CLINICAL ORTHOPAEDICS AND RELATED RESEARCH
Number 460, pp. 130–136

SECTION II
ORIGINAL ARTICLES

Temporal Variations in a Modified Neer Impingement Test Can Confound Clinical Interpretation

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High variability in the time required for patients to have substantial pain relief after Neer-type subacromial impingement tests might help explain conflicting data regarding their effectiveness in guiding treatment and predicting surgical outcomes. To focus on quantifying temporal variability associated with a modified (local anesthetic and corticosteroid) impingement test, we hypothesized that substantial pain relief (greater than 75% reduction) can occur beyond the 10-minute interval many clinicians use for determining results of this test. Fourteen females and 12 males (mean age, 55.6 years) who received subacromial injections for Stage II impingement completed 10-cm visual analog scales for pain at 5, 10, 20, 30, and 40 minutes postinjection. There were 11 patients (42%) who attained at least 75% relief by 10 minutes compared with nine (35%) additional patients who subsequently attained 75% relief after 10 minutes. On average, 75% reduction in pain did not occur until after 30 minutes postinjection. Data analysis also revealed two groups: (1) rapid responders with greater than 50% pain relief by 10 minutes; and (2) delayed responders with greater than 50% pain relief after 10 minutes. Assessing pain at 10 minutes for a Neer-type impingement test can fail to accurately determine a positive test in a substantial percentage of patients.

Level of Evidence: Level II, diagnostic study. See the Guidelines for Authors for a complete description of levels of evidence.

In 1983, Neer described two techniques for distinguishing subacromial impingement lesions from other painful shoulder conditions: the impingement sign and test.[23] The Neer impingement sign is a provocative maneuver (see Materials and Methods) that is considered by many to be reliable for differentiating subacromial impingement from other painful shoulder conditions.[22–24,35] A positive impingement sign, eliciting pain from this maneuver, may indicate the presence of an impingement lesion. The Neer impingement test, which is based on a subacromial injection with local anesthetic (see Materials and Methods), helps to further determine whether the pain associated with a positive impingement sign can be attributed to subacromial impingement lesions or to other painful conditions that can cause shoulder pain. This test also can be used to help determine whether the cause of limited range of motion is the result of shoulder pain or weakness attributed to a rotator cuff tear.[3] Although Neer did not specify how much time should be allotted before determining the results of the injection, this test has since evolved in the literature to be interpreted as comparing preinjection pain with pain 10 minutes postinjection.[10,16,19] However, routine use of a steroid and local anesthetic mixture (often with bupivacaine and lidocaine) administered into the subacromial space as a diagnostic tool, instead of performing the classic Neer impingement test (lidocaine only), is gain-

Received: September 13, 2006
Revised: December 29, 2006
Accepted: February 12, 2007
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Each author certifies that he has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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DOI: 10.1097/BLO.0b013e31804a8581

ing popularity.[4,6,18,29,39] This is because, in addition to reducing acute pain associated with injecting a corticosteroid, it also potentially is curative and diagnostic.[1,6,14,18,29,37]

The impingement test also has been used to predict outcomes of surgery.[2,19,26,38] However, conflicting reports question the ability of the Neer impingement test to predict surgical outcomes. Kirkley et al[16] concluded that the impingement test correlated poorly with surgical outcome in a study of 30 patients with rotator cuff tendinosis. In contrast, Mair et al[19] found the impingement test a good predictor of surgical outcome; a positive impingement test showing greater than 75% pain relief was six and 11 times more likely to have a positive outcome at 3 and 12 months after surgery, respectively, than a negative impingement test.[19] These disparate findings, and our observations, prompted us to further investigate limitations of this important clinical tool.

