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THE FROZEN SHOULDER

CLINICAL AND RADIOGRAPHICAL OBSERVATIONS
THE EFFECT OF MANIPULATION UNDER GENERAL ANESTHESIA
STRUCTURE AND GLYCOSAMINOGLYCAN CONTENT OF THE JOINT CAPSULE
LOCAL BONE METABOLISM

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I. INTRODUCTION

A. THE FROZEN SHOULDER

DUPLAY in 1872 described a condition, "péri-arthrite scapulo-humérale", which differed from arthritis in its symptoms and clinical course.

He also suggested manipulation of the shoulder joint under general anaesthesia as a treatment for the restricted mobility in this disorder.

The true nature of this condition has been discussed ever since. DUPLAY himself believed that a subacromeal bursitis was the basic cause of the pain and dysfunction. However, already KLAPP (1916) and RIEDEL (1916) believed that the joint capsule was affected, and in consequence, PAYR (1931) tried to accomplish a distension of the retracted capsular tissue by intraarticular injections.

CODMAN (1934) pointed out that stiffness and pain in the shoulder could occur without noticeable exogenous influences and he separated this condition from the heterogenous group referred to as "periarthritis of the shoulder". He termed the condition "frozen shoulder", an expression which later has been generally accepted and used synonymously with humeroscapular periarthritis in a restricted sense.

CODMAN was of the opinion that the frozen shoulder was caused by tendinitis in the short rotators. Several investigators have related the condition to changes in various periarticular structures (BOSWORTH 1940, LIPPMANN 1943, MOSELEY 1945, DEPALMA 1952, MCLAUGHLIN 1961, LIDSTRÖM 1963).

However, other investigators (NEVIASER 1945, YOUNG and PEARSON 1952, QUIGLEY 1956, HARMON 1958, DE SÈZE et al. 1960, 1961) favoured the opinion that the joint capsule was the site of the basic pathological changes in frozen shoulders.

Attempts have been made to relate the disease to various circumstances such as inactivity, strain and pre-existing shoulder affection. The importance of the latter was studied by PASILA (1965). Examining cases of periarthritis of the shoulder, "tendinitis" without restricted mobility, he did not find that this condition during the course of the disease developed into frozen shoulder.

The therapy of frozen shoulders has been based on the varying opinions of the basic cause of the disease. It is rather difficult to draw any final conclusions from the literature. One reason is the indistinct definitions. The lump diagnosis "periarthritis" has been used in a wide as well as in a limited sense and this has greatly contributed to the confusion. It seems important to restrict the diagnosis of frozen shoulders to cases with a distinct limitation of mobility in the humero-scapular joint. It is also necessary to separate cases with known exogenous causes or pre-existing injuries from cases without or with a doubtful history of exogenous influence.

B. PURPOSE

The purpose of the present investigation was to collect further information from a series of individuals suffering from the frozen shoulder syndrome. Except for clinical observations of these cases the following methods were applied:

1. Manipulation under general anaesthesia.
2. Arthrography.
3. Measurements of the joint volume.
4. Surgical exposure.
5. Histological examination.
6. Chemical analysis.
7. In vivo bone densitometry.
8. Mineral tracer studies.

The emphasis in the study has been on the examination and presentation of clinical variables.

II. CLINICAL MATERIAL

A. PRIMARY FROZEN SHOULDERS

Primary frozen shoulders (F.S.) in this study were defined as follows:

a) The total elevation in the shoulder joint restricted to 135° or less.

b) The restriction of motion localized to the humero-scapular joint.

c) No findings in the case history or in the clinical or radiological examination which could explain the decrease of the range of motion; by the latter criterion cases with post-traumatic conditions, rheumatoid arthritis, osteoarthritis, hemiplegia and other such more obvious changes, were excluded.

The investigation included 147 Primary F.S. in 135 individuals who sought medical advice in the Department of Orthopaedic Surgery, General Hospital, Malmö, during the years 1964—1967.

In addition 85 Primary F.S. in 81 patients were available for evaluation who were examined in the Department of Orthopaedic Surgery, Central Hospital, Jönköping, during the years 1960—1963.

Both samples were drawn from populations of 250,000—300,000. Although there were no other orthopaedic departments in the sampling areas, the hospital in Malmö is expected to receive a larger portion of the total number of cases in the population than the hospital in Jönköping.

B. SECONDARY FROZEN SHOULDERS

Sixty-nine F.S. in 67 individuals were sampled from the Malmö area, 34 F.S. in 34 individuals from the Jönköping area. The range of motion was similarly decreased but following a traumatic lesion. The associated injuries are presented in Table I. Cases with a transitory decrease of the range of motion were excluded.

Table I. *Secondary frozen shoulders: Cause and sex.*

	Men	Women	Total
Soft tissue injury to the shoulder region	42	13	55
Intra- and juxtaarticular fractures	15	21	36
Other fractures of the upper limb	4	8	12

III. CLINICAL AND EPIDEMIOLOGICAL OBSERVATIONS

In this chapter data from all the cases of Primary F.S. were included, except in the attempt to calculate a minimum incidence, which was based on the population of Malmö only.

A. MINIMUM INCIDENCE

The sampling procedure does not permit an accurate estimate of the incidence of the disease in the population. However, during one year, 1965, altogether 72 cases were recorded in the hospital of Malmö although some were treated by other physicians. As the number of individuals within each year group of the population at risk was about 3,400,[1] the cumulative risk of at least one episode of F.S. can be estimated to minimum 2 per cent.

B. SEX AND AGE DISTRIBUTION

Among the Primary F.S. 134 (58 %) were female and 98 (42 %) male. The age at onset of the disease was for women 52 $\pm$7 and for men 55 $\pm$7 (Fig. 1). The age difference was significant.

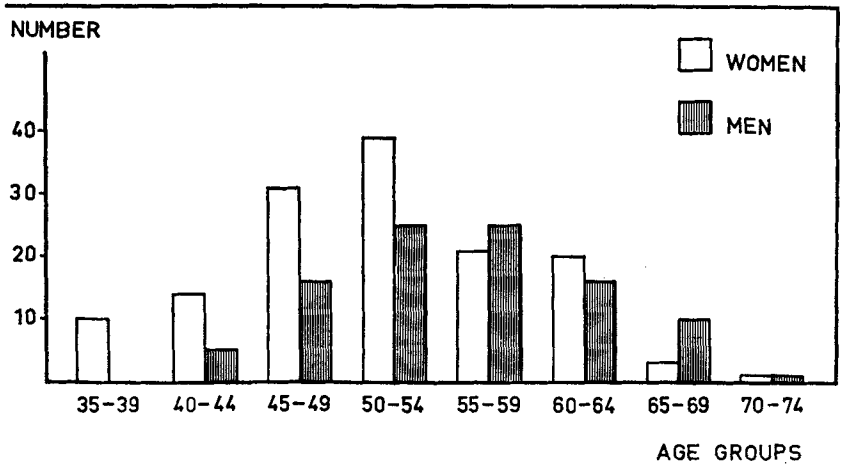


Fig. 1
Age and sex distribution of primary frozen shoulders.

[1] Department of Statistics, Financial Committee of Malmö.

Comment

Codman (1934) found in 100 cases of F.S. 58 women and an average age of the cases of 52 years. Brimberg (1952) found in cases of F.S. an average age of 53 years but no sex difference.

In cases of F.S. secondary to injury in this study, the sex relationship was 42 women to 61 men, the age 58 ± 10 and 53 ± 10, respectively.

C. SIDE INVOLVED

There were 142 left side and 90 right side involvements. Left side involvement was significantly more frequent in women (Table II).

Table II. *Primary frozen shoulders: Side involved and sex.*

	Men	Women	Total
Left	51	91	142
Right	47	43	90

Comment

Previous investigators (Dickson and Crosby 1932, Klami 1962 and Pasila 1965) found the right shoulder to be more often involved in cases of periarthritis of the shoulder. The discrepancy may be explained by the selection of cases. Lippman (1951), DePalma (1952) and Lorentz and Musser (1952) found a preponderance for the left shoulder but did not stress the sex difference in this respect. Possibly the selection of cases in the latter studies is more similar to that of the present investigation.

It may be suspected that lesser use of the left arm contributes to the F.S. syndrom. There is, however, no evidence that such disuse should be more common in women. As suggested by bone density data of reference cases (Chapter X) the bone mass in the head of humerus was lower on the left side. The difference was significant only in women.

