Application of a 6Sigma-Based Nursing Intervention to Improve Postoperative Recovery in Patients Undergoing Total Hip Arthroplasty: A Retrospective Study

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AIM: Total hip arthroplasty (THA) is a well-established procedure for treating various hip joint diseases. However, postoperative complications and negative outcomes can affect patient recovery and satisfaction. Conventional perioperative interventions have demonstrated limited effectiveness in addressing these challenges. This study aimed to evaluate the effectiveness of a Six Sigma-based intervention model in patients undergoing THA, with a focus on improving postoperative outcomes, reducing complications, and enhancing patient satisfaction.

METHODS: A retrospective study was conducted at a single center, including 155 patients who underwent THA between February 2024 to February 2025. Patients were allocated to either a control group (n = 78), which received standard perioperative care, or an experimental group (n = 77), which received Six Sigma-based perioperative care. The intervention included preoperative education, postoperative rehabilitation guidance, and improved communication between healthcare providers and patients. Primary outcomes included postoperative complications, length of hospital stay, pain levels (visual analog scale (VAS)), hip joint function (Harris Hip Score), functional independence measure (FIM), kinesiophobia (Tampa Scale for Kinesiophobia-11 (TSK-11)), and mental health status (self-rating anxiety scale (SAS), self-rating depression scale (SDS)). Patient satisfaction was evaluated using a custom questionnaire.

RESULTS: No significant differences were observed between the two groups regarding demographic characteristics, American Society of Anesthesiologists (ASA) classification, surgery duration, or intraoperative blood loss ($p > 0.05$). The experimental group experienced significantly shorter hospital stays and earlier postoperative ambulation ($p < 0.001$). At 8 days postoperatively, the experimental group demonstrated significantly higher Harris and FIM scores, and lower TSK-11 scores compared to the control group. Additionally, the experimental group had significantly higher activities of daily living (ADL) and World Health Organization Quality of Life-BREF (WHOQOL-BREF) scale, and significantly lower SAS and SDS scores ($p < 0.05$). Pain scores (VAS) at 48 hours postoperatively were significantly lower in the experimental group ($p < 0.001$). Patient satisfaction was also significantly higher in the experimental group compared to the control group ($p < 0.001$).

CONCLUSIONS: The Six Sigma-based perioperative intervention significantly improved clinical outcomes in THA patients by reducing recovery time, enhancing functional recovery, and improving psychological well-being and patient satisfaction. This model represents an effective approach for optimizing perioperative care in patients undergoing THA.

Keywords: total hip arthroplasty; 6 Sigma theory; rehabilitation nursing

Introduction

Total hip arthroplasty (THA) is a widely utilized surgical technique for the treatment of various hip disorders [1,2]. By implanting a prosthetic device to replace the diseased hip joint, THA restores normal joint function, significantly improving patients' quality of life [3]. With the global aging population and an increasing incidence of hip diseases among younger individuals, the indications for THA have expanded beyond the original age group of 60–75 years to a broader patient population [4]. The spectrum of conditions treated has also widened, now encompassing not only osteoarthritis but also femoral head necrosis, hip fractures, rheumatoid arthritis, ankylosing spondylitis, and other hip pathologies [5,6]. Despite these advances, postoperative complications and adverse reactions remain significant barriers to optimal recovery following THA.

Common postoperative complications of THA include wound infection, prosthetic loosening or displacement, deep vein thrombosis (DVT), and restricted joint mobility [7,8]. These complications can impede recovery, diminish long-term quality of life, and increase the risk of revision surgery. Additionally, since most THA patients are elderly, their declining physiological functions and weakened immune systems further exacerbate the risk of postoperative complications [9]. Therefore, optimizing perioperative management to reduce postoperative adverse reactions and improve recovery outcomes remains a critical challenge in THA care.

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Traditional perioperative care interventions typically include environmental management, health education, posture care, complication prevention, and dietary guidance [10–12]. While these measures can help alleviate postoperative symptoms and promote recovery to some extent, their effectiveness is often limited, particularly when addressing individualized patient needs and variations in recovery. The limitations of conventional care models become more apparent in these contexts. Patients may experience anxiety, depression, and other psychological issues after surgery, and inadequate communication between healthcare providers and patients can lead to suboptimal care outcomes and lower patient satisfaction. These challenges highlight the need for more effective intervention strategies to optimize the postoperative recovery experience for patients.