After performing a modified Neer impingement test (which includes local anesthetic and corticosteroid) for symptoms consistent with Stage II subacromial impingement, we have observed substantial pain reduction often occurring beyond 15 minutes postinjection. We became aware of this when some of our patients telephoned our office to inform us their pain decreased substantially 30 to 40 minutes after they had left our clinic. This temporal variation might be one reason for the disparate findings of recent studies that challenge the use of the impingement test to predict surgical outcomes. Although many orthopaedists probably recognize temporal variation is common after these subacromial injections, our review of the English literature failed to locate a prior quantitative study directly examining this issue.

We therefore hypothesized that for a modified impingement test (1) pain relief can be substantial (greater than 75% reduction) well beyond the current 10-minute recommendation of Neer-type impingement tests, and (2) current recommendations of 10 minutes are inadequate to accurately assess a positive test. We report additional findings that occurred during the data and outcome analyses.

MATERIALS AND METHODS

Based on a preliminary sample of enrolled patients, sample size analysis showed 22 or more patients were required to resolve differences in pain on the order of 1 cm on a visual analog scale (VAS) with statistical probability of $\alpha \leq 0.05$ and 95% statistical power ($p = 0.95$; $\beta = 0.05$).[13] Therefore, a sample size of 26 patients (14 females and 12 males with a mean age of 55.6 years [range, 17–84 years]) who met rigorous enrollment criteria (Table 1) was selected during a 2-year period. During the study, 65% of the patients in the surgeon's (JGS) practice were seen for shoulder pain and 184 subacromial injections were performed. Because of strict enrollment criteria, which minimized variables that could confound results of the injection, the study cohort represented a relatively small percentage (14%) of these injected patients.

TABLE 1. Inclusion and Exclusion Criteria

1. Shoulder pain for at least 2 months
2. No trauma as a potential cause of pain
3. No evidence of adhesive capsulitis*
4. No cervicalgia or cervical radiculalgia
5. No rheumatoid arthritis or rheumatologic conditions
6. No previous surgery on the affected shoulder or corticosteroid injections into any region of the affected shoulder
7. No pain with the cross-body (horizontal) adduction maneuver (which, if present, might suggest acromioclavicular joint pathology)
8. No radiographic evidence of calcific tendinitis or significant humeral head elevation (the latter, if present, suggests rotator cuff tear or weakness)
9. No clinically significant acromioclavicular or glenohumeral arthritis
10. No clinical evidence of rotator cuff tear (ie, weak arm elevation, positive "drop arm" sign, and so on)
11. No evidence of bicipital tendonitis (eg, no pain with Yergason's, Speeds, and direct palpation tests)
12. No evidence of glenohumeral instability
13. No diabetes mellitus
14. No involvement in a workers' compensation case or medical malpractice case
15. No significant resistance to infusion of the solution during the injection

*Flexion 120° or greater and external rotation 45° or greater

Each patient received a shoulder injection in our clinic by the same surgeon (JGS) and indicated pain relief on a 10-cm VAS at preinjection and at 5, 10, 20, 30, and 40 minutes postinjection. The first 5- and 10-minute intervals were performed to mirror the times represented in current literature that are associated with the impingement test.[10,16,19] As described subsequently, the injection was considered a modified Neer-type impingement test because it included local anesthetic and corticosteroid. Each patient had no evidence of a rotator cuff tear by physical examination in addition to meeting the additional criteria that generally are consistent with Stage II subacromial impingement syndrome (Table 1). However, we imposed no age restriction and, although not precluded from enrollment in this study, there were no overhead athletes. None of the patients had syncopal episodes or other untoward events or reactions during or after the injections. All patients completed an informed consent form that was approved by an Institutional Review Board (LDS Hospital, Salt Lake City, UT).

The patients were not informed at the time of injection that results of the injection subsequently would be studied; this intentional study design parameter served to reduce additional bias that might have occurred if patients had this knowledge preinjection.

