Scand J Rehab Med 30: 253–262, 1998

THE SUBACROMIAL IMPINGEMENT SYNDROME

A study of results of treatment with special emphasis on predictive factors and pain-generating mechanisms

Hans Rahme, MD[1], Eva Solem-Bertoft, PT, PhD[1], Carl-Einar Westerberg, MD[2], Elisabeth Lundberg, PT[1], Stefan Sörensen, PhD[3] and Sören Hilding, MD[1]

From the [1]Department of Orthopedics, Central Hospital, Västerås, [2]Department of Neurology, University Hospital, Uppsala, [3]Department of Research, Central Hospital, Västerås, Sweden

ABSTRACT. Forty-two patients with subacromial impingement syndrome entered a randomized prospective study comparing open anterior acromioplasty with a physiotherapy regime. The criterion for a successful outcome of treatment was a reduction of the initial pain score of more than 50% using the visual analogue scale (VAS) technique. The evaluation was performed by an independent observer. At the 6-month follow-up, treatment in the surgical group had been successful in 12/21 (57%) patients versus 6/18 (33%) in the physiotherapy group. A one-year evaluation revealed 16/21 (76%) "successes" in the surgical group. A direct and unbiased comparison with the physiotherapy group was not possible at one year, since 13 patients chose surgery after initial physiotherapy. However, in "an intention to treat" analysis outcome at one year was significantly better in those randomized to surgery. We found two standardized, composite, active movements—the "Pour out of a Pot" manoeuvre requiring the emptying of a pot of water, and the "Hand in Neck" manoeuvre—to be of predictive value for the outcome of surgery. When combining three pain-related variables into a criterion for prediction of success, a sensitivity of 78% ($p < 0.02$) and a specificity of 90% ($p < 0.03$) were attained. We advance the hypothesis that pain in the impingement syndrome is mainly elicited by compression of the subacromial bursa. In some patients a traction-responsive pain generator in the supraspinatus tendon may be present as well.

Key words: functional assessment, impingement syndrome, pain generator, physiotherapy, shoulder, shoulder joint.

INTRODUCTION

The term "impingement syndrome of the shoulder" implies that a compression of the subacromial structures produces characteristic symptoms. Patients suffering from shoulder pain due to subacromial impingement have pain at rest that is worsened by certain movements involving elevation of the upper arm, particularly if this movement is combined with internal rotation. We regard loss of function mainly as a consequence of pain. The main goal of any treatment should therefore be a reduction or, preferably, the elimination of pain and the evaluation of results should focus on the reduction of pain, a view that is also held by Lirette et al. (11).

Two standardized, composite, active movements—the Pour out of a Pot (POP) manoeuvre and the Hand in Neck (HIN) manoeuvre—were used as tools for analysis of pain mechanisms.

The aims of this study were to compare the results of surgical treatment (anterior acromioplasty (12), supplemented by repair of rotator cuff tears, when present) with the results of a standardized physiotherapy regime and, if possible, to identify predictors for successful surgery. Data, obtained from two pain-provoking tests, permitted an analysis of pain mechanisms in the impingement syndrome.

MATERIAL AND METHODS

Patients

All patients were referred to the Department of Orthopedic Surgery at Västerås Hospital between 1986 and 1988. Positive criteria for inclusion were: isolated shoulder disease; working age; pain which for the duration of at least one year had been present at rest and was reported to be accentuated by movements involving elevation; a positive impingement sign—pain is elicited by forced elevation and internal rotation; a positive impingement test (13)—pain on elevation is markedly reduced

by injection of lidocaine in the subacromial bursa. Patients requiring resection of the lateral end of the clavicle as well as those with glenohumeral osteoarthrosis were excluded.

Forty-two patients (19 males, 23 females) with a mean age of 42 (28–63 years) fulfilled these criteria. The dominant shoulder was affected in 25 cases. In 10 patients there was a history of trauma as an initiating factor. The duration of pain was on average almost four years. Pain had not been satisfactorily alleviated by traditional physiotherapy or corticoid injections (37 patients). Thirty-two of the patients (76%) had been on sick-leave prior to inclusion in the study and these patients were convinced that their shoulder disorder was work-related.

Impingement test

Thirteen patients became completely free of pain, 25 experienced good pain relief, 3 experienced fair degree of pain relief and one refused the injection.

The physiotherapist's examination

While sitting relaxed in front of the examiner the patients rated their pain at rest using a visual analogue scale (VAS) graded from 0 to 10 (8). They also rated the pain experienced during performance of the POP manoeuvre (22). The manoeuvre involves emptying a one-litre pot, filled with water, with the arm held in front of the body. This movement requires an isometric postural fixation of the upper arm in forward flexion, and an eccentrically performed internal rotation. The motor performance was rated on a scale comprising steps 0–4, where 4 indicates normal performance (see Appendix 1 and photographic illustrations in reference 22).

