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The Application Effect and Management Strategies of Photobiomodulatory Therapy in the Perioperative Nursing of Patients with Traumatic Spinal Cord Injury

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Abstract: *To explore the application effect of professional perioperative nursing program in the adjuvant treatment of Photobiomodulation (PBM) in patients with Traumatic Spinal Cord Injury (TSCI).As a new adjuvant therapy, PBM has been proved to be safe and effective, but its special treatment mode (laser acting directly on the surface of the spinal cord and having skin outlet) poses challenges to perioperative care. A total of 34 patients with TSCI admitted to our hospital from October 2022 to October 2024 were included in this study. All patients received PBM irradiation treatment for 7 days after emergency decompression, and a systematic nursing intervention program was implemented, including multidisciplinary collaborative nursing, standardized management of optical fiber pipeline, and prevention of complications. The study showed that all 34 patients successfully completed PBM treatment, and during the nursing intervention, no common complications such as bladder and stool dysfunction, pressure injury, and deep vein thrombosis were observed, and no adverse events such as fiber pipe prolapse, treatment-related infection, or spinal cord nerve function aggravation occurred. By establishing a professional PBM nursing team and integrating evidence-based nursing measures, 34 patients in this study achieved zero complications and the completion rate of the whole treatment was 100%, which provides a practical paradigm for perioperative PBM nursing of TSCI patients.*

Keywords: *Spinal Cord Injury; Photobiomodulation; Perioperative Nursing; Prevention of Complications*

1. Introduction

Traumatic Spinal Cord Injury (TSCI) is a serious disabling central nervous system disease, which causes motor and sensory dysfunction and secondary complications, posing a great threat to the health of patients [1]. However, at present, there are few treatment methods to prevent secondary injury after early emergency surgical decompression in patients with TSCI. In addition, the efficacy and potential role of the commonly used methylprednisolone hormone therapy have also been questioned [2]. Recent studies have shown that Photobiomodulation (PBM), as an emerging treatment method, has significant potential in the treatment of TSCI [3]. PBM therapy can activate mitochondrial cytochrome C oxidase, enhance mitochondrial function and optimize energy metabolism by accurately irradiating damaged tissues with low-energy laser of specific wavelength [4-6]. At present, this therapy has been widely used in many medical fields [4].

When traditional PBM therapy is used to treat craniocerebral and spinal cord injuries, it usually uses percutaneous indirect irradiation to act on the damaged nerve tissue [7,8]. However, previous studies have shown that even the most penetrating near-infrared laser's energy has been significantly attenuated when it reaches the spinal cord injury site, and only about 6% of the energy can be effectively used in the target area [9]. In addition, if the laser power is further increased to enhance the tissue penetration depth, it may cause significant skin and deep tissue thermal damage, which greatly limits the application of PBM therapy in the treatment of nervous system diseases [10]. Compared with the traditional indirect skin irradiation method, PBM therapy with direct irradiation that can be

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implanted in the body is simpler, safer, sustained and more efficient [3].

With the in-depth application of photobiological modulation in the treatment of spinal cord injury, the key problems in clinical nursing have become increasingly prominent, mainly reflected in the following aspects: 1) the construction of specialized nursing team is lagging behind, and there is a lack of PBM special nursing team with multidisciplinary cooperation from spine surgery, rehabilitation medicine, and nursing; 2) The patient education system is not perfect, and the standardized process of health education for key information such as treatment principles, expected efficacy and precautions has not been established; 3) Postoperative fiber optic catheter fixation should be optimized to prevent complications such as local skin infection, pressure injury, and deep vein thrombosis. In this study, the clinical data of 34 patients with TSCI treated with PBM in our hospital were retrospectively analyzed, and the perioperative clinical characteristics and nursing experience were summarized. The results are reported as follows.

2. Materials and methods

2.1 General Information

From October 2022 to October 2024, the data of patients who underwent PBM after TSCI decompression in the spine Surgery Department of our hospital were collected. Inclusion criteria: 1) Age between 18 and 70 years old; 2) Spinal cord injury, the time of injury is not more than 72 hours; 3)ASIA grade A-C [11]; 4) Posterior decompression was used in all patients. 5) Fiber-optic PBM device was placed during operation. Exclusion criteria: 1) Combined with multiple spinal cord injury or cauda equina injury; 2) Complicated with craniocerebral injury or multiple limb injury, unable to cooperate with neurological function evaluation; 3) Severe skin and soft tissue defect or infection due to open neck injury; 4) For severe vertebral fracture and dislocation, combined anterior and posterior approach should be used; 5) previous autoimmune diseases of the nervous system (such as multiple sclerosis, demyelinating diseases); 6) patients participating in clinical trials of other drugs or devices. A total of 34 patients were collected according to the inclusion and exclusion criteria, including 25 males and 9 females. The average age was 51.7 (28-64) years old. Among them, 19 patients with cervical spinal cord injury and 15 patients with thoracic spinal cord injury received PBM. There were 19 patients with ASIA grade A, 6 patients with ASIA grade B, and 9 patients with ASIA grade C. The study was approved by the Ethics Committee of the 970 Hospital (batch number: KY20202062-F-1) and was conducted in accordance with the Declaration of Helsinki, and all patients provided written informed consent.

