RESEARCH PAPER

Pain Relief Strategies after Acromioclavicular Joint Corticosteroid Injection as a Predictor of Final Functional Outcome: A Prospective Observational Study

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ABSTRACT

Background: Acromioclavicular (AC) joint pain is a prevalent source of shoulder disability, frequently managed with corticosteroid injections. Despite the widespread use of this intervention, the early post-injection pain relief trajectory as a predictive marker for long-term functional recovery has not been systematically studied.

Objective: To evaluate whether the pattern and magnitude of pain relief in the first four weeks following AC joint corticosteroid injection predicts the final functional outcome at six months.

Methods: A prospective observational cohort study was conducted over 24 months at a tertiary orthopaedic referral centre. Eighty-six patients with clinically and radiologically confirmed AC joint pathology receiving ultrasound-guided corticosteroid injections were enrolled. Pain was assessed using the Visual Analogue Scale (VAS) and Numerical Rating Scale (NRS) at baseline, 1 week, 2 weeks, and 4 weeks post-injection. Functional outcome was assessed at 6 months using the Disabilities of the Arm, Shoulder and Hand (DASH) score and the Constant-Murley Score (CMS). Receiver Operating Characteristic (ROC) analysis and logistic regression were used to identify predictive thresholds.

Results: A clinically significant pain reduction of ≥50% NRS at 2 weeks post-injection was identified as the strongest independent predictor of favourable 6-month functional outcome (AUC = 0.84; sensitivity 78%, specificity 82%). Patients achieving this threshold demonstrated significantly superior DASH (mean 18.4 ± 6.2 vs. 41.7 ± 9.8; $p < 0.001$) and Constant-Murley scores (74.3 ± 8.1 vs. 51.2 ± 10.4; $p < 0.001$) at follow-up. Persistent pain at 4 weeks was associated with a 3.8-fold increased risk of poor outcome (OR 3.82; 95% CI 1.94–7.51).

Conclusion: Early pain relief trajectory following AC joint corticosteroid injection is a reliable and clinically practical predictor of final functional outcome. A ≥50% reduction in NRS pain score at 2 weeks should be incorporated into decision-making algorithms to identify patients requiring earlier escalation of care.

Keywords: *Acromioclavicular joint; corticosteroid injection; pain trajectory; functional outcome; DASH score; Constant-Murley score; shoulder pain; predictive markers; ultrasound-guided injection; musculoskeletal medicine*

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INTRODUCTION

The Acromioclavicular joint (AC joint), which is a small diarthrodial joint located at the bottom end of the clavicle, often causes shoulder pain as well as limitation in terms of function, even though it represents a very small part of the overall clinical evaluation of the shoulder compared to Rotator Cuff pathology and Glenohumeral pathology. AC joint disease, either alone or along with other shoulder conditions, accounts for a large number of patients who present with shoulder complaints in primary care, sports medicine and orthopedic practices [1,2]. AC joint conditions include acute traumatic separations and post-traumatic arthritis, which may develop into degenerative osteoarthritis or Distal Clavicular Osteolysis, and together these conditions produce a clinical syndrome that is diagnosed with specific procedures—pain (localized to the superior shoulder region), tenderness over the AC joint, and specific positions (cross body adduction and flexion) that provokes pain in the patient, indicating the diagnosis of shoulder pathology exists [3]. Conservative treatment options for patients with AC joint pain have evolved and changed dramatically over the last 20 years. Corticosteroid injections are now routinely performed in patients with AC joint pain, either with traditional landmark guidance or, more recently, under real-time ultrasound guidance [4]. There are scientific reasons why this is beneficial to patients with AC joint pathologies because steroids significantly reduce inflammation within the joint, resulting in both symptomatic relief as well as improvement in patient function, both during and after rehabilitation. Data regarding the effects of corticosteroid injections on long-term outcomes of patients with AC joint conditions and the relationship between long-term outcomes and definitive clinical improvement have been the subject of considerable interest and debate over the past few years [5]. The major difficulty associated with managing AC joint pathology is that reliable early prognostic indicators are currently not available.Currently, clinicians have no validated tools to identify patient progression toward meaningful functional result or failure of conservative therapy and need for surgical consideration in the few days to weeks post corticosteriod injection. Due to this uncertainty, clinicians often utilize long, watchful waiting periods before proceeding to surgical referral, or perform early operative intervention [6,7]. The economic and quality of life ramifications of the diagnostic uncertainty surrounding this issue is immense, especially in light of the number of individuals diagnosed with this condition who participate in athletics and are working aged [8].

The use of early response to treatment as a predictor of future success is commonplace with other musculoskeletal disorders. In people with lumbar radiculopathy, the amount of pain relief following epidural steroid injection is correlated with long-term functional outcome [9]. With knee osteoarthritis, the early response to intra-articular corticosteroid injections is moderately predictive of a sustained functional benefit [10]. No one has conducted prospective cohort studies to determine if this same relationship exists with AC joint injections.

Patients employ various strategies (i.e., pharmacologic/non-pharmacologic) for the relief of pain following injection, and these methods are heterogeneous based on personal circumstances. Pharmacologic options available include NSAIDs, analgesic strategies, topical therapies, in addition to non-pharmacologic options (i.e., physiotherapeutic exercises, modification of activity, off-loading the joint, and physical agents, including therapeutic ultrasound and TENS, etc.) [11,12]. The ways in which pharmacologic and non-pharmacologic strategies combine and interact with one another, and ultimately affect the patient's trajectory of pain following corticosteroid injection, likely yield critical prognostic information. However, this topic remains largely understudied within the scientific literature regarding post-injection management.

