Article

# Analysis of Factors Affecting Range of Motion Loss after Elbow Joint Release Surgery in Elderly Patients with Traumatic Elbow Stiffness

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AIM: Elbow joint release surgery is commonly used to treat elbow joint stiffness. Though it can restore elbow joint mobility, some patients may still experience range of motion (ROM) loss after surgery. Therefore, this study aims to explore the factors influencing ROM loss after elbow joint release surgery in elderly patients with traumatic elbow stiffness.

METHODS: This retrospective study included 122 elderly patients with traumatic elbow stiffness who underwent elbow joint release surgery at Hanzhong Central Hospital from January 2023 to April 2024. The patients with range of motion loss were included in the observation group (n = 41), and those without range of motion loss were placed in the control group (n = 81). The general data of the two groups were compared, and Logistic regression analysis was performed to identify factors influencing the loss of ROM after elbow joint release surgery in elderly patients with traumatic elbow stiffness. A risk prediction model was also established based on the identified risk factors.

RESULTS: Multivariate Logistic regression analysis unveiled that high-energy injury (odds ratio (OR) = 4.632, 95% confidence interval (CI) = 1.363∼15.737), open injury (OR = 3.967, 95% CI = 1.308∼12.029), passive rehabilitation method (OR = 10.115, 95% CI = 1.113∼91.924), injury-to-release surgery time of ≥6 months (OR = 5.983, 95% CI = 1.677∼21.350), heterotopic ossification traumatic factors (OR = 5.409, 95% CI = 1.316∼22.224), and complex elbow joint damage (OR = 5.658, 95% CI = 1.457∼21.962) were all independent risk factors for ROM loss following elbow joint release surgery in elderly patients with traumatic elbow stiffness ($p < 0.05$). A risk prediction model was developed based on these factors, indicating a predictive sensitivity of 73.17%, a specificity of 69.14%, and an area under the curve (AUC) of 0.767.

CONCLUSIONS: Clinically, the independent risk factors identified in this study should be closely monitored. Furthermore, treatment should be tailored based on the specific conditions of the patient, and high-risk factors should be effectively controlled to reduce the risk of ROM loss after elbow joint release surgery in traumatic elbow joint stiffness elderly patients.

**Keywords:** traumatic elbow joint stiffness; elderly; elbow joint release surgery; postoperative loss of range of motion; influencing factors

## Introduction

Elbow stiffness is a general term describing the loss of elbow joint function due to various causes, such as articular cartilage defects, contractures of periarticular soft tissue, bone nonunion, malunion, and heterotopic ossification [1, 2]. Complex elbow fractures resulting from high-energy injury damage the bone structure and influence the joint capsule and ligaments, complicating treatment. Fragility fractures from low-energy injuries, where the fracture ends are near the joint, often lead to poor surgical fixation outcomes. These cases require prolonged immobilization with plaster, elevating the risk of elbow stiffness [3, 4]. Clinically, patients exhibit symptoms including limited elbow movement, inability to fully extend or flex the joint, and, in some cases, complete immobility [5]. Additionally, patients may experience stiffness, pain, and swelling in the elbow, affecting various aspects of daily life. To restore normal elbow function, elbow joint release surgery is widely utilized to treat elbow stiffness. Nevertheless, postoperative loss of range of motion (ROM) remains a significant concern [6, 7].

As the population ages, the incidence of elbow stiffness among the older people is gradually increasing. This condition limits elbow movement, prevents normal flexion and extension, and severely impacts the daily lives and work of patients [8]. Therefore, restoring normal elbow mobility is particularly crucial for elderly patients and elbow joint release surgery is considered an effective treatment approach. This surgery involves surgical intervention to alleviate elbow stiffness, typically including the incision of the joint capsule and ligaments to restore joint mobility [9, 10]. Nonetheless, studies have indicated that even after surgical treatment, many patients still experience a recurrence of ROM loss over time. This affects the surgical outcome and also poses significant challenges to the patient's life and rehabilitation. The causes of this phenomenon are