In the HIN manoeuvre (23), the patient is instructed to put his hand around the base of the neck while attempting to extend the upper arm so that the elbow reaches the coronal plane. Performance is rated on a scale graded from 0 to 5, where 5 indicates normal performance (see Appendix 1 and photographic illustrations in reference (23).

The active and passive range of motion in forward flexion and abduction was measured goniometrically.

The muscle force of the hand grip was determined by using a dynamometer. The force of the wrist extensors was estimated manually. The physiotherapist was particularly observant of any signs of psychogenic weakness, such as cocontraction of antagonists and uneven activation. Such signs were noted and are labelled "markers of psychogenic weakness".

Following the same method of assessment, all patients who took part in the study were examined 8 weeks, 16 weeks, 6 months, and one year after the operation or after initiation of physiotherapy treatment.

Radiologic examination

Bilateral plain radiographs of the shoulder in internal and external rotation were obtained using a 15 degree caudal angulation of the central X-ray beam, with the patient in an upright position.

Randomization procedure, drop-outs, formation of subgroups

The patients were randomized into two groups using blocked randomization. Twenty-one patients received surgical treatment followed by postoperative physiotherapy (group A). Twenty-one patients started physiotherapy treatment after randomization (group B). After at least 6 months of physiotherapy, patients in group B were allowed to choose surgical treatment if they were not satisfied with the result of non-surgical treatment. Eleven patients chose surgery after 6 months, another two chose surgery after one year. Patients randomized to physiotherapy who later wanted surgery formed group C. There were two drop-outs from the initial group B, and one from group C. This means that all three drop-outs belonged to the initial group B. At the 6 months' follow-up, data were missing from one patient in group B. At the one-year follow-up, group A comprised 21 patients, group B 6 patients, and group C 12 patients. Thirty-three patients (groups A + C) were given surgery and were eligible for evaluation.

Surgical treatment

Anterior acromioplasty was performed according to Neer (12, 13). Particular attention was paid to the portion of the acromion that may extend beyond the anterior border of the clavicle (17), which if present was osteomized vertically before removing the anteroinferior surface of the acromion. Five tendon ruptures were sutured. Biopsies from the subacromial bursa were taken for microscopic examination, the results of which are presented in a separate article (16).

Physiotherapy treatment

The treatment regime was based mainly on the principles according to Böhmer (3):

Information to the patient on functional anatomy and biomechanics of the shoulder.

Advice on how to avoid positions for "wear and tear" of the subacromial structures.

Unloaded movements of the shoulder.

Measures to normalize the scapulohumeral rhythm and to increase postural awareness.

Strengthening of the shoulder muscles and endurance training.

Submaximal training of the rotator cuff was started about three months after the operation in groups A and C and when pain had subsided in group B. Initially, all patients were seen 2–3 times a week. The intervals between treatments were successively increased as the patient became more familiar with the object of the exercises.

Evaluation criterion

The evaluation was based solely on the pain ratings. Total pain score was obtained by adding the VAS score for pain at rest with the pain experienced during performance of the POP manoeuvre. The total pain score at the 6-month follow-up was subtracted from that of the initial rating, whereupon the difference was divided by the initial total score. A ratio was thus formed that reflects relative reduction of pain. Patients with a reduction greater than 50%, i.e. a ratio >0.5, were classified as "successes". The "successes" were further divided into a group with complete pain relief (ratio 1.0), and a group with partial pain relief (ratio 0.51–0.99). Patients with a reduction of 50% or less were classified as "failures". The same procedure was followed at one year.

The psychogenic pain syndrome (PPS)

In all series of patients with long-standing pain there will be an admixture of patients with a psychogenic pain syndrome, which in the context of this article is defined as a condition, where psychogenic factors are the main determinants of the pain reports of the patient. The distribution of pain is often unusual in comparison to the "organic" condition considered. Signs of psychogenic weakness (manifested as cocontraction of antagonists and uneven activation of tested muscles) are very common.

Furthermore, these patients tend to use very high VAS ratings for pain. In an attempt to identify such patients, it was decided that those rating at least "one 9 or two 8s" should be regarded as probable PPS patients. To validate this assumption it was decided early on that such patients should be examined by a neurologist (CEW) after conclusion of the study (Appendix 2).

Statistical methods

All p-values are two-sided. Proportions were compared using the scaled χ^2 test (26). Tests for the significance of a change were performed using McNemar's test. The multiple regression analysis was performed using rank of scores assigned to the three outcome categories as the Y-variable, rank of POP-performance ratings as the X_1-variable and the dichotomous HIN 5/<5 variable as a dummy X_2-variable.