This study was designed to investigate this gap of knowledge using a prospective observational design. We hypothesized that the pattern of pain relief during the first four weeks following an AC joint injection will serve as a critical predictor of functional outcomes at the six-month follow-up. The results of this study may provide additional information for developing monitoring protocols after injection and discussing shared decision-making goals with the patients, thus aiding in the timing and criteria for when to refer for surgery [13].

OBJECTIVES

The primary objective of this study was to determine whether the magnitude and pattern of pain relief within the first four weeks following ultrasound-guided AC joint corticosteroid injection is a statistically significant and clinically reliable predictor of functional outcome at six months.

MATERIALS AND METHODS

Study Design

This was a prospective observational cohort study conducted over a 24-month period at the Department of Orthopaedic Surgery of a tertiary referral hospital. Written informed consent was obtained from all participants prior to enrolment.

Study Population

Consecutive patients referred to the outpatient orthopaedic and sports medicine clinic with a primary complaint of AC joint pain were screened for eligibility over the study period. Inclusion and exclusion criteria were applied as follows.

Inclusion criteria: age between 18 and 70 years; clinical diagnosis of AC joint pathology confirmed by a fellowship-trained orthopaedic surgeon; positive cross-body adduction test and tenderness localised to the AC joint; radiological evidence of AC joint pathology on weight-bearing anteroposterior shoulder radiograph

(Zanca view) and/or dynamic ultrasound assessment; symptom duration of at least four weeks refractory to initial conservative management (rest, analgesics, activity modification); decision to proceed with AC joint corticosteroid injection as primary treatment modality.

Exclusion criteria: prior corticosteroid injection to the ipsilateral AC joint within the preceding 12 months; concurrent glenohumeral joint or rotator cuff pathology requiring separate injection; systemic inflammatory arthropathy (rheumatoid arthritis, psoriatic arthritis, ankylosing spondylitis); ipsilateral shoulder surgery within the preceding 24 months; active infection at the proposed injection site; pregnancy; allergy to corticosteroids or local anaesthetic agents; cognitive impairment precluding reliable self-reported outcome assessment; inability to attend follow-up appointments.

Injection Protocol

All injections were administered by a single experienced musculoskeletal radiologist with greater than ten years of experience in ultrasound-guided procedures, ensuring consistency of technique across the study population. Each injection was performed under real-time ultrasound guidance using a high-frequency linear transducer (10–15 MHz, Siemens ACUSON Juniper). Patients were positioned in the seated position with the arm resting at the side. The AC joint was identified sonographically and the needle tip was confirmed within the joint space prior to injection.

The injectate consisted of 1 mL of methylprednisolone acetate (40 mg) combined with 1 mL of 1% lidocaine hydrochloride, delivered through a 23-gauge, 1.5-inch needle using an in-plane technique. A standardised post-injection protocol was provided to all patients in written format: relative rest for 24–48 hours, ice application for 15 minutes three times daily for the first 72 hours, and avoidance of heavy overhead activities for one week.

Post-Injection Pain Management Strategies

Data regarding adjunctive pain management strategies employed during the first four weeks post-injection were prospectively collected at each follow-up visit using a standardised structured interview and patient-completed diary. The following categories were documented:

- Pharmacological strategies: NSAID use (type, frequency, duration), paracetamol use, opioid analgesic use (recorded but documented as a separate covariate given clinical significance), and topical NSAID or anaesthetic application.
- Physiotherapy and rehabilitation: formal physiotherapy participation (frequency, duration, treatment modalities including manual therapy, exercise prescription, and electrotherapy), home exercise programme adherence, and use of TENS devices.
- Activity modification: degree of occupational modification, avoidance of provocative movements, and use of slings or bracing.
- Physical agent modalities: therapeutic ultrasound application, cryotherapy, and heat therapy.

Each strategy was recorded on a validated five-point Likert scale of adherence (0 = never used, 4 = used consistently as advised) and analysed both as individual predictors and as a composite post-injection management adherence score.

Outcome Measures

Pain was assessed at baseline (pre-injection), 1 week, 2 weeks, and 4 weeks post-injection using two validated instruments: the 100-mm Visual Analogue Scale (VAS) and the 11-point Numerical Rating Scale (NRS). Both instruments demonstrated high test-retest reliability in the shoulder pain population (ICC >0.85) [14]. Functional outcome was assessed at baseline and at 6 months using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (scored 0–100, lower scores indicating better function) and the Constant-Murley Score (CMS; scored 0–100, higher scores indicating better function). Both instruments are validated for use in AC joint pathology [15,16].

A 'favourable outcome' at 6 months was defined a priori as: DASH score ≤25 AND Constant-Murley Score ≥70, consistent with published thresholds for clinically meaningful recovery in shoulder pathology [17]. The primary predictor variable of interest was the percentage reduction in NRS score from baseline at 2 weeks post-injection.

Statistical Analysis

Sample size was calculated a priori using data from a pilot study of 18 patients, which estimated a correlation coefficient of $r = 0.45$ between 2-week NRS reduction and 6-month DASH score. With $\alpha = 0.05$ and power $(1-\beta) = 0.80$, a minimum of 38 patients per outcome group was required; accounting for an anticipated 15% dropout rate, a target enrolment of 90 patients was established.