D. BILATERAL INVOLVEMENT AND UNILATERAL RELAPSE

In 206 patients a careful case history was taken with regard to possible earlier episodes of Primary F.S. Among these patients there were 35 who either had a history of earlier F.S. or had a contralateral involvement during the follow-up study. These figures may be compared to the findings in the cases of F.S. secondary to injury. A careful history was taken in 96

cases, 3 of these had a history suggesting Primary F.S. earlier in life. There was no further sign of contralateral involvement during the period of follow-up in these cases.

From these data it may be concluded that contralateral involvement is significantly more common in cases of Primary F.S. than in cases with F.S. secondary to injury. Furthermore 17 % of contralateral involvement among the cases of Primary F.S. is more than can be expected from the minimum incidence even if the inaccuracy of this latter value is taken into account.

In 5 of the 35 cases with bilateral involvement the onset of symptoms was simultaneous in both shoulders; of the remaining 30 cases 4/5 had their contralateral relapse within 5 years.

With regard to possible earlier episodes of stiffness in the currently frozen shoulder—unilateral relapse—a careful history was taken in 214 patients. None had a history of Primary F.S. in the involved side previous to the current episode.

Comment

Cases with bilateral involvement have been observed by several investigators. Codman (1934) and Lippmann (1944) believed that a relapse does not occur in the same shoulder.

E. SEASONAL VARIATION

For 231 Primary F.S. the time for onset of symptoms could be estimated from the case history. The seasonal variation is shown in Figure 2. The onset was significantly less frequent during the first part of the year than during the second. This pattern which has not been previously investigated cannot, at this time, be explained on rational grounds.

F. CONCOMITANT CONDITIONS

1. *Menopause*

In 97 women with a first episode of Primary F.S. it was possible to obtain information with regard to menopause. Eighteen women were menopausal at onset of F.S. Fifty-six were post-menopausal. The average age at menopause in these women was 48.8 $\pm$3.4. Samuelsson (1942), Alffram (1964) and Danielsson (1964) found values just over 48 for the age of menopause in various groups of women from the same area.

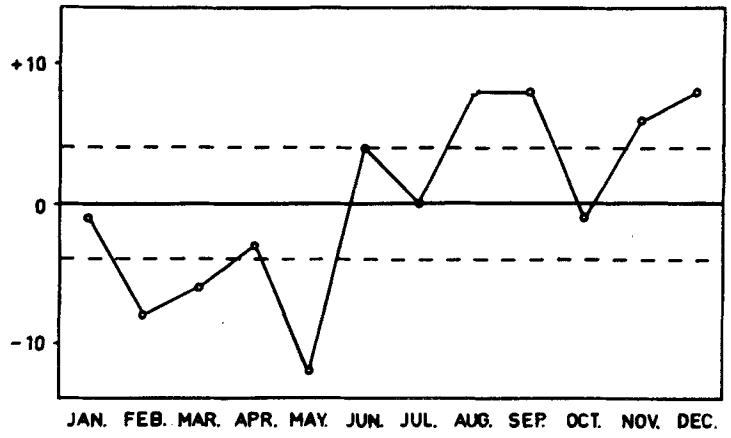


Fig. 2
Seasonal variation of onset of primary frozen shoulder. Deviation from expected value, random deviation (interrupted line) = $\pm \sqrt{N \frac{1}{12} \cdot \frac{11}{12}}$

Taking into account the age distribution of menopause and of onset of the F.S. syndrome and the duration of menopausal symptoms, the number above may be expected to result from coincidence.

There was also a significant negative correlation between the age at menopause and the time interval between menopause and onset of symptoms. The younger the women were at menopause the longer was the time interval to the first sign of F.S. This implies that age rather than menopause is important.

Comment

Codman (1934) suggested a relationship between F.S. and menopause in women. His belief was probably based on observed coincidences. There is no convincing evidence of a true relationship.

2. *Trauma*

In 34 shoulders (15 %) of the total number of Primary F.S. the onset of symptoms was in time related to a minor trauma or strain such as lifting, slight concussion or similar minor everyday incident which *per se* could not be expected to cause an injury to the shoulder. These incidents did not initially disable the patients to any extent but left behind some discomfort and were eventually followed by a decreased range of motion.

Comment

Previous investigators have found high incidences of predisposing external factors in cases of F.S. Dickson and Crosby (1932) found an incidence of 30 %. Codman (1934) stated that these cases usually gave a history of slight trauma or strain, and Brimberg (1952) found the same.

The importance of such minor incidents as causative factors is difficult to evaluate, as the symptoms associated with these events may simply be the first signs of the disease.

3. *Inactivity*

In 12 cases (5 %) of the Primary F.S. the first symptoms occurred during a period of forced inactivity such as bed rest after surgery, cardiac infarction or similar conditions.

Comment

Johnsson (1959) found a high incidence of F.S. in patients confined to bedrest in a tuberculosis sanitarium. Although, in the present study, the number of cases with a time relation to such inactivity is fairly small, one cannot disregard the possibility of a relationship between inactivity and F.S., particularly when the secondary cases are considered where the trauma to the shoulder or upper limb usually causes a decreased activity. The importance of inactivity for the production of the shoulder-hand syndrome has been stressed previously (Moberg 1955).

4. *Disease*

a. *Cervical pain*

This condition included pain either in the neck or radiating from the neck in conjunction with movements of the head.

In 121 women with Primary F.S. the occurrence of cervical pain at the time of onset was investigated; 35 of the women had such symptoms. Similarly, out of 90 men 19 had cervical pain. There was no difference in incidence between men and women. During the course of the Primary F.S. syndrome an additional 13 cases were observed who had cervical pain.

At the time of onset of Secondary F.S., 3 women out of 41 and 5 men out of 56 had cervical pain.

The incidence of such symptoms was significantly higher in cases of Primary F.S. as compared to cases of Secondary F.S.

Comment

Totally 25 % of the cases with Primary F.S. had cervical pain. This high incidence might be compared to the data of Hult (1954) who, in a field study, found 3.5 % of current "brachialgia". The same author found a coincidence of shoulder stiffness and cervical symptoms in 28 % of his cases.

Owing to interaction of symptoms between the regions, the present observations do not allow conclusions as to whether the cervical pain is causative to or caused by the shoulder condition.

b. *Calcareous Deposit*

Periarticular calcareous deposits were observed in 24 out of 232 Primary F.S. (10 %). In 66 cases of Secondary F.S. in the Malmö series there were 5 with calcareous deposits.

Comment

This is in agreement with the findings of Quigley (1956) who found calcareous deposits in 16 % of his cases and Harmon (1958), 12 %. Dickson and Crosby (1932) found calcareous deposits in as much as 35 % of their cases. Klami (1962) found 6 calcified deposits in 66 individuals of the appropriate age distribution but without symptoms from their shoulders.

The number of calcareous deposits in Primary F.S. did not significantly exceed what could be expected when compared with the findings by Klami and the incidence in Secondary F.S.

c. *Diabetes*

Twelve out of 216 patients with Primary F.S. had a diagnosis of diabetes. This incidence, 6 %, should be compared to the incidence in the same age

group, less than 2 %, found in a population from the south of Sweden (SILWER 1958). The limited number of observations in the present study does not permit final conclusions but the data suggest an increase of the number of diabetics above the expected.

d. *Other Diseases*

Some diseases could not be analysed with regard to incidence because of the limited number available: cardiosclerosis 7, epilepsia 5, pulmonary disorder 2, disorders of the digestive tract 3, thyroide disorder 4, symptoms from the central nervous system 6, transient joint symptoms 4.

IV. THE EFFECT OF MANIPULATION AND JOINT DISTENSION

A. MATERIAL

The 147 Primary F.S. sampled in the Malmö series were divided as follows:

Untreated controls : 36 shoulders, 18 female and 18 male.

Distended: 43 shoulders, 19 female and 24 male.

Manipulated: 35 shoulders, 22 female and 13 male.

Distended and manipulated: 22 shoulders, 14 female and 8 male.

Open manipulation: 11 shoulders, 9 female and 2 male.

The cases were randomly assigned to the manipulated and the control groups. The selection of cases for distension was made by one radiologist.

Except for the described therapeutic procedures, all the cases were given symptomatic treatment, *i.e.* analgetics, local injections and physiotherapy. This treatment was evenly distributed among the cases.

For comparison the 85 manipulated Primary F.S. of the Jönköping series were included.

In this series the manipulation was followed by about one week of intensive physiotherapy in hospital. Some data from this study have been presented earlier (LUNDBERG, 1967).

In the Malmö series only cases who were operated on were hospitalized.

