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RESEARCH ARTICLE

The Effect of Ultrasound-Guided Treatment of Symptomatic Partial Rotator Cuff Injury Under the Background of Deep Learning

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Abstract

Deep learning is one of the most powerful machine learning algorithms at present. The convolutional neural network model has the ability to automatically learn features, and has a greater performance advantage than other deep learning models in the field of image processing. Based on deep learning, the effects of platelet-rich plasma injection of betamethasone on shoulder pain and function in patients with partial rotator cuff injury were investigated. Eighty patients with tendinosis or a partial tear (<1.0 cm) were recruited between 2021 and 2022. Mixed injection of 1 mL betamethasone and 5 mL lidocaine, following 5 mL PRP injected in 7-day intervals, were infiltrated directly into the lesion of supraspinatus interstitial RCT under ultrasound control. The patients were assessed by the SPADI, CMS and ASES before and 1, 3, 6, 9 months after injection. MRI was also performed before and 6 months after injection. All patients had significant better ASES, SST, CMS score and improvement of motion and pain relief after PRP injection, compared with the baseline before injection ($p < 0.05$). In the MRI data, statistical pre- and post-comparisons revealed significant differences between location of partial rupture and grade of tendinopathy. There were no mortality and major complications observed during follow-up. Under the background of deep learning, ultrasound-guided injection of PRP with betamethasone can progressively relieve shoulder joint pain and improve motor function in patients with partial rotator cuff injury. Ultrasound-guided injection of PRP with betamethasone is safe and useful for rotator cuff disease.

Keywords Rotator cuff · Deep learning · Platelet-rich plasma · Betamethasone · Ultrasound-guided injection

Abbreviations

SPADI	Shoulder Pain and Disability Index
ASES	American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form
CMS	The Constant Murley Score

1 Introduction

In recent years, rotator cuff injury is one of the main clinical diseases that lead to shoulder joint pain and motor dysfunction. The incidence of shoulder joint diseases is increasing as high as 25–54% in the population [1, 2]. The rotator cuff's normal movement helps to complete internal rotation, external rotation and lift of shoulder joint. However, rotator cuff injury will cause the weakening or even loss of these functions. Completely torn rotator cuff injuries usually require surgical repairment, while partially torn rotator cuff injuries are usually treated nonsurgically with topical steroids, local anesthetics, and nonsteroidal anti-inflammatory drugs [3, 4]. However, rotator cuff is relatively deficient tissues with limited regenerative capacity, and conservative treatment is usually less effective. Few studies have focused on new conservative approaches to partial rotator cuff injuries, such as platelet-rich plasma therapy.

Platelet-rich plasma is a platelet-rich plasma concentrate, isolated from fresh whole autologous blood after centrifugation. It contains a large number of bioactive growth factors

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to promote tissue repair in the emerging regenerative therapy for tissue injury and degeneration [5, 6]. PRP releases a variety of signal proteins through α-particle degranulation in platelets, which bind to membrane receptors. PRP activates intracellular signal transduction pathways and induces intracellular gene expression, thus promoting cell proliferation, matrix formation and collagen synthesis. It plays an important role in the repair and regeneration of bone fracture, osteoarthritis, tendon ligament injury and other orthopedic diseases [7, 8]. However, there are few clinical randomized controlled studies on PRP injection for partial rotator cuff injury, and most clinical injections are based on body surface markers with less accuracy. The use of corticoids alone can relieve local symptoms, but it takes longer time for anti-inflammation or damage repairment.

Musculoskeletal ultrasound can observe the movement of muscles and tendons, as well as the position of puncture needle in real time. Accurately ultrasound-guided injection of drugs to the injured site could effectively avoid damage to important nerve vessels and relieve regional pain [9]. This study intends to explore the clinical effect of ultrasound-guided rotator cuff-injection of PRP combined with corticoids therapy in partial rotator cuff injury patients. The report is as follows.

