types of tumors, due to atypical imaging findings, false negative results may occur, leading to a missed diagnosis.

4.2.2. Technical and equipment limitations

The development of imaging technology relies on advanced equipment and professional technical personnel for support. In general, some primary healthcare institutions may lack high-end CT, MRI, and other equipment, or have outdated and outdated equipment, which affects image quality and diagnostic accuracy. Similarly, there may also be a lack of high-level, high-quality, experienced, and professionally qualified physicians, leading to inconsistent diagnostic results that must be improved and transformed.

5. Conclusion

Overall, radiological imaging technology is constantly advancing and developing. It is believed that in today's era of technology and medical industry integration, promoting transformation and upgrading, there will be increasingly better solutions for combating malignant tumors and diagnosis and treatment. Frontline clinical and scientific researchers should also actively explore and practice key technology applications based on actual situations to achieve precise diagnosis and personalized treatment of tumors.

Disclosure statement

The author declares no conflict of interest.

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