In recent years, the Six Sigma (6Sigma) theory has emerged as an advanced quality management tool with significant potential for application in healthcare field [13]. Originating in industry and proposed by Bill in 1986, Six Sigma aims to identify and eliminate defects and variations in processes through five systematic steps: Define, Measure, Analyze, Improve, and Control (DMAIC), thereby improving the quality of services and products [14]. The successful application of this theory in industrial production and management has led to its gradual introduction in healthcare to enhance medical quality and optimize patient management processes. Six Sigma has already achieved remarkable results in clinical practices such as operating room management, nursing quality control, and health education [15,16]. Six Sigma theory emphasizes data-driven, patient-centered approaches and uses scientifically rigorous methods to solve clinical problems, characterized by strong systemization and high accuracy [17]. Therefore, applying Six Sigma theory to perioperative nursing interventions in THA may provide new opportunities for improving nursing quality, reducing postoperative complications, and enhancing patient recovery outcomes.

This study aims to explore a perioperative intervention model for THA based on Six Sigma theory. By optimizing the traditional intervention model, the goal is to establish a more scientific, rational, and personalized nursing process that comprehensively enhances postoperative recovery outcomes and quality of life for patients. The study follows the five steps of Six Sigma theory: Define, Measure, Analyze, Improve, and Control. First, patient needs are defined, with particular focus on the differences in psychological and physiological needs after surgery. Next, through interviews and data analysis, the study identifies the deficiencies in current nursing practices. Subsequently, reasonable improvement plans are developed to address these deficiencies. Finally, continuous monitoring and control ensure the stability and ongoing improvement of the intervention's effectiveness.

To verify the practical effectiveness of the Six Sigma intervention model, dividing THA patients to either an experimental group or a control group. The experimental group will receive perioperative nursing interventions based on Six Sigma theory, while the control group will receive conventional nursing care. By comparing clinical indicators such as postoperative pain, functional recovery, psychological state, and quality of life between the two groups, the study aims to evaluate the application value of Six Sigma theory in improving postoperative recovery for THA patients.

Through systematic, data-driven nursing interventions, the model will address the personalized needs of patients, maximize their satisfaction with nursing care, and provide scientific evidence and clinical practice support for the future improvement of perioperative management in THA.

Materials and Methods

General Information

This single-center retrospective study included 155 patients who underwent hip arthroplasty at the Fourth Hospital of Hebei Medical University between February 2024 and February 2025. Patients were divided into two groups based on the type of perioperative care they received. During the initial period, patients receiving conventional perioperative care were assigned to the control group. Subsequently, our hospital implemented perioperative interventions based on the Six Sigma model, and patients who received this new model of care were assigned to the experimental group. Retrospectively, 78 patients were assigned to the control group and 77 to the experimental group. All participants provided written informed. The study was conducted in accordance with the ethical guidelines outlined in the Declaration of Helsinki and received approval from the Ethics Committee of the Fourth Hospital of Hebei Medical University (No. 2024KY255).

The inclusion criteria were the following: (1) patients were diagnosed based on comprehensive clinical symptoms and diagnostic tests, with consent from both the patient and their family for hip arthroplasty; (2) patients were able to tolerate anesthesia; (3) patients had normal limb muscle strength; (4) preoperative ultrasound confirmed normal lower limb blood flow; (5) patients were in a normal mental state and able to communicate effectively with medical staff; and (6) only patients with a hospital stay longer than 8 days.

The exclusion criteria were: (1) presence of neurological disorders leading to limb mobility impairment or hemiplegia due to nerve function deficits; (2) severe damage or infection of the heart, lungs, liver, or kidneys; (3) presence of malignant tumors; (4) patients with coagulation disorders; (5) patients with osteoporosis; (6) patients with immune system disorders; (7) patients who had recently undergone or were undergoing other major surgical procedures; and (8) patients with recent use of antithrombotic drugs.