Continuous variables were summarised as mean ± standard deviation (SD) or median (interquartile range), as appropriate following Shapiro-Wilk normality testing. Categorical variables were expressed as frequencies and percentages. Between-group comparisons were performed using independent-samples t-tests, Mann-Whitney U tests, or chi-square tests as appropriate. Pearson or Spearman correlation analyses were conducted to examine bivariate associations between pain trajectory variables and functional outcomes.

Receiver Operating Characteristic (ROC) curve analysis was performed to determine the optimal NRS reduction threshold at each time point for predicting favourable 6-month outcome, with the Youden Index used to identify the optimal cut-point. Multivariable binary logistic regression was performed to identify independent predictors of favourable outcome, incorporating variables with $p < 0.10$ in univariate analysis. Results were expressed as odds ratios (OR) with 95% confidence intervals (CI). All analyses were performed using SPSS

Statistics version 27.0 (IBM Corporation, Armonk, NY) and R version 4.2.1. Statistical significance was set at $p < 0.05$ (two-tailed).

RESULTS

Of 103 patients screened, 90 were enrolled and 86 completed the full 6-month follow-up (4 patients were lost to follow-up and were excluded from the primary analysis; dropout rate 4.4%). The mean age of the study cohort was 46.3 ± 11.7 years (range: 21–68 years), with a male predominance (n = 54, 62.8%). The dominant shoulder was affected in 69 cases (80.2%). The most common underlying diagnoses were degenerative AC joint osteoarthritis (n = 48, 55.8%), post-traumatic arthritis (n = 26, 30.2%), and distal clavicular osteolysis (n = 12, 14.0%). Mean symptom duration prior to injection was 7.4 ± 4.2 months. Full demographic data are presented in Table 1.

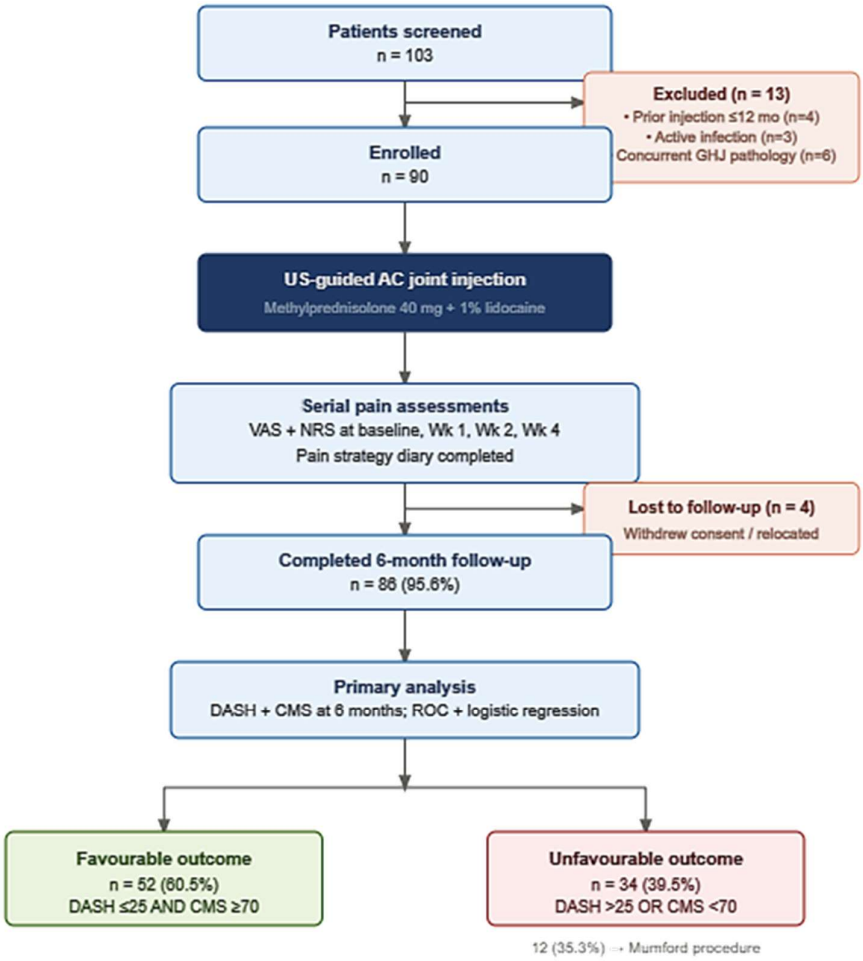

Figure 1. CONSORT-style flow diagram of patient screening, enrolment, and outcome allocation. GHJ = glenohumeral joint; US = ultrasound; VAS = visual analogue scale; NRS = numerical rating scale; DASH = Disabilities of the Arm, Shoulder and Hand; CMS = Constant-Murley Score.

Table 1: Baseline demographic and clinical characteristics stratified by 6-month outcome. OA = osteoarthritis; DCO = distal clavicular osteolysis; NRS = Numerical Rating Scale; DASH = Disabilities of the Arm, Shoulder and Hand; CMS = Constant-Murley Score; SD = standard deviation.