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complex and may be associated with the patient's underlying pathology, intraoperative techniques, and postoperative rehabilitation training [11]. Hence, investigating the factors influencing the recurrence of ROM loss following elbow joint release surgery in elderly patients with traumatic elbow stiffness is essential for developing individualized prevention and intervention strategies. Current clinical research primarily focuses on analyzing specific factors affecting joint range of motion after traumatic elbow surgery. However, there is no comprehensive study investigating the factors influencing the loss of ROM in elderly patients with traumatic elbow stiffness following elbow joint release surgery. Therefore, conducting research in this area could fill the existing gap in the literature, providing a more comprehensive and systematic understanding, thereby optimizing the management and rehabilitation strategies following elbow joint release surgery.

This research employs a retrospective cohort approach to analyze elderly patients with traumatic elbow stiffness treated at Hanzhong Central Hospital, China. The investigation primarily assesses factors correlated with the loss of ROM post-surgery, including the general condition of patients, types of traumas, intraoperative procedures, and postoperative rehabilitation training. The objective of this study is to provide a foundation for clinical diagnosis and treatment and to offer new insights for improving the prognosis of these patients.

## Materials and Methods

*General Data of Study Participants*

A retrospective analysis was performed on the general clinical data of 122 elderly patients with traumatic elbow stiffness who underwent elbow joint release surgery at Hanzhong Central Hospital from January 2023 to April 2024. Based on the latest follow-up evaluations of elbow joint rotation and flexion-extension post-surgery, study participants were divided into two groups. Patients with an elbow flexion-extension range or forearm rotation range of 100° or less were classified as having experienced a loss of ROM and were included in the observation group (n = 41). However, those with an elbow flexion-extension range or forearm rotation range greater than 100° were classified as not having experienced a loss of ROM and were included in the control group (n = 81). This research complies with the ethical guidelines of the Helsinki Declaration. All patients signed written informed consent forms. Furthermore, the study followed the guidelines of the World Medical Association Declaration of Helsinki and obtained approval from the Ethics Committee of Hanzhong Central Hospital (ethics approval number: 20230115-HZ-0029).

*Inclusion and Exclusion Criteria*

The inclusion criteria were as follows: (1) The patients were diagnosed with traumatic elbow stiffness [12], showing significant movement restriction in the affected limb, and were non-responsive to over six months of conservative treatment. (2) Imaging examinations indicated no abnormalities in the joint space, with normal elbow cartilage. (3) Patients with normal muscle strength. (4) Those who underwent elbow joint release surgery at Hanzhong Central Hospital. (5) Those aged 60 years and above. (6) Patients with the American Society of Anesthesiologists (ASA) classification ranging from I to II.

However, exclusion criteria included (1) hemiplegic and chronic infections patients, (2) patients intolerant to surgery, (3) primary arthritis patients, (4) those with elbow joint bone deformities due to orthomorphia, and (5) patients with severe immune system diseases.

*Surgical Interventions*

All patients received either local or combined general anesthesia. A Kocher incision was made on the lateral aspect of the elbow. The elbow joint capsule was exposed between the triceps muscle of the arm and brachioradialis, as well as between the anconeus and the extensor carpi ulnaris. Adhesions anterior and posterior to the joint capsule were dissected and removed. The joint capsule was then opened, and intra-articular adhesions were cleared, with particular attention to thoroughly removing scar tissues in the coronoid fossa and the olecranon process. Under direct vision, the elbow joint was passively extended and flexed (with moderate force), stretching tense muscles and remaining adhesions to achieve near-normal ROM. Loose bone fragments or misaligned healing bone blocks within the joint were removed. If joint movement did not reach the normal range, the thickened joint capsule was probed and excised. During the procedure, the radial nerve was protected from any damage. When heterotopic ossification and/or ulnar nerve symptoms were present on the medial side, a medial incision centered on the medial epicondyle was adopted to explore and anteriorly reposition the ulnar nerve. Heterotopic ossification tissues were removed, and adhesions on the medial and posterior sides were examined and cleared if present.