At the time of manipulation or first examination the duration of symptoms indicating stiffness of the shoulder was 4 ± 2.3 months (Malmö) and 3.7 ± 2.3 months (Jönköping).

The initial range of motion evaluated from the total elevation of the arm was $101° \pm 24°$ (Malmö) and $83° \pm 23°$ (Jönköping). As may be expected from the random sampling there was no difference in these variables between manipulated and control cases in the Malmö series. The initial range of motion was significantly lower in the Jönköping series.

In some instances it was also of value to compare the findings in Primary F.S. and Secondary F.S.

B. METHODS

1. *Closed Manipulation*

Manipulation under general anesthesia and muscle relaxation was carried out as follows:

The arm of the patient was elevated and outward rotated. The force was applied at the elbow using the humerus as a lever. The manipulation was completed by an inward rotation which was not forced if the tissues offered resistance.

2. *Open Manipulation*

The anterior aspect of the joint was exposed through an incision between the pectoral and deltoid muscles. The manipulation was then carried out as described above. During the manipulation the anterior aspect of the joint was inspected; the inferior border of the joint was palpated.

3. *Joint Distension*

Distension of the shoulder joint capsule was attempted by injecting contrast medium and/or saline solution under pressure as described in detail by ANDRÉN and LUNDBERG (1965).

4. *Evaluation of the Range of Motion*

Humero-scapular elevation was defined as the maximum angle of elevation between the medial edge of the scapula and the humerus.

Total elevation was defined as the maximum elevation of the humerus in relation to the vertical axis of the trunk.

Rotation was recorded as the ability to inward-rotate the humerus and measured as the level which could be reached; from the iliac crest to the 8th thoracic spinous process.

All these variables refer to the passive range of motion.

The speed of restoration of motion may, to some extent, be evaluated from *the total duration of stiffness*, that is the period from onset of symptoms estimated from the case history to the time when full range of motion was attained.

The time required to attain 160° of total elevation may also be used as a parameter of restoration.

However, the best measure appears to be the variable itself, that is the *speed at which the range of motion is increased.* For this purpose the relation-

ship between time and total elevation was studied. Starting from the first observation or, in the treated cases, from the manipulation, and continuing to 160° of total elevation, it was found that this relationship did not systematically deviate from a straight line (Figure 3). This approach has the added advantage that fluctuations in the range of motion during the course of the disease are given less weight. Such fluctuations may be due both to irregularities in the course of the disease, and inaccuracy in the measurements.

For each case a straight line was fitted to the observations by the method of least squares up to 160° of total elevation. The slope of this line, degrees per month, was used as a measure of the *speed of restoration* of mobility and the intercept with the ordinate was used as a measure of the *initial range of motion.*

The mobility of the shoulder joint was, in this study as is usual in clinical work, represented by the total elevation. The variable of interest is, however, the range of motion in the humero-scapular joint. There was a highly significant positive correlation between total and humero-scapular elevation, which implies that one variable may replace the other. The

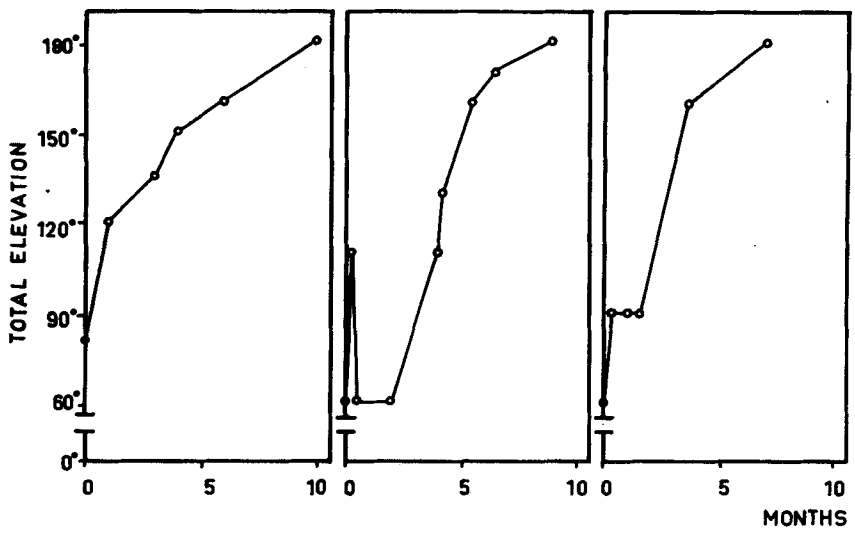


Fig. 3
Observations of total elevation in relation to time in a control case (to the left) and two manipulated cases of primary frozen shoulders. The slope of this line expresses the speed of restoration in degrees/month.

scapular rotation, calculated from this regression (Fig. 4), 73°, is slightly more than the 65° found in a roentgenographic study on normal subjects (FRIDMAN and MONROE 1966).

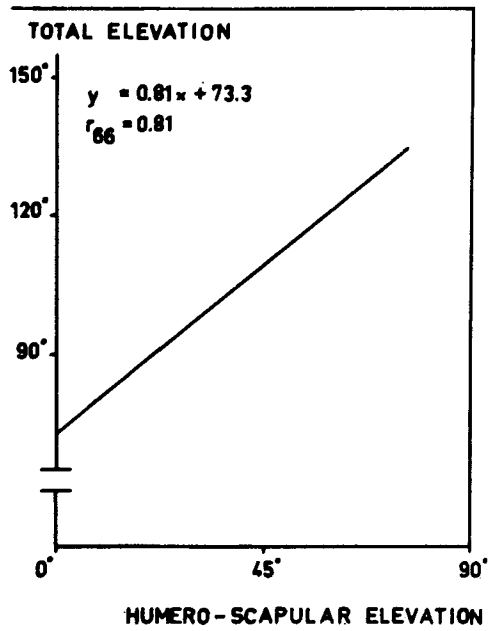


Fig. 4
The relationship between the humero-scapular and the total elevation. Initial values in 66 cases of primary frozen shoulders. The intercept with the ordinate may be interpreted as the range of scapular rotation.

There was a relationship between total elevation and inward rotation of the humero-scapular joint as exemplified in Figure 5. However, within each rank of rotation mobility there was a considerable scatter of total elevation values probably indicating that the shoulder may "freeze" in different positions.

C. RESULTS

1. *The Immediate Effect of Manipulation*

a. *Completeness and Brisement*

In the Malmö as well as in the Jönköping series observations with regard to the completeness of the manipulation and to breaking sounds,

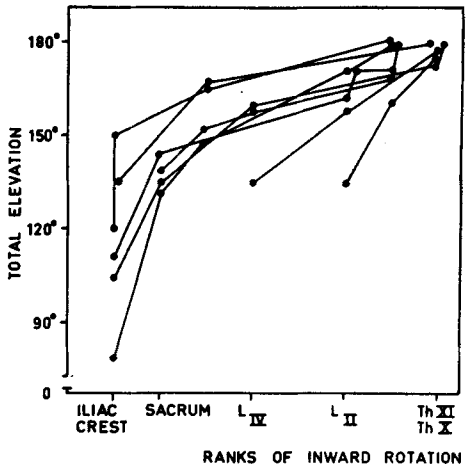


Fig. 5
Relationship between total elevation and inward rotation represented as ranks; the change with time in 8 randomly selected cases of primary frozen shoulders.

brisement, were recorded in 141 Primary F.S. and 65 Secondary F.S. As shown in Table III it was possible to complete the manipulation in a majority of the cases (total elevation the same as on the unaffected side). The remaining cases were not completed because of a resistance which could not be overcome with a reasonable force. Also, brisement was noted in the majority of the cases. Complete manipulation and brisement were significantly less common in cases with Secondary F.S. (Table III).

There were 5 Primary and 5 Secondary F.S. which did not yield measurably to the force applied.

Of 27 shoulders in which the brisement phenomenon had been noticeable at manipulation, a repeated manipulation was attempted because of continued stiffness. Except in a few cases re-manipulated within a month after the first attempt, there were signs of brisement also at the repeated

Table III. *Completeness and brisement.*

	Manipulation		Brisement	
	Complete	Not complete	Present	Not present
Primary F.S.	115	26	131	10
Secondary F.S.	30	35	49	16

manipulation. This indicates a relapse. The findings also suggest that re-manipulation within one month has little purpose (Fig. 6).

