International Journal of Anesthesia and Clinical Medicine
2025, Vol. 13, No. 1, pp. 13-19
https://doi.org/10.11648/j.ijacm.20251301.12

Review Article

Observation on the Clinical Effect of Hyperbaric Oxygen Therapy on Postoperative Recovery of Patients with Kashin-Beck Disease in Plateau Areas After Total Knee Arthroplasty (TKA)

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Abstract

Background: When the altitude is 0 meters above sea level, the oxygen concentration in the air is approximately 21%. As the altitude increases, the oxygen concentration gradually decreases. At an altitude of 3,000 meters, the oxygen concentration in the air is about 15%. The low oxygen concentration seriously affects the recovery after knee joint surgery and is more likely to lead to postoperative complications. This study aims to explore the efficacy of hyperbaric oxygen therapy on the early postoperative recovery of patients with Kashin-Beck disease in high-altitude areas after undergoing total knee arthroplasty (TKA). Methods: The clinical data of 58 patients with Kashin-Beck Disease who were hospitalized and underwent TKA in Ruoergai County People's Hospital at an average altitude of 3,500 meters were retrospectively analyzed. According to whether hyperbaric oxygen therapy was used after surgery, they were divided into two groups: the hyperbaric oxygen group (HO group, hyperbaric oxygen therapy was administered daily from the 1st to the 7th day after surgery) and the conventional group (GO group, only normal pressure oxygen inhalation was carried out without hyperbaric oxygen therapy after surgery). Finally, a total of 56 patients were included in the study, with 22 patients in the HO group and 34 patients in the GO group, and the evaluation was carried out based on the recovery status of all selected patients at the time of discharge after surgery. Results: There was no significant difference in the general clinical data between the two groups; the overall incidence of adverse reactions after surgery in the HO group was significantly lower than that in the GO group ($P<0.01$); the postoperative quality of recovery score (QoR-40) of the HO group was significantly higher than that of the GO group on the 3rd, 7th, and 14th days after surgery ($P<0.01$); although there was no significant difference in the pain (NRS) score, knee joint score, and surgical satisfaction between the two groups at 2 hours, 12 hours, 24 hours, 48 hours, and 72 hours after surgery, the length of hospital stay in the HO group was significantly shorter than that in the GO group, and this difference was statistically significant ($P<0.05$). Conclusion: Hyperbaric oxygen therapy for patients with Kashin-Beck Disease in plateau areas after TKA is beneficial to the early postoperative recovery process, can reduce the incidence of postoperative complications, and shorten the length of hospital stay, which has significant clinical application value.

Keywords

Plateau Area, Total Knee Arthroplasty, Hyperbaric Oxygen, Efficacy

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Received: 20 December 2024; **Accepted:** 2 January 2025; **Published:** 22 January 2025

1. Introduction

Kashin-Beck Disease, a chronic osteoarthropathy predominantly manifesting in plateau regions, is characterized by its propensity to affect multiple weight-bearing joints, including the hip, knee, and ankle joints. Notably, the knee joint stands out not only for its high incidence but also for the relatively severe pathological alterations it endures [1, 2]. Within the domain of clinical treatment, total knee arthroplasty (TKA) has come to the fore as a crucial treatment approach for advanced Kashin-Beck Disease and knee osteoarthritis. Specifically, the application of total knee arthroplasty in treating KBD is capable of reconstructing the joint architecture, rectifying the alignment of the lower extremities, enhancing joint functionality, alleviating pain, and augmenting the quality of life [3-5]. However, it is of particular significance to note that the hypoxic milieu ubiquitously present in plateau areas poses a formidable impediment to the rehabilitation of knee joint injuries among patients in these regions. Consequently, only by efficaciously augmenting the blood oxygen supply to the damaged tissues, facilitating the efficient abatement of the inflammatory response, and expediting the rate of tissue repair can a conducive environment for the postoperative recuperation of patients be established [6]. This study undertook a retrospective analysis of the clinical data of 56 patients afflicted with Kashin-Beck Disease, who underwent TKA treatment under the auspices of orthopedic experts providing support in Tibet at Ruoergai County People's Hospital from March 2021 to June 2024. The primary objective was to meticulously scrutinize the actual impact of the early application of hyperbaric oxygen therapy following TKA on the postoperative rehabilitation of these patients. The ensuing details are presented herein.