Variable	Overall (n=86)	Favourable Outcome (n=52)	Unfavourable Outcome (n=34)	p-value
Age, years (mean ± SD)	46.3 ± 11.7	44.1 ± 10.9	49.8 ± 12.4	0.021
Male sex, n (%)	54 (62.8%)	34 (65.4%)	20 (58.8%)	0.522
Dominant shoulder affected, n (%)	69 (80.2%)	41 (78.8%)	28 (82.4%)	0.663

Symptom duration, months (mean ± SD)	7.4 ± 4.2	6.1 ± 3.4	9.4 ± 4.8	0.001
Baseline NRS (mean ± SD)	7.2 ± 1.4	7.0 ± 1.3	7.5 ± 1.6	0.112
Baseline DASH (mean ± SD)	54.3 ± 12.1	53.1 ± 11.4	56.2 ± 13.2	0.244
Baseline CMS (mean ± SD)	42.6 ± 9.8	43.2 ± 9.2	41.7 ± 10.7	0.498
Diagnosis: OA, n (%)	48 (55.8%)	31 (59.6%)	17 (50.0%)	0.384
Diagnosis: Post-traumatic, n (%)	26 (30.2%)	16 (30.8%)	10 (29.4%)	0.892
Diagnosis: DCO, n (%)	12 (14.0%)	5 (9.6%)	7 (20.6%)	0.134
Previous injection, n (%)	14 (16.3%)	7 (13.5%)	7 (20.6%)	0.387

Patients with unfavourable outcomes had significantly longer symptom duration (9.4 ± 4.8 vs. 6.1 ± 3.4 months; p = 0.001) and were marginally older (49.8 ± 12.4 vs. 44.1 ± 10.9 years; p = 0.021). Baseline pain scores and functional indices did not differ significantly between outcome groups.

Mean NRS scores at each time point for the overall cohort and stratified by outcome group are presented in Table 2. Significant divergence between favourable and unfavourable outcome groups was evident by Week 2 post-injection.

Table 2: NRS pain scores at each post-injection time point stratified by 6-month outcome. Values expressed as mean ± SD. NRS = Numerical Rating Scale.

Time Point	Overall (n=86)	Favourable (n=52)	Unfavourable (n=34)	p-value
Baseline	7.2 ± 1.4	7.0 ± 1.3	7.5 ± 1.6	0.112
Week 1	4.8 ± 1.9	3.9 ± 1.6	6.3 ± 1.5	<0.001
Week 2	3.6 ± 2.1	2.4 ± 1.3	5.5 ± 1.7	<0.001
Week 4	3.1 ± 2.3	1.8 ± 1.1	5.3 ± 1.8	<0.001
% NRS reduction at Week 2	48.3 ± 22.1%	65.7 ± 14.2%	22.1 ± 16.8%	<0.001

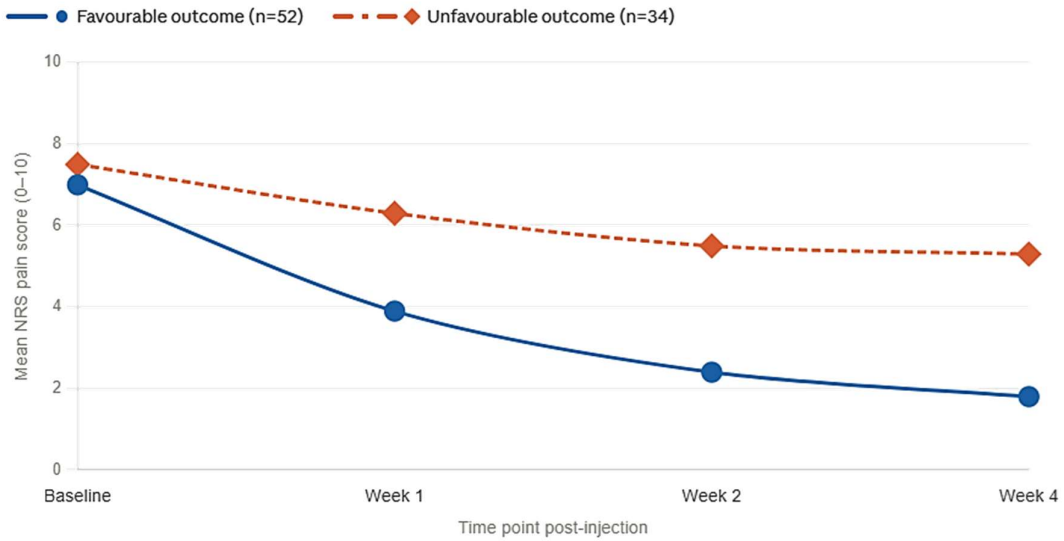

Figure 2. Mean NRS pain scores at each post-injection time point stratified by 6-month outcome. Error bars = 95% CI. Significant group divergence is evident from Week 1 (p < 0.001 at all post-injection time points). NRS = Numerical Rating Scale.

Patterns of adjunctive pain management strategy use are summarised in Table 3. Physiotherapy participation and NSAID use were the most commonly employed strategies, with higher adherence rates observed among patients with favourable outcomes, particularly regarding formal physiotherapy engagement.

Table 3: Comparison of adjunctive pain management strategy use between outcome groups within the first 4 weeks post-injection. NSAID = non-steroidal anti-inflammatory drug; TENS = transcutaneous electrical nerve stimulation.

