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Effect of ultrasound-guided nerve blocks on anesthesia and pulmonary function in patients undergoing distal radius fracture surgery

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Abstract

This study aimed to assess the impact of ultrasound (US)-guided nerve blocks (NBs) on anesthesia and their protective effect on pulmonary function (PF) in patients undergoing distal radius fracture (DRF) surgery. A total of 122 patients undergoing DRF surgery between April 2020 and June 2023 were included. According to the type of peripheral NB technique, these patients were randomized into a control group (CG; n = 60) receiving brachial plexus block (BPB) using blinded techniques, and an observation group (OG; n = 62) receiving US-guided supraclavicular BPB. Anesthetic effects, BPB-related indexes, adverse events, PF parameters (forced expiratory volume in 1 second, forced vital capacity, peak expiratory flow), and serum biochemical indexes (interleukin [IL]-6/10) were compared. The OG showed a relatively higher proportion of good anesthetic effects, shorter onset and completion times of block, and longer block duration compared to the CG, with a lower AE rate. Despite reductions in PF parameters and IL-10 levels after intervention, the OG maintained higher values than the CG. IL-6 levels increased significantly in the OG but remained lower than in the CG. In conclusion, US-guided NBs demonstrated significant anesthetic efficacy and apparently reduced anesthesia adverse events while also exerting a protective effect on PF in DRF surgery patients.

Abbreviations: AEs = adverse events, BPB = brachial plexus block, CG = control group, DRFs = distal radius fractures, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IL = interleukin, NBs = nerve blocks, OG = observation group, PEF = peak expiratory flow, PF = pulmonary function, SCBPB = supraclavicular BPB, SPSS = Statistic Package for Social Science, US = ultrasound.

Keywords: anesthesia effect, distal radius fracture surgery, protection, pulmonary function, ultrasound-guided nerve blocks

1. Introduction

The incidence of distal radius fractures (DRFs), a kind of upper limb fractures second only to hip fractures, is increasing year by year.[1,2] The disease accounts for approximately 18% of all fractures and has a bimodal age distribution, occurring not only in young patients with severe trauma, but also in older adults who have suffered relatively minor falls.[3,4] Its occurrence is affected by a variety of factors. Besides personal factors such as age, sex and living habits, it is also influenced by environmental inducements like climate and population density.[2] The major treatment options for DRFs include open reduction and internal fixation. Although surgical treatment has achieved good results, anesthesia and surgery-induced trauma may affect the surgical progress, postoperative rehabilitation, and prognosis of patients.[5–7] This study attempts to start from the perspective of anesthesia to contribute to the optimization of anesthesia effect and the promotion of postoperative functional recovery of patients with DRFs.

Preoperative anesthesia for DRF surgery should ensure the safety of anesthesia on the premise of reaching the required anesthesia depth. It would be better if it could also shorten the recovery time from anesthesia and promote the patient's functional recovery, which is helpful to prevent postoperative adverse events (AEs).[8–10] Ultrasound (US)-guided nerve blocks (NBs) are one of the anesthetic options for DRF surgery.[11] Under the guidance of ultrasonic technology, it has become a dynamic, visual and sustainable anesthesia technology that can accurately clarify the puncture tip and the path of drug diffusion, which not only ensure the established anesthesia effect, but also help to improve anesthesia safety.[12,13] In the study of Cai Q et al,[14] the use of US-guided NBs is not only effective in anesthesia for patients undergoing fracture surgery, but also can maintain the stability of vital signs. A case report of US-guided

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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NBs in the patient undergoing bilateral DRFs demonstrated that the use of US-guided NBs provided ideal postoperative analgesic effect without causing undesirable motor paralysis.[15] The primary outcomes included anesthetic effects and anesthesia AEs. Secondary outcomes included dynamic pulmonary function and changes of serum interleukin levels before and after the intervention.

Currently, the research on the anesthetic effect of US-guided NBs and the protection of pulmonary function (PF) on patients undergoing DRF surgery is still limited. This study attempts to analyze this aspect and is hereby reported.