Other methods are mentioned in their context.

RESULTS

Comparisons between treatments

At 6 months the proportion of patients who had achieved a >50% reduction of the initial *total pain score* was 12/21 (57%) in the surgical group compared with 6/18 (33%) in the physiotherapy group. The corresponding figures at one year were 16/21 (76%) in group A and 23/33 (70%) in the combined A + C groups versus 4/6 (67%) in group B (Table I). None of these differences was statistically significant.

Alternatively, one can compare group A ("surgery + postoperative physiotherapy") and group B ("physiotherapy only") by counting the number of successes at one year in each group, dividing it by the original number of patients ($n = 21$) allocated to each group. This leads to a comparison of the proportions 16/21 (76%; group A) and 4/21 (19%; group B). This difference was strongly significant ($p < 0.0005$).

Relation between initial pain ratings and outcome of surgical treatment

For the four patients who had initial pain ratings of "at least one 9 or two 8s" the mean rank of outcome scores was 5.5. The corresponding figure for the patients rating "just one 8" was 18.1, while for the remaining 22 it was 18.7. The first mentioned figure (5.5) differed significantly ($p < 0.05$; Kruskal-Wallis test) from the other two groups, which among themselves did not differ. This finding indicates that our choice of the criterion "at least one 9 or two 8s" worked very well as a predictor of poor outcome. The four patients with these very high pain ratings were examined by a neurologist (CEW) after conclusion of the study and were diagnosed as PPS patients. Among the remaining 29 patients there was no correlation at all between the outcome category and initial pain rating. Kendall's non-parametric correlation coefficient was near zero (tau <0.06; $p > 0.65$) irrespective of whether the comparison was made with pain at rest, POP-induced pain or total pain score. We concluded that very high pain ratings were associated with a poor outcome. Otherwise, there was no correlation between initial pain rating and outcome.

Relation between initial performance of the POP and HIN manoeuvres and outcome of surgical treatment

Because the relationship between pain and motor behaviour is quite unpredictable in PPS patients, these four patients, all failures, should be excluded from analyses of pain-performance relations. As a consequence, $n = 29$ in this paragraph unless otherwise specified.

None out of the 14 patients with substantial loss of function in the POP test (POP 1 or 2) versus 6/15 (40%) patients with slight or no loss of function in the POP test (POP 3 or 4) turned out as failures ($p < 0.02$), i.e. normal or near normal performance in the POP test was associated with an increased risk of poor surgical outcome.

Eleven out of 14 patients (79%) with normal performance in the HIN test (HIN 5) versus 12/15 (80%) performing subnormally (HIN <5) turned out as successes. Thus the HIN variable is not capable of differentiating between failures and successes.

However, 10/14 (71%) in the HIN 5 group versus 5/15 (33%) in the HIN <5 group achieved *complete* pain relief ($p < 0.05$). If the analysis was restricted to the 23 successes, 10/11 (91%) became completely free of pain in the HIN 5 group as compared with 5/12 (42%) in the HIN <5 group ($p < 0.02$). This means that normal performance in the HIN test at entry was associated with a high probability that surgery would abolish pain completely.

Surgical results in subgroups with different combinations of HIN and POP ratings at entry into the study are

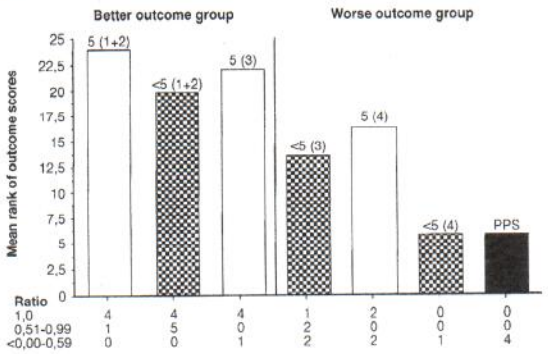

Fig. 1. Comparison of outcome of different subgroups on a "better than–worse than" scale. Scores were assigned to the three outcome categories (pain reduction ratios 1.0; 0.51–0.99; <0.00–0.50). Ordinate values denote mean rank of outcome scores. Figures above the bars denote initial HIN and POP performance ratings (the latter within parentheses). POP 1 + 2 means a POP rating of 1 or 2. The figures below each column give the number of patients by subgroup and outcome category. HIN 5: □; HIN <5: ▨; the four PPS patients, who initially had pain ratings of "at least one 9 or two 8s": ■.

visualized on a "better than–worse than" scale in Fig. 1. The ordinate values denote mean rank of scores, assigned to the three outcome categories—pain reduction ratios 1.0; 0.51–0.99; <0.51. A higher column always indicates a better outcome than a lower one.

