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Analysis of Surgical Strategies and Efficacy of Single-Door Laminoplasty in Complex Cervical Spondylotic Myelopathy

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Abstract: This paper aims to explore the surgical strategies and efficacy of single-door laminoplasty (SDLP) in the treatment of complex cervical spondylotic myelopathy (CSM). By analyzing surgical principles, technical details, postoperative recovery, and complication management, and combining existing literature and clinical practice, this paper demonstrates the effectiveness and safety of SDLP in treating complex CSM.

Keywords: Single-door laminoplasty; cervical spondylotic myelopathy; surgical strategy; efficacy analysis

Introduction

Cervical spondylotic myelopathy (CSM) is a severe disease caused by spinal cord compression due to cervical degeneration, leading to spinal cord dysfunction. Complex CSM often presents as multilevel spinal cord compression with varied and complex symptoms, making treatment challenging. Single-door laminoplasty, as an effective decompression method, has been widely used in clinical practice in recent years. This paper will conduct an in-depth analysis from the perspectives of surgical strategies, technical points, and efficacy evaluation.

1. Surgical Principles of Single-Door Laminoplasty

The surgical principle of single-door laminoplasty (SDLP) primarily involves posterior cervical incision to expand the spinal canal and decompress the spinal cord. Specifically, during the surgery, one side of the lamina is cut and elevated towards the opposite side, creating a "door-opening" effect. This effectively enlarges the volume of the spinal canal, allowing the compressed spinal cord to shift dorsally, thereby achieving decompression[1]. Compared to other surgical methods, SDLP uniquely preserves the integrity of the posterior cervical column, which reduces the risk of postoperative cervical kyphosis and helps maintain spinal stability. Additionally, SDLP utilizes specific fixation techniques, such as spinous process bone bridge grafting technique, to further enhance postoperative stability and improve surgical success and patient recovery.

2. Surgical Strategies for Single-Door Laminoplasty in Complex Cervical Spondylotic Myelopathy

2.1 Preoperative Assessment and Preparation

A detailed history collection is essential, including the

patient's symptoms, duration, and previous treatments, to fully understand the condition. A comprehensive physical examination, especially focusing on cervical mobility, tender points, and neurological abnormalities, is required to preliminarily assess the location and degree of spinal cord compression. Imaging plays a crucial role in preoperative evaluation. X-rays provide basic information on cervical curvature, intervertebral space narrowing, and potential bone spurs. CT scans offer clearer details of bony structures such as osteophytes and canal narrowing, helping to determine the exact surgical site. MRI, with its high soft tissue resolution, accurately displays spinal cord compression, including its location, degree, and extent, providing crucial information for surgical planning. Preoperative blood tests, including CBC, coagulation, liver and kidney function, should also be performed to ensure the patient can tolerate surgery. For patients with special medical histories such as diabetes or hypertension, additional specialist exams and preoperative management are necessary to reduce surgical risks.

2.2 Surgical Approach Selection

For complex cervical spondylotic myelopathy (CSM), SDLP generally adopts a posterior surgical approach, chosen for its multiple advantages. The posterior approach provides a broad field of view, allowing the surgeon to clearly observe the posterior cervical structures, facilitating precise operations. This approach also allows multilevel decompression of the spinal cord, making it particularly suitable for complex CSM patients with multilevel compression. With one surgery, multiple segments can be decompressed, avoiding the risks and additional pain of multiple surgeries. The most common approach is a posterior midline incision, which sufficiently exposes the spinous processes, laminae, and facet joints from C2 to C7, offering a good view and space for subsequent laminoplasty. During exposure, care is taken to protect the surrounding muscles, ligaments, and nerves to minimize surgical trauma and reduce complications[2]. In addition, the posterior approach is relatively simple and requires less technical expertise from the surgeon, though it is still necessary to strictly adhere to surgical protocols and procedures. After exposing the target structures, the surgeon proceeds with laminoplasty and decompression, which involves removing portions of the lamina and ligamentum flavum to expand the spinal canal, thereby relieving compression on the spinal cord.