Patients recorded pain on a 10-cm VAS (0, no pain; 10, most severe pain) indicating the amount of preinjection and postinjection pain. There were six 10-cm VAS on a preprinted form,

which corresponded to the recordings made at Time 0 (preinjection) and at 5, 10, 20, 30, and 40 minutes postinjection. All injections were administered by the same fellowship-trained shoulder surgeon (JGS).

Standard radiographs (anteroposterior, supraspinatus outlet, axillary lateral, and Zanca views)[31] were taken of each patient's affected shoulder and were examined after the physical examination. The radiographs also were scored independently by two orthopaedic surgeons (JGS, RLN) who recorded the following: (1) morphologic features of the acromion (Type 1 [flat], Type 2 [moderately curved], Type 3 [very curved]);[5,30,33] (2) the magnitude of arthritic changes (if present) of the acromioclavicular or glenohumeral joints (none, mild, moderate, severe);[8,27] (3) the presence or absence of calcific tendinitis based on size of the calcific lesion (none, small [up to 0.5 mm], medium [0.5–1.5 mm], large (greater than 1.5 mm]);[7,34] and (4) humeral head elevation as measured at the acromial-humeral interval (none [7–14 mm], mild [5–7 mm], significant [less than 5 mm]).[36] Analysis of the independent radiograph viewings by the two surgeons revealed no differences in acromial morphology, acromioclavicular arthritis, glenohumeral arthritis, or humeral head elevation. Because the evaluators only differed in one to two patients in three of these four parameters, the statistical analyses reported subsequently were conducted using their averaged values.

At the end of the examination, the surgeon (JGS) performed the Neer and the Hawkins-Kennedy[11] maneuvers twice. The Neer impingement maneuver (the impingement sign) is performed as the examiner causes forced forward flexion of the patient's upper extremity (with elbow extended and forearm pronated) while the examiner's other hand prevents compensatory upward scapular rotation. This causes the greater tuberosity of the humerus to encroach on or impinge against the anterior acromion.[22,24,35] The Hawkins-Kennedy[11] maneuver is forward flexion to 90º combined with maximal internal rotation of the shoulder. In the few instances in which active forward flexion was limited to approximately 90º because of pain, the surgeon was able to exceed 120º. This observation, in addition to external rotation exceeding 45° in all patients, further ensured that patients with adhesive capsulitis were not included in the study.

The surgeon then exited the examination room. A trained medical assistant (VJM) asked the patients to mimic these maneuvers without assistance. The patients marked the first of six VASs to indicate the maximum pain provoked during the assisted and unassisted Neer and Hawkins-Kennedy maneuvers. At that time, each patient was asked to indicate if they noted differences in pain elicited by assisted versus nonassisted maneuvers; in all cases, there were no differences (ie, 1.0 cm or less on the VAS).

After the first VAS measurement (Time 0), the medical assistant (VJM) prepared the skin over the superolateral shoulder using alcohol swabs followed by Betadine® swabs (povidone-iodine 10%; Purdue Frederick Co, Norwalk, CT). The surgeon again entered the room and performed the injection by first spraying Gebauer's ethyl chloride (Gebauer Co, Cleveland, OH) for 10 seconds to numb the skin. The skin and subcutaneous tissues were anesthetized with 2 mL of 1% lidocaine (Abbott Laboratories, North Chicago, IL) using a 1.5-inch (38.1-mm) 25-gauge needle. After the needle was pushed into the subacromial space, the syringe barrel was exchanged for one containing the modified impingement test solution of 1.0 mL methylprednisolone acetate (Depo-Medrol®; Pfizer Inc, New York, NY) (80 mg/mL), 5 mL of 1% lidocaine (no epinephrine), and 5 mL of 0.5% bupivacaine (no epinephrine) (Abbott Laboratories) for a total volume of 11 mL. One-third of this suspension was injected medially, one-third 30° anteriorly, and one-third 30° posteriorly.