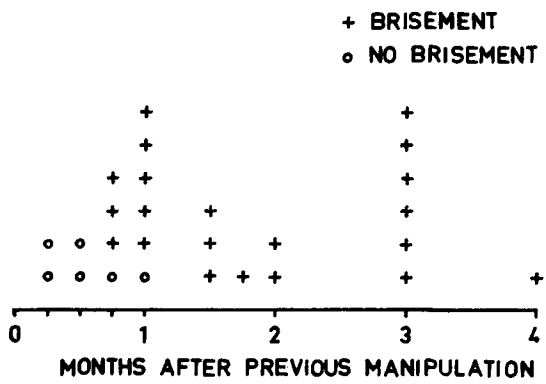


Fig. 6
Brisement at re-manipulation in relation to time.

b. *Joint Haemorrhage*

In 94 of the shoulders of Primary F.S. the manipulation was immediately followed by puncture of the joint, injection of physiological saline and aspiration in order to evaluate intraarticular bleeding. Blood discolouration was present in 85 of these shoulders.

Similarly in 42 out of 44 Secondary F.S. tested in the same way there were signs of intraarticular bleeding.

Comment

At surgical exposure McLaughlin (1951) observed a minimal degree of haemorrhage in all structures stretched by the manipulation. Quigley (1956) found intraarticular bleeding following closed manipulation and suggested intraarticular injection of corticosteroids as an adjuvant therapy.

It must be concluded that intraarticular haemorrhage is a regular consequence of manipulation and should not be regarded as an undue complication.

2. *The Therapeutic Effect*

The speed of restoration in degrees per month is given for Primary F.S. in Table IV. The treated groups, except for the operated one, all regained

the range of motion at a higher speed than the non-treated controls. The difference was significant only in the manipulated cases.

The scatter of the data in relation to the averages suggests skewed distributions of the variable. The distributions are shown graphically in Figure 7. In the groups two subsets can be traced, one which does increase the speed of restoration after treatment and one which does not.

The total duration of stiffness was, however, not significantly different between the groups in the Malmö series (Fig. 8).

When the time from the first observation or manipulation to 160° total elevation was related to the initial range of motion there was a significant difference between manipulated and control cases (Fig. 9). In the control group there was a significant negative regression indicating a longer time required for restoration in cases who initially had less range of motion.

This regression was significantly less steep in the manipulated cases. The finding indicates that manipulation may be comparatively more effective in stiffer shoulders.

The variable in Table IV, speed of restoration, was also tested between the groups by covariance analysis using the initial range of motion and duration of symptoms prior to manipulation or first observation as covariant factors. This procedure increased somewhat the confidence level for significance of difference between controls and manipulated cases but did not otherwise change the outcome of the analysis.

There was no significant difference in any of these variables between left and right shoulders or between the sexes.

The data collected in the series of manipulated Primary F.S. from the Jönköping area cannot be directly compared with the data above which are randomised from a different population. The speed of restoration of the range of motion in 76 Primary F.S. in the Jönköping series was 94.3± 94.4. This value indicates another skewed distribution (Fig. 7) and is significantly greater than that of the Malmö controls as well as that of the Malmö manipulated cases. The total duration of stiffness was in the

Table IV. *Speed of restoration of range of motion (degrees/month) after different types of treatment. (Only cases with complete data included).*

	Controls	Distended	Manipulated	Manipulated +Distended	Hospitalized Manipulated	Open Manipulation
Speed						
Average	14.5	19.2	23.2	20.7	94.3	11.9
S D	9.3	19.6	17.5	24.2	94.4	10.0
N	34	39	35	22	76	11

Malmö controls 11.8±4.8 months and in the Malmö manipulated cases 12.5±5.0 months. In the Jönköping series the total duration was significantly shorter, 8.3±3.8 months.

The hospital care in the Jönköping series including intensive physiotherapy after the manipulation may prevent a relapse of the condition immediately after treatment. Such relapse tendencies were noted in the Malmö series as visualized in Figure 3.

3. *Complications*

In 176 closed manipulations in 143 Primary F.S. there was one complication which may have been caused by the manipulation.

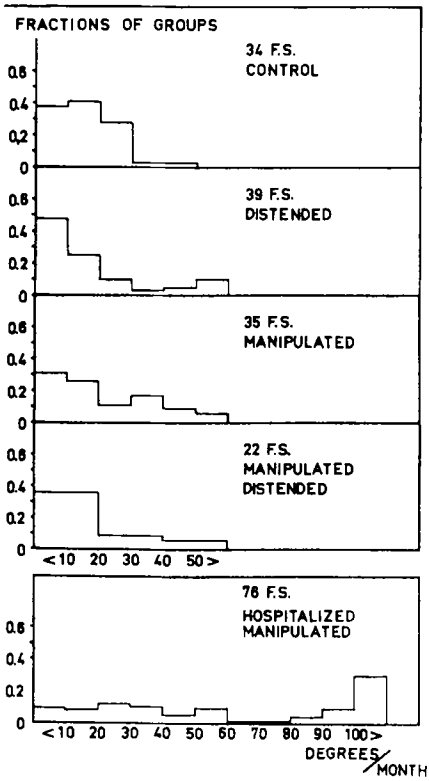


Fig. 7
Speed of restoration (degrees/month) in control cases and after various treatment.

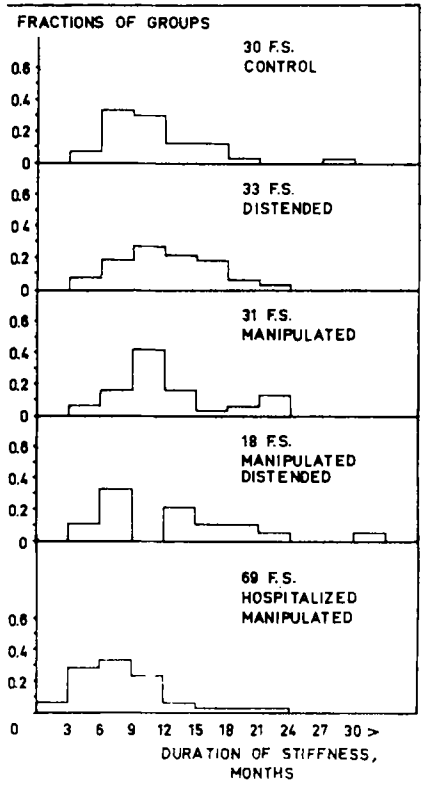


Fig. 8
The total duration of stiffness (months) in control cases and after various treatment.

A woman, age 52, was manipulated with brisement. Three years and seven years later she had full passive range of motion but could not, because of pain, elevate more than 120°. This symptom may be due to a partial rupture of the rotator cuff. There was no arthrography done before or after the manipulation.

The 79 manipulations of Secondary F.S. are more difficult to evaluate as the primary injury in some instances left behind symptoms which included a decreased range of motion. However, there was no indication of harmful effects of manipulation in these cases.

Comment

A number of complications in conjunction with manipulation of F.S. have been described; subscapular and biceps tendon rupture, rupture of the rotator cuff, subluxation of the shoulder joint, fracture of the surgical

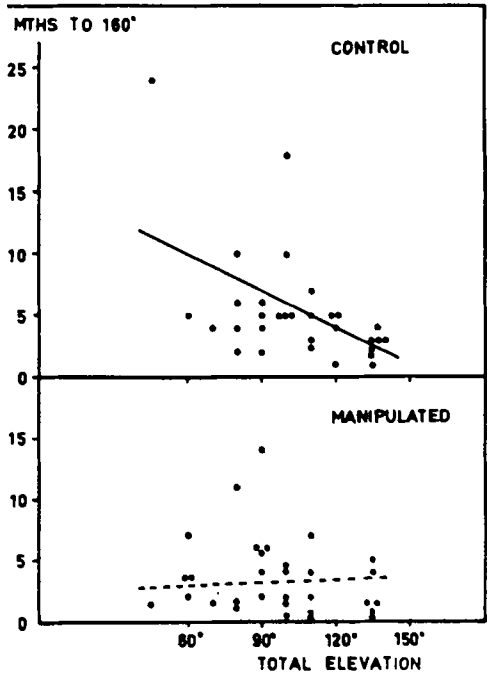


Fig. 9
Relationship between the time required to attain 160 degrees of total elevation, and initial range of motion.

neck of the humerus, nerve injuries and rupture of the axillary artery (DePalma 1952, Quigley 1956, Bloch and Fischer 1958, Charnley 1959, Board of Malpractice Investigation 1968). In the present study, as previously pointed out, complete release of the shoulder could in some cases not be attained, indicating that the investigator had not carried on with the mobilization when the resistance had been evaluated as definite. The exact circumstances of the complications described in the literature are, however, not known.

