Biomechanics and Materials of Reconstruction After Tumor Resection in the Spinal Column

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KEYWORDS

- Spinal tumor • Spinal metastasis • Anterior support
- Posterior tension band • Titanium mesh cage
- Pedicle screw

Surgical treatment of tumors in the muscular-skeletal system often requires extensive resection with safety margins reaching far into adjacent structures. This is often not possible for the surgical treatment of spinal tumors because of the close proximity of important neural and vascular tissue. However, improvement of surgical techniques,[1–3] as well as surgical tools, has resulted in better outcomes.[4,5]

An important aspect of spinal tumor surgery is the reconstruction and stabilization after wide resections of one or multiple spinal segments. With today's available resources and knowledge of biomechanical principles it should be possible to accomplish stable reconstructions in nearly all patients. The benefit of spinal stabilization is early mobilization, particularly in patients with limited survival time because of the nature of their malignancy. This early mobilization allows for resumption or improvement of motor function as well as quality-of-life parameters. In contrast, one should also avoid inadequate and inconsequent reconstruction causing early failure and further deterioration of the patient's conditions that may finally result in life-threatening revision surgery. It is also important to realize that tumor surgery is not always the treatment of choice for patients with an unfavorable prognosis. Especially when performing instrumented surgery of benign tumors in young patients, one should consider the long-term consequences.

We initially review the general biomechanical principles that should be considered in surgical reconstruction of spinal tumors. This will be further clarified by more detailed descriptions for individual spinal regions in the subsequent part of the article.

GENERAL CONSIDERATIONS

Decision Making

The following questions need to be answered as part of the decision-making process defining the most adequate surgical and reconstructive options:

Is complete resection of the tumor feasible? This should be the goal for benign tumor intervention of the spine. Unfortunately, such is not the case with many malignant tumors of the spinal axis. This often includes use of adjuvant treatment options such as chemo and radiation therapy. The dilemma becomes even more challenging in patients with a solitary metastasis, such as in carcinoma of the breast, kidney, or lung. Recent studies have conclusively shown the benefit of initial surgical

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intervention in patients with neurologic compromise to spinal metastasis.[4,5]

Biomechanical Considerations for Reconstruction

One of the basic prerequisites for biomechanically intact reconstructions is knowledge in principles of load transfer through the so-called central axis organ of the human body.[6] The predominant amount of axial load is transferred anteriorly, whereas only a small quantity runs posterior. These loads change upon flexion and extension of the spine. On principle, the anterior column consists of the vertebral bodies and the intervertebral discs representing the ''load-sharing'' portion of the spine. The posterior osseous structures in combination with the ligaments and joint capsules reflect the tension band of the construct. One feature that tumor invasion and surgical intervention have in common is the disruption of this antero-posterior balance.

Options for Reconstruction

When the stability of the anterior column is compromised by tumor destruction, surgical options vary quite considerably. They range from percutaneous cement injection to complete vertebral body replacement with interbody spacer. The expectation of such an anterior spacer is to compensate for the load-bearing capacity of the removed vertebra, and indirectly decrease the load to the adjacent segment. To achieve anterior support following tumor resection, autologous or allogeneic tricortical bone blocks of different origin are used as well as individually formed polymethyl-methacrylat inlays with or without metal reinforcement. Today, a large selection of reinforcement devices made from different metal alloys, carbon fibers, synthetic plastics, or ceramic is on the market. Although most have been initially designed for trauma surgery, they have found their way into tumor surgery. To fit the defect, the spacers are trimmed, stacked, or expanded. Especially in patients with a good prognosis, the spacers should allow for enough room for osseous integration, partially at the endplates of the construct. The association between the required volume of a spacer for providing enough anterior support with prevention of severe subsidence, and its relationship to the outcome of osseous incorporation has been investigated for cervical spine fusion devices by Kandziora and colleagues.[7] In their conclusion, the ''volume-related stiffness'' was essential for the outcome of a fusion, and this was best accomplished by use of a mesh spacer.

Failures of anterior support after reconstruction in tumor surgery can have multiple factors. They include the following:

- The tendency for dislocation of a graft will increase where the rotational forces in the reconstructed area has not been sufficiently reduced. Graft designs resulting in good primary anchoring at the graft-bone interface can provide further rotational stability, whereas grafts with smooth surfaces will increase the rotational instability.
- Subsidence of the spacer into the adjacent vertebrae is a result of excess stress to the bone, and can be caused by two main sources. They are poor bone quality and mechanical overload owing to incorrect construct design. A surgeon's option for poor bone quality is limited, although augmentation with small amounts of bone cement can possibility increase the stability of the augmented segments and contribute to overall construct stability.
- Fracture or collapse of the anterior device is observed with long bone graft constructs.[8] However, collapse of manufactured devices has also been reported. This is especially true where the weight-bearing capacity of the graft is overestimated or the occurring forces acting on the graft have been underappreciated.
- Despite adequate anterior construct, neglect of the status within the posterior tension band has been problematic. Functional interaction between the pressure-resisting anterior column and a stable posterior tension band provides a high likelihood for spinal stability.[9]

Posterior stabilization techniques have progressed a great deal over the past 30 years. Wiring techniques have been surpassed by hook- or screw-based fixation devices.[10] The latter technique provides a more rigid stabilization and has shorter construct length.

Although advances have been made, complications with posterior instrumentation do exist. They include pullout or breakage of the anchor points or longitudinal connectors, likely because of a mechanical overload of the system.

Since long-term survival rates have improved with many forms of cancer, it should be noted that patients with spinal involvement have a different measurement of success. For patients with long-term survival, it is important that osseous fusion accompany the cancer survival. This can sometimes be accomplished with the first surgery, but may often require a reoperation for