Intervention Methods

Control Group Intervention Methods

The control group received care according to a conventional intervention protocol, as detailed below:

(1) Environmental care: the ward environment was maintained by regularly disinfecting and ventilating the area. Special attention was paid to anti-slip measures in activity areas. Patients were assigned hardboard beds whenever possible.

(2) Health education: patients were provided with information regarding their disease, surgery, and postoperative rehabilitation precautions to enhance their understanding of the disease and nursing care.

(3) Positioning care: postoperatively, patients were instructed to elevate the affected limb by approximately 20° to promote venous blood return. Patients were guided to perform foot, ankle, and knee movements while in bed. Muscle massages were conducted 3–5 times a day, each session lasting about 15 minutes.

(4) Complication care: postoperative monitoring included assessment of limb blood flow, with particular attention to swelling and pain. Medications such as heparin or aspirin were administered as needed. For patients diagnosed with venous thromboembolism, bed rest was advised, limb massage was strictly prohibited, and emergency treatment protocols were prepared.

(5) Dietary guidance: the dietary approach involved a gradual transition from liquid to semi-liquid food and then to a regular diet. Patients were advised to consume high-quality proteins, vitamin supplements, and a low-salt, low-fat diet. Dietary fiber was included to prevent constipation.

Experimental Group Intervention Methods

The experimental group received an intervention based on the Six Sigma theory, with the process detailed as follows:

(1) Define: in the definition phase, the issue was considered from the patient's perspective, focusing on their needs. The research topic was defined as "improving the clinical outcomes of hip arthroplasty patients through a reasonable perioperative intervention model". The aim was to explore scientific, rational, and efficient intervention methods for THA patients during the perioperative period. A multidisciplinary perioperative intervention team was formed, consisting of three experienced physicians and 8 nurses. The team received training on disease knowledge and THA surgery, focusing on both preoperative and postoperative interventions. This training ensured the professionalism of the basic operations when conducting clinical work.

(2) Measure: due to the advanced age and limited health knowledge of many patients, traditional questionnaires were deemed less effective. Instead, patient interviews were conducted to assess their needs. The results showed that most patients experienced emotions such as fear and anxiety, and expressed a desire for more detailed care and nursing, detailed postoperative rehabilitation guidance, and a kinder and friendlier communication attitude from medical staff.

(3) Analyze: analysis of the interview data identified two key factors influencing THA outcomes: psychological and physiological. Psychological: patients demonstrated limited understanding of the surgical procedure, insufficient communication with medical staff, concerns regarding surgical outcomes, and fear of postoperative complications, leading to negative psychological states. Additionally, the communication between doctors and patients was often brief and impersonal, failing to address higher-level psychological needs such as love, belonging, and respect. Physiological: patients expressed a need for more detailed care, nursing, and specific guidance on postoperative rehabilitation to better understand medical instructions and improve recovery outcomes.

(4) Improve: targeted optimizations were implemented based on the analysis. Personnel training was prioritized to improve healthcare staff's communication skills and attitudes, with the introduction of incentive and accountability measures. Specific interventions included: preoperative health education using images and videos to enhance patient understanding of the disease and surgery; comprehensive assessment of patient information to increase the frequency and quality of communication; postoperative care, involving positioning and complications was provided through one-to-two specialized guidance, with nurses demonstrating the correct rehabilitation exercises, allowing patients to observe and practice, thus improving adherence to medical instructions.

(5) Control: in the Six Sigma theory, the control phase is critical for reducing operating costs and ensuring long-term quality improvement. Continuous monitoring for problems and implementation of solutions ensured ongoing enhancement of service quality. The intervention duration for both groups was 8 days.

Observation Indicators

Postoperative comparisons: the two groups were compared with respect to the occurrence of postoperative infectious complications, urine output, length of hospital stay, and time to first ambulation.

Functional and recovery assessments: assessments were conducted preoperatively and at 8 days postoperatively and included the following:

- Harris hip function score [18]: this scale evaluates four dimensions: function, pain, deformity, and range of motion. Scores range from 0 to 100, with higher scores indicating better hip function recovery.
- Functional independence measure (FIM) [19]: this scale assesses self-care, control, mobility, and social cognition, consisting of 18 items. Total scores range from 18 to 126, with higher scores indicating greater functional independence.
- Tampa Scale for Kinesiophobia-11 (TSK-11) [20]: this

scale measures the severity of kinesiophobia (fear of movement), with a maximum score of 44. Higher scores indicate more severe fear symptoms.