1.1. Participants and methods

1.1.1. Patient data. All participants signed informed consent after the study was approved by the hospital's Ethics Committee (Institutional Review Board number: SB20240125). The study population comprised 122 patients undergoing surgery for DRFs between April 2020 and June 2023, including 60 cases (control group, CG) receiving brachial plexus block (BPB) using blinded techniques and 62 cases (observation group, OG) anesthetized by supraclavicular BPB (SCBPB) under US guidance. The baseline data of 2 groups of patients are clinically comparable.

1.1.2. Criteria for patient enrollment and exclusion. Patients were considered eligible if they meet all the following criteria: diagnosis of DRF by clinical and imaging examinations; American Association of Anesthesiologists Grade II–III; no contraindication to peripheral NBs; complete medical records; high compliance and willingness to cooperate with the research.

In contrast, cases meeting any of the following were excluded: those on sedative or antidepressant drugs, drug addicts, or long-term alcoholics; allergies to the study medication; blood, respiratory diseases, or coagulation dysfunction; cognitive dysfunction or mental illness.

2. Methods

This study was a randomized controlled trial. According to the process of brachial plexus block, total of 122 patients were randomized using a computer-generated randomization sequence to receive anesthesia with or without US-guidance. Preoperative fasting (6 hours) and water-deprivation (4 hours) were carried out in both groups. After entering the operating room, venous access was opened, and blood pressure, electrocardiogram and blood gas were routinely monitored. Surgery and anesthesia operations were all completed by same group of experienced surgeons and anesthesiologists. Both electrical nerve stimulation and injection pressure monitor were used to minimize the risk of intraneural or intravascular injections. Trained recovery ward nurses assessed the blocks, which include both sensory testing and motor testing.

CG was given BPB using blinded techniques: The patient was lying flat on the back with arms fitted naturally and the head turned to the unaffected side. After determining the position of the anterior and middle scalene muscle space, the needle was inserted vertically into the outer edge of the intermuscular groove and advanced slowly to explore the foreign body sensation, during which the patient was asked for any paresthesia. Anesthetic drugs (0.375% ropivacaine mesylate 15 mL) were injected after it was determined that the needle tip reached the cords of the brachial plexus with no blood reflux after needle withdrawal.

In OG, SCBPB was performed under US guidance, and SonoSite Portable Color Doppler US System (linear array probe frequency: 6–13 MHz) was used. The probe was placed close to the patient's supraclavicular fossa, and the US images of supraclavicular brachial plexus were obtained on the lateral side of the subclavian artery and the superior side of the first rib. In this process, the probe was kept perpendicular to the supraclaricular brachial plexus nerve to obtain the best image effect. Then, under real-time ultrasonic monitoring, the needle was inserted and advanced slowly to ensure that it reached the target nerve plexus and was withdrawn without causing cerebrospinal fluid reflux or blood reflux, followed by the injection of 15 mL of 0.375% ropivacaine mesylate; the position of the needle tip was adjusted appropriately according to the inflow direction of anesthetic drugs to ensure that the anesthetic drugs were around the target nerve.

2.1. Endpoints

Anesthetic effect. Evaluation criteria: excellent: no pain during surgery; good: mild pain during the operation with the need for additional sedative and analgesic drugs; poor: conversion to general anesthesia due to poor anesthetic effect that cannot meet the needs of surgery, or the addition of other approaches to achieve BPB.

Block-related indicators. The onset time, completion time and duration of block were observed and recorded in both groups.

Adverse events. We also observed and recorded the number of cases of AEs such as mesentry into blood vessels, hematoma at the puncture site, dyspnea, pneumothorax, and paresthesia in the 2 groups, and calculated the incidence rate.

PF indexes. Pulmonary function was tested using a portable spirometer (Micro Loop II). Forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC) and peak expiratory flow (PEF) were performed. Measurements were recorded at 2 time points: before block and 30 minutes after induction of anesthesia.

Serum biochemical indexes. 3 mL of venous blood samples were collected before block and 30 minutes after induction of anesthesia, and the serum was isolated to measure interleukin (IL)-6 and IL-10. The levels of IL-6 and IL-10 were detected by double-antibody sandwich enzyme-linked immunosorbent assay.

2.2. Statistical analysis

Continuous variables were statistically described by mean ± standard deviation ($\bar{\chi} \pm s$), and the differences between and within groups were analyzed by independent sample *t*-test and paired *t*-test, respectively. Categorical variables were expressed by the rate (percentage), and the between-group comparison was made by χ^2 test. The collected experimental data were input into Statistic Package for Social Science 22.0 for analysis (IBM, Armonk, NY), and differences with $P < .05$ were deemed statistically significant.