The surgeon again performed the Neer and Hawkins-Kennedy maneuvers to distribute the local anesthetic. The medical assistant reentered the room and instructed the patients to perform these maneuvers. The Betadine® then was wiped off and the patients rerobed. Patients marked the second VAS (the 5-minute recording). The third VAS (10 minutes) also was completed after they again performed the assisted and unassisted Neer and Hawkins-Kennedy maneuvers. The patients were given a prescription for physical therapy that emphasized isometric exercises to strengthen the rotator cuff to enhance the depressor effect on the humeral head.[15,21] The patients then departed the clinic with instructions to complete the VAS at 20, 30, and 40 minutes postinjection. The 40-minute duration was selected because it (1) allowed for sufficient data points for regression analyses, and (2) it spanned a range that we have empirically observed as sufficient for attaining maximal pain relief. The patients returned the VAS form by mail in a stamped envelope that we provided. We did this for patient convenience, allowing them to leave the clinic and not prolong their stay. All VAS forms were returned with a postmark within 3 days, and there were no missing data on any of the VAS forms.

Substantial pain relief was defined as 75% or more improvement when compared with the pain recorded on the first VAS as recommended in Mair et al.[19] For example, if a patient initially had marked 8 on the VAS, pain relief would be considered significant when a subsequent VAS marking was 2. This level of pain reduction (75%) represents a positive Neer impingement test.[19] Outcomes were evaluated 3 months postinjection in terms of pain relief measured on a VAS and with the American Shoulder and Elbow Surgeons (ASES) subjective shoulder score.[17] This followup time was selected because of data showed it is sufficient for detecting patients who might have substantial recurrence of pain, which could suggest they had more serious disorders when compared with those who had sustained relief.[1,32] For patients who did not return for followup, telephone interviews were used to determine if they had surgery and if they were happy with their shoulder function.

Data are reported as means with standard deviations (SD). Paired comparisons were assessed using a one-way analysis of variance design with Fisher's probable least-squares difference tests for identifying post hoc differences at $\alpha \leq 0.05$.

RESULTS

Analysis of all patients showed greater than 75% pain relief generally was not observed until after 30 minutes postinjection (81% average pain relief), whereas at 10 minutes, 64% average pain relief was achieved, supporting

our hypotheses. When allowing each patient to be listed at only one time, the number of patients who had a positive test (at least 75% pain reduction) at each time are as follows: nine (35%) at 5 minutes, two (7.7%) at 10 minutes, four (15%) at 20 minutes, four (15%) at 30 minutes, and one (4%) at 40 minutes. Averaged data from all patients showed peak pain relief was 82% at 40 minutes postinjection. When using average percent relief data for all patients, regression analysis showed a linear ($r^2 = 0.956$) trend in pain relief over 40 minutes (Fig 1A). The preinjection pain marked on the 10-cm VAS, averaged for all patients, was 6.8 cm (SD, 1.8). No patient had worse pain.

The time of pain reduction of the 26 patients could be best described as two groups: (1) rapid responders, who achieved greater than 50% pain relief by 10 minutes postinjection; and (2) delayed responders, who achieved greater than 50% pain relief only after 10 minutes postinjection. Although these groups differed in the percent pain relief at 10 minutes, they did not differ in age, gender, range of motion measurements, use of pain medications, occupations requiring repetitive overhead reaching, outcome measures at 3 months (see subsequently), and in various other characteristics or measures of shoulder disorders or function ($p > 0.2$ in all comparisons) (Table 2).

Group 1 ($n = 12$) consisted of six women and six men with a mean age of 59.6 years (range, 32–79 years). Their average preinjection pain level was 6.4 cm (SD, 1.5), which was similar to the preinjection pain level of Group 2 (6.0 cm). At 10 minutes postinjection, average pain relief was 90% with 10 of 12 (83%) patients reporting greater than 75% pain relief. Peak pain relief was 93% at 20 minutes postinjection with 11 of 12 (92%) patients having greater than 75% pain relief at 20 minutes. One of 12 (8%) patients did not achieve more than 75% pain relief by 40 minutes postinjection (the percent pain relief for this patient was 60% at 40 minutes). The rapid responders showed a nonlinear trend in average percent pain relief ($r^2 = 0.003$ for the linear regression; $r^2 = 0.982$ for the nonlinear regression) (Fig 1B).