2. Materials and Methods

2.1. General Information

The clinical data of patients with Kashin-Beck Disease who underwent TKA treatment at Ruoergai County People's Hospital from March 2021 to June 2024 were retrospectively analyzed. According to the inclusion and exclusion criteria, a total of 56 patients were included in the study, among which there were 22 patients in the HO group, including 12 males and 10 females, with an age range of 58 - 76 years and an average age of (63.3 ± 5.00) years. There were 34 patients in the GO group, including 18 males and 16 females, with an age range of 55 - 72 years and an average age of (64.8 ± 4.25) years.

Inclusion criteria: a) All patients were diagnosed in accordance with the "Diagnosis of Kashin-Beck Disease" standard (WS/T 2007 - 2010); b) The anesthesia method was lumbar anesthesia with a fine lumbar puncture needle, and the anesthesia level was below T6 without anesthesia complications; c) There was no severe heart, liver, kidney, rheumatic, or endocrine disease; d) The patient had not taken analgesic and sedative drugs for a long time before surgery; e) There was no mental or neurological disease; f) The patient underwent unilateral TKA for the first time, and the operation time was less than 3 hours.

Exclusion criteria: a) Complicated with other diseases affecting the evaluation of knee joint function, such as rheumatoid arthritis, post-traumatic arthritis, ankylosing spondylitis, etc.; b) Having other diseases affecting the postoperative wound healing of patients, such as heart failure, uncontrolled or poorly controlled hypertension, diabetes, etc.; c) Severe pulmonary hypertension; d) SPO_2 < 80% without oxygen inhalation; e) Incomplete clinical or imaging data. The surgeries of both groups of patients were performed by experienced orthopedic experts who worked on the front line of clinical practice all year round.

2.2. Anesthesia and Surgical Methods

After admission, comprehensive health education was carried out for each patient, and various routine examinations and accurate preoperative evaluations were completed before surgery. When the patient entered the operating room, the blood oxygen saturation (SPO_2), electrocardiogram (ECG), non-invasive blood pressure (NIPB), heart rate (Hr), and respiratory rate (RR) were closely monitored, and mask oxygen inhalation was given at an oxygen flow rate of 5 L/min. After re-checking and ensuring that the patient had no contraindications for spinal anesthesia, the patient was assisted to take the left lateral position. An ultrasonic probe was used to perform a scanning operation from the caudal side, and the target interspace position was accurately determined by counting upward from the L5 - S1 interspace. Subsequently, 2 ml of 1% lidocaine was used for local infiltration anesthesia, and then a fine lumbar puncture needle was used for puncture. When the puncture needle successfully penetrated the arachnoid membrane and entered the subarachnoid space, and clear cerebrospinal fluid flowed out, a syringe containing 2 ml of 1% ropivacaine hydrochloride, which had been prepared in advance, was quickly connected to the syringe connection of the lumbar puncture needle. The cerebrospinal fluid was aspirated until the total volume reached 3 ml, and then it was slowly injected into the subarachnoid space at a constant speed of 1 mL/8 s in the cephalic direction. After the injection was completed, the cerebrospinal fluid was aspirated again to ensure smooth reflux. Then, the patient was helped to smoothly change to the supine position, and the anesthesia level was accurately adjusted according to the actual situation.

The operation officially began. A midline anterior knee incision was selected, and the medial parapatellar approach was used to carefully remove the surrounding osteophyte

tissue, fully expose the medial border of the tibia, turn the patella outward, and sequentially resect the suprapatellar bursa, infrapatellar fat pad, medial and lateral menisci, and anterior and posterior cruciate ligaments to achieve sufficient surgical field exposure and then perform tibial and femoral osteotomy. After the osteotomy was completed, the lower limb alignment, joint range of motion, varus and valgus balance, and patellar motion trajectory were comprehensively confirmed. Subsequently, 15 ml of a specially prepared "cocktail" injection solution (prepared by mixing 100 mg of ropivacaine, 7.5 mg of betamethasone, 1 g of tranexamic acid, and normal saline to 60 ml) was accurately injected into the posterior, posterolateral, and posteromedial regions of the joint capsule. After the prosthesis was installed, the knee joint was kept in the extended position, waiting for the bone cement to solidify. After the solidification was completed, the knee joint was converted to the flexed position for wound suturing. At the same time, the remaining 45 ml of the "cocktail" injection solution was evenly infiltrated and blocked in the joint capsule, periarticular muscles, ligaments, and subcutaneous nerve endings before and after closing the knee joint incision to achieve a good postoperative analgesic effect and create favorable conditions for the patient's postoperative recovery.