2.3 Surgical Steps and Technical Highlights

2.3.1 Anesthesia and positioning

The patient is placed in the prone position with the head secured in a special head frame and protected by soft pads, ensuring a slight cervical flexion for better surgical exposure. Anesthesia can be local or general, depending on the patient's condition and surgical team's preference. If general anesthesia is chosen, an experienced anesthesiologist monitors the patient's vital signs, including ECG, blood pressure, and oxygen saturation, to ensure safe and appropriate anesthesia depth.

2.3.2 Incision and exposure

A vertical incision of approximately 10-15 cm is made along the posterior midline of the neck, ensuring accurate positioning to avoid damage to nearby vessels and nerves. After the skin and subcutaneous tissue are incised, electrocautery is used to control bleeding and maintain a clear surgical field. Muscles are separated layer by layer, with care taken to protect their attached fascia to reduce postoperative muscle adhesion and pain. The spinous processes, laminae, and facet joints from C2 to C7 are exposed using a retractor, protecting surrounding soft tissues and providing a clear surgical view. During exposure, particular care is taken to protect the paraspinal venous plexus to avoid massive bleeding.

2.3.3 Laminoplasty (Open-Door Technique)

During the laminoplasty, the surgical target area must first be identified, specifically both sides of the lamina where the “door” is to be created. Generally, author prefer to create the opening on the left side, while the right side serves as the hinge side. Hinge side treatment: Using an electric drill, thin the outer cortical bone at the junction of the right lamina and lateral mass, shaping it into a wedge-shaped bone groove, wider at the top and narrower at the bottom, with an angle of 45° to 50°. Leave approximately 1 mm of cancellous bone and inner cortical bone intact. Opening side treatment: On the left lamina, use an electric drill to carefully remove bone at the junction of the left lamina and lateral mass, along with the attachment of the ligamentum flavum. Care must be taken to avoid any unnecessary damage to the spinal cord and nerve

roots. During the cutting of the ligamentum flavum, avoid any form of traction or accidental injury. A longitudinal bone groove is created on this side. The width of the grooves on both the opening and hinge sides is typically 3-5 mm. Once the grooves on both sides are prepared, carefully lift the lamina toward the right side. As the door opens, use a nerve dissector to gently separate the fibrous connections between the ligamentum flavum, the inner wall of the lamina, and the dura mater, progressively lifting each lamina. This creates a “door” approximately 1.5 cm wide. Continuously use the nerve dissector to probe the spinal cord, ensuring that it is not subjected to any pressure or injury during the entire process. At the same time, ensure that the opening angle of the "door" is appropriate to achieve sufficient decompression of the spinal cord without compromising spinal stability or function.

2.3.4 Fixation and bone grafting

To maintain the open state of the lamina, laminar titanium plates can be used for fixation and support. After opening the door, laminar titanium plates are used on the opening side to ensure the sustained open state of the lamina. Titanium plates have excellent biocompatibility and stability, making them an ideal fixation material. Specific procedure: First, place the titanium plate in the pre-determined position on the lamina, ensuring it covers and secures the edges of both the opening and hinge sides of the lamina. Then, use specialized screws to securely fix the titanium plate onto the lamina. The screws must be placed with precision and at an appropriate depth to avoid penetrating the lamina and damaging the spinal cord or nerve roots. In the hinge side gap, bone grafting can be performed to promote bone healing. Select suitable bone fragments, trim them to the appropriate shape and size, and then insert them into the hinge side gap. Ensure the bone fragments fit tightly against the lamina without gaps. This fixation with titanium plates and bone grafting at the hinge side effectively maintains the open state of the lamina and promotes bone healing, providing the patient with better therapeutic outcomes.

2.3.5 Wound closure

After thorough hemostasis, place a drainage tube deep within the incision to allow postoperative drainage of any accumulated blood or fluid. The drainage tube should be securely fixed to prevent displacement or blockage after surgery. Sequentially suture the muscle, subcutaneous tissue, and skin layers, ensuring proper alignment without tension. The suturing should use appropriate sutures and spacing to ensure good wound healing. Finally, cover the wound with sterile dressings and apply a pressure bandage to reduce postoperative bleeding and swelling. The bandage should be neither too tight, which could cause discomfort, nor too loose, which could lead to dressing displacement or leakage.