3. Results

3.1. Comparative analysis of baseline data

A total of 122 patients were included as study subjects, with an average age of 62.5 years. According to whether brachial plexus block had the technique of US-guidance, the subjects were divided into control group (CG; n = 60) without US-guidance and observation group (n = 62) receiving US-guided SCBPB. Patients age, gender ratio, body mass index, disease severity and duration, pulmonary function indexes such as FEV1, FVC, and PEF between 2 groups were statistically analyzed by *t*-test or χ^2 test. No statistically significant differences were observed between the 2 groups at baseline parameters (all $P > .05$) as shown in Table 1.

Table 1

Comparative evaluation of baseline data.

Indicators	Control group (n = 60)	Observation group (n = 62)	*r*	95%CI	*P*
Age (years)	62.27 ± 5.07	62.87 ± 5.79	0.056	-0.123–0.231	.541
Sex (male/female)	32/28	36/26	-0.048	-0.223–0.131	.602
Course of disease (d)	3.22 ± 1.08	3.58 ± 1.40	0.145	-0.033–0.315	.110
BMI (kg/m^2)	23.03 ± 1.81	22.46 ± 1.65	-0.165	-0.333–0.014	.070
ASA classification (I/II)	38/22	35/27	0.070	-0.109–0.245	.442
FEV1 (L)	2.89 ± 0.48	3.00 ± 0.52	0.107	-0.072–0.279	.241
FVC (L)	3.28 ± 0.75	3.19 ± 0.62	-0.063	-0.238–0.116	.490
PEF (L/s)	6.19 ± 1.74	5.85 ± 1.95	-0.092	-0.266–0.087	.311

Bivariate correlation analysis was applied.

ASA = American Association of Anesthesiologists; BMI = body mass index; CI = confidence intervals; FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity; PEF = peak expiratory flow; r = Pearson correlation coefficient.

Table 2

Comparative evaluation of anesthesia effects.

Indicators	Control group (N=60)	Observation group (N=62)	*P*
Excellent and good	46 (76.67%)	56 (90.32%)	0.042
Poor	14 (23.33%)	6 (9.68%)	

3.2. Comparative assessment of anesthetic effects

According to the established evaluation criteria of anesthetic effect, the proportion of excellent and good indicators in OG group (90.32%), compared with CG group (76.67%) obviously increased. The difference in the indicators was analyzed by χ^2 test with contingency table analysis. The result showed no significant difference between 2 group patients ($P = .052$), but the proportion of excellent and good anesthetic effects in OG group was high (refer to Table 2), which might be explained by the limited amounts of subjects. More subjects are required in further research.

3.3. Comparative assessment of AEs

AEs were recorded in both CG and OG groups. There were 2 patients (CG group: 3.33% vs OG group: 3.23%) complained of dyspnea or chest pain, and 1 patient with paresthesia (CG group: 1.67% vs OG group: 1.61%) in each group. Pneumothorax and hematoma at the puncture site occurred in 3 patients of CG group (5.00%) and none in OG group. Other adverse event like mesentry into blood vessels occurred in 4 CG group patients (6.67%) and 2 cases in OG group (3.23%). Thus, it can be seen, the complication occurring rate in OG group was obviously lower than that of CG group. Statistical analysis showed significant difference between 2 groups (OG: 21.67% vs CG: 8.06%; $P = .034$) (refer to Table 3).

3.4. Comparative assessment of block-related indexes

Anesthetic block-related indexes such as the blocking onset time, completion time, and duration time of block were recorded and analyzed, as shown in Figure 1. In comparison to CG group, OG group patients showed significant differences with shorter onset time (OG: 4.19 ± 1.10 minutes vs CG: 6.45 ± 1.64 minutes, $P < .001$, $r = -0.633$, 95%CI: -0.729 to -0.513), shorter block completion time (OG: 12.63 ± 3.13 minutes vs CG: 16.47 ± 3.78 minutes, $P < .001$, $r = -0.487$, 95%CI: -0.612 to -0.399) and longer duration of block (OG: 314.18 ± 39.27 minutes vs CG: 265.67 ± 38.57 minutes, $P < .001$, $R = 0.532$, 95%CI: 0.391 to 0.648). Bivariate correlation analysis was applied. *r* means Pearson correlation coefficient and CI represents confidence intervals.