*Collection of General Data*

We collected baseline data on age, body mass index (BMI), gender, location of stiffness, preoperative Mayo Elbow Performance Score (MEPS), preoperative disabilities of the arm, shoulder and hand (DASH) score, preoperative visual analogue scale (VAS) score, presence of other fractures, complex elbow joint injury, concomitant shoulder stiffness, concomitant wrist stiffness, ulnar neuritis, myositis ossificans, trauma types, open injury, rehabilitation methods, time from injury to release surgery, traumatic factors, postoperative complications, vascular injury, and nerve damage from both cohorts of patients.

**Table 1. Univariate analysis of factors influencing ROM loss after elbow joint release surgery in traumatic elbow stiffness elderly patients.**

| General data | | Observation group (n = 41) | Control group (n = 81) | $\chi^2/t$ | $p$-value |
|---|---|---|---|---|---|
| Age (years) | | 51.26 $\pm$ 6.44 | 51.34 $\pm$ 6.19 | 0.067 | 0.947 |
| BMI (kg/m$^2$) | $\geq$24 | 16 | 35 | 0.196 | 0.658 |
| | <24 | 25 | 46 | | |
| Gender | Male | 19 | 41 | 0.199 | 0.655 |
| | Female | 22 | 40 | | |
| ASA classification | ASAI | 20 | 39 | 0.004 | 0.947 |
| | ASAII | 21 | 42 | | |
| Stiffness location | Left side | 23 | 35 | 1.813 | 0.178 |
| | Right side | 18 | 46 | | |
| Trauma types | High-energy injury | 29 | 36 | 7.557 | 0.006 |
| | Low-energy injury | 12 | 45 | | |
| Open injury | Presence | 30 | 39 | 6.937 | 0.008 |
| | Absence | 11 | 42 | | |
| Rehabilitation methods | Passive | 31 | 45 | 4.661 | 0.031 |
| | Non-passive | 10 | 36 | | |
| Preoperative MEPS score | | 61.25 $\pm$ 7.44 | 62.35 $\pm$ 7.49 | 0.768 | 0.444 |
| Preoperative DASH score | | 41.26 $\pm$ 5.11 | 40.98 $\pm$ 5.36 | 0.277 | 0.782 |
| Preoperative VAS score | | 2.13 $\pm$ 0.25 | 2.15 $\pm$ 0.26 | 0.406 | 0.685 |
| Time from injury to release surgery (months) | $\geq$6 months | 29 | 25 | 17.537 | <0.001 |
| | <6 months | 12 | 56 | | |
| Combined fractures | Presence | 21 | 35 | 0.703 | 0.402 |
| | Absence | 20 | 46 | | |
| Traumatic factors | Fractures | 11 | 34 | 14.054 | 0.001 |
| | Heterotopic ossification | 21 | 15 | | |
| | Elbow replacement | 9 | 32 | | |
| Postoperative complications | Presence | 26 | 35 | 4.445 | 0.035 |
| | Absence | 15 | 46 | | |
| Complex elbow joint damage | Presence | 27 | 37 | 4.443 | 0.035 |
| | Absence | 14 | 44 | | |
| Concomitant shoulder stiffness | Presence | 16 | 32 | 0.003 | 0.959 |
| | Absence | 25 | 49 | | |
| Concomitant wrist stiffness | Presence | 19 | 36 | 0.040 | 0.842 |
| | Absence | 22 | 45 | | |
| Concomitant ulnar neuritis | Presence | 23 | 56 | 2.028 | 0.154 |
| | Absence | 18 | 25 | | |
| Concomitant myositis ossificans | Presence | 27 | 45 | 1.194 | 0.275 |
| | Absence | 14 | 36 | | |
| Vascular injury | Presence | 31 | 52 | 1.630 | 0.202 |
| | Absence | 10 | 29 | | |
| Nerve damage | Presence | 28 | 36 | 6.208 | 0.013 |
| | Absence | 13 | 45 | | |

ROM, range of motion; BMI, body mass index; ASA, American Society of Anesthesiologists; MEPS, Mayo Elbow Performance Score; DASH, disabilities of the arm, shoulder and hand; VAS, visual analogue scale.