Fig. 1 suggests that the relation between outcome and the HIN and POP variables might be graphically represented by two parallel regression lines. Indeed, a multiple regression analysis of ranks of outcome using rank of POP and HIN5/HIN <5 as independent variables, restricted to the 29 non-PPS patients, substantiated this suggestion. Outcome as a function of the HIN and POP variables is graphically described in Fig. 2. There was no statistical evidence of non-linearity ($p > 0.5$), nor of non-parallelism ($p > 0.5$). The vertical distance between the two parallel lines was 6.2 rank units ($p < 0.04$), the coefficient for the slope (−0.41) ($p < 0.03$). Consequently, this analysis established the HIN and POP variables, when used together, as significantly associated with the outcome of treatment at one year.

Surgical treatment—comparisons between successes and failures

All 33 surgically treated patients (groups A + C) fulfilled all the conventional criteria for a diagnosis of an impingement syndrome (with the exception of one—patient no. 10 in Table V, who refused injection). Even so, 10 patients turned out as failures according to our

Table I. *Relative reduction of pain scores at 6 and 12 months*

	Group		
Ratio	**A** $n = 21$	**B** $n = 18$	**C**
6 months			
1.0	**5**	**4**	
0.51–0.99	**7**	**2**	
<0.51	**9**	**12**	
12 months	$n = 21$	$n = 6$	$n = 12$
1.0	**11**	**1**	**4**
0.51–0.99	**5**	**3**	**3**
<0.51	**5**	**2**	**5**

A = Surgery + postoperative physiotherapy; B = physiotherapy only; C = surgery after initial physiotherapy + postoperative physiotherapy.
Total pain score was obtained by adding the VAS score for pain at rest and pain experienced during performance of the POP manoeuvre. Total pain score at 6 months was subtracted from the initial total score, whereupon the difference was divided by the initial total score. A ratio was thus formed reflecting relative reduction of pain. The same calculation was performed with the 12 months' data.

criterion. Individual characteristics of the failures are presented in Table II. In Fig. 3 a comparison is made with regard to different degrees of "subacromial pathology" between successes and failures. As, for technical reasons, bursal specimens were not obtained

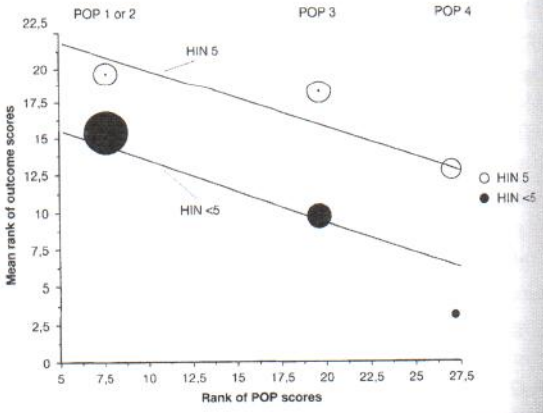

Fig. 2. Graphic representation of the association between outcome, expressed as mean rank of outcome scores, and the initial HIN and POP values, the latter expressed as rank of POP scores. The size of the symbols are proportional to the number of patients in each subgroup. The two parallel regression lines are based on a multiple regression analysis comprising all 29 observations (the four PPS patients are not included), not on the six subgroup means. The coefficient for the slope is −0.41 ($p < 0.03$), the vertical distance between the two parallel lines is 6.2 rank units ($p < 0.04$).

Table II. *Some characteristics of the failures* (n = *10*)

Patient No.	Ratio	R/P	F/NF	MP
6	−0.14	4/3	NF	a
10	−0.13	6/9	F	ab
19	0.25	8/8	NF	ab
20	0.38	7/9	F	ab
21	0.27	5/6	NF	a
24	0.47	7/8	NF	a
26	0.00	5/0	F	c
27	0.13	3/5	F	
30	0.00	5/0	F	ac
31	0.08	9/9	F	ab

Ratio = pain reduction ratio. Failures are defined by a ratio of <0.51; R/P = pain scores at rest/during POP at entry; F/NF denotes fibrosis/non-fibrosis of the subacromial bursa; MP = presence of markers of possible psychogenic pain mechanisms; a = the patient exhibits signs of psychogenic weakness; b = the patient's condition was diagnosed as a psychogenic pain syndrome (PPS) after conclusion of the study; c = these two patients gave a pain rating of 5 at rest but a rating of 0 during performance of the POP test.

from four patients in the success group, data on subacromial pathology are given for 19 patients in this group. Results of microscopic examination were present for all patients in the failure group. Among the successes 18/19 = 95% of the bursae examined microscopically were fibrotic compared with 6/10 = 60% ($p < 0.03$) among the failures. All tendon ruptures observed at operation were found among the successes, none among the failures. Fig. 3 gives a clear visual impression that pathology of subacromial structures is not only more common among the successes, but also more severe in comparison with the failures. The tendency towards "more" pathology in the success group in comparison to the failure group is clearly significant ($p < 0.0005$; Mann-Whitney U-test).