Periarticular injuries such as rupture of the biceps or subscapular tendon can not be completely ruled out in the present study. There was, however, no clinical or arthrographic evidence of such injuries, nor were injuries to the subscapular tendon found in any of the cases manipulated under surgical exposure.

V. ARTHROGRAPHY[1]

A. RANGE OF MOTION

There were 168 arthrographies of 138 Primary F.S. in 130 patients available for evaluation of capsular retraction. According to ENNEVAARA (1967) the capsular retraction was rated as *obvious*, *doubtful*, or *none* with regard to the appearance of the axillary recess.

Figure 10 demonstrates the relationship between total elevation and rank of arthrographic capsular retraction. Although obvious retraction was found in several F.S. with an almost normal range of motion there was, on the whole, a good agreement between the arthrographic and the clinical findings in this respect. In 123 Primary F.S. with a total elevation of 135° or less there were 7 negative and 5 doubtful arthrograms, the remainder were positive.

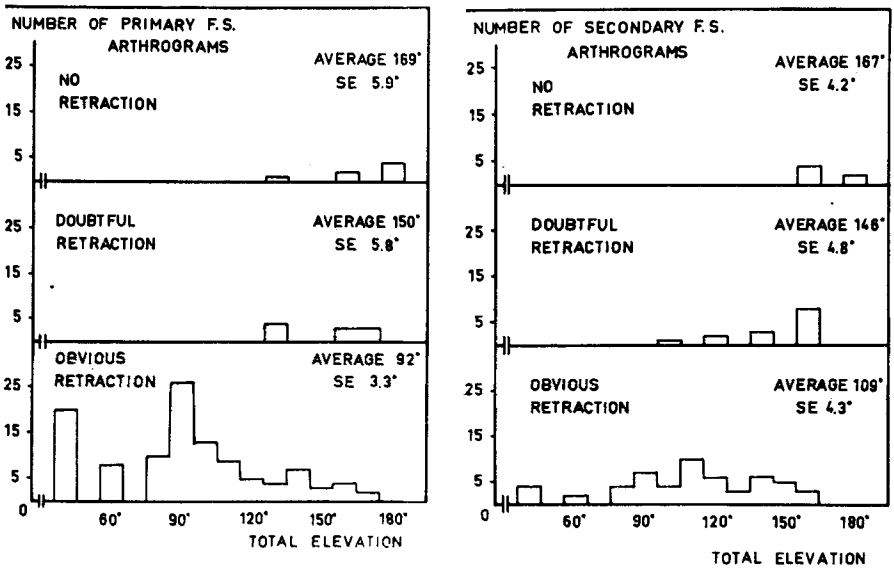


Fig. 10
Relationship between total elevation and ranks of arthrographic capsular retraction in primary and secondary frozen shoulders.

[1] Evaluation was supervised by L. Andrén, M.D., Department of Radiology, General Hospital, Malmö.

In 95 arthrograms from 76 shoulders in 74 patients with Secondary F.S. similar findings were demonstrated (Fig. 10).

B. RUPTURE OF THE CAPSULE

Contrast medium was injected intraarticularly immediately prior to 64 manipulations of Primary F.S. Roentgenograms were taken immediately after the procedure. In all but 2 of these arthrograms there were signs of contrast in the extraarticular space indicating a rupture of the capsule. In the two cases where rupture could not be arthrographically demonstrated the manipulation was not associated with brisement. In two of the cases with extracapsular contrast no brisement was noted. Otherwise, brisement and extraarticular contrast coincided.

In 25 arthrograms taken at various periods of time after the manipulation there was some degree of joint obliteration. Seven of these cases, examined within 2 months after the manipulation also had deposits of contrast close to the inferior aspect of the main contrast image, possibly indicating pouches or tears in the capsule.

Out of 39 arthrographies in Secondary F.S. extra-articular contrast was demonstrated immediately following manipulation in all but 3 cases.

C. RUPTURE OF THE ROTATOR CUFF

In 103 manipulations of 64 Primary and 39 Secondary F.S. the effect of manipulation on the rotator cuff was observed by simultaneous arthrography.

In no instance the manipulation could be demonstrated to cause a rupture of this structure.

In 16 shoulders the joint space communicated with the subacromeal bursa. However, 13 of these communications were visible also in pre-manipulation arthrograms. In the remainder there were no pre-manipulation studies.

D. CINEARTHROGRAPHY

The sequence of events during manipulation of a F.S. can be demonstrated with cinearthrography.[1] A series of 3 shoulders with normal range

[1] Supervised by N. M. Olsson, M.D. and Å. Brodelius, M.D., Department of Radiology, General Hospital, Malmö.

of motion, 3 Primary F.S. and 1 F.S. secondary to fracture of the surgical neck of the humerus was studied by this method (Appendix A).

In contrast to the normal, the joint recesses in the F.S. appeared to be diminished and the initial motion was combined with rotation of the scapula. When the manipulation continued the joint yielded in one or several sudden steps. Within seconds some of the contrast medium left its confinement and dispersed in the surrounding tissues. The appearance of contrast followed almost immediately upon the breaking sound, the brisement.

Comment

The characteristics of arthrography in F.S. have been pointed out by Kessel (1950), Nelson (1952), de Sèze et al. (1961), Lundberg (1965) and others. The common finding has been signs of retraction of the joint capsule including obliteration of the axillary recess. In the present study, it has additionally been demonstrated that the degree of arthrographic changes is related to the degree of restriction of mobility. The arthrographies have served the purpose to demonstrate a relationship between rupture of the capsule and release of the joint. The findings in this respect are controversary to those of Bloch and Fischer (1958) but support the observations of Neviaser (1962).

Furthermore the findings contradict the statement of Samilson et al. (1961) that rupture of the rotator cuff is a frequent complication to manipulation.

The clinical usefulness of arthrography is limited. In some instances, however, arthrography can reveal obliterations also in cases with a fairly good range of motion and thereby explain the symptoms. In cases with a decreased range of motion following injuries it is also of value to be able to detect a possible secondary involvement of the joint capsule.

VI. VOLUMETRY

As the arthrographies in the present and previous studies indicate a decreased volume in F.S. it is of interest to measure the volume of the frozen shoulder joint and relate it to the range of motion.

Twenty-nine measurements were done in Primary F.S. and 18 in Secondary F.S. Joints in which communication to the subacromeal bursa had been demonstrated were not included.

Saline solution was injected by anterior puncture of the shoulder joint; the injection was continued until a definite resistance was felt, and the injected amount was recorded.

There was a significant positive correlation between joint volume and total elevation in Primary as well as in Secondary F.S. (Fig. 11.)

At lower values small increments of volume appeared to be associated with great increments of range of motion.

Between Primary and Secondary F.S. there was no significant difference in the relationship of joint volume and total elevation.[1]

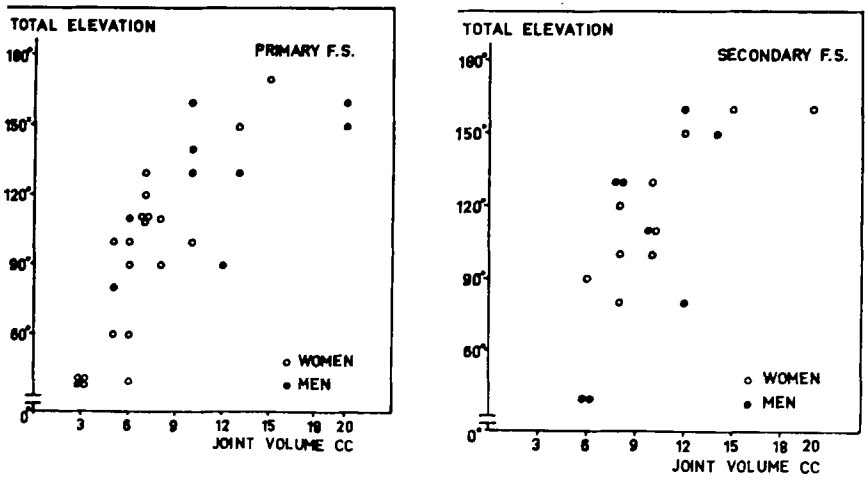


Fig. 11
Relationship between joint volume and total elevation in primary and secondary frozen shoulders.

[1] Analysis of covariance.

Comment

Payr (1931) noticed a reflux when he injected periarthritic joints. The volume in normal shoulder joints has been estimated to 16—35 cc (Harmon 1958, De Sèze 1961 and Reeves 1966). It has previously been stated that the joint capacity is reduced in F.S. (Nelson 1952, Harmon 1958). De Sèze et al. (1916) found volumes as small as 5—6 cc in F.S. Vialla et al. (1964) found higher intraarticular pressures for a given injected volume in F.S. as compared to normal joints. Both variables, pressure and volume, reflect the same condition, capsular retraction.