2 Materials and Methods

A total of 80 patients (age 18–60 years) with partial rotator cuff injury admitted to pain department of the 72nd Group Military Hospital between 2021 and 2022 were screened in this study. Inclusion criteria were continuous shoulder pain and lifting weakness for at least 3 months with Neer plaques, Hawkins plaques and other positive signs. MRI and musculoskeletal ultrasonography proved rotator cuff tear, but the thickness of supraspinatus tendon tear was <50%. The patient did not receive corticosteroid injection therapy within 3 months. Exclusion criteria included tendinitis glenohumeral arthritis, fracture, infection or tumor, pregnancy, history of shoulder surgery, serious organ dysfunction, mental illness, serious adverse reactions. Approval was obtained from the Clinical Trial Ethics Committee of 72nd Group Military Hospital and written informed consent was obtained from all participants.

Eight milliliters of autologous blood was collected from the antecubital vein in MyCells Vacutainer. The blood sample was placed into the Arthrex Centrifuge (SF-TDL-4A-5C) and centrifuged for 10 min at 5000 rpm to separate erythrocytes from the plasma. 2 mL of citrate dextrose was mixed to prevent clotting during the extracorporeal blood processing. Approximately 4 mL of platelet-rich plasma was obtained for each patient. In the sitting position, the point of injection was the lateral subacromial space under aseptic conditions. Mixture of 1 mL betamethasone and 5 mL lidocaine, following 5 mL PRP injected in 7-day intervals, were infiltrated directly into the lesion of supraspinatus interstitial RCT under ultrasound control. Three months of sequential treatment were performed in every patient. All procedures were performed by the same offer.

2.1 Clinical Evaluation

Outcome measures were the Shoulder Pain and Disability Index (SPADI), American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), the Constant Murley Score (CMS) [10, 11]. All assessments of shoulder joint pain and function were executed by the same rehabilitation therapist.

2.2 Radiological Evaluation

MRI was performed using a 3.0 Tesla scanner (GE general system, Siemens, HDX 1.5) before and 1, 3, 6, 9 months after PRP injection. MRI was scored on a 0–5 severity scale (modified from Lewis by Scarpone et al.) with Axial (T1, fat saturated), coronal (proton density, T1, T2, fat saturated) and sagittal (T1, fat saturated) views. The observation time points were before intervention, 3 and 6 months after intervention.

2.3 Statistical Analysis

Statistical analysis independent-sample two-tailed t tests were used to analyze mean between pre- and post-infiltrative values (SPADI, ASES and CMS). SPSS 23.0 was used for statistical analysis. Mean standard deviation was used for measurement data to represent full normal distribution and homogeneity of variance, and independent sample t test was used. If they did not conform to the normal distribution, the measurement data of non-parametric and test repeated measurements were used for repeated measurement variance analysis, and the count data were used for Pearson 2 test. $p < 0.05$ was considered to be statistically significant.

3 Results

In 80 of total patients with rotator cuff injury, 47 patients were males (58.8%) and 33 females (43.4%) recruited in this study, with a mean of 43 ± 6.2 years (range 30–65 years). Location of injury were 44(55.0%) involved left side. 32 patients presented partial-thickness tears (19 articular surface tears, 10 bursal surface tears, and 3 intrasubstance tears) and 48 patients presented tendinosis in sonographic findings of the supraspinatus tendon. Duration of pain ranged with a mean of 9.2 ± 2.7 and follow-up

with 9.2 ± 2.7 months. The underlying diseases included hypertension (5, 6.2%), diabetes (3, 3.8%) and cardiovascular disease (2, 2.5%). The patient demographic data are summarized in Table 1.

In all, all patients had significant better ASES, SST, CMS score and improvement of motion and pain relief after Betamethasone and PRP injection, directly into the lesion of supraspinatus interstitial RCT under ultrasound control, compared with the baseline before injection ($p < 0.05$, Table 2, Fig. 1). All parameters showed a time effect. In the MRI data, statistical pre- and post-comparisons revealed significant differences between location of partial rupture and the grade of tendinopathy (Fig. 2). In this series, there were no mortality and major complications observed during follow-up, such as aggravation, anaphylaxis, neurovascular injury and infections (Table 2).