Group 2 ($n = 14$) consisted of eight females and six males with a mean age of 52.2 years (range, 17–84 years). Their average preinjection pain level was 6.0 cm (SD, 2.1). At 10 minutes postinjection, average pain relief was 40%. Peak pain relief was 80% at 40 minutes postinjection with nine of 14 (64%) patients having greater than 75% pain relief. Five of 14 (36%) patients did not achieve more than 75% pain relief by 40 minutes postinjection (the percent pain relief for these patients at 40 minutes was 40%, 43%, 60%, 68%, and 70%). The delayed responders showed a linear trend ($r^2 = 0.987$) in average percent pain relief (Fig 1C). In the delayed responder group, the five patients who did not achieve greater than 75% pain relief by 40 minutes postinjection differed ($p < 0.05$) from the other

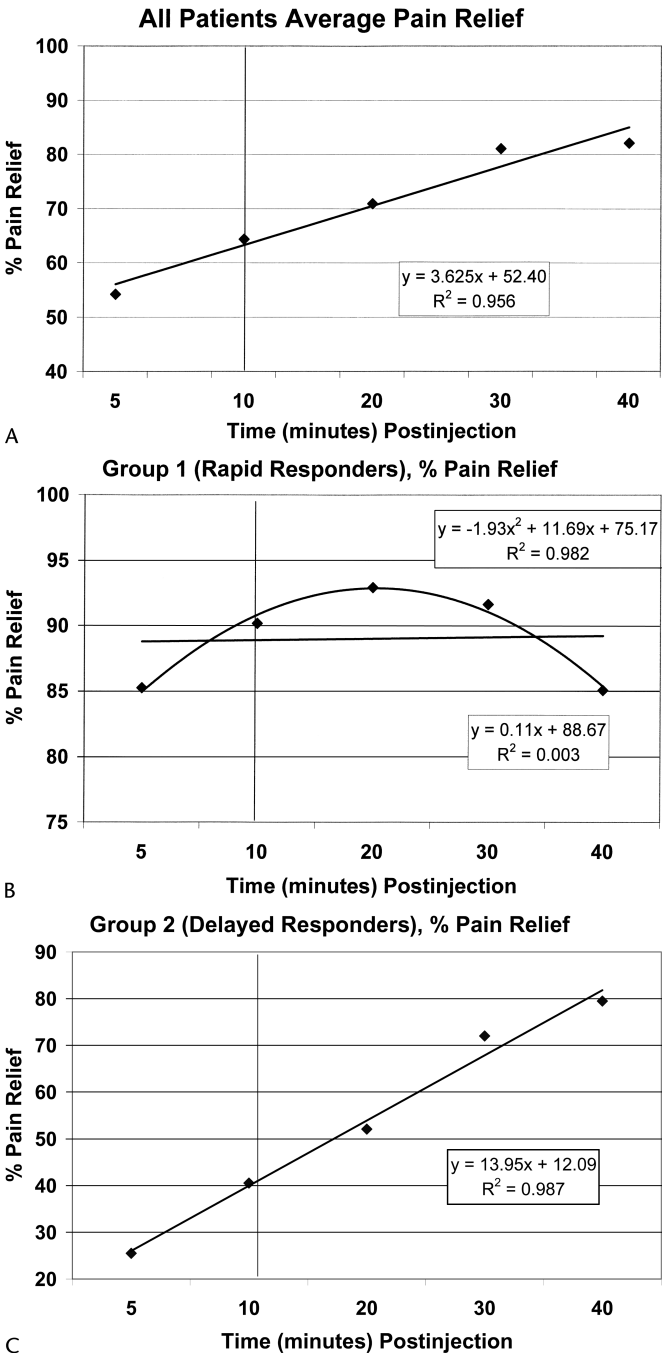

Fig 1A–C. The graphs show average pain relief reported as a percentage in (A) all patients, (B) rapid responders (Group 1), and (C) delayed responders (Group 2). In contrast to all patients and delayed responders, rapid responders exhibit nonlinearity in their temporal variation; this pattern exhibits much greater fit to this nonlinear function: $y = -1.93x^2 + 11.69x + 75.17$ ($r^2 = 0.982$, $p = 0.016$).

TABLE 2. Rapid Responders (Group 1) versus Delayed Responders (Group 2)

Patient Characteristics	(n = 12)	Group 1 (n = 14)	Group 2 p Value
Active ER			
Mean	71°	76°	0.3
SD	13°	11°	
Range	45°–80°	45°–80°	
Active IR			
Mean	74°	79°	0.2
SD	11°	6°	
Range	65°–80°	65°–80°	
Active FE			
Mean	138°	144°	0.6
SD	27°	26°	
Range	95°–180°	90°–180°	
ASES score			
Mean	40	47	0.9
SD	16	17	
Range	15–77	15–82	
Duration of symptoms			
Mean	4.8 months	4.3 months	0.6
SD	2.7	1.6	
Range	2–9 months	2–7 months	
Regular NSAID use	5/12	4/14	0.5
Degree of A-C arthritis			
None	7	10	0.5
Mild	5	4	
Moderate	0	0	
Degree of G-H arthritis			
None	9	13	0.3
Mild	3	1	
Moderate	0	0	
Acromial morphology			
Type 1	3	4	0.6
Type 2	9	10	
Humeral head elevation			
None	11	12	0.7
3–6 mm	1	2	
Greater than 6 mm	0	0	

nine patients only in having a longer duration of preinjection symptoms (mean duration, 5.4 months [SD, 1.2] versus 3.6 months [SD, 1.3], respectively).