In the present study it has been demonstrated that the volume of the joint is related to the severity of the disease. The finding suggests volumetry as a complimentary diagnostic test of capsular retraction.

VII. OPERATIVE FINDINGS

Twenty shoulders were exposed surgically through an anterior incision before the manipulation; 15 were Primary and 5 Secondary F.S. In 6 shoulders the subscapular tendon was dislocated and the capsule incised. In these cases the incision considerably released the humero-scapular mobility. The manipulation was then completed in the usual way. After the brisement, the joint surface of the head of the humerus could be felt through the ruptured capsule.

In conjunction with the surgical exposure of these joints the following observations were made:

a) Periarticular inflammatory changes, especially in the insertion of the rotator cuff on the greater tubercle.

b) Thickening of the joint capsule.

c) No intraarticular adhesions.

d) No signs of rupture of the subscapular tendon during the manipulation.

The surgical exposure also provided material for the chemical analysis and the histological examinations described later.

VIII. HISTOLOGICAL EXAMINATION OF THE JOINT CAPSULE

A. LIGHT MICROSCOPY

From 14 F.S., 12 Primary and 2 Secondary, in which the shoulder was exposed surgically, biopsies were taken from the lower anterior portion of the joint capsule. The samples were embedded in paraffin, sectioned and stained with haematoxylin-eosin, with toluidine and according to VAN GIESON.

Samples were also collected from the same part of the shoulder joint in individuals with a normal range of motion, who were operated on for various reasons, mostly habitual dislocation of the shoulder.

In the reference cases S.S. and D.A. (Table V) the biopsies were taken within a month after traumatic lesions, which, however, were not associated with a decreased range of motion (rotator cuff rupture and traumatic shoulder dislocation, respectively).

The samples were studied with respect to thickening and vascularity of the synovial lining and denseness, vascularity and hyperplasia of the adjacent fibrous layer. The morphological ranking of the sections was done by a pathologist who did not know their origin.[1]

The results of the histological study are shown in Table V. In general, the connective tissue in the reference shoulders was organized in bundles or groups of bundles with comparatively few fibrocytes. In sections from joint capsules of F.S. the fibrous tissue appeared more compact or dense (referred to as denseness in the Table). In addition to the impression of denséness there were more cells, mostly fibroblasts, and sometimes, increased vascularity (Appendix A). The synovial lining was largely unchanged except for the fact that in F.S., capillaries were observed more often. No difference between F.S. and normal could be demonstrated in the metachromatic staining of the toluidine treated sections.

The general impression of the morphological changes in the joint capsule in F.S. was that of fibrosis and fibroplasia.

COMMENT

It was not possible to collect reference cases of the appropriate age and sex distribution. There is, however, no evidence that changes of the type found in the F.S. reflect age and sex only.

[1] J. G. Nordén, M.D., Department of Pathology, General Hospital, Malmö.

NEVIASER (1945) found signs of chronic inflammation and fibrosis in the sub-synovial layers of F.S., "capsulitis". DEPALMA (1952) found histological evidence of a low grade chronic inflammatory process not only in the fibrous joint capsule but also in various periarticular structures.

The present study supports these findings but no significant amount of inflammatory cells was found. The morphology was similar to that of DUPUYTREN'S contracture (NORDÉN 1969). ASK-UPMARK (1944) stated that

Table V. *Histological findings in sections of shoulder joint capsules.*

0 no changes
1 slight changes
2 obvious changes
3 extensive changes
— missing in the section

Case	Sex	Age	Synovial lining		Fibrous layer		
			Thickening	Vascularity	Denseness	Fibroplasia	Vascularity
References							
M.N.	M	19	0	0	0	0	0
A.C.	M	22	0	0	0	0	0
K.O.	M	22	0	0	0	0	0
M.P.	M	25	0	0	0	0	0
H.R.	M	26	—	—	0	0	0
S.A.	M	35	0	0	0	0	0
K.R.	M	44	0	0	0	0	0
G.J.	M	52	—	—	0	0	0
S.S.	M	63	1	0	0	1	2
I.M.J.	F	25	0	0	0	0	0
D.A.	F	75	2	2	1	1	2
Frozen shoulders							
E.R.	M	55	0	0	2	2	2
S.B.	M	64	0	2	2	2	0
G.K.	F	42	—	—	1	1	0
E.B.N.	F	45	—	—	1	0	0
G.A.	F	45	1	1	2	2	0
E.S.	F	47	0	0	2	2	0
E.H.	F	50	0	2	2	2	0
I.P.	F	51	0	2	2	3	2
J.P.	F	52	0	0	2	0	0
E.M.	F	53	0	2	2	3	2
M.M.	F	55	—	—	1	0	0
H.N.	F	64	0	0	2	3	0
P.W.[1]	F	51	—	—	2	2	0
T.S.[1]	F	55	0	0	0	0	2

[1] Secondary frozen shoulders.

such palmar infiltrations were common in cardiosclerotic patients with shoulder disorders. DUPUYTREN'S contracture was present in 25 % of SCHAER'S (1936) cases of periarthritis of the shoulder. KLAMI (1962), however, could not demonstrate any such relationship.

B. ELECTRON-MICROSCOPY

In order to obtain information concerning the individual fibrils, including their periodicity, the ultrastructure of the joint capsule was studied in samples from 4 normal shoulders and 3 Primary F.S.

The samples were prefixed in 2.5 % glutaraldehyde in phosphate buffer, pH 7.2, fixed in 1—2 % osmium tetroxide (MILLONIG 1962) and embedded in Vestopal W. Sections were made with an LKB microthome, Ultrotome, and examined in a Hitachi HS-7S electron microscope. Some sections were stained in lead-citrate (REYNOLDS 1963).[1]

The sections were studied and photographed with special reference to the appearance and arrangement of the collagen bundles and individual fibrils. The general impression in F.S. was that of a more compact arrangement of the collagen fibres; there were also, as was expected from light microscopy, more cellular elements present. Between normal shoulders and F.S. there was no indication of differences in structure or periodicity of the fibrils. (Appendix A.) The variation of collagen appearance was not greater between pathological and normal sections than between sections from the same shoulder.

COMMENT

The character of the capsular changes in the F.S. leads to the suspicion that the properties of collagen in the tissue are changed, and that the F.S. is a symptom of disease in the collagen itself. Electron-microscopy of capsules from a limited number of shoulders did not indicate structural changes.

[1] The preparation was supervised and the photographs examined by C. v. Mecklenburg, Ph. D., Department of Zoology, University of Lund, Lund.

IX. ANALYSIS OF GLYCOSAMINOGLYCANS[1] IN THE JOINT CAPSULE

A. MATERIAL

From 14 surgically exposed F.S., two of which were secondary, biopsy specimens were taken from the joint capsule for chemical analysis (LUNDBERG 1969). Similarly, biopsies were taken from 13 cases with a free range of motion, who were operated on, mostly because of habitual shoulder dislocation. Differences in age and sex distribution between the two groups existed to the same extent as in the histological study and for the same reasons.

B. CHEMICAL ANALYSIS.[2]

The glycosaminoglycans were liberated from the capsular tissue by papain digestion according to SCOTT (1960).

The glycoproteins were separated from the glycosaminoglycans by chromatography of 50 μl of the digestion mixture (corresponding to about 2.5 mg dry weight of the capsule) on ECTEOLA-columns as described by RINGERTZ and REICHARD (1960). By this procedure the glycoproteins were recovered after elution with water and 0.02 M HCl, the unsulfated glycosaminoglycans with 0.5 M NaCl and the sulfated with 6 M HCl (Table VI: 1).

For further determination of the glycosaminoglycans, they were precipitated as water-insoluble cetylpyridinium complexes on columns of powdered cellulose and fractionated as described by ANTONOPOULOS et al. (1964) by washing with salt solutions of increasing concentrations (Table VI: 2). To each micro-cellulose column was added 50 μl of a digest equivalent to approximately 2.5 mg dry capsule.

Larger amounts of material, corresponding to approximately 25 mg of dry tissue weight, were fractionated on cetylpyridinium chloride (CPC)-cellulose microcolumns according to THUNELL's (1967) modification. With this method the glycosaminoglycans were precipitated with 1 % aqueous CPC and fractionated before and after treatment with testicular hyaluronidase (Table VI: 3).