Pain and Emotional Assessments:

- Visual analog scale (VAS) [21]: pain intensity was assessed at 24 and 48 hours postoperatively using the VAS, which ranges from 0 to 10. Higher scores indicate more severe pain.
- Self-rating depression scale (SDS) [22] and self-rating anxiety scale (SAS) [23]: these scales assess patients' negative emotional status. Both scales include 20 items, each rated on a 4-point scale (1–4), with higher total scores indicating more severe anxiety or depression.
- Activities of daily living (ADL) scale [24]: this scale measures the ability to perform basic daily activities, with a total score of 100. Higher scores indicate greater independence in daily activities.
- World Health Organization Quality of Life-BREF (WHOQOL-BREF) scale [25]: this scale evaluates overall health and well-being, including physical health, psychological health, social relationships, and environmental factors, with a total score of 100. Higher scores indicate better quality of life.

Patient Satisfaction: patient satisfaction was evaluated using a self-designed rehabilitation satisfaction questionnaire that was specifically developed for this study to assess patients' perceptions of postoperative recovery care. The questionnaire consisted of 28 items, designed based on literature review and consultation with clinical rehabilitation experts, to ensure both content validity and practical applicability.

The items were categorized into the following four dimensions:

Medical and nursing care (8 items)-including staff responsiveness, professionalism, and communication.

Physical rehabilitation support (7 items)-covering pain management, physical therapy effectiveness, and rehabilitation equipment.

Emotional and psychological support (6 items)-including patient encouragement, anxiety management, and mental well-being support.

Environment and facilities (7 items)-including ward cleanliness, environment comfort, and facility convenience.

Each item was rated on a 4-point Likert scale: 1 = very dissatisfied, 2 = somewhat satisfied, 3 = satisfied, 4 = very satisfied.

The questionnaire was administered 2 months after surgery, and the total satisfaction score was calculated as: (Actual Score/Maximum Total Score) × 100%.

Statistical Analysis

Data were analyzed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Categorical variables were analyzed using the χ^2 test and are presented as [n (%)]. Continuous variables were compared between groups using the *t*-test. The Kolmogorov–Smirnov (K–S) test was used to assess the normality of the data. For data that conforms to normal distribution, data are presented as mean ± standard deviation (SD). A p-value < 0.05 was considered statistically significant.

Results

Analysis of Patient General Information

In the control group, there were 41 males and 37 females. A total of 71 cases underwent unilateral hip arthroplasty, and 7 cases underwent bilateral hip arthroplasty. According to the American Society of Anesthesiologists (ASA) classification, 38 patients were classified as ASA I and 40 as ASA II. In the experimental group, there were 42 males and 35 females; 69 patients underwent unilateral hip arthroplasty, and 8 underwent bilateral hip arthroplasty. According to the ASA classification, 37 patients were classified as ASA I and 40 as ASA II. The surgery duration for the control group was 0.79 ± 0.08 hours, while for the experimental group it was 0.80 ± 0.11 hours. The intraoperative blood loss for the control group was 268.76 ± 15.26 mL, and for the experimental group it was 267.69 ± 15.93 mL. There were no statistically significant differences in the general data between the two groups ($p > 0.05$), allowing for comparison and analysis (Table 1).

Comparison of Functional Recovery Between the Two Groups

There were no statistically significant differences between the two groups regarding postoperative infection complications and urine output ($p > 0.05$). The experimental group had a significantly shorter hospital stay and a shorter time to first ambulation compared to the control group ($p < 0.001$). Preoperatively, there were no significant differences between the two groups in Harris scores, FIM scores, and TSK-11 scores ($p > 0.05$). However, at 8 days postoperatively, both Harris and FIM scores were significantly higher, and TSK-11 scores were significantly lower than preoperative levels in both groups. Furthermore, at 8 days postoperatively, the experimental group demonstrated significantly higher Harris and FIM scores and significantly lower TSK-11 scores compared to the control group ($p < 0.001$) (Table 2).