Table 3

Comparative evaluation of adverse events.

Indicators	Control group (n = 60)	Observation group (n = 62)	χ^2/t	*P*
Mesentry into blood vessels	4 (6.67%)	2 (3.23%)		
Hematoma at the puncture site	3 (5.00%)	0 (0.00)		
Dyspnea	2 (3.33%)	2 (3.23%)		
Pneumothorax	3 (5.00%)	0 (0.00)		
Paresthesia	1 (1.67%)	1 (1.61%)		
Total	13 (21.67%)	5 (8.06%)	4.486	.0423

3.5. Comparative evaluation of pulmonary function

To assess the effect of US-guided supraclavicular BPB on pulmonary function in patients undergoing distal radius fracture surgery, the PF indexes including FEV1, FVC, and PEF, were evaluated. OG group patients showed higher average levels in FEV1, FVC, and PEF compared to CG group, with values of 2.49 ± 0.55 L vs 1.94 ± 0.40 L ($P < .001$), 2.84 ± 0.43 L vs 2.58 ± 0.53 L ($P = .004$) and 4.76 ± 1.31 L/s vs 4.04 ± 1.70 L/s ($P < .001$) respectively. Bivariate correlation analysis results showed that the use of US-guided supraclavicular BPB was correlated with patient's pulmonary function (all $P < .05$), refer to Figure 2.

3.6. Comparative evaluation of serum biochemical indexes

Serum biochemical indices IL-6 and IL-10 were measured. Figure 3 showed the test results. The levels of IL-6 before intervention in CG and OG were 10.47 ± 2.49 ng/L and 10.91 ± 1.49 ng/L respectively, and IL-10 were 12.51 ± 2.10 ng/L (CG) and 11.85 ± 2.59 ng/L (OG). The data were expressed as $\bar{\chi} \pm s$. No significant intergroup difference was identified ($P > .05$). After intervention, IL-6 in both groups increased significantly, with detection values of 62.70 ± 8.04 ng/L and 44.58 ± 5.75 ng/L in CG and OG, respectively, while the level of IL-10 decreased to 6.77 ± 1.72 ng/L (CG) and 8.98 ± 1.74 ng/L (OG), statistical analysis revealed that the difference in the levels of IL-6 and IL-10 after intervention were significant ($P < .05$). In addition, the inter-group comparison revealed lower IL-6 and higher IL-10 in OG compared with CG ($P < .05$).

4. Discussion

In our study, those who received BPB using the blinded technique were used as CG and those receiving US-guided SCBPB

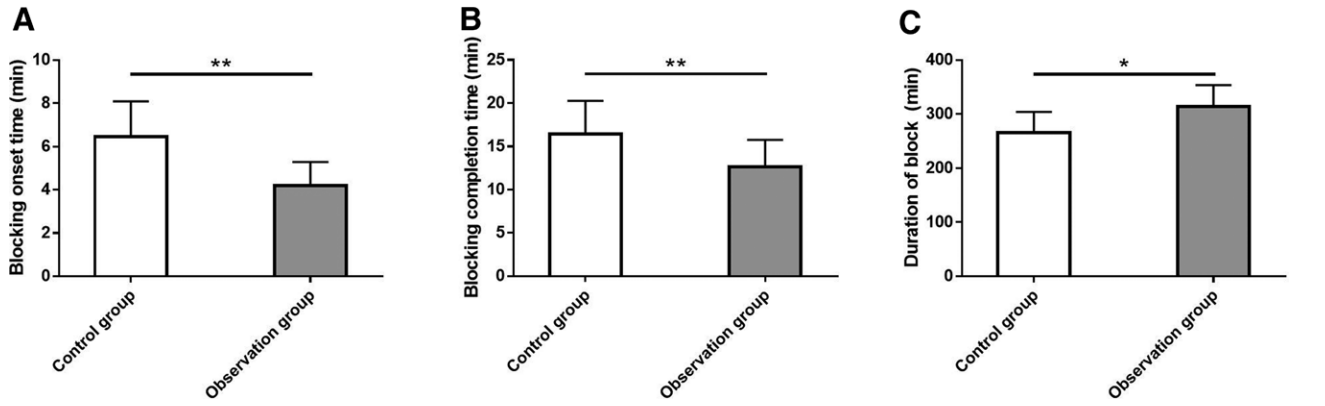

Figure 1. Comparative assessment of block-related indexes. (A) The observation group had obviously shorter onset time of block than the control group. (B) The observation group had obviously shorter completion time of block than the control group. (C) The observation group had markedly longer duration of block than the control group. *Note*: * and ** represent $P < .05$ and $P < .01$, respectively.