[1] Equivalent to mucopolysaccharides according to the terminology of BALAZS and JEANLOZ (1965).

[2] The work was carried out under supervision of S. Gardell, M.D. at the Department of Physiological Chemistry, University of Lund, Lund.

Table VI. *Hexosamine from ECTEOLA (I) and CPC-microcellulose column (II, III) fractionation as percentage of total, in dry defatted synovial tissue from shoulder joints with unlimited and restricted mobility. In III the tissue glycosaminoglycans have been precipitated by CPC prior to fractionation. Stepwise elution with 1 ml of each of the solutions. (Average ± S.E.)*

		I				II						III					
	Fraction	H_2O and 0,02 M HCl	0,5 M NaCl	6 M HCl	Total ug/mg dry tissue wt	1 % CPC	0,3 M NaCl	0,3 M(neutral) $MgCl_2$	0,75 M (acid) $MgCl_2$	6 M HCl	Total ug/mg dry tissue wt	1 % CPC	0,3 M NaCl	0,3 M (acid) $MgCl_2$	0,7 M (acid) $MgCl_2$	6 M HCl	Total ug/mg dry tissue wt
References	Average	64.2	15.9	20.2	8.0	71.8	15.7	1.6	2.0	9.0	7.3	10.9	40.9	2.5	5.1	41.3	1.6
	S E	2.17	0.82	1.73	0.39	1.44	0.91	0.80	0.76	1.16	0.44	2.70	3.39	1.13	2.17	3.81	0.19
	N	13				13						12					
Frozen Shoulders	Average	54.0	16.7	29.6	9.9	67.4	12.6	6.0	5.0	9.0	8.76	7.1	20.9	7.0	13.4	51.9	2.14
	S E	2.05	1.09	1.89	0.52	2.35	1.28	1.24	0.60	1.62	0.55	1.14	1.46	2.98	1.57	4.03	0.16
	N	12				14						8					
	P (t-test of difference)	<0.01	—	<0.001	<0.01	—	—	<0.01	<0.01	—	<0.05	—	<0.001	—	<0.01	—	<0.05

C. RESULTS

The available amount of material was too small to permit an identification of the glycosaminoglycans in the synovial tissue from shoulder joints. However, on the basis of results obtained from studies on the glycosaminoglycans in human knee joint capsules (HEINEGÅRD et al. 1968) it was possible to determine the origin of the hexosamines in the present study.

The results presented in Table VI imply, regardless of method, an increased total amount of hexosamines in the synovial tissue of the F.S. as compared to normal. The increase was confined to the sulfated glycosaminoglycans. There was a significant reduction of the glycoprotein content in the F.S. joint capsule as evaluated from the decreased amount of hexosamine recovered after elution with water and 0.02 M HCl of the digested material on ECTEOLA-columns. The hyaluronic acid, exclusively present in the 0.3 M NaCl fraction (HEINEGÅRD et al. 1968), was also reduced (Table VI: 3). Concerning the sulfated glycosaminoglycans the same study indicated that the 0.3 $MgCl_2$ fraction corresponded to heparan sulfate while the chondroitin-6 sulfate and the dermatan sulfate were recovered in the subsequent fractions.

The values of the latter fractions were higher in samples from the F.S. There were no differences in the degree of dermatan sulfate hybridization between frozen and normal shoulders as indicated by the effect of hyaluronidase treatment (FRANSSON and RODÉN 1967). This analysis revealed that dermatan sulfate is a major component of the glycosaminoglycans in joint capsules.

COMMENT

Some parallels may be drawn between the composition of granulation tissue and synovial tissue of F.S. SYLVÉN (1941) found metachromasia in regenerating tissue of healing wounds. VINOGRADOV (1966) demonstrated that an increase of glycosaminoglycans was associated with intense proliferation of fibroblasts. Hyperplasia of the fibroblasts and an increase of the glycosaminoglycans are characteristic for the joint capsules of F.S. BERENSEN and DALFERES (1960) found that the content of chondroitin sulfate in granulation tissue increased more rapidly than that of hyaluronic acid; in the present study those components were changed in the same direction. It may be suggested that the changes in the glycosaminoglycans are characteristic for a repair reaction. AKESON et al. (1967) found in experimentally immobilized knees of dogs a decrease of the contents of hyaluronic acid and chondroitin sulfate in the periarticular connective tissue. Therefore the findings in the present study may reflect not a secondary effect of immobilization but rather the pathogenesis of the condition.

X. LOCAL CHANGES IN BONE METABOLISM

A. BONE DENSITOMETRY

1. Material and Methods

In 40 cases of Primary F.S., 23 women and 17 men, the bone mineral mass of the head of the humerus was evaluated. In addition 10 men and 10 women, randomly selected among persons without any history of injury to the upper limb, were measured. The method, which has been described in detail elsewhere (NILSSON 1966, LUNDBERG and NILSSON 1968), made use of the radiation from a source of Americium-241. The attenuation of a photon beam from the source was measured as the beam passed through the head of the humerus; the soft tissue was accounted for by the use of a water phantom of the same thickness as the bone and soft tissue interposed in the path-way of the beam.

All individuals included in this study were right-handed. There was no preponderance for left or right in this group of Primary F.S. Their average age is given in figure 12.

2. Results

In the reference cases the head of the left humerus contained less mineral expressed as the thickness in the path-way of the beam (g/cm^2) than did the right. This difference was, however, significant only in women.

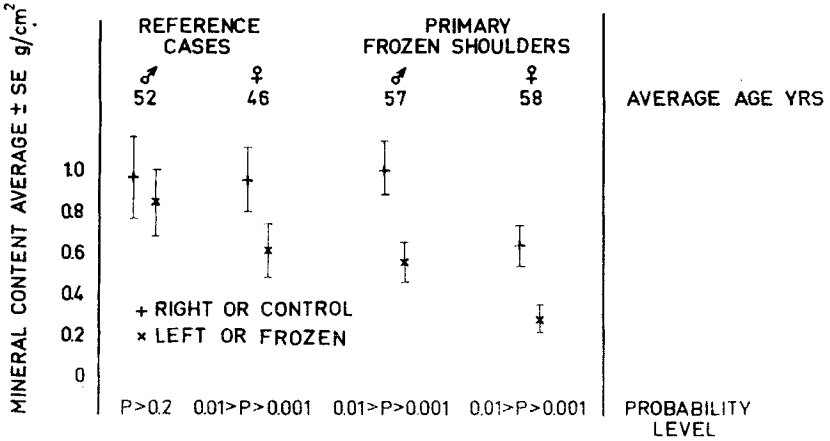


Fig. 12
The mineral content of the head of the humerus.

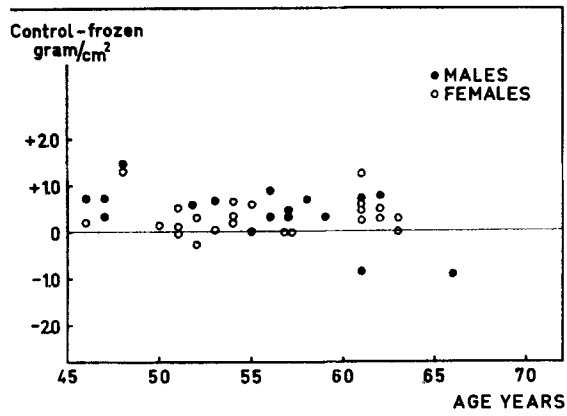


Fig. 13
Degree of osteopenia in primary frozen shoulders as a function of age.

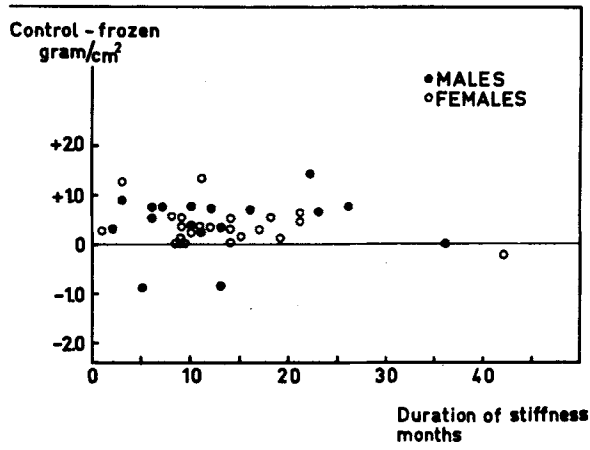


Fig. 14
Degree of osteopenia in primary frozen shoulders as a function of the duration of stiffness.