Table 1 Patient demographics and characteristics

Variables	PRP injection ($n = 80$)
Age (years)	43 ± 6.2
Gender (female/male, *n*)	33 (43.4%)/47 (58.8%)
Involved side (left/right, *n*)	44 (55.0%)/36 (45.0%)
Underlying diseases	
Hypertension (*n*, %)	5 (6.2%)
Diabetes (*n*, %)	3 (3.8%)
Cardiovascular disease (*n*, %)	2(2.5%)
Duration of pain (months)	9.2 ± 2.7
Follow-up (months)	12 ± 3.2

4 Discussion

Rotator cuff tissue mainly plays a role in the dynamic stability of the shoulder joint. The prominent symptoms of rotator cuff injury are persistent shoulder pain and limited mobility. Most patients avoid large-scale activities due to fear of pain. Long-term insufficient joint activity lead to adhesion of joint capsule, which further aggravates restricted joint activity [10]. The joint pain caused by sleeve injury was mainly manifested in the subacromial space and supraspinatus insertion at 1 cm. Pain may be caused by two aspects: (1) Acute injury of rotator cuff muscle group leads to intraarticular metabolic abnormalities, inflammation, reduction of proteoglycans, peripheral. (2) Inflammatory substances, such as IL-1β, bFGF, TGF-α, VEGF, MMP-9, COX-2, were significantly expressed in acromial sliding sac. TNF-α can promote cell production of NO and aggravate cell apoptosis. IL-1 stimulates the bursa to produce metalloproteinases by binding with target cell receptors, resulting in aseptic inflammatory degradation of tendon tissue [11].

Sengodan et al. conducted a randomized controlled trial of 28 patients with rotator cuff injury, treated with ultrasound-guided injection of PRP, and found significant improvement in shoulder range of motion. Yung et al. conducted a randomized clinical trial in which 102 patients with rotator cuff injury and PRP injection was administered to the experimental group. 30 UCLA scores and Constant scores were significantly higher than control group. Rha et al. screened patients with PRP injection treatment. The shoulder motion of PRP group was higher than that of dry needle treatment group after 3 months [12–14].

Table 2 Clinical evaluation and outcomes

Variables	PRP injection ($n = 80$)				*p* value
	1	3	6	9	
	Months after injection				
Pre-in SPADI	65.3 ± 8.2				
Post-in SPADI	42.8 ± 7.8	37.3 ± 8.6	26.5 ± 5.4	19.1 ± 6.5	*P1 = 0.033, *P2 = 0.013 **P3 = 0.008, **P4 = 0.001
Pre-in CMS	68.9 ± 18.2				
Post-in CMS	78.5 ± 15.6	92.6 ± 10.5	90.5 ± 8.4	91.7 ± 7.5	*P1 = 0.046, **P2 = 0.004 **P3 = 0.003, **P4 = 0.003
Pre-in ASES	49.6 ± 13				
Post-in ASES	65.5 ± 14.2	72.5 ± 14.2	80.9 ± 12.9	82.7 ± 11.4	*P1 = 0.026, **P2 = 0.012 **P3 = 0.006, **P4 = 0.006
Satisfactory rate, *n* (%)	62 (77.5%)				
Aggravation/major complications/mortality, *n*	0				0

Pre-in pre-injection; *Post-in* post-injection; *SPADI* Shoulder Pain and Disability Index; *ASES* American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *CMS* the Constant Murley Score. Significant difference between two groups: *$p < 0.05$, **$p < 0.001$