2.2 Intraoperative embedding methods of PBM

TSCI patients were treated with posterior laminectomy decompression, lateral mass/pedicle screw fixation, and bone graft fusion under general anesthesia. The decompression range was increased by 1 to 2 segments above and below the high signal area on magnetic resonance T2 image. After the main operation was completed, a 5cm opening was made at the end of the incision. The opening was punctured and the optical fiber was embedded to ensure that the optical fiber did not bend more than 30 ° throughout the operation. After the optical fiber was fixed with the silk thread, the optical fiber interface was connected to the output interface of the photobiological therapeutic instrument. The photobiological therapeutic instrument was turned on to detect whether the light energy was directly transmitted to the surface of the injured spinal cord.

2.3 PBM irradiation plan

Before irradiation, the end of the fiber tube is connected to the laser emitter, and then the irradiation device is turned on. When the green light is displayed, the laser has been emitted normally. Patients were continuously irradiated once daily for 30 minutes at a wavelength of 810nm and a power of 300 mW from day 1 to day 7 after surgery. The output power of the device was detected using a power meter before the start of each treatment to ensure that the device was functioning properly, and the photobiomodulation treatment mode is shown in Figure 1.

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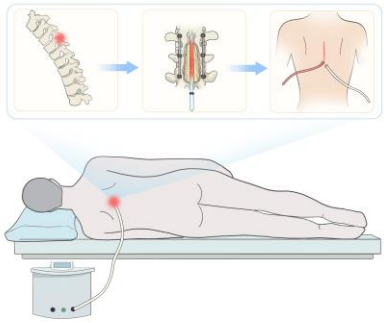

Figure 1: PBM treatment model diagram

3. Nursing difficulties and measures

3.1 Lack of standardized nursing process of PBM therapy

This study aimed at the nursing difficulties of PBM therapy and implemented special nursing measures on the basis of routine nursing [12]. Four to five nurses with more than 5 years of spinal surgery nursing experience were screened through the examination, and a PBM special nursing team was established. The team members were organized to receive systematic training on PBM theory and operation technology to ensure that they were proficient in the following contents: 1) the physical mechanism and biological characteristics of the interaction between light energy and biological tissue [13]; 2) Operation specification, precautions and daily maintenance of photobiological therapy equipment [14]; 3) Nursing points of optical fiber interface, catheter access, skin and puncture site [15]; 4) Monitoring and recording vital signs, skin temperature, psychological state and complications of patients during the whole treatment process [3]; 5) Establish the continuing education mechanism of PBM nursing team to promote evidence-based nursing practice [16].

3.2 Nursing difficulties and management strategies of PBM therapy in TSCI patients

The treatment process of spinal cord injury is complex and the incidence of postoperative complications is high [12]. Major complications include anxiety, depression, neurogenic bladder/bowel dysfunction, pressure injury, and deep vein thrombosis [17].

3.2.1 Psychological nursing

Studies have shown that TSCI patients are more likely to have psychological disorders than other traumatic patients [18]. In addition, TSCI can also have a significant impact on the physical and mental health of family caregivers of patients, mainly manifested as anxiety, depression and sadness and other emotional disorders [19,20]. In view of the fact that PBM therapy is an emerging treatment to prevent secondary injury after TSCI decompression, patients' awareness of PBM therapy is low. Therefore, the following intervention measures were adopted in this study. First, multi-dimensional and easy-to-understand education methods such as lectures on PBM therapy, physical models, influence materials and surgical videos were used to improve the cognitive level of patients and their families. Secondly, based on animal experiments and clinical cases, the safety and effectiveness of PBM treatment were systematically described to enhance patient compliance and trust in the medical team [3,10]. Studies have confirmed that the above interventions can effectively improve the psychological state of patients and caregivers, relieve stress and fatigue symptoms [18]. In this study, 34 patients and their family members were successfully treated with PBM after individualized psychological intervention, and there were no psychological complications such as anxiety and depression.

3.2.2 Bladder and bowel care

According to literature reports, bladder dysfunction is common in patients with TSCI [21,22], of which 20%-60% are accompanied by intestinal dysfunction [22]. It is worth noting that urinary tract infection caused by bladder and bowel dysfunction is the main factor leading to patient readmission [22]. Eren O Kuris et al. confirmed that a multidisciplinary team consisting of medical staff in spine surgery, gastrointestinal surgery and occupational therapists plays a key role in the management of patients' bladder/bowel function [22]. On the basis of traditional nursing, a multidisciplinary team

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including family caregivers, medical staff from spine surgery and gastrointestinal surgery was established. After admission, the patients' urinary and digestive functions were evaluated by gastrointestinal surgeons, and perioperative monitoring and bladder/intestinal function training were implemented [23]. Postoperative clinical symptoms such as urinary retention and urinary incontinence were closely observed, and the gastrointestinal surgery team formulated treatment plans such as bladder drainage, drugs or surgery according to the monitoring results [22]. For patients with neurogenic intestinal symptoms, intestinal and skin care should be strengthened, dietary intake, water, drugs and activity should be monitored and recorded, fecal characteristics should be evaluated, and high-fiber diet should be guided [24]. Meanwhile, family caregivers were trained to master drinking water management, abdominal massage and anal contraction exercises [25]. After the above intervention, no complications such as urinary retention, constipation and incontinence occurred in all patients.