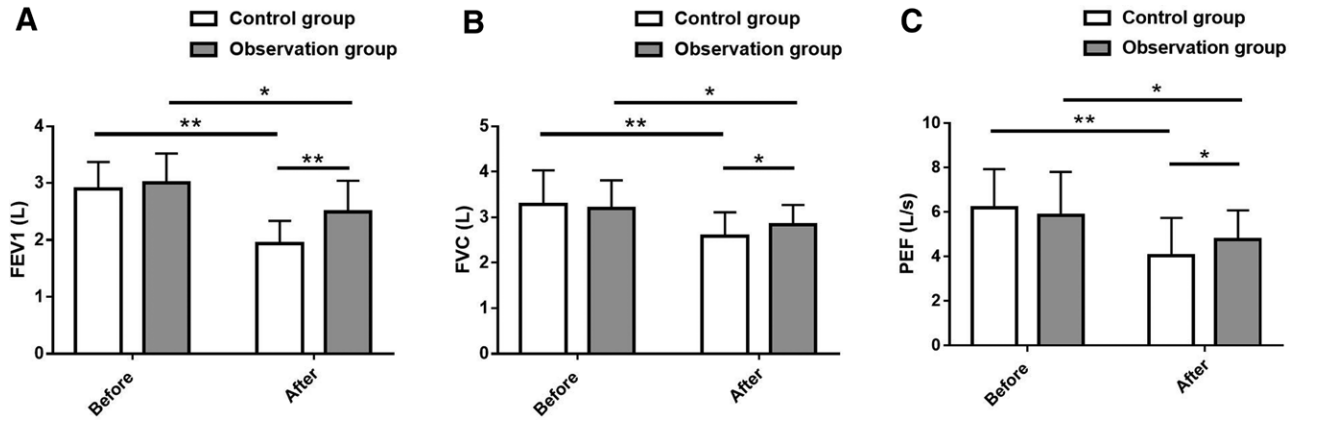

Figure 2. Comparative evaluation of pulmonary function. (A) FEV1 in the observation group decreased after intervention, but was higher than that in the control group. (B) FVC in the observation group decreased after intervention, but was higher than that in the control group. (C) PEF in the observation group decreased after intervention, but was higher than that in the control group. FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, PEF = peak expiratory flow.

were used as OG. We conducted a comparative analysis of the clinical application effects of the 2 anesthesia modes in patients undergoing DRF surgery from the aspects of anesthesia effects, block-related indexes, safety, PF, and serum biochemical indices, and confirmed the significant clinical advantages of US-guided SCBPB in patients undergoing DRF surgery.

First of all, the anesthesia effect evaluation revealed an evidently higher excellent and good rate of anesthesia in OG (90.32%) compared with CG (76.67%), indicating that US-guided SCBPB can significantly improve the excellent and good rate of anesthesia, help to alleviate surgery-induced pain and reduce the demand for sedative and analgesic drugs. This may be attributed to the accurate acquisition of the relevant information of the target nerve plexus under US guidance, which allows the needle tip to reach the target nerve plexus and ensures the sufficient diffusion of the local anesthetic drugs in the nerve area, thus giving full play to the anesthetic effect, reducing the risk of block failure, preventing nerve and blood vessel damage to some extent, and alleviating pain.[16,17] In addition, the local anesthesia drug selected in this study is ropivacaine mesylate, which, as an amide anesthetic that can be used for NB anesthesia, exerts anesthesia effects by inhibiting the conduction of sodium ions in nerve cells and exerting blocking functions on the conduction of nerve excitement and pain sensation.[18,19] In the study of Blichfeldt-Eckhardt MR et al,[20] US-guided phrenic NB has a significant analgesic effect on ipsilateral shoulder pain after lobectomy or pneumonectomy, similar to our research results. Wang Y et al[21] also pointed out that US-guided pericapsular nerve group block applied to hip surgery patients has effective analgesic effects which was similar to the effectiveness data obtained from our study.