2.3. Postoperative Treatment

After the operation, the patient needed to lie flat for 4 hours and receive 24-hour electrocardiogram monitoring and first-level nursing measures. After the anesthesia level completely subsided, the patient resumed a normal diet. Low molecular weight heparin was given for anticoagulation treatment according to the conventional regimen, and 0.1 g of diclofenac sodium sustained-release tablets was taken orally once a day for postoperative analgesia. For the patients in the HO group, a hyperbaric oxygen treatment regimen was initiated on the 1st day after the operation for 7 consecutive days; while the patients in the GO group only received oxygen inhalation at a normal pressure environment with an oxygen flow rate of 3 L/min and did not receive hyperbaric oxygen treatment. During this process, multiple indicators of the two groups of patients were recorded in detail: including the incidence of overall postoperative adverse reactions; the quality of recovery scores (QoR - 40) on the 1st, 3rd, 7th, and 14th days after the operation; the pain (NRS) scores at 2 hours, 12 hours, 24 hours, 48 hours, and 72 hours after the operation and the knee joint score at the time of discharge (using the Knee Society Score, KSS, of the American Knee Society); the length of hospital stay and the surgical satisfaction of the two groups of patients.

Hyperbaric oxygen treatment method: The treatment pressure was set at 2 atmospheres, and the specific operation process was as follows: first, a pressure increase operation was carried out for 20 minutes; then, a pressure stabilization stage was entered, which lasted for 50 minutes; finally, a pressure reduction step was implemented, which took 20 minutes. During the entire treatment process, the patient's oxygen inhalation time totaled 70 minutes. The patients in the HO group were strictly given a hyperbaric oxygen treatment once a day according to this process, and 7 treatments constituted a complete course.

2.4. Statistical Methods

SPSS 22.0 statistical software was used to analyze the data. Measurement data were expressed as ($x \pm s$), and variance analysis was used for multiple group comparisons, and t-test was used between groups; count data were expressed as a rate and χ^2 test was used. A P value of less than 0.05 was considered statistically significant.

3. Results

3.1. Basic Information Comparison

There was no statistically significant difference between the two groups in terms of age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, and preoperative comorbidities ($P > 0.05$). See Table 1.

Table 1. *Comparison of Baseline Data of Patients in the Two Groups.*

Items	HO Group	GO Group	P Value
Gender (male/female)	12/10	22/12	0.156
Age (years, x ±s)	63.3 ±5.00	64.8 ±4.25	0.810
BMI (kg, x ±s)	58. 22 ±2.03	58.83 ±1.96	0.868
Height (cm, x ±s)	163.16 ±2.14	164. 66 ±1.50	0.463
A S A grade (Ⅱ /Ⅲ)	16/6	24/8	0.623
Total comorbidities (cases *)	10	14	0.321

Items	HO Group	GO Group	P Value
Diabetes	1	2	
Hypertension	5	8	
Chronic Bronchitis, Pulmonary Hypertension and other Pulmonary Lesions	7	12	

3.2. Comparison of Postoperative Rehabilitation Therapy Between Two Groups of Patients

There was no significant difference in the QoR-40 score between the two groups on the first day after surgery. However, the QoR-40 scores of the HO group were significantly higher than those of the GO group on the 3rd, 7th, and 14th days after surgery. The overall incidence of postoperative complications in the HO group was lower than that in the GO group, and the difference was significant and statistically significant ($P < 0.05$). See Table 2.

Table 2. *QoR-40 Scores and Complications.*

Category	QoR-40 (x ±s)				Complications (cases)		
	1 day after surgery	3 day after surgery	7 day after surgery	14 day after surgery	Infection	Thrombosis	others
HO group	98.4 ±6.31	122.1 ±4.12	179.3 ±3.36	192.1 ±1.91	0	2	3
GO group	96.1 ±8.11	106.8 ±2.71	152.4 ±4.19	172.6 ±2.42	4	6	4
P Value	0.342	0.012	0.031	0.004	0.001		

Note: The QoR - 40 scale score includes five parts: physical comfort, emotional state, self - care ability, psychological support, and pain, with a total of 40 sub - items. Each item is scored from 1 to 5 points, and the total score ranges from 40 to 200 points. The higher the score, the better the quality of recovery.

3.3Comparison of postoperative knee function and complications between two groups of patients

There was no significant difference in the pain (NRS) score at 2 hours, 12 hours, 24 hours, 48 hours, and 72 hours after surgery, the KSS score at discharge, and the surgical satisfaction in the HO group. However, the average length of hospital stay in the HO group was significantly lower than that in the GO group, and the difference was significant and statistically significant ($P < 0.05$). See Table 3.