Comparison of VAS, ADL, SAS, SDS, WHOQOL-BREF, and Patient Satisfaction Between the Two Groups

There were no statistically significant differences in VAS scores between the two groups at 24 hours postoperatively ($p > 0.05$). Additionally, at 48 hours, the experimental group exhibited significantly lower VAS scores than the control group ($p < 0.001$). Preoperatively, no statistically significant differences were observed between the two groups in ADL, SAS, SDS, and WHOQOL-BREF scores ($p > 0.05$). Furthermore, at 8 days postoperatively, the experimental group had significantly higher ADL and WHOQOL-

Table 1. General information of patients.

Factors	Control group (n = 78)	Experimental group (n = 77)	χ^2/t	p
Gender (n/%)				
Male	41 (52.56)	42 (54.55)	0.061	0.805
Female	37 (47.44)	35 (45.45)		
Age (years)	61.89 ± 4.01	61.00 ± 3.90	1.403	0.163
Replacement type (n/%)				
Unilateral hip replacement	71 (91.03)	69 (89.61)	0.089	0.766
Bilateral hip replacement	7 (8.97)	8 (10.39)		
ASA classification (n/%)				
I	38 (48.72)	37 (48.05)	0.007	0.934
II	40 (51.28)	40 (51.95)		
Duration of surgery (h)	0.79 ± 0.08	0.80 ± 0.11	0.648	0.518
Intraoperative blood loss (mL)	268.76 ± 15.26	267.69 ± 15.93	0.428	0.669

ASA, American Society of Anesthesiologists.

Table 2. Comparison of functional recovery between the two groups.

Factors	Control group (n = 78)	Experimental group (n = 77)	χ^2/t	p
With or without complications (n/%)				
With complications	6 (7.69)	5 (6.49)	0.084	0.771
Without complications	72 (92.31)	72 (93.51)		
Urine output (mL)	151.67 ± 18.32	151.28 ± 16.49	0.139	0.889
Length of stay (days)	11.23 ± 1.15	9.57 ± 1.00	9.591	<0.001
Time to first ambulation (days)	2.09 ± 0.18	1.45 ± 0.16	23.720	<0.001
Preoperative Harris score	66.77 ± 6.66	65.67 ± 6.45	1.047	0.297
Postoperative 8-day Harris score	78.99 ± 7.93	86.70 ± 8.26	5.931	<0.001
Preoperative FIM score	63.44 ± 5.98	62.54 ± 6.08	0.927	0.355
Postoperative 8-day FIM score	87.78 ± 8.88	98.65 ± 9.54	7.347	<0.001
Preoperative TSK-11 score	35.67 ± 3.81	34.91 ± 3.54	1.292	0.198
Postoperative 8-day TSK-11 score	22.33 ± 2.38	18.54 ± 1.77	11.250	<0.001

FIM, functional independence measure; TSK-11, Tampa Scale for Kinesiophobia-11.

BREF scores and significantly lower SAS and SDS scores than the control group ($p < 0.001$). In addition, the patient satisfaction was significantly higher in the experimental group than in the control group ($p < 0.001$) (Table 3).

Discussion

In this study, we explored the effects of applying Six Sigma (6Sigma) theory to perioperative intervention in THA. The experimental group received an intervention model based on Six Sigma theory, while the control group followed the conventional nursing model. By comparing clinical outcomes between the two groups, we derived the following findings and discussion.

First, patients in the experimental group demonstrated significantly better functional recovery compared to the control group. At 8 days postoperatively, the Harris Hip Scores and FIM scores were significantly higher in the experimental group, while the TSK-11 scores were significantly lower ($p < 0.05$). These results suggest that the Six Sigma-based intervention not only accelerated hip joint functional recovery but also effectively reduced patients' fear of postoperative activities. This is consistent with findings reported by Wang *et al*. [26], who found that personalized nursing plans can effectively improve postoperative functional outcomes. In this study, the implementation of a dedicated nursing approach with clearly defined responsibilities enabled more detailed guidance on postoperative positioning, complication care, and rehabilitation training, thereby significantly enhancing recovery.