In addition, the results of block showed that compared with CG, the onset time and completion time of block in OG were significantly shorter and the duration of block was significantly longer. This is related to the improvement of puncture efficiency by US-guided SCBPB, thus shortening the puncture time and improving the blocking effect.[22] After safety assessment, we determined a markedly lower overall incidence of AEs (mesentry into blood vessels, hematoma at the puncture site, dyspnea, pneumothorax, and paresthesia) in OG compared with CG (8.06% vs 21.67%), suggesting that US-guided SCBPB can reduce the risk of postoperative AEs in patients undergoing DRF surgery by 13.61%. The localization accuracy of NB under US guidance can effectively control the dosage of local anesthetics, which is conducive to reducing the risk of AEs after anesthesia.[23] Stav A et al[24] have also confirmed the safety of US-guided SCBPB in patients undergoing upper limb surgery below the shoulder, which supports our research results. After evaluation of PF, FEV1, FVC, and PEF were found to be reduced markedly in OG after surgery, but were still significantly higher compared with CG, indicating that US-guided SCBPB can significantly protect the PF of patients undergoing DRF surgery. Furthermore, according to the detection results of serum biochemical indices, OG had evidently elevated IL-6 after surgery that was still lower compared with CG; while IL-10 decreased but remained significantly higher than that of CG. This shows that US-guided SCBPB can repair the abnormal inflammatory microenvironment in patients undergoing surgery for DRFs.

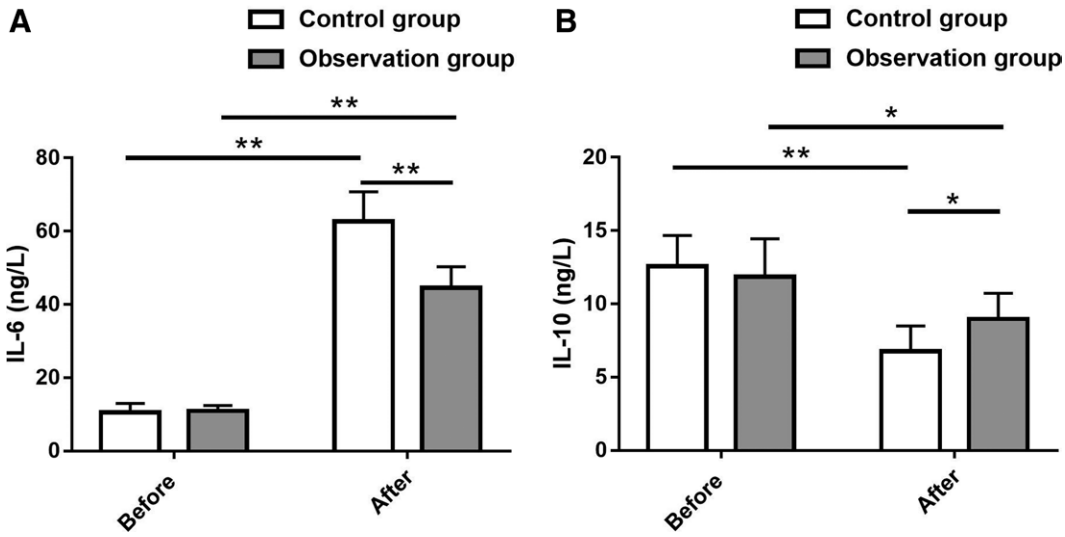

Figure 3. Comparative evaluation of serum biochemical indices. (A) The observation group showed increased IL-6 after intervention that was still lower compared with the control group. (B) The observation group showed decreased IL-10 after intervention that was still higher compared with the control group. *Note*: * and ** represent $P < .05$ and $P < .01$, respectively. IL = interleukin.

To sum up, US-guided SCBPB is superior to BPB using the blinded technique in patients undergoing DRF surgery, which can significantly reduce the occurrence rate of postoperative AEs, protect patients' PF, and correct the inflammatory microenvironment imbalance.

Author contributions

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