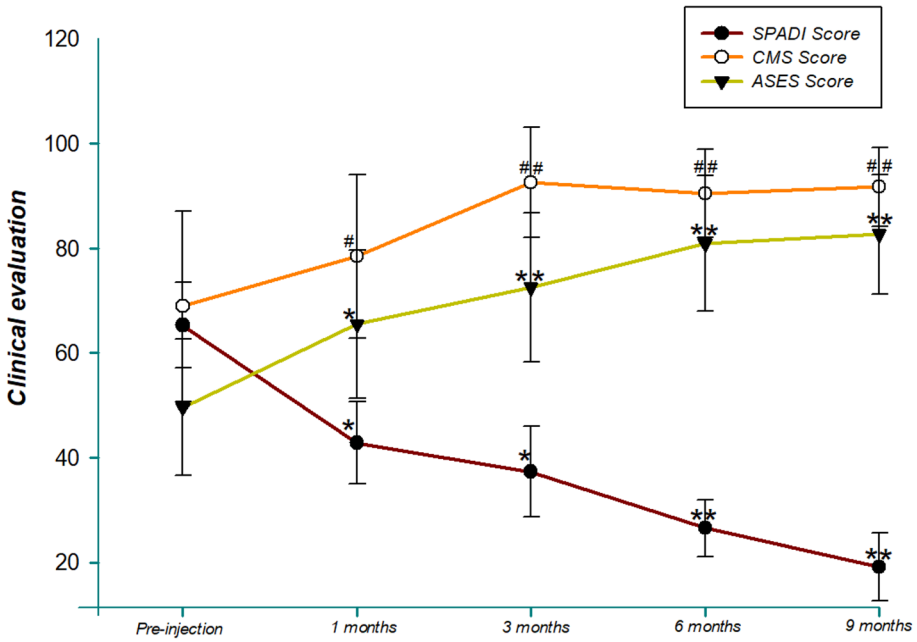

Fig. 1 SPADI, CMS and ASES Score of patients with PRP and corticosteroid injection over time (pre-injection, 1, 3, 6, 9 months). Significant difference between two groups: $^{\#}*p<0.05$, $^{\#\#}**p<0.001$

Fig. 2 The procedure of ultrasound-guided injection of PRP with betamethasone for symptomatic partial rotator cuff injury (figure above). In the MRI data, statistical pre-and post-comparisons revealed statistically significant differences between location of partial rupture and the grade of tendinopathy

The mechanism is that after PRP is activated, α particles rapidly cleave and secrete a large number of growth factors, such as PDGF, TGF-β, IGF and EGF, which promote inflammatory factors such as IL-2 and TGF-β for fibroblast differentiation and inhibit MMP-13 to play a local anti-inflammatory effect [15]. The hepatocyte growth factor secreted by PRP can reduce the concentrations of prostaglandin E2 and cyclooxygenase-1, thus achieving the analgesic effect. In the middle and late stage, platelet growth factors are activated to form a loose network structure of fibrin clots at the site of tendon injury and promote the proliferation and mitosis of tendon cells, thus accelerating the repair of muscles, tendons and tendino-bone joints [16].

Injection of Betamethasone can improve capillary permeability and relieve congestion and edema, thus playing a local anti-inflammatory effect. Local injection of small dose and low concentration of lidocaine can block local nerve to improve pain symptoms. Menjie et al. screened 90 patients with partial rotator cuff injury and treated them with betamethasone injection. It could effectively and rapidly reduce patients' pain and improve shoulder joint function under precise positioning of ultrasound [16].

Ultrasound-guided injection improved the accuracy and success rate of injection, avoiding injury to the nerves and blood vessels around the shoulder joint. Milosa et al. found the sensitivity and specificity of ultrasonic diagnosis for rotator cuff tear were over 90% [17].

The results showed that PRP and betamethasone injection in the acromial sliding sac could relieve shoulder pain in patients with rotator cuff injury in the short term and improve shoulder flexion and abductor motion. Betamethasone takes effect quickly but the sustained improvement effect is not obvious, while PRP slowly but obvious. It may be because PRP's fluid viscosity is higher than hormone and intraarticular diffusion time is longer. The α particles released by PRP take a longer time to activate to secrete platelet growth factors [18].

In this study, PRP combined with betamethasone, infiltrated directly into the lesion of supraspinatus interstitial RCT under ultrasound control, could achieve the purpose of rapid onset and continuous treatment effect. More strict inclusion criteria were adopted, which stipulated that rotator cuff injury degree was less than 50% tear thickness, to ensure homogeneity of subjects. The injection of PRP combined with Betamethasone under ultrasound guidance could reduce the deficiency caused by blind penetration. In this experiment, the white blood cells in PRP were not separated and the concentration of white blood cells was higher than the normal physiological level, which could effectively clear the local necrotic tissue and enhance the anti-infection ability. These strategies could evaluate the effect of PRP injection for rotator cuff disease more objectively and accurately.

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Author Contributions Treatment was performed by PX and TC. XL, FQZ and YF were major contributors in writing the manuscript. SHZ and ZFZ analyzed the radiographic data. All authors read and approved the final manuscript.

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Availability of Data and Material The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics approval Not applicable.

Consent for publication Not applicable.

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