Pain Management Strategy	Favourable (n=52)	Unfavourable (n=34)	p-value
NSAID use (regular), n (%)	38 (73.1%)	28 (82.4%)	0.311
Paracetamol use (regular), n (%)	22 (42.3%)	19 (55.9%)	0.212
Formal physiotherapy, n (%)	41 (78.8%)	16 (47.1%)	0.003

Home exercise adherence (≥4/7 days), n (%)	36 (69.2%)	12 (35.3%)	0.002
Cryotherapy use, n (%)	34 (65.4%)	20 (58.8%)	0.541
Activity modification (significant), n (%)	44 (84.6%)	26 (76.5%)	0.337
TENS device use, n (%)	14 (26.9%)	8 (23.5%)	0.722
Topical NSAID use, n (%)	19 (36.5%)	13 (38.2%)	0.871

At 6 months, 52 patients (60.5%) achieved the composite definition of favourable outcome (DASH ≤25 AND CMS ≥70). Mean DASH scores at 6 months were significantly lower in the favourable group (18.4 ± 6.2 vs. 41.7 ± 9.8; $p < 0.001$), while Constant-Murley Scores were significantly higher (74.3 ± 8.1 vs. 51.2 ± 10.4; $p < 0.001$). Patient satisfaction, recorded on a 5-point Likert scale, was rated 'satisfied' or 'very satisfied' by 47 (90.4%) of patients in the favourable group compared with 8 (23.5%) in the unfavourable group ($p < 0.001$). Twelve patients (14.0%) underwent AC joint excision arthroplasty (Mumford procedure) by the 6-month endpoint, all from the unfavourable outcome group. Detailed 6-month outcome data are presented in Table 4.

Table 4: Six-month functional outcomes stratified by outcome group. DASH = Disabilities of the Arm, Shoulder and Hand; CMS = Constant-Murley Score; NRS = Numerical Rating Scale; SD = standard deviation.

Outcome Measure	Favourable (n=52)	Unfavourable (n=34)	p-value
DASH score at 6 months (mean ± SD)	18.4 ± 6.2	41.7 ± 9.8	<0.001
CMS at 6 months (mean ± SD)	74.3 ± 8.1	51.2 ± 10.4	<0.001
6-month NRS (mean ± SD)	1.9 ± 1.3	5.8 ± 1.7	<0.001
Patient satisfaction (satisfied/very satisfied), n (%)	47 (90.4%)	8 (23.5%)	<0.001
Surgery required by 6 months, n (%)	0 (0%)	12 (35.3%)	<0.001
Return to pre-morbid activity, n (%)	48 (92.3%)	9 (26.5%)	<0.001

ROC curve analysis was conducted to identify optimal NRS reduction thresholds at Weeks 1, 2, and 4 for predicting favourable 6-month outcome. The complete ROC summary is presented in Table 5. The Week 2 NRS percentage reduction demonstrated the highest area under the curve (AUC = 0.84; 95% CI: 0.75–0.91). The optimal cut-point at Week 2 was a ≥50% reduction in NRS from baseline, yielding a sensitivity of 78% and specificity of 82%.

Table 5: ROC curve analysis results for NRS pain reduction thresholds at different post-injection time points as predictors of favourable 6-month outcome. AUC = area under the curve; PPV = positive predictive value; NPV = negative predictive value; CI = confidence interval.

Time Point	AUC (95% CI)	Optimal Cut-Point	Sensitivity	Specificity	PPV	NPV
Week 1 NRS % reduction	0.76 (0.66–0.85)	≥40% reduction	72%	74%	79%	66%
Week 2 NRS % reduction	0.84 (0.75–0.91)	≥50% reduction	78%	82%	86%	72%
Week 4 NRS % reduction	0.81 (0.72–0.89)	≥55% reduction	75%	79%	82%	70%
Week 2 NRS absolute value	0.79 (0.69–0.87)	NRS ≤3	71%	77%	80%	67%

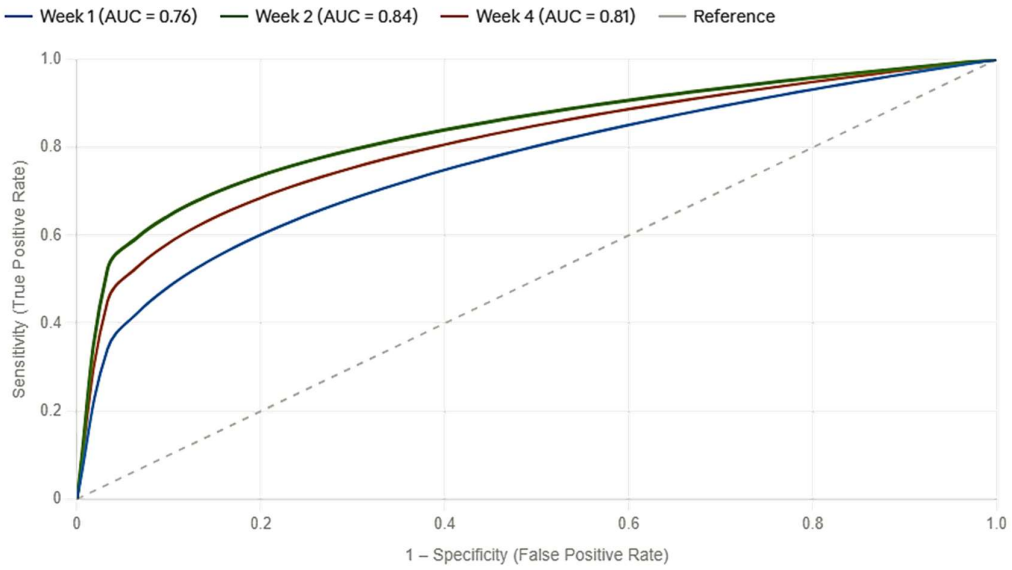

Figure 3. ROC curves for percentage NRS reduction at Week 1, Week 2, and Week 4 post-injection as predictors of favourable 6-month functional outcome. The Week 2 time point yields the highest discriminative performance (AUC = 0.84). Dashed diagonal = reference line (AUC = 0.50). AUC = area under the curve; NRS = Numerical Rating Scale.