Markers of possible psychogenic pain mechanisms, as defined in the right-hand column in Table II, was present in 9/10 (90%) patients in the failure group, but only in 6/23 (26%) in the success group ($p < 0.001$).

Prediction of outcome of surgery

The patients were allocated either to a predicted "better outcome group" or a predicted "worse outcome group". The allocation was based on the initial HIN and POP ratings and absence/presence of very high initial pain ratings. This led to the formulation of a composite criterion for successful outcome of surgery: *(HIN 5–POP 1, 2 or 3) or HIN <5–POP 1 or 2) and absence of an initial pain rating of "one 9 or two 8s".*

Application of this criterion (Table III) led to a fairly good separation between the predicted "better outcome group" (success rate 18/19 = 95%) and the predicted "worse outcome group" (success rate 5/14 = 36%). The sensitivity was 78% ($p < 0.02$; binomial test), the specificity 90% ($p < 0.03$; binomial test). The predictive value for successful surgery was 95%.

The one false positive patient reported freedom from pain at follow-up 3 years after conclusion of the study, explaining that the pain had disappeared on transferral to a job that gave him more satisfaction. One out of five false negative patients (pain reduction ratio 0.60) lacked bursal fibrosis.

The VAS ratings of pain were used for detecting probable PPS patients. It merits repeating that our criterion , "at least one 9 or two 8s", was determined at an early point of time, when the one-year follow-up results were not available. Owing to small numbers, this criterion is difficult to evaluate statistically. Clinical data are given in some detail regarding these patients in Appendix 2.

Association between predicted outcome and markers of organic and psychological factors

The relative frequencies of observations that reflect organic affection of subacromial structures are also compared in Table III. In the predicted "better outcome group" there was a clear preponderance of markers of organic pathology both in the subacromial bursa and in the tendon itself. On the other hand, there was a

Table III. *Comparison of predicted "better outcome group" and predicted "worse outcome group" in Fig. 1. The vertical line in Fig. 1 divides the patients into two groups. Outcome parameters and characteristics of interest are compared*

	Better outcome group	Worse outcome group	*p*-values
Successes	18/19 (95%)	5/14 (36%)	–
Pain-free	12/19 (63%)	3/14 (21%)	–
Failures	1/19 (5%)	9/14 (64%)	–
Fibrotic bursa	16/16 (100%)	8/13 (62%)	<0.01
Tendon ruptures	6/19 (32%)	0/14 (0%)	<0.03
Signs of p.w.	5/19 (26%)	9/14 (64%)	<0.04

p.w. = psychogenic weakness.
p-values are not given for comparisons of different outcome measures, because the location of the dividing line was determined *a posteriori*, i.e. after seeing the figures.

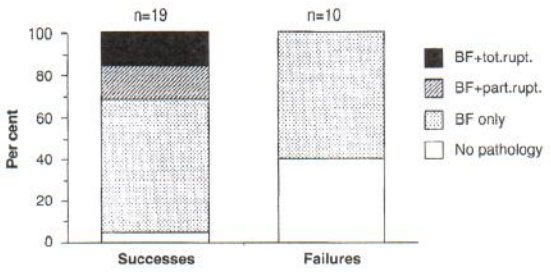

Fig. 3. Comparison of the "amount of subacromial pathology" between the successes and failures in 29/33 surgically treated patients. In four cases microscopic examination of the subacromial bursa had not been performed, none of these patients had tendon rupture. The figure shows the proportions of patients, expressed as percent, with different degrees of subacromial pathology. BF = bursal fibrosis; tot. rupt. = transverse full thickness tendon rupture; part. rupt. = partial rupture.

significant preponderance of patients with signs of psychogenic weakness in the "worse outcome group".

DISCUSSION

Comparison between treatments

A direct comparison between surgery and physiotherapy could only be made at 6 months. The results at 6 months, however, should be regarded with caution, as this is probably a too early point in time for a valid evaluation of the outcome. In group A, the success rate rose from 57% at 6 months to 76% at one year. According to Sahlstrand (19) and Altchek et al. (1), a one-year follow-up is sufficient.

In an "intention to treat" analysis, where both drop-outs and those patients who secondarily chose surgery were regarded as physiotherapy treatment failures, there was a substantial and strongly significant difference between the success rates at one year—76% among those randomized to surgery versus 19% among those randomized to physiotherapy. However, the magnitude of this difference was probably inflated by the fact that all included patients were dissatisfied with previous conservative treatment.