*Establishment of the Risk Prediction Model*

Using the identified risk factors, a logistic regression model was constructed to predict the loss of ROM after elbow joint release surgery in elderly patients with traumatic elbow stiffness. The partial regression coefficients from the logistic regression analysis were incorporated into the predictive model. The model's performance was evaluated using the area under the curve (AUC), with an AUC above 0.7 indicating good predictive efficiency for the endpoint event.

*Statistical Analysis*

The data were statistically analyzed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). The normality of the

**Table 2. Assignment methods.**

| Factors | Assignment methods |
|---|---|
| Trauma types | 1 = high-energy injury; 0 = low-energy injury |
| Open injury | 1 = presence; 0 = absence |
| Rehabilitation methods | 1 = passive; 0 = non-passive |
| Time from injury to release surgery | 1 = $\geq$6 months; 0 = $<$6 months |
| Traumatic factors | 1 = heterotopic ossification; 0 = fractures, elbow replacement |
| Complex elbow joint damage | 1 = presence; 0 = absence |
| Postoperative complications | 1 = presence; 0 = absence |
| Nerve injury | 1 = presence; 0 = absence |

**Table 3. Multivariate analysis of factors affecting the loss of ROM following elbow joint release surgery in elderly patients with traumatic elbow stiffness.**

| Independent variables | $\beta$ value | *SE* value | *Wald*$\chi^2$ value | *OR* | 95% CI | *p*-value |
|---|---|---|---|---|---|---|
| Trauma types | 1.533 | 0.624 | 6.036 | 4.632 | 1.363∼15.737 | 0.014 |
| Open injury | 1.378 | 0.566 | 5.927 | 3.967 | 1.308∼12.029 | 0.015 |
| Rehabilitation methods | 2.314 | 1.126 | 4.223 | 10.115 | 1.113∼91.924 | 0.040 |
| Time from injury to release surgery | 1.789 | 0.649 | 7.599 | 5.983 | 1.677∼21.350 | 0.006 |
| Traumatic factors | 1.688 | 0.721 | 5.481 | 5.409 | 1.316∼22.224 | 0.020 |
| Complex elbow joint damage | 1.733 | 0.692 | 6.272 | 5.658 | 1.457∼21.962 | 0.013 |
| Postoperative complications | 1.254 | 0.712 | 3.102 | 3.504 | 0.868∼14.147 | 0.079 |
| Nerve injury | 1.154 | 0.822 | 1.971 | 3.171 | 0.633∼15.881 | 0.161 |

CI, confidence interval; SE, standard error; OR, odds ratio.

data was examined using the Kolmogorov-Smirnov test. Unordered categorical data were analyzed using the $\chi^2$ test, while measurement data were presented as mean $\pm$ standard deviation ($\bar{x} \pm$ s) and analyzed using an independent sample *t*-test. Logistic regression analysis was employed to identify factors influencing the loss of ROM after elbow joint release surgery in elderly patients with traumatic elbow stiffness. Sensitivity, specificity, and AUC were determined utilizing the receiver operating characteristic curve (ROC). Finally, cross-validation was used to evaluate the performance of the prediction model. Differences were considered statistically significant when $p < 0.05$.

## Results

### *Univariate Analysis of Factors Influencing ROM Loss after Elbow Joint Release Surgery in Traumatic Elbow Stiffness Elderly Patients*

There were no significant differences between the two groups regarding age, BMI, gender, stiffness location, preoperative MEPS score, preoperative DASH score, preoperative VAS score, combined fractures, combined shoulder stiffness, vascular damage, combined wrist stiffness, combined ulnar neuritis, and combined myositis ossificans ($p >$ 0.05). Nevertheless, there were substantial differences between the two cohorts regarding trauma types, open injury, rehabilitation methods, time from injury to release surgery, traumatic factors, complex elbow joint damage, postoperative complications, and nerve damage ($p < 0.05$). Univariate analysis of factors influencing ROM loss is shown in Table 1.