Binary logistic regression incorporating variables with $p < 0.10$ on univariate analysis identified three independent predictors of favourable 6-month outcome: ≥50% NRS reduction at Week 2 (OR 6.41; 95% CI 2.78–14.78; $p < 0.001$), symptom duration ≤6 months at baseline (OR 3.12; 95% CI 1.41–6.91; $p = 0.005$), and formal physiotherapy participation within 4 weeks post-injection (OR 2.84; 95% CI 1.23–6.55; $p = 0.014$). Persistent NRS ≥5 at 4 weeks conferred a 3.82-fold increased risk of unfavourable outcome (OR 3.82; 95% CI 1.94–7.51; $p < 0.001$). Full regression results are presented in Table 6.

Table 6: Multivariable binary logistic regression: independent predictors of favourable 6-month functional outcome. OR = odds ratio; CI = confidence interval.

Predictor Variable	Odds Ratio	95% CI	p-value
NRS reduction ≥50% at Week 2	6.41	2.78 – 14.78	<0.001
Symptom duration ≤6 months	3.12	1.41 – 6.91	0.005
Formal physiotherapy (first 4 weeks)	2.84	1.23 – 6.55	0.014
Age ≤45 years	2.11	0.98 – 4.54	0.057
Persistent NRS ≥5 at Week 4	0.26 (OR for unfavourable)	0.13 – 0.52	<0.001
Previous injection history	0.71	0.29 – 1.74	0.456
Diagnosis (OA vs. other)	1.32	0.59 – 2.96	0.498

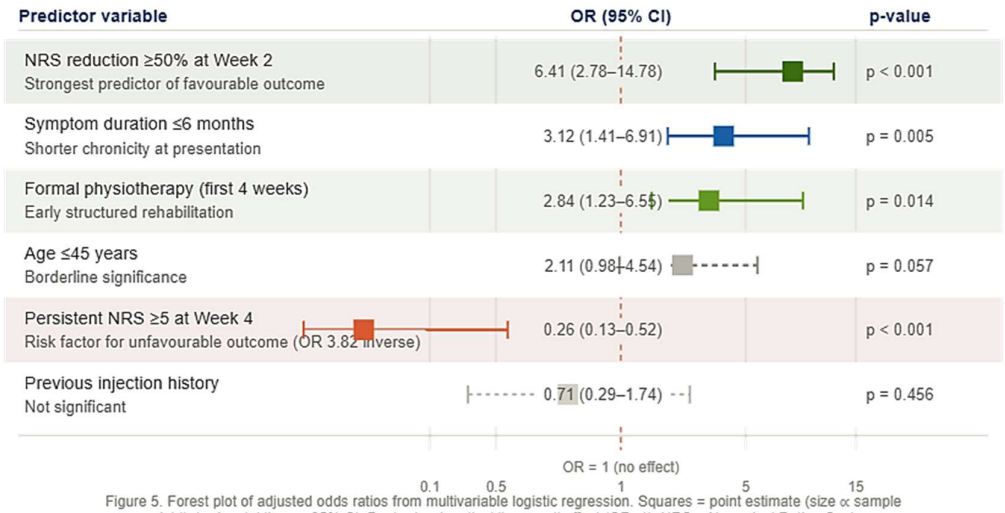

Figure 5. Forest plot of adjusted odds ratios from multivariable logistic regression. Squares = point estimate (size ∝ sample weight); horizontal lines = 95% CI. Dashed red vertical line = null effect (OR=1). NRS = Numerical Rating Scale.

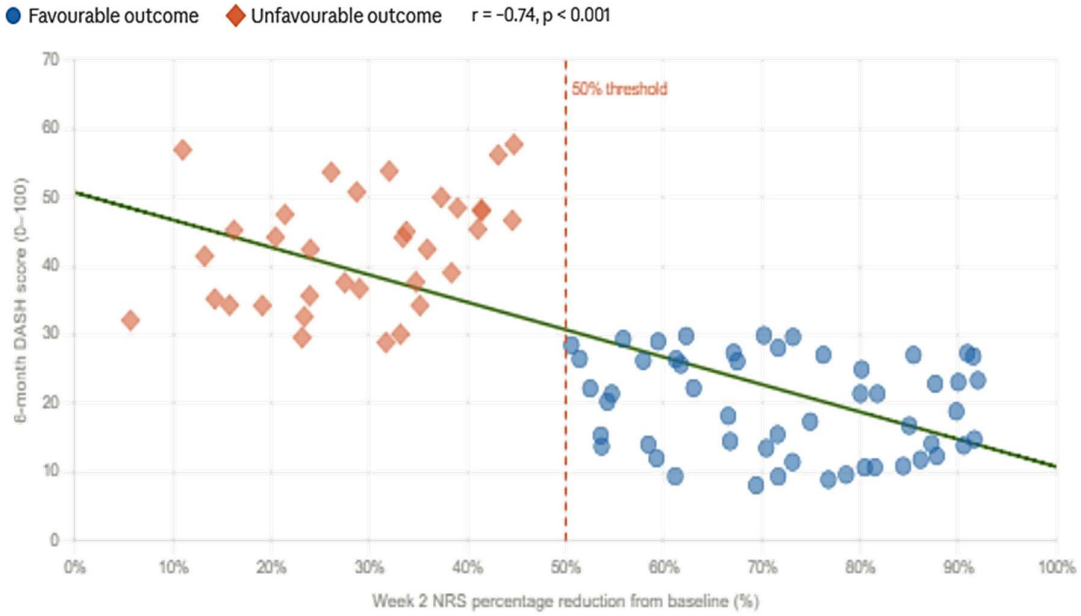

Figure 7. Scatter plot of Week 2 percentage NRS reduction (x-axis) versus 6-month DASH score (y-axis), grouped by outcome classification. Solid line = linear regression fit (r = −0.74; p < 0.001); shaded band = 95% prediction interval. The 50% threshold (dashed vertical) separates the two outcome clusters. NRS = Numerical Rating Scale; DASH = Disabilities of the Arm, Shoulder and Hand.