One patient in each group failed to appear at their scheduled 3-month followup. Telephone correspondence revealed they had not had surgery and were happy with their shoulder function. Excluding these two patients, there was no difference between Groups 1 and 2, respectively, in their preinjection versus 3-month postinjection percentage pain relief (75.9% versus 47.1%) and ASES scores (Group 1, 43.0 versus 77.7 [44.7% difference]; Group 2, 45.8 versus 64.8 [32.2% difference]). No patients had surgery or were planning to have surgery at 3 months postinjection.

DISCUSSION

Temporal variations in pain reduction might help to explain why some investigators have found the conventional Neer impingement test (1% lidocaine only and 10 minutes) or modified Neer-type impingement tests (local anesthetic and corticosteroid) poorly correlate with the success of surgery.[16] It is plausible that allowing up to 40 minutes postinjection before determining whether these tests are positive or negative could yield improvements in their predictive power in the diagnosis and treatment of subacromial impingement lesions. However, because the patients included in our study were not followed through to surgery, we were not able to correlate surgical outcomes with pain relief from our modified test at 10 versus up to 40 minutes postinjection. Studies are needed to determine how temporal variations in pain relief from the conventional and modified Neer impingement tests are correlated with surgical findings (eg, presence of occult rotator cuff tear, acromion morphology, degree of biceps tendon disorder, etc), and long-term surgical outcomes. Although our study had adequate statistical power to detect temporal variations in our modified impingement test, an additional study limitation was there was insufficient power to rigorously evaluate patient characteristics that might help explain why the two groups (rapid versus delayed responders) existed. Ongoing prospective studies addressing these various issues, which ultimately will require approximately 50 patients in each group, are being conducted in our clinic.