3.2.3 Prevention strategies of deep vein thrombosis and pressure injury

It is reported that the incidence of deep vein thrombosis in patients with TSCI is as high as 10.9%[26], while pressure injury affects almost all patients [27], which not only aggravates the pain of patients, but also significantly prolongs the length of hospital stay and increases the social and economic burden [28]. In this study, individualized decompression strategies were adopted according to the age, weight, degree of spinal cord injury and skin condition of bone carins, including the use of various types of turning pads and decompression dressings [29]. Regular body position change is implemented to reduce skin damage caused by friction, pressure and shear force [29]. Early pneumatic therapy combined with low molecular weight heparin subcutaneous injection can effectively prevent deep vein thrombosis [30]. At the same time, family caregivers were instructed to assist patients with lower limb elevation, gastrocnemius muscle massage, knee joint and ankle joint passive activities [31]. After the coordinated care of the research team and family caregivers, no pressure injury and deep vein thrombosis occurred in 34 patients.

3.3 PBM nursing strategies

After complete decompression of the spinal cord injury, absorbable suture was used to firmly fix the outlet end of the fiber skin during the operation to ensure its stability [3]. Postoperative nursing of fiber optic catheter should be strengthened to prevent distortion, prolapse or displacement of wound drainage tube and fiber optic catheter [32]. Drainage tube care twice daily to prevent retrograde infection. Before PBM treatment, nursing staff assessed the patient's state of consciousness, checked the functional status of instruments and rescue equipment, and the treatment was suspended for patients with restlessness. Before treatment, the family was instructed to avoid mobile devices and looking directly at the laser source. During the treatment, special monitoring was performed to observe and record the adverse reactions of irradiation and the changes of body position. After the treatment, the skin temperature at the exit of the optical fiber was monitored, the pipe was properly fixed, and the equipment was maintained. In this study, fiber implantation did not increase the discomfort of patients, did not affect the position change, and no complications such as catheter prolapse occurred.

3.4 Surgical site infection prevention strategies

The incidence of surgical site infection after spinal surgery is 16%[15], and intraoperative placement of drainage tubes or optical fibers may further increase the risk of infection [33]. Although previous studies have confirmed that no infection occurred in TSCI patients treated with PBM [3], the prevention of surgical site infection after optical fiber implantation is still the focus of nursing management. Nursing interventions for PBM treatment in this study included daily monitoring of vital signs and skin temperature at the exit of the fiber; The volume and shape of drainage fluid were observed and recorded [34]. Before and after treatment, the wound skin was evaluated for signs of infection such as redness, swelling, heat, pain, and purulent secretion. White blood cell count (WBC), percentage of neutrophils (NEUT), hypersensitive C-reactive protein (hs-CRP), procalcitonin (PCT) and other infection-related indicators were regularly monitored [35]. Keep the skin of the wound and fiber exit clean and dry. The results showed that none of the patients developed infection.

3.5 Observation and nursing of nerve function

Traumatic spinal cord injury often leads to severe damage of motor, sensory and autonomic nerve function in patients, and causes lasting dysfunction [36]. Therefore, promoting the recovery of neurological function is one of the core goals of clinical treatment and nursing [36]. In this study, the

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sensory and motor functions of patients with TSCI were systematically evaluated before and 7 days after surgery using the American Spinal Injury Association neurological function scoring criteria. The results showed that none of the TSCI patients treated with PBM for 7 days showed deterioration in ASIA sensory and motor function scores. During this period, the key points of nursing included: keeping the axis of the cervical spine, thoracic spine and lumbar spine consistent when the body position changed, preventing secondary injury; Through spinal cord reorganization, motor learning and muscle sensory system remodeling, the neuromuscular system below the lesion level can be activated to promote the recovery of motor function [33]. After surgery, repetitive training of fine movements of upper limbs and somatosensory electrical stimulation of peripheral nerves were combined to improve pinch and grip strength and upper limb function [34]. Once vital signs had stabilized, patients were assessed by a spine surgeon and a rehabilitation practitioner, and functional training was performed for 60 minutes daily. The results showed that after 7 days of photobiomodulation treatment, the sensory and motor nerve functions of the patients did not deteriorate.

4. Summary

As a minimally invasive and effective treatment for patients with spinal cord injury, photobiomodulation therapy is a new technique in the field of spinal surgery. In view of the lack of relevant nursing measur sent, this study summarizes the difficulties in perioperative nursing of patients with TSCI treated with es at pre PBM, and obtains the following experience: It plays a key role in the success of PBM treatment to establish a professional nursing team, combine multidisciplinary collaboration and family main caregivers, strengthen the skin and tube care at the fiber puncture site on the basis of traditional nursing, prevent postoperative complications, especially to avoid further damage to sensory and motor nerve function.

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