### *Multivariate Analysis of Factors Influencing the Loss of ROM Following Elbow Joint Release Surgery in Elderly Patients with Traumatic Elbow Stiffness*

The single-factor variables listed above were assigned values as mentioned in Table 2 and entered into a Logistic regression equation for multivariate analysis. The findings revealed that high-energy injury, open injury, passive rehabilitation methods, time from injury to release surgery of $\geq$6 months, heterotopic ossification traumatic factors, and complex elbow joint damage were all independent risk factors affecting ROM loss after elbow joint release surgery in elderly patients with traumatic elbow stiffness ($p < 0.05$). A multivariate analysis of factors influencing the loss of ROM is shown in Table 3.

### *Construction of the Risk Prediction Model for ROM Loss after Elbow Joint Release Surgery in Elderly Patients with Traumatic Elbow Stiffness*

A risk prediction model for the loss of ROM following elbow joint release surgery in elderly patients with traumatic elbow stiffness was established using factors such as high-energy injury, open injury, passive rehabilitation methods, time from injury to release surgery of $\geq$6 months, heterotopic ossification traumatic factors, and complex elbow joint damage. The probability *p* was calculated using the formula:

$$p = 1/[1 + e^{(1.533\times\text{high-energy injury}+1.378\times\text{open injury}+2.314\times\text{passive rehabilitation methods}+1.789\times\text{time from injury to release surgery}\geq\text{6months}+1.688\times\text{heterotopic ossification traumatic factor}+1.733\times\text{complex elbow joint injury})}].$$

**Table 4. Construction of the risk prediction model for ROM loss after elbow joint release surgery in elderly patients with traumatic elbow stiffness.**

| Factors | AUC | *SE* | 95% CI | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|
| Trauma types | 0.631 | 0.045 | 0.539∼0.717 | 70.73 | 55.56 |
| Open injury | 0.644 | 0.045 | 0.552∼0.728 | 73.17 | 55.56 |
| Rehabilitation methods | 0.600 | 0.044 | 0.508∼0.688 | 75.61 | 44.44 |
| Time from injury to release surgery | 0.699 | 0.044 | 0.610∼0.779 | 70.73 | 69.14 |
| Traumatic factors | 0.664 | 0.045 | 0.572∼0.747 | 51.22 | 81.48 |
| Complex elbow joint damage | 0.601 | 0.047 | 0.508∼0.688 | 65.85 | 54.32 |
| Prediction | 0.767 | 0.042 | 0.682∼0.839 | 73.17 | 69.14 |

AUC, area under the curve.

**Table 5. Validation of predictive model performance.**

| Actual range of motion loss groups | Predicted range of motion loss groups | | | | Total |
|---|---|---|---|---|---|
| | Observation group | | Control group | | |
| | Number of cases | Composition ratio (%) | Number of cases | Composition ratio (%) | |
| Observation group | 39 | 95.12 | 2 | 4.88 | 41 |
| Control group | 11 | 13.58 | 70 | 86.42 | 81 |

The ROC curve analysis of the risk factors unveiled a sensitivity of 73.17%, a specificity of 69.14%, and an AUC of 0.767, as shown in Table 4 and Fig. 1.

*Validation of the Predictive Performance of the Model*

Using loss of range of motion as the categorical variable and the predicted probability *p*-value as the independent variable, cross-validation was employed to assess the model's predictive performance. The results showed that the classification accuracy of the predictive model was 89.34% (109/122, Table 5).

## Discussion

Traumatic elbow stiffness is a prevalent and severe joint disease that restricts the elbow joint ROM of patients, severely affecting their quality of life and daily activities. To help patients regain normal elbow joint function, elbow joint release surgery is extensively used [13, 14]. However, while surgery usually helps patients recover to a certain extent, sometimes patients may lose ROM postoperatively, posing new challenges to their recovery and daily life [15, 16]. In clinical practice, research on the factors influencing the loss of ROM following elbow joint release surgery in elderly patients with traumatic elbow stiffness has not received sufficient attention.