Results of surgical treatment—comparison with other series

We focus this discussion on the proportion of failures in different series. Payne & Craig (15) have recently reviewed the results of anterior acromioplasty in 24 published series (13 concerning open surgery and 11 dealing with arthroscopic acromioplasty). They found no difference between the two different surgical techniques with respect to the results of treatment. Although they included only cases without tendon ruptures and our criterion of success, focusing on reduction of pain, is different, a comparison with other series is still of interest. We had a 30% failure rate, which corresponds to a ranking of 5 out of 25, if the failure rates are ranked from highest to lowest.

As pointed out by many authors, the outcome of surgery tends to be less favourable in workers' compensation cases. In Table IV a review is presented of those publications where data permit a statistical comparison between workers' compensation cases and those without workers' compensation claims. A pooled estimate of odds ratio or approximate relative risk from Table IV gives the value 4.4 (95% c.i. 2.9–6.7), which

Table IV. *Surgical failures in relation to presence/absence of workers' compensations claims*

				Failures as percent of		
Study	Operation	N	%WCc	N	WCc	non-WCc
1.	OS	108	32	13	23	8
2.	ASD	151	37	19	30	13
3.	OS	54	33	30	39	25
4.	ASD	61	39	20	50	0
5.	ASD	96	40	52	68	41
6.	ASD	44	38	27	77	6
7.	OS	53	68	2	3	0
8.	OS	33	88	30	34	0

1. Hawkins et al. (7); 2. Gartsman (6); 3. Lirette et al. (11); 4. Olsewski & Depew (14); 5. Saddemi et al. (18); 6. Johannsen et al. (9); 7. Frieman & Fenlin (5); 8. Present study.
OS = Open surgery; ASD = arthroscopic decompression; N = total number of patients; WCc = Workers' compensation cases.

means that there is most probably a fourfold increase of the risk of becoming a failure among workers' compensation cases. Two explanations for the increased risk have been discussed—frequent exposure to hard manual labour among workers' compensation cases and secondary gain.

When our study was carried out, the Swedish legislation regarding workers' compensation was very generous—those who did not return to work were guaranteed full economic compensation amounting to the same salary as if they had been working full time. The high incidence, 9/10 (90%), of different markers of psychogenic pain mechanisms among our failures, all of whom were workers' compensation cases, makes it probable that secondary gain was an important mechanism among our patients. The relative paucity of "subacromial pathology" in the failure group, particularly the absence of bursal fibrosis in 4/10 cases, raises the suspicion that some of these patients lacked a mechanical impingement mechanism at entry into the study, although they passed through the conventional "diagnostic machinery".

It is obvious that our study stands out from the others with respect to the very high, 29/33 (88%), proportion of patients that considered their symptoms to be work-related. Among these patients 10/29 (34%) were failures, a proportion that is actually below the median value in the workers' compensation cases group in Table IV. All four patients without workers' compensation claims were successes. Thus, after splitting the results into one group of workers' compensation cases and one group without compensation claims, our results are fairly average.

We conclude that our rather high (30%) failure rate is mainly due to the extraordinarily high proportion (88%) of workers' compensation cases.

Prediction of outcome of surgery

We have investigated the predictive value of three pain-related variables—pain estimated by the VAS technique at rest and during performance of the POP manoeuvre, rating of POP performance and of HIN performance.

The pain-related variables (Fig. 1), when rated at entry, can achieve a partitioning of patients into subgroups with different outcomes after surgery. A multiple correlation analysis established an association between the HIN and POP variables and surgical results. These variables are validated not only by statistical considerations of their influence on the outcome of surgery, but also by their association with factors that are reasonably of logical importance (Table III).

The pain-related variables permitted a fairly good differentiation of the patients into a "better prognosis group" and "worse prognosis group" and can be of reasonable value for selection of patients for surgery (Fig. 1).

The relation between pain and motor performance

We regard the scores obtained in the two standardized, composite, active movement tests, the POP and HIN manoeuvres, as essentially pain-related variables. In patients without major defects in the rotator cuff, range of motion is usually not restricted. It is important to keep in mind the mechanisms that may interrupt an active movement that causes pain. Via a spinal loop, an inhibition of the prime movers and an activation of their antagonists can occur, although it is more likely that the movement will be interrupted at an earlier stage by supraspinal mechanisms, reflecting the effect of "anticipation of worsening pain" (23). An inverse correlation between the POP and HIN ratings, and the rating of provoked pain during these tests is therefore expected.