The lack of objective proof that the injection was placed in the subacromial bursa is another important study limitation. Unrecognized inaccurate injection might provide an explanation for the existence of the delayed responder group.[25,39] Kirkley et al[16] observed this placement using ultrasound. However, confirmatory imaging by MRI or ultrasound was not feasible or practical for our study, which was designed to mimic the clinical setting of the impingement test. In contrast, and similar to our study, recent studies of Mair et al[19] and Lim et al[18] used only the skill of the injecting physician, which is more reflective of the results of common clinical practice. Consequently, the delayed responders might be patients who had injections that were partially infused into the bursal wall or into tissues near the subacromial bursa. This also is supported by results showing only 29% accurate placement in a study of rheumatologists who used radiopaque dye to track subacromial injection accuracy.[9] A study of an orthopaedic shoulder specialist also showed a high rate of missed injections with only 39 of 56 (70%) injections reaching the

subacromial bursa and 12 of 56 (21%) inadvertently being placed in the deltoid muscle.[39] Similar results have been reported in a study using MRI to evaluate the injection accuracy of orthopaedic surgeons.[12] However, even if inaccurate injections occurred in our cohort of patients, this might actually strengthen the conclusions of our study. This is because, in contrast to the shoulder specialist who performed the injections in our study, physicians with less experience and/or comfort performing these injections might be expected to have a larger percentage of delayed responders. This supports extending the time well beyond 10 minutes for determining if the test is positive or negative.

Another explanation for the existence of a delayed responder group is the presence of occult attritional rotator cuff tears, which can be asymptomatic and also increase with age.[20,28] This possibility further supports allowing more time for the local anesthetic to have full effect when performing a Neer-type impingement test. However, the prognostic value of an impingement test that becomes positive between 10 and 40 minutes postinjection could be confounded by anesthetized regions that would not be addressed with subacromial decompression surgery (eg, anesthetizing an arthritic glenohumeral joint through an occult rotator cuff tear). This possibility, although minimized by the strict enrollment criteria used in our study, seems possible because 54% (14 of 26) of the patients injected were older than 50 years. However, the fact that the two groups did not differ in mean age reduces this association with age and with the likelihood of an unrecognized correlation between patient age and the presence of an occult cuff tear.

A delayed response to our modified impingement test might correlate with the use of bupivacaine (in addition to lidocaine) because this has prolonged onset of anesthesia (approximately 2–10 minutes) when compared with lidocaine (seconds to minutes) (package product information; Abbott Laboratories). However, the fact that nearly 50% of our patients had pain relief within 10 minutes suggests bupivacaine was not an important factor in this context. Furthermore, Kirkley et al[16] used 5 cc of 1% lidocaine, which is the same volume of 1% lidocaine used in our patients. However, this issue might be more important when bupivacaine is the only local anesthetic. For example, Lim et al[18] described using 40 mg methylprednisolone acetate and 10 mL 0.5% bupivacaine in a study of the prognostic value of the subacromial injection test. In this case, the relatively delayed onset of anesthesia from bupivacaine might confound assessment of the pain at the conventional time of 10 minutes postinjection. Clearly, clinicians who use bupivacaine must account for distribution of the medication and the delay in onset; allowing up to 40 minutes might serve as an appropriate benchmark for determining results of the injection in these cases.

Our data support the hypothesis that pain relief after a modified (steroid/local anesthetic) Neer-type impingement test can be important well beyond the current 10-minute recommendation. In turn, two important conclusions can be stated: (1) measuring pain at 10 minutes after administering this modified Neer-type impingement test can fail to accurately assess pain relief in a substantial percentage of patients; and (2) there may be delayed responders, which warrants allowing up to 40 minutes postinjection before the test is deemed positive or negative.

Acknowledgments

We thank Drs. Mark W. Mason, Russell L. Nelson, Wayne Z. Burkhead, and Kenneth J. Hunt for assistance in completing the study and/or for criticisms of the manuscript, Vickie J. Martin for clinical support for this study, and Krista Jensen for assistance with statistical analyses.

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