Using multivariate Logistic regression analysis, we identified high-energy injury, open injury, passive rehabilitation, injury-to-release surgery time of $\geq$6 months, heterotopic ossification traumatic factors, and complex elbow joint damage as independent risk factors affecting ROM loss following elbow joint release surgery among elderly patients with traumatic elbow stiffness. Analyses of these factors unraveled the following: (1) High-energy injuries are often accompanied by severe soft tissue damage, such as muscle, ligament, and nerve damage, which can influence the stability and functional recovery of the elbow joint [17]. Additionally, high-energy injuries may lead to multiple or open fractures, and the type and complexity of fractures can influence recovery and ROM after elbow joint release surgery [18]. High-energy injuries can also cause severe damage to the elbow joint surface, such as damage to the articular cartilage, which can affect normal joint function and ROM [19]. Therefore, in clinical treatment, it is crucial to closely monitor and manage patients with high-energy injuries, develop personalized rehabilitation plans, and attenuate the risk of ROM loss. (2) In this study, open injuries were found to increase the risk of postoperative loss of ROM in elderly patients with traumatic elbow stiffness following elbow joint release surgery. This finding aligns with the findings of Chen Chen *et al*. [20], who indicated that open injuries could lead to poor outcomes in the treatment of post-traumatic elbow stiffness with modified elbow release surgery. This suggests that clinical practice should focus on better monitoring and management of open injuries in patients with traumatic elbow conditions before surgery. Furthermore, our findings indicated that open injuries increase the risk of surgical complications, such as infections and tissue damage, which can hinder postoperative rehabilitation and lead to a further loss of ROM [21]. Compared to closed injuries, open injuries typically cause greater tissue damage and trauma, affecting the surgical process and postoperative healing, thereby elevating the risk of ROM loss [22]. Thus, special attention should be paid to the risk factor of open injury, and appropriate preventive and management measures should be taken to alleviate the risk of ROM loss after surgery. (3) If the plan for passive rehabilitation is unreasonable or too intense, it can cause overstretching or damage to the elbow joint, negatively impacting the recovery of ROM [23]. Improper or intense passive rehabilitation may lead to complications, such as muscle injuries or joint dislocations, further affecting ROM recovery [24]. Hence, personalized rehabilitation plans should be developed based on the patient's specific conditions to ensure the safety and effectiveness of passive rehabilitation, maximizing elbow joint ROM recovery and alleviating the risk of ROM loss. (4) Prolonged injury time can result in severe elbow stiffness, requiring longer time and effort to restore joint ROM following release surgery, thereby increasing the risk of ROM loss [25]. Prolonged periods of restraint and restricted activity can lead to substantial alterations in the soft tissue structures around the joint, such as muscle atrophy and ligament contracture, complicating the recovery process and bolstering the risk of ROM loss [26]. Therefore, conservative treatment, such as joint activity training and physical therapy, should be administered to patients before surgery to enhance joint ROM and mitigate surgical difficulty. (5) Heterotopic ossification can restrict and compress the soft tissues around the joint, limiting the normal ROM of the elbow joint and elevating the likelihood of ROM loss [27]. It may also result in complications such as arthritis, heightening the risk of recurring elbow stiffness and further ROM loss [28]. Hence, the evaluation of heterotopic ossification in patients preceding surgery, the development of corresponding surgical plans and rehabilitation plans, and close monitoring of patient recovery progress after surgery are warranted to intervene and handle heterotopic ossification in a timely manner, attenuating the risk of ROM loss and ensuring the best rehabilitation outcomes. (6) Complex elbow joint damage can impair the structural stability of the elbow joint, increasing the risk of ROM loss again. Even following release surgery, the complexity of the injury can make it challenging to restore elbow joint function [29]. Such damage can affect joint stability, making the elbow joint more prone to stiffness during activity and boosting the risk of ROM loss [30]. Therefore, a comprehensive preoperative assessment of the elbow joint damage and the development of personalized treatment plans, including surgical and rehabilitation approaches, are essential to reduce the risk of ROM loss. Additionally, the study found that factors such as high-energy injury, open injury, passive rehabilitation, injury-to-release surgery time of $\geq$6 months, heterotopic ossification traumatic factors, and complex elbow joint injury were more effective in predicting the ROM loss after elbow joint release surgery in elderly patients with traumatic elbow stiffness. This substantiates that identifying these factors can help doctors better assess the risk of elbow joint ROM loss following release surgery in elderly patients, providing a solid basis for targeted interventions to reduce this risk. Additionally, our findings revealed that the model's predictive performance, assessed through cross-validation, demonstrated a high accuracy. This suggests that the model developed in this study effectively predicts ROM loss in elderly patients with traumatic elbow stiffness following elbow joint release surgery. Overall, our study may help optimize surgical treatment strategies, reduce the risk of postoperative activity loss, and positively impact recovery and quality of life for elderly patients.