Table 3. *Comparison of Postoperative Scores, Satisfaction, and Hospital Stay.*

Category	Postoperative Pain Score (NRS)					Knee joint score at discharge	Surgical Satisfaction Score	Average Length of Hospital Stay (days)
	2h	12h	24h	48h	72h			
HO group	2.0 ±0.5	3.1 ±0.2	3.5 ±1.2	2.5 ±1.3	1.6 ±0.8	93.6 ±2.18	4.8 ±1.08	12.3 ±0.8
GO group	2.2 ±0.2	3.5 ±0.4	3.7 ±0.9	2.9 ±0.8	2.2 ±0.4	92.9 ±3.24	4.6 ±0.75	16.5 ±1.4
P Value	0.740	0.545	0.432	0.230	0.659	0.327	0.142	0.021

4. Discussion

Zoige County is located in the northwest of Aba Prefecture, Sichuan Province. The average altitude here reaches 3,500 meters, and the oxygen content in the air is only about 13.5%, accounting for only 64% of that in the plain area [7]. The annual average temperature is at a relatively low level of 1.3 ℃, which is a high-incidence area for Kashin-Beck disease. In such an environment, the interaction between hypoxia and cold causes the blood circulation to be relatively slow, the peripheral blood vessels to contract, which in turn leads to ischemia and hypoxia in the microcirculation, and finally results in the delay of ulcer and wound healing [8]. The hyperbaric oxygen treatment method has the ability to significantly increase the partial pressure of blood oxygen, the partial pressure of tissue oxygen, and the effective blood oxygen diffusion rate and diffusion radius, and has a significant effect on the improvement of microcirculation [9]. At the same time, relevant studies have shown that hyperbaric oxygen treatment can promote the regeneration and repair process of damaged spinal cord neurons [10]. During the total knee arthroplasty (TKA) operation, it is necessary to use a tourniquet to block the blood supply in the surgical area. In addition, the operation itself lasts for a long time, and the ischemia-reperfusion injury is relatively serious. These factors have become the key to affecting the postoperative recovery effect. It was found through animal experiments that hyperbaric oxygen treatment has a certain protective effect on ischemia-reperfusion [11, 12].

In this study, we adopted the method of retrospective analysis to conduct an in-depth exploration of the differences in the early postoperative efficacy between hyperbaric oxygen treatment and conventional oxygen inhalation treatment for patients with Kashin-Beck disease in the plateau area after total knee arthroplasty (TKA). The research results clearly showed that hyperbaric oxygen treatment can significantly reduce the incidence of postoperative complications, effectively shorten the length of hospital stay, and promote wound healing. This is consistent with the research results of Gao Fuan [13], Wei Yiling [14] and others, which showed that hyperbaric oxygen therapy can increase the blood oxygen content of the body and improve tissue function, and thus can be used as a major and necessary adjuvant treatment method in clinical practice. From the perspective of the mechanism of action, hyperbaric oxygen treatment can increase the partial pressure of blood oxygen and the oxygen content in tissues, which is particularly crucial and important in the hypoxic environment of the plateau area. Under normal environmental conditions, the tissue repair after surgical trauma is highly dependent on an adequate supply of oxygen. However, in the plateau area, the hypoxic environment itself is likely to cause the tissue to be in a relatively hypoxic state, which has an adverse impact on the healing process. Hyperbaric oxygen treatment creates more favorable conditions for the tissue repair at the surgical site by increasing the diffusion distance and concentration of oxygen, and then promotes the smooth progress of the repair processes such as cell proliferation and collagen synthesis. This may be the key factor why the postoperative recovery quality score (QoR - 40) of the patients in the hyperbaric oxygen treatment group (HO group) was significantly higher than that in the conventional oxygen inhalation treatment group (GO group) at multiple time points. This result is similar to the conclusion confirmed by Marx RE et al. [15] in animal experiments that hyperbaric oxygen can promote the formation of collagen matrix and angiogenesis in the irradiated mandible, and then promote wound healing. The knee joint damage of patients with Kashin-Beck disease is often relatively severe. The research results of Xiao Yong [6] et al. have definitely confirmed that hyperbaric oxygen can effectively improve various symptoms caused by knee joint injury by eliminating the edema of knee joint tissue, reducing the adhesion of knee joint tissue, promoting tissue repair, and accelerating tissue growth. The internal mechanism of action lies in that under the hyperbaric oxygen environment, the tissue endothelial cells and fibroblasts show an active growth trend, and the content of fibroblast growth factor (b - FGF) and transforming growth factor (TGF) increases, thus creating favorable conditions for tissue growth and shortening the time required for tissue healing. This is consistent with the situation in the analysis results of this study that the QoR - 40 score of the patients in the hyperbaric oxygen treatment group was significantly higher than that in the conventional postoperative treatment group on the 1st, 3rd, and 7th days after surgery. In addition, through further analysis and observation, we also found that although the length of hospital stay of the patients in the HO group was significantly shorter than that in the GO group, there was no significant difference in the satisfaction of the two groups of patients with the hospitalization surgery. This may be related to the fact that the surgeries of both groups of patients were performed by experts from Class III Grade A hospitals in Sichuan Province and the surgery fees were waived.

