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Research Progress on Comprehensive Management Strategies for Patients with Spinal Metastases

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Abstract: Spinal metastases are among the most common complications of advanced malignant tumors, significantly affecting patients' neurological function, quality of life, and survival time. This paper systematically outlines the epidemiological characteristics, pathophysiological mechanisms, and clinical manifestations of spinal metastases, with a particular focus on multidisciplinary comprehensive management strategies. These strategies include conservative treatment, surgical intervention, radiotherapy, targeted and immunotherapy, as well as rehabilitation and psychological support. The importance of individualized treatment and multidisciplinary collaboration in improving patient outcomes is emphasized, providing a systematic reference for clinical management.

1. Introduction

Spinal metastases refer to malignant lesions formed by the spread of primary tumors to the spinal bones via hematogenous or lymphatic routes. They represent the most common and clinically challenging type of bone metastases. With the prolonged survival of cancer patients, the incidence of spinal metastases has been steadily increasing, becoming a frequent complication in patients with advanced cancer. Spinal metastases not only cause severe bone pain and motor dysfunction but may also result in spinal cord compression, severely impairing patients' quality of life, increasing the risk of disability, and even shortening survival time—thereby placing a heavy burden on patients and their families [1].

In recent years, advancements in diagnostic technologies and treatment modalities have underscored the positive impact of comprehensive management on extending survival, alleviating symptoms, and improving quality of life. The study of comprehensive management strategies for spinal metastases aims to optimize diagnostic and therapeutic procedures, standardize treatment protocols, and maximize patient benefits. This has significant clinical and social value, providing scientific evidence and guidance for clinical practice [2].

2. Pathophysiology and Clinical Manifestations of Spinal Metastases

Spinal metastases commonly originate from primary tumors such as breast cancer, lung cancer, prostate cancer, renal cell carcinoma, and thyroid cancer, which metastasize to the spinal skeleton via the hematogenous route [3]. Tumor cells infiltrate the rich vascular network of the spine through the bone marrow sinusoids, attaching to and eroding the bone tissue, leading to pathological bone

destruction and abnormal resorption. The spine, as a critical weight-bearing structure of the human body, consists of vertebral bodies, vertebral arches, and associated ligaments. Its complex anatomy and rich blood supply provide a favorable microenvironment for tumor cell colonization and proliferation.

When spinal metastases grow within bone, they typically first destroy the vertebral body structure, potentially leading to pathological fractures and compromised spinal stability. Clinically, patients often present with progressively worsening localized bone pain, particularly at night. This pain is typically severe and difficult to relieve, making it the earliest and most common symptom [4]. As the disease progresses, the tumor may compress or invade the spinal cord and nerve roots, resulting in sensory abnormalities, motor dysfunction, or even paralysis—severely impacting the patient's quality of life. Additionally, pathological fractures exacerbate pain, may cause spinal deformities and neurological impairment, and increase the complexity of treatment.

3. Comprehensive Management Strategies for Spinal Metastases

3.1 Multidisciplinary Team (MDT) Collaboration Model

The treatment of spinal metastases is complex and highly individualized, rendering single-discipline approaches insufficient for comprehensive patient management. Therefore, the multidisciplinary team (MDT) model has become central to clinical care [5]. An MDT typically includes specialists from medical oncology, orthopedics, radiation oncology, radiology, pathology, rehabilitation medicine, and psychological counseling. Regular case discussions ensure seamless integration across diagnosis, treatment, and rehabilitation stages. Team members utilize their respective expertise to develop individualized treatment plans, balancing tumor control with spinal stability and preservation of neurological function. The MDT model not only enhances the scientific basis and precision of treatment decisions but also facilitates optimal allocation of medical resources and follow-up management, ultimately improving patient survival and quality of life [6]This collaborative model can respond more promptly to changes in the patient's condition, such as when tumor progression or treatment complications occur, experts from various disciplines can quickly coordinate and adjust the plan. At the same time, MDT integrates cutting-edge research results and clinical experience to provide patients with diverse choices including emerging targeted therapies, minimally invasive interventions, etc., reducing treatment delays and repeated examinations. While ensuring medical safety, MDT allows patients and their families to have a clearer understanding of the entire treatment process, enhancing treatment confidence and compliance.

3.2 Conservative Treatment Strategies

Conservative treatment is an essential part of managing spinal metastases, particularly for patients with mild symptoms or those contraindicated for surgery. Core measures include pain control, supportive care, and maintenance of function [7]. Pain management is primarily pharmacological, involving nonsteroidal anti-inflammatory drugs (NSAIDs), opioids, and adjuvant medications, which are highly targeted and have manageable side effects. Nerve blocks and radiotherapy are also valuable adjuncts to conservative care. Supportive therapies focus on nutritional support, bone protection, and fracture prevention, with bisphosphonates and denosumab commonly used to reduce bone resorption [8]. Physical therapy and rehabilitation help maintain or restore spinal stability and function, preventing muscle atrophy and joint stiffness. Psychological support is equally crucial, as it alleviates anxiety and depression and enhances the overall treatment experience. In addition, regular follow-up and evaluation of changes in the patient's condition,

dynamic adjustment of treatment plans, can better meet the individual needs of patients and improve the effectiveness of conservative treatment.