Regarding pain management, the VAS scores at 48 hours postoperatively were significantly lower of patients in the experimental group compared to the control group ($p < 0.001$), indicating superior pain control with the Six Sigma intervention. This aligns with Li *et al*. [27], who demonstrated that enhanced pain management strategies such as postoperative health education and communication skills training, improve early postoperative pain outcomes. These findings validate the importance of the "improvement" phase in Six Sigma theory, where optimization of nursing processes effectively alleviates patients' pain experiences.

Table 3. Comparison of VAS, ADL, SAS, SDS, WHOQOL-BREF, and patient satisfaction between the two groups.

Factors	Control group (n = 78)	Experimental group (n = 77)	*t*	*p*
Postoperative 24-h VAS Score	3.67 ± 0.90	3.47 ± 0.88	1.382	0.169
Postoperative 48-h VAS Score	2.57 ± 0.57	2.14 ± 0.51	4.984	<0.001
Preoperative ADL Score	64.56 ± 5.60	65.79 ± 3.98	1.570	0.118
Postoperative 8-day ADL Score	78.26 ± 4.61	87.73 ± 5.16	12.052	<0.001
Preoperative SAS score	57.23 ± 5.25	56.33 ± 4.53	1.148	0.253
Postoperative 8-day SAS score	38.14 ± 3.51	30.20 ± 3.13	14.856	<0.001
Preoperative SDS score	59.16 ± 7.07	58.16 ± 6.40	0.922	0.358
Postoperative 8-day SDS score	40.21 ± 4.04	35.49 ± 3.15	8.113	<0.001
Preoperative WHOQOL-BREF score	38.69 ± 5.15	39.16 ± 5.27	0.562	0.575
Postoperative 8-day WHOQOL-BREF score	55.23 ± 6.78	74.33 ± 7.34	16.806	<0.001
Patient satisfaction	91.34 ± 5.60	97.77 ± 6.12	6.826	<0.001

VAS, visual analog scale; ADL, activities of daily living; SAS, self-rating anxiety scale; SDS, self-rating depression scale; WHOQOL-BREF, World Health Organization Quality of Life-BREF.

Furthermore, patients in the experimental group showed significant improvements in quality of life and psychological state. At 8 days postoperatively, ADL and WHOQOL-BREF scores were significantly higher, while the SAS and SDS scores were significantly lower compared to the control group ($p < 0.001$). This indicates that the Six Sigma intervention not only enhanced physical recovery but also achieved notable progress in mental health. These results corroborate those of Li *et al*. [28], who highlighted the positive impact of comprehensive nursing interventions on patients' psychological states. Through detailed psychological care, personalized communication, and attention, anxiety and depression of patients in the experimental group were significantly alleviated, contributing to improved overall quality of life.

Finally, patient satisfaction was significantly higher in the experimental group than in the control group ($p < 0.001$), reflecting the unique advantages of the Six Sigma theory in enhancing patient-centered care. During the phases of definition, measurement, analysis, and improvement, the research team conducted interviews to thoroughly understand individual needs and developed personalized care plans based on those needs. The data indicate that the Six Sigma approach notably improved doctor-patient communication, enhanced care quality, and reduced negative emotional experience, ultimately increasing overall patient satisfaction.

Conclusions

In conclusion, this study demonstrates the significant advantages of the Six Sigma-based intervention model in the perioperative management of THA surgery. By systematically implementing the phases of definition, measurement, analysis, improvement, and control, the Six Sigma intervention model effectively improves patients' functional recovery, pain management, and psychological well-being, thereby significantly improving quality of life and patient satisfaction. Compared to traditional care models, this intervention shows superior clinical outcomes and holds broad application prospects. Future research should explore its use in other types of surgeries and further validate its effectiveness across different patient populations.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

XG drafted the manuscript. XG and JG designed the research study. XG and JG performed the research. XG analyzed the data. Both authors have been involved in revising it critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Fourth Hospital of Hebei Medical University (NO. 2024KY255). All procedures utilized in this study adhered to the ethical principles outlined in the Declaration of Helsinki. All participants provided written informed.

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Conflict of Interest

The authors declare no conflict of interest.

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