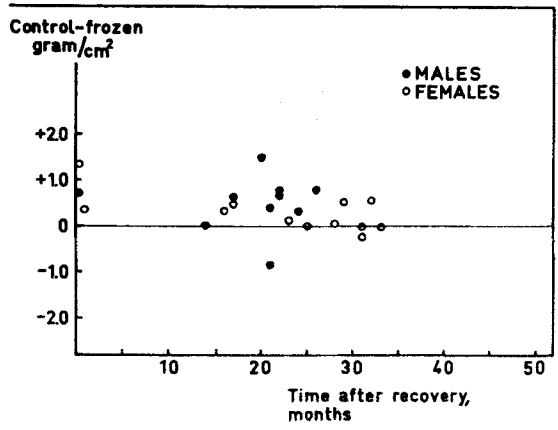


Fig. 15
Degree of osteopenia in primary frozen shoulders as a function of time after recovery.

In the cases of F.S. there was a significant decrease of bone mass in the affected side as compared to the unaffected one. The average difference amounted to about 50 % of the mineral content of the unaffected side (Fig. 12). There was no evidence that the degree of osteopenia associated with F.S. was age-dependant (Fig. 13), nor that it increased with an extended duration of the condition (Fig. 14). There was no evidence of restoration of the mineral mass with time (Fig. 15).

B. TURNOVER OF ^{85}SR[1]

1. Material and Methods

Fifteen cases suffering from unilateral Primary F.S., 7 men and 8 women, were included in this study. Another 6 unilateral but recovered cases, 2 men and 4 women, were included. They had recovered from their F.S. 9 months to 4 years before the measurement and had regained full range of motion and normal function of their shoulder joints. For reference, 8 individuals, 3 men and 5 women, without history or clinical signs of symptoms of shoulder disease or injury were measured. Another 6 references, 5 men and 1 woman, with pain in one shoulder for 3 months or more but without decreased range of motion were measured. The age of references and F.S. cases was about the same.

All the patients were injected intravenously with 50 μCi of $^{85}Sr\ (NO_3)_2$. Two weeks later the activity was recorded over the shoulder and over the elbow using a lead-shielded scintillation detector with a 12° wide angle collimator (diameter of outer aperture 65 mm). The geometry of the detector in relation to the shoulder joint is shown in Figure 16. The uptake in the elbow was measured with the detector in skin contact facing the lateral aspect of the joint.

For evaluation of the changes in uptake a ratio was formed between the background-corrected count rates obtained from the affected and the unaffected limbs respectively (Fig. 17).

2. Results

The uptake in Primary F.S. was significantly increased when compared to the reference cases. In cases who had restored their range of motion the uptake was significantly decreased as compared to the current cases. (Tab-

[1] The investigation was carried out in the Department of Nuclear Medicine, General Hospital, Malmö (Head: B. Nosslin, M.D.).

le VII). In painful shoulders without decreased range of motion the uptake did not exceed that of the other reference group.

There was also some indication of increased uptake in the elbow region of the F.S.-affected limb. Again the uptake in the restored cases was significantly less (Table VIII).

There was no difference between men and women in either group.

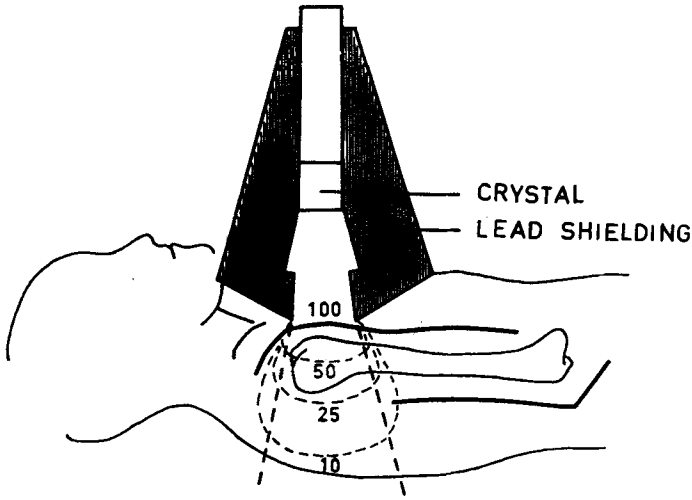


Fig. 16
The detector positioned over the shoulder. The isoresponse areas shown in relation to the upper end of the humerus.

Comment

Within a few months after a tibial shaft fracture a loss of mineral in the knee region of about 25 % has been demonstrated (Nilsson 1966). At the same time the uptake of ^{85}Sr in the same area is usually about quadrupled (Wendeberg 1961). These findings indicate a primary loss of bone due to resorption followed by a response of increased bone formation as evaluated from the ^{85}Sr uptake. In the present study the loss of bone exceeds that found in the knee region following fracture and is much greater than could be expected from immobilization; so far, nobody has been able to demonstrate a convincing local osteopenia in man as a result of immobilization only. A joint affection, such as a tear of the semilunar cartilage results in a loss of no more than 10 % of the bone mass (Nilsson and Westlin 1968). The loss of bone associated with F.S., 50 %, is therefore remarkably large.

If the continuous loss of bone is taken into account, the initial uptake

of ^{85}Sr per unit bone approached that of a fractured leg and also lasted far out in time.

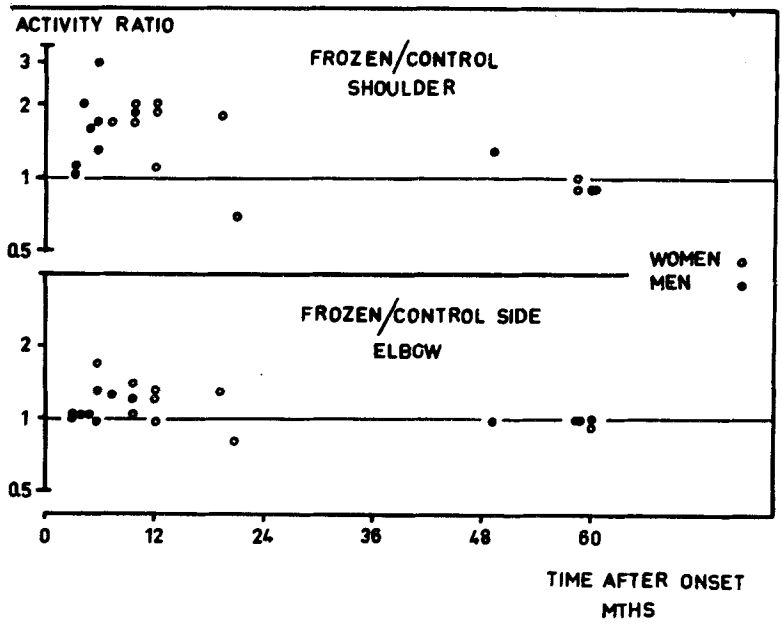


Fig. 17
Uptake of ^{85}Sr in the frozen shoulder and in the elbow of the affected limb in relation to the unaffected side.

Table VII. *Uptake of ^{85}Sr expressed as the ratio between the affected and the unaffected (frozen shoulders and reference shoulders with pain) or between right and left (reference shoulders without pain).*

	Primary frozen shoulders		Reference shoulders	
	Current	Restored	With pain	Without pain
Number	15	6	6	8
Average ratio	1.75	0.97	1.06	1.05
S E	0.13	0.08	0.04	0.04

Table VIII. *Uptake of ^{85}Sr in the elbow region expressed as the ratio between the affected and the unaffected limbs.*

	Current	Restored
Number	15	6
Average ratio	1.20	0.94
S E	0.05	0.03

XI. DISCUSSION

A. PATHOLOGY OF THE FROZEN SHOULDER

The findings in this study support the concept that retraction of the joint capsule is the basic component in the syndrome. In Primary as well as Secondary F.S. the retraction was demonstrated by arthrography, by volumetric studies, by rupture of the capsule when tension was applied and by the fact that rupture was necessary to release the joint. The restriction of elevation and rotation suggests involvement of the whole capsule.

It may be suspected that the changes in the capsule are secondary to other, possibly exogenous, factors such as inactivity. One of the effects of disuse is changes in the regional vascular supply (HULTH and OLERUD, 1961, LUNDBERG 1969), signs of which also occur in the F.S. On the other hand the histological findings and the changes in the content of glycosaminoglycans rather suggest an active capsular process, the target tissue of which is the fibrous layer.

Furtherwore the local changes in bone metabolism of Primary F.S., osteopenia and increased turnover rate, are not of the order of magnitude expected to result from immobilization only but rather what could be expected in arthritis. However no signs of mesothelial involvement indicating