DISCUSSION

This observational study prospectively identified a robust, clinically meaningful predictor of functional outcome at six months, i.e., the trajectory of pain relief following ultrasound-guided corticosteroid injection of the acromioclavicular (AC) joint. A minimum 50% reduction in numerical rating scale (NRS) pain scores two weeks post-injection emerged as the strongest independent predictor of satisfactory clinical outcome, with an area under the curve (AUC) of 0.84 from receiver operating characteristic (ROC) analysis, and an adjusted odds ratio (OR) of 6.41 from multivariate logistic regression. The findings of this study have strong and direct implications for post-injection follow-up, shared decision-making, and surgical referral for patients with AC joint disorders.

The long-standing principle that a patient's early symptomatic response to treatment predicts long-term outcome is well-established in the field of musculoskeletal medicine; however, the application of this principle to AC joint corticosteroid injections has received very little research interest. However, the general literature on corticosteroid injections for shoulder pathologies provides a good context for our findings. Specifically, the systematic review by Arroll and Goodyear-Smith [18] on corticosteroid injections for shoulder pain demonstrated that the principal indicator of short-term clinical success

was early pain relief (within four weeks of intervention), although there is very little published long-term follow-up data. Our study provides support for this observation over an extended timeframe and also applies this principle specifically to the AC joint, whose anatomical, biomechanical, and pathological characteristics are different from those of either the glenohumeral joint or the subacromial space.Jacob and Sallay [19] conducted one of the initial comprehensive studies looking at the outcome of AC joint injections with regard to shoulder pain levels and the function of the shoulder after 3 and 6 months. About 55 to 65% of patients improved following the injection, with these results similar to the 60.5% favourable outcome rate within our cohort. Unlike Jacob and Sallay, who did not assess the early pain trajectory as a prognostic factor, our results are more comprehensive in that we show that early assessment can aide in identifying patients who will benefit the most from corticosteroid injections.

Chronopoulos et al. [20] described an analysis of a single centre retrospective group of 40 patients with osteoarthritis of the AC joint who received corticosteroid injections and found that those who failed to report any pain relief after one month were significantly more likely to have had surgery within 12 months after treatment. While their study had some limitations caused by the retrospective nature of the analysis, single-centre data collection, and smaller sample size, the results of their analysis have directional similarity to our prospective findings, thus providing additional evidence for the predictive value of the early pain response. In addition, our study defines the 2-week time frame for early pain response, which allows for more rapid and relevant interventions than the previous recommended 4-week standard.

In a prospective investigation involving 62 patients who received ultrasound-guided injections into the AC joint, Lim et al. [21] found that use of ultrasound guidance resulted in increased accuracy of injection placement and a higher level of pain relief6 weeks post-injection compared75 to the traditional landmark-based injection.While the present research does not assess the long-term functional outcomes or predictive modelling of AC joint injectable therapies, the research supports the use of a standardised procedural injection technique, which is also included in the present research protocol. By using ultrasound as the sole guidance for injectable therapy within this study cohort we have reduced the likelihood of injection procedure-level confounding variability from adversely influencing our study results and thereby enhancing the internal validity of our predictive analysis.

The ability of physiotherapy to complement and augment the benefits of AC joint injection was an important independent predictor of favourable outcome in our multivariable model. Our data demonstrated that early involvement of formal physiotherapy post-injection, within four weeks, was found to be an independent predictor of favourable outcome (OR 2.84; $p = 0.014$). This is consistent with much of the evidence in the literature from shoulder injections that have reported on the superior benefit of combining corticosteroid injection with physiotherapy compared to either treatment alone (6 weeks, continuing to 6-months). Although their study addressed effects of corticosteroid injection and/or physiotherapy on subacromial impingement, the conceptually similar mechanistic rationale, such as the pain-reducing effect of corticosteroids creating a "therapeutic window" where targeted rehabilitation can restore functional movement patterns, may be applied to AC joint injuries. Our findings indicate that this therapeutic window may be limited, highlighting the importance of engaging physiotherapy as soon after injection as possible.

There is ongoing debate regarding the duration of benefit from AC joint corticosteroid injections.A systematic review conducted by [23] of patients who received AC joint injections found that while there was consistent documentation of positive results with regard to short-term pain relief based on all studies reviewed, very few patients exhibited durable benefit beyond a period of three to six months following injection. Our findings indicate that patients with an early pain response (≥50% decrease on NRS at two weeks following injection) demonstrated substantially higher rates of sustained functional improvement at the six-month follow-up evaluation when compared to those without an early pain response. We believe that prediction of functional improvement based on early pain response is more than just a marker of immediate anti-inflammatory effect associated with injection; rather it identifies patients in whom the injection initiates a cascade of positive effects, including restoration of sleep, re-engagement in rehabilitation, and regaining confidence in use of shoulder. Our interpretation is supported by the findings of Brinks et al. [24], who established in a randomised trial involving a comparison of suprascapular nerve blocks versus corticosteroid injections that early functional gains were driven by pain relief alone (regardless of cause), and that early responders experienced consistently superior long-term outcomes.