3. Analysis of the Efficacy of Single Open-Door Laminoplasty in Complex Cervical Myelopathy

3.1 Decompression Effect Analysis

Single open-door laminoplasty has demonstrated remarkable decompression effects in the treatment of complex cervical myelopathy. This surgical technique effectively enlarges the spinal canal, allowing the compressed spinal cord to drift posteriorly, thereby relieving the pressure on it. During the procedure, by removing part of the lamina and the ligamentum flavum, the volume of the spinal canal is significantly increased. This change provides more space for the spinal cord, which alleviates compression and restores its normal physiological functions. Postoperatively, patients generally report a significant reduction in symptoms such as limb numbness, weakness, and unsteady gait. This is due to the relief of spinal cord compression, which restores neural conduction, thereby improving motor and sensory functions. Specifically, the improvement in limb numbness and weakness is attributed to the restoration of normal functioning in the nerve fibers within the spinal cord, allowing sensory signals to be smoothly transmitted to the brain.[3] The alleviation of unsteady gait results from the restoration of spinal cord control over the lower limb muscles, enabling patients to regain a stable walking pattern.

3.2 Spinal Stability Analysis

While expanding the spinal canal and relieving spinal cord compression, this procedure cleverly preserves the integrity of the posterior column of the cervical spine through the use of titanium plate fixation. This effectively reduces the risk of postoperative cervical kyphosis and maintains spinal stability. Specifically, titanium plate fixation provides structural support by securing the opened lamina with titanium plates that

cover and stabilize both the open side and the hinge side of the lamina, forming a stable support structure. This structure not only enhances postoperative spinal stability but also preserves the integrity of the posterior cervical column, preventing post-surgical cervical kyphosis deformity[4]. Moreover, the procedure minimizes damage to surrounding muscles, ligaments, and other soft tissues, contributing to the maintenance of spinal stability. Postoperatively, patients can further enhance spinal stability and promote recovery through appropriate rehabilitation exercises.

3.3 Complication Analysis

Following single open-door laminoplasty, patients may experience certain complications, with C5 nerve root palsy and axial neck pain being the most common. The incidence of C5 nerve root palsy ranges from 0% to 50%, typically manifesting as deltoid paralysis and upper limb numbness and weakness. Although this complication may cause some discomfort for patients, its prognosis is generally favorable. Most patients gradually recover within two years post-surgery as the nerves regenerate and heal. Axial neck pain is another potential complication, though its incidence is relatively low. This pain is often related to the surgical procedure, postoperative cervical spine mobility, and individual differences. To alleviate this complication, surgeons can optimize the surgical approach, such as performing more delicate surgical maneuvers and minimizing soft tissue damage. Postoperative symptomatic treatment is also essential, including the use of non-steroidal anti-inflammatory drugs and physical therapy, which can effectively relieve pain. In addition to the two aforementioned common complications, patients may also experience other issues such as wound infection and cerebrospinal fluid leakage.

4. Discussion and Summary

Single open-door laminoplasty has shown excellent efficacy and safety in treating complex cervical myelopathy. Its significant advantages include thorough decompression, effectively relieving spinal cord compression, and a relatively simple procedure that reduces both surgical time and patient trauma. Moreover, this technique minimally disrupts spinal stability, and by utilizing titanium plate fixation, it effectively lowers the risk of postoperative cervical kyphosis. However, the success of the surgery does not rely solely on the technique itself; comprehensive preoperative assessment is required to ensure the individualization and appropriateness of the surgical plan. During surgery, the surgeon must possess precise technical skills to minimize damage to surrounding tissues. Postoperative management, including rehabilitation exercises and pain control, is equally important in ensuring surgical outcomes and reducing complications.

Conclusion

Single open-door laminoplasty is an effective method for treating complex cervical myelopathy. Through appropriate surgical strategies, meticulous technical execution, and scientific postoperative management, this technique can significantly relieve patient symptoms, improve spinal cord function, and enhance quality of life. In clinical practice, the surgical approach should be selected based on the patient's specific condition to achieve the best therapeutic outcome.

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