However, the limitation of the study is its reliance on retrospective analysis of past data, which may be incomplete or biased and could affect the evaluation of the conclusions. Future efforts should focus on enhancing data collection and management and incorporating cutting-edge technologies such as big data and artificial intelligence to expand the sources and types of data, improving the coverage and accuracy of the analysis.

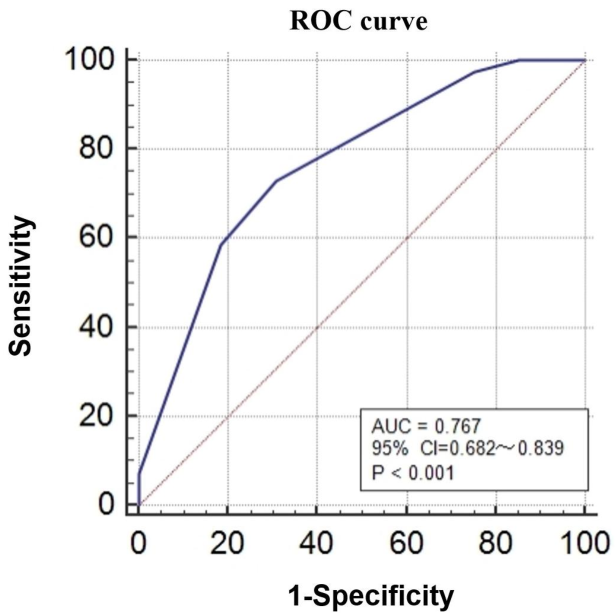


**Fig. 1. ROC curve of the risk prediction model for ROM loss after elbow joint release surgery in elderly patients with traumatic elbow stiffness.** ROC, receiver operating characteristic curve.

## Conclusions

In summary, for elderly patients with traumatic elbow stiffness undergoing elbow joint release surgery, clinicians should closely monitor factors such as high-energy injury, open injury, passive rehabilitation methods, injury-to-release surgery time of $\geq$6 months, heterotopic ossification traumatic factors, and complex elbow joint damage during the perioperative period. Implementing proactive and efficacious preventive and intervention measures is crucial to prevent ROM loss post-surgery and enhance treatment outcomes. These findings provide valuable insights for developing more effective rehabilitation strategies and surgical interventions in the future, thereby optimizing treatment outcomes and advancing clinical practice.

## Availability of Data and Materials

The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

## Author Contributions

LPZ and FFQ designed the research study; LPZ, FFQ and XDZ performed the research; FFQ and XDZ collected and analyzed the data. LPZ, FFQ and XDZ has been involved in drafting the manuscript and all authors have been involved in revising it critically for important intellectual content. All authors give final approval of the version to be published. All 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 has been approved by the Ethics Committee of Hanzhong Central Hospital (ethics approval number: 20230115-HZ-0029). This research complies with the ethical guidelines of the Helsinki Declaration. All patients signed written informed consent forms.

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## Conflict of Interest

The authors declare no conflict of interest.

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