3.3 Surgical Treatment

Surgical intervention is a key method for improving neurological function and maintaining spinal stability in patients with spinal metastases. It is primarily indicated in cases of severe neurological compression, spinal instability, or intractable pain. Surgical candidacy should be based on comprehensive evaluation, including the patient's general condition, tumor burden, and expected survival. Common surgical approaches include decompression and tumor debulking, as well as spinal reconstruction. Decompression relieves spinal cord pressure, while reconstruction restores structural integrity to prevent pathological fractures. Minimally invasive techniques such as percutaneous vertebroplasty and kyphoplasty are increasingly utilized to reduce surgical trauma and recovery time. Preoperative planning requires detailed imaging and anesthesia assessments, while postoperative care emphasizes early rehabilitation and complication prevention [9].Intraoperative neurophysiological monitoring can provide real-time assessment of spinal cord function and reduce the risk of nerve injury. For patients with oligometastases, surgical combined with local ablation and other methods can further improve tumor control effectiveness and create favorable conditions for subsequent systemic treatment.For patients with short expected survival but significant symptoms, palliative surgery can prioritize relieving pain; The use of 3D printed personalized internal fixation prostheses in complex cases can improve reconstruction accuracy, and postoperative anti infection and bone fusion monitoring need to be strengthened.

3.4 Radiation Therapy

Radiation therapy is an important modality for local control of spinal metastases. It can effectively relieve pain, inhibit tumor growth, and slow down bone destruction. Common techniques include traditional three-dimensional conformal radiotherapy (3D-CRT) and advanced intensity-modulated radiotherapy (IMRT), both of which can accurately target the tumor area while maximizing protection of the adjacent spinal cord and neural tissues. In recent years, stereotactic body radiotherapy (SBRT) has gained widespread attention due to its high-dose precision and excellent local control rates, making it suitable for patients with a longer expected survival and localized lesions. Radiation therapy also plays an important role as an adjuvant treatment after surgery, reducing the risk of local recurrence. Potential side effects include fatigue, skin reactions, and occasional radiation-induced osteomyelitis, which require strict dose and field control. For radiation sensitive tumors such as lymphoma, myeloma, etc., radiotherapy is often the preferred local treatment; For tumors that are resistant to radiotherapy, surgery or targeted drugs can be combined to enhance efficacy, and individualized selection of treatment plans should be based on the pathological type of the tumor.

3.5 Targeted Therapy and Immunotherapy

With advances in tumor molecular biology, targeted therapy and immunotherapy have become increasingly important in the systemic treatment of spinal metastases. Targeted therapies intervene in specific signaling pathways of tumor cells—such as tyrosine kinase inhibitors and angiogenesis inhibitors—and have shown significant efficacy in breast cancer, lung cancer, and renal cancer. Immunotherapy activates the patient's own immune system to recognize and eliminate tumor cells, offering long-term therapeutic benefits. Novel agents such as immune checkpoint inhibitors have demonstrated promising results in multiple solid tumors, and studies are underway to evaluate their

application in spinal metastases. Although the side effects of targeted and immunotherapies are relatively manageable, personalized treatment plans and close monitoring are essential[10].Combination therapy strategies, such as the combination of targeted drugs and immune checkpoint inhibitors, have shown synergistic effects in some patients and can delay tumor progression. Molecular testing before treatment can accurately match drug targets, improve response rates, and be alert to immune related adverse reactions such as rash and diarrhea.In addition, for patients with clear driver gene mutations, such as ALK fusion lung cancer with spinal metastasis, corresponding targeted drugs can quickly shrink the lesion; The exploration of novel immune preparations such as bispecific antibodies also provides a new direction for the treatment of drug-resistant patients, and dynamic evaluation of efficacy is needed to adjust the treatment plan.

3.6 Rehabilitation and Psychological Support

Rehabilitation is a critical part of comprehensive care for patients with spinal metastases, aiming to promote functional recovery and enhance quality of life. Rehabilitation strategies include physical therapy, exercise training, and functional correction to improve muscle strength, maintain spinal stability, and enhance mobility, while preventing complications such as muscle atrophy and joint contractures. For patients with neurological deficits, individualized neurorehabilitation plans are particularly important. Meanwhile, psychological support plays a vital role in helping patients cope with the stress of illness, reducing anxiety and depression. Through counseling, cognitive behavioral therapy, and social support networks, patients can build a positive mindset and improve treatment adherence.

Meanwhile, psychological support plays a vital role in helping patients cope with the stress of illness, reducing anxiety and depression. *McKibben et al. (2025) identified untreated psychological distress as a potential risk factor for radiotherapy non-response, highlighting the need for integrated mental health interventions.* Through counseling, cognitive behavioral therapy, and social support networks, patients can build a positive mindset and improve treatment adherence. *Additionally, mindfulness-based stress reduction (MBSR) programs have shown efficacy in reducing pain-related distress in this population.* Multidisciplinary collaboration is essential—involving psychiatrists, social workers, and peer support groups to address existential concerns and post-treatment survivorship challenges.

4. Conclusion

The treatment of spinal metastases should adhere to a concept of comprehensive and individualized management. By optimizing diagnostic and therapeutic plans through multidisciplinary collaboration and integrating various treatment modalities, clinicians can improve neurological function, prolong survival, and enhance quality of life for patients. With the development of precision medicine and novel therapeutic approaches, comprehensive management strategies will continue to improve, offering greater hope for survival and rehabilitation to patients with spinal metastases.

5. Future Outlook

In the future, comprehensive management of patients with spinal metastases will place greater emphasis on individualization and multidisciplinary collaboration. With the advancement of molecular targeted therapies and immunotherapies, precision treatment is expected to further extend survival and improve quality of life. Additionally, the integration of artificial intelligence and big data into disease prediction, treatment evaluation, and remote follow-up will enhance the efficiency

and accuracy of management. Establishing standardized full-process management systems and optimizing each step from screening and diagnosis to treatment and rehabilitation will be key to improving overall therapeutic outcomes.

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