Regarding the role of hyperbaric oxygen treatment in reducing the incidence of postoperative adverse reactions, it may be reflected in several different aspects. On the one hand, the improved oxygen supply condition helps to enhance the immune function of the body, enabling the body to better resist the occurrence of various complications such as postoperative infection. On the other hand, an adequate oxygenation state can reduce the degree of ischemia-reperfusion injury to the tissue and the level of inflammatory reaction, and then reduce the frequency and severity of adverse reactions such as swelling and pain, which is also consistent with the research result in this study that the overall incidence of adverse reactions in the HO group was lower than that in the GO group.

Although there were no significant differences between the two groups in terms of the postoperative pain (NRS) score, knee joint score, and surgical satisfaction in the short term, the significant shortening of the length of hospital stay

in the HO group has clinical and economic values that cannot be ignored. A shorter length of hospital stay can not only effectively reduce the economic burden on patients but also help to improve the turnover rate of hospital beds, enabling medical resources to be allocated and utilized more reasonably and efficiently. From a longer-term perspective, this may indirectly reflect that hyperbaric oxygen treatment helps patients to recover their daily living abilities more quickly, enabling them to return to society and family more smoothly, and thus improve the quality of life. Although in this study, we did not conduct a detailed and in-depth assessment of the long-term quality of life of patients, this undoubtedly provides an inspiring idea for the follow-up research directions.

However, this study inevitably has certain limitations. First, since a retrospective research method was adopted in this study, there are inevitably problems such as selection bias and information bias during the research process, and the existence of these problems may have a certain impact on the accuracy of the research results. Second, the sample size of this study is relatively small, which largely limits the wide representativeness and statistical power of the research results. For some subgroup analyses and potential influencing factors, it may not be possible to conduct in-depth and detailed discussions. Third, this study only focused on the early postoperative recovery situation and did not conduct continuous follow-up observations on the long-term efficacy of hyperbaric oxygen treatment. For example, the service life of the joint prosthesis, the long-term recovery of joint function, and whether there are potential adverse effects all need to be further explored in subsequent studies.

In view of this, future studies can actively carry out large-sample, multicenter prospective randomized controlled trials based on this study. During the trials, the inclusion and exclusion criteria should be strictly controlled to minimize the impact of bias factors on the research results. At the same time, the follow-up time should be further extended to comprehensively and systematically evaluate the long-term efficacy and safety of hyperbaric oxygen treatment for patients with Kashin-Beck disease in the plateau area after TKA, covering multiple aspects such as the long-term stability of joint function, the improvement of patients' quality of life, and potential complications. In addition, the key factors such as the optimal timing, course of treatment, and pressure parameters of hyperbaric oxygen treatment can be further explored. By optimizing the treatment plan, more precise and effective treatment strategies can be provided for patients with Kashin-Beck disease in the plateau area, thus effectively improving the overall treatment level and the prognosis quality of patients.

5. Conclusion

This study preliminarily verified the positive role of hyperbaric oxygen treatment in the early recovery stage after TKA for patients with Kashin-Beck disease in the plateau area. However, in order to further improve its clinical application value and treatment plan, more in-depth and comprehensive research work is still needed.

Abbreviations

TKA	Total Knee Arthroplasty
SPO_2	Saturation of Peripheral Oxygen
ECG	Electro Cardio Gram
NIPB	Non-Invasive Blood Pressure
Hr	Heart Rate
RR	Respiratory Rate
QoR - 40	Quality of Recovery-40
NRS	Numerical Rating Scale
KSS	Knee Society Score
BMI	Body Mass Index
ASA	American Society of Anesthesiologists
b - FGF	Basic Fibroblast Growth Factor
TGF	Transforming Growth Factor

Conflicts of Interest

In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work. Human subjects: Consent was obtained by all participants in this study.

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