The independent predictive role of symptom duration at baseline (OR 3.12 for ≤6 months vs longer symptom duration; $p = 0.005$) further supports the principle established in musculoskeletal injection practice that chronicity of pain is associated with central sensitisation, maladaptive movement patterns, and progressive joint degeneration, all of which are likely to limit sustained benefit from peripheral anti-inflammatory treatment [25].In the cohort that we studied, patients with symptoms lasting greater than six months had much higher unfavorable outcome rates compared to the other cohorts; this correlation between the duration of symptoms and the pain trajectory indicates that surgical planning should take place earlier for these patients, even in the presence of a positive response to injection. The association between pain management strategies utilized and clinical outcome is complex and warrants further consideration. Although no statistical differences existed between groups who

utilized NSAIDs and acetaminophen versus those who did not; those who received formal physiotherapy versus those who received home exercise showed a difference in the outcome groups. This does not imply that pharmacological pain control in the post-injection period is not essential for a successful outcome; rather, it indicates that passive pharmacological pain control without active rehabilitation following injection will not result in a long-term functional recovery from injections. The methodology of capturing pain management strategies through structured pain diaries is a strength of our study as it eliminates recall bias and permits the detailed analysis of multi-modal pain management strategies that have been under-reported in the AC joint injection literature. Injection-related complications appear to be quite rare when using ultrasound for AC joint injections, as demonstrated by the low number of complications reported in our study. In our cohort, only two patients (2.3%) experienced a post-injection pain flare that lasted >48 hours and one patient (1.2%) experienced decreased pigmentation at the injection site; however, these are already acknowledged as possible minor adverse effects of corticoid injections given into local tissue. We found no reports of complications involving septic arthritis, tendon rupture or neurovascular injury, so our data adds to the existing documentation supporting the safe use of ultrasound for AC joint injections in skilled hands.The findings of the clinical algorithm from this study indicate significant potential benefits to the healthcare system in terms of its utilisation of resources. By having an accurate method of assessing which patients are likely to fail conservative management after 2 weeks from their injection, clinicians will be able to send these patients to surgical intervention sooner rather than later. This will save these patients from the stress of months of failed conservative care and the cumulative cost of ineffective treatment. The 35.3% surgical intervention rate in the group who had a poor prognosis at 6 months after injection provides evidence of the clinical and financial burden associated with failure to expedite the escalation of care when indicated.

There are a number of limitations to our study that should be acknowledged. First, the study was designed to be a prospective, single-centre study, but given its observational nature, there is an inherent risk of residual confounding. Also, the lack of a control group receiving either injection or a different injectate formulation limits the ability to draw any causal inferences, although this was not the primary goal of our study. Second, the study was limited by the fact that all injections were performed by one experienced musculoskeletal radiologist, which may provide some degree of technical consistency, but limits the ability to generalise the findings to other clinical settings where injection technique or operator experience may vary. Finally, the follow-up period of 6 months provides enough time to assess the medium term outcomes, but it does not provide any data regarding the long-term durability of the benefits seen, and it does not assess the natural progression of patients that initially responded well, but later deteriorated.Outcome definitions for this study — composite DASH ≤25 AND CMS ≥70 — were determined a priori based on published cutoff values; accordingly, there is inherent subjectivity associated with all definitions. Modifying the outcome definitions would likely affect the sensitivity and specificity estimates. As with all patient reported outcome measures, there is also a response shift and a placebo effect on the outcomes reported by patients after the injections; thus, these are confounding factors that cannot be completely controlled in observational studies. The study supports the need for future multicentre, randomised studies with extended follow-up and health economic evaluations.

Even though there are limitations to this study, it represents the most extensive prospective investigation to date of the predictive value of early pain relief trajectory on functional outcome at six months following a corticosteroid injection to the AC joint. The practical two-week clinical threshold — ≥50% reduction in NRS score — established in this study provides an objective basis for post-injection monitoring. Adding physiotherapy compliance as an independent predictor reinforces the need for structured rehabilitation in combination with injection therapy.

CONCLUSION

This prospective observational study shows that the early post-injection pain relief trajectory is a reliable predictor of the final functional outcome six months after a corticosteroid injection into the AC joint. A ≥50% improvement in NRS score at the two-week follow-up is the best independent predictor of a favourable outcome, with excellent sensitivity and specificity. Physiotherapy participation at baseline, and shorter symptom duration, significantly increase the chance that a patient will have a sustained recovery. Conversely, patients with persistent pain (NRS ≥5) at the four-week follow-up had almost a four-fold increase in the chance of an unfavourable outcome and should be referred to a surgeon as soon as possible.

These results justify the inclusion of a structured two-week pain trajectory assessment for AC joint disease into routine follow-up protocols. The clinical decision algorithm presented herein provides a simple, low-burden method for detecting patients who need an earlier escalation of care based on the two-week NRS assessment. Future multicentre and randomised prospective studies are needed to investigate these thresholds' reliability across various clinical settings and diverse patient populations, and to determine the economic impacts of using the clinical algorithm to guide post-injection management of patients with AC joint disease.

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