A study in patients with fracture of the upper end of the humerus, in which three standardized, active motor tests, including the HIN and POP tests, were used, specifically addressed the question of pain-performance relationships. It was shown that movement-induced pain was a major determinant of function loss in such tests (22). We therefore regard function loss in the HIN and POP tests as essentially determined by one or more, possibly different, pain generators in the shoulder joint.

The HIN test—possible pain generators responsible for loss of function

Normal performance of the HIN test requires unhampered external rotation, abduction and extension in the shoulder joint. Pain, if present, will interrupt the movement at a subnormal level. When analysing our data, we treated the HIN scores as a dichotomous variable, i.e. we compared HIN 5 to HIN <5. The reasons are as follows: Normal performance necessitates a build-up of tension in the supraspinatus tendon. Pathological changes in the impingement syndrome are relatively often found, or presumed, in this structure. The presence of a traction-responsive pain generator in the supraspinatus tendon would be liable to cause a reflex-mediated interruption of an intended movement. It has been shown (23) that the

HIN 5 position requires a tension that is about four times higher than all HIN <5 positions, which, by themselves, do not differ in this respect.

An essential part of the impingement concept is the assumption of a disproportion of the contents of the subacromial space and its boundaries, i.e. some kind of compression is presumed. Sigholm et al. (21) found that the pressure in the subacromial space was reduced, even to negative values and that pain was not elicited in seven patients with the impingement syndrome, when the arm was brought into a position that closely resembles HIN 5. These findings are clearly at variance with an interpretation that involves a compression-sensitive pain generator in the subacromial space as the cause of function loss in the HIN test. Another observation that agrees with this line of argument is the demonstration that the anterior opening of the subacromial space widens in retraction of the shoulder (24)—a position that is a prerequisite of normal performance of the HIN test.

We suggest that subnormal performance in the HIN test indicates the presence of a traction-responsive pain generator in the rotator cuff in patients clinically diagnosed as having an impingement syndrome. Two consequences of this suggestion are statistically testable:

1. An operation that is primarily designed to achieve a widening of the supraspinatus outlet is not supposed to affect a traction-sensitive pain generator. Furthermore, surgical repair of the rotator cuff (performed in five cases) is of doubtful value as a means of eliminating or reducing pain (4). No significant changes in the HIN-ratings (HIN5/HIN <5) are therefore expected as a result of surgery. None were found—24/29 patients had unchanged HIN-ratings, 4 changed from a rating of <5 to 5, one in the opposite direction ($p > 0.37$).

2. Another consequence of the suggested mechanism for loss of function in the HIN test is the expectation of an association between subnormal HIN performance at the end of the study and only partial pain relief among the 23 successes. Seven out of 8 patients (88%) with incomplete relief (ratio 0.51–0.99) had HIN <5 ratings compared with 2/15 patients (13%) with complete pain relief, i.e. ratio 1.0, ($p < 0.001$).

The POP test—possible pain generators responsible for loss of function

As demonstrated in a previous study in normal subjects (23), the EMG activity of the supraspinatus muscle did not differ significantly during normal performance of the POP and HIN manoeuvres. If exactly the same mechanism were responsible for loss of function in both tests, one would expect all patients with normal performance in the HIN test to perform normally in the POP test too. Before surgical treatment, 11 of the 23 surgically treated "successes" had a normal HIN test. In contrast, only 2 of these 11 patients also performed normally in the POP test. If it is accepted that normal function in the HIN test indicates absence of a traction-responsive pain generator in the supraspinatus tendon, it is obvious that some other mechanism, for instance compression, must have been the main cause of loss of function in the POP test.

The POP manoeuvre is necessarily performed with the shoulder in protraction, and the humerus in flexion and internal rotation. The protracted position has been shown to be associated with narrowing of the anterior opening of the subacromial space (24), and flexion combined with internal rotation causes impingement of the supraspinatus tendon and greater tuberosity against the coracoacromial arch (2). Furthermore, a considerable increase in pressure in this space has been demonstrated in an upper arm position similar to that in the POP test (21).

Based on the arguments given above we suggest that subnormal (POP <4) performance in the POP test indicates activation of one or possibly two different pain generators by a compression mechanism, a traction mechanism, or both.

Three consequences of this suggestion are statistically testable:

1. As anterior acromioplasty brings about a decompression of the subacromial structures a statistically significant increase in the initial POP ratings is expected as a result of surgery. Twenty out of 29 patients increased their POP ratings, only 3 had lower ratings at one year postoperatively ($p < 0.001$). The improvement in POP performance does not seem to be an unspecific effect of treatment, since the HIN performance was not improved.

2. During normal performance the tension in the supraspinatus tendon is the same in the POP test as in the HIN test (23). After surgical decompression concordant HIN and POP ratings at the end of the study, i.e. either HIN 5/POP 4 or HIN <5/POP <4, are expected. Twenty-three out of 29 patients were concordant according to this definition ($p < 0.006$ against a null hypothesis of random coincidence).

3. As the combination HIN 5/POP 4, according to our suggested interpretation, means absence of both a traction-responsive and a compression-sensitive pain generator, it is predicted that this combination of motor

performance variables will be associated with a higher proportion of patients that are completely free of pain at one year postoperatively than all others. Twelve out of 15 patients 80%) scoring HIN 5/POP 4 were free of pain compared with all other patients, in which only 3/14 (21%) achieved complete pain relief ($p < 0.002$).

Pathogenesis of pain in the impingement syndrome—a hypothesis

Summarizing the evidence given in the last two paragraphs, we suggest that there are two different pain mechanisms in the impingement syndrome. The main cause of pain is probably compression of structures that contain sensitized nociceptors. An obvious candidate for the role as a compression-responsive pain generator is the subacromial bursa. It is well equipped with a neural apparatus for conveying pain impulses from sensitized nociceptors to the central nervous system (10, 20, 25). It has been demonstrated that bursal fibrosis is a very common finding in patients with an impingement syndrome (16). Fibrosis can be regarded as a marker of a chronic low-grade inflammation, probably caused by iterated microtrauma.

We also hypothesize, that some patients, in addition, have a traction-responsive pain generator located in the supraspinatus tendon, a view previously expressed by Lirette et al. (11). These patients are likely to obtain only partial pain relief by anterior acromioplasty.

Summary

Our data suggest (a) that surgical treatment is more effective than a standardized physiotherapy regime in patients with long-standing pain due to an impingement syndrome; (b) that pain in the impingement syndrome is mainly caused by pressure on the subacromial bursa that acts as a compression-sensitive pain generator; (c) that a traction-responsive pain generator located in the supraspinatus tendon is also present in some patients; (d) that initial pain ratings and ratings of motor performance in the HIN and POP manoeuvres are of predictive value for the outcome of surgery.

Appendix 1

Scoring system for the Hand in Neck manoeuvre

HIN 0: Cannot reach the back of the neck with the hand.
HIN 1: Can hold the hand around the neck, but compensates by holding the neck in ventroflexion and rotation to the opposite side. The shoulder is elevated, the arm adducted.
HIN 2: Can hold the arm around the back of the neck, but compensates by elevating the shoulder and adducting the arm.
HIN 3a: Can hold the arm around the back of the neck, but compensates by elevating the shoulder.
HIN 3b: Can hold the arm around the back of the neck, but compensates by adducting the arm.
HIN 4: Can hold the arm around the back of the neck, but cannot extend the upper arm to the coronal plane.
HIN 5: Can perform the test normally, i.e. the elbow reaches the coronal plane.
Photographic illustrations of the different scale steps are given in reference 23.

Scoring system for the Pour out of a Pot manoeuvre

POP 0: Cannot pour the water out of a pot.
POP 1: Can pour the water out of a pot, but compensates by support of the other hand, by elevating the shoulder and by bending to the contralateral side.
POP 2: Can pour the water out of a pot, but compensates by elevating the shoulder and by bending to the contralateral side.
POP 3a: Can pour the water out of a pot, but compensates by elevating the shoulder .
POP 3b: Can pour the water out of a pot, but compensates by bending to the contralateral side.
POP 4: Can pour the water out of a pot normally, i.e. without compensatory movements.
The patient should be instructed to "freeze" the final position for 3–5 seconds in order to facilitate the observation.
Photographic illustrations of the different scale steps are given in reference 22.

Appendix 2

Patients diagnosed as having a psychogenic pain syndrome

Woman, aged 45. Reports continuous pain in the left shoulder, the whole arm, and the three radial fingers. Exhibits weakness with cocontraction and uneven activation in all muscle groups in the arm and hand as well as in the proximal part of the left leg.
Male, aged 51. Reports continuous pain in the whole right arm. Exhibits weakness with cocontraction and uneven activation in all muscle groups of the arm and hand.
Woman, aged 58. Reports continuous pain in the whole left arm. Exhibits weakness with cocontraction and uneven activation in all muscle groups of the arm and the proximal part of the left leg. Exhibits psychogenic past-pointing in the finger-to-nose test on the left side.
Male, aged 56. Reports pain in both shoulders. Exhibits weakness with cocontraction and uneven activation in all muscle groups in the contralateral (to the operation) arm.

REFERENCES

1. Altchek, D. W., Warren, R. F., Wickiewicz, T. L., Shyhar, M. J., Ortiz, G. & Shwartz, E.: Arthroscopic acromioplasty. J Bone Joint Surg *72A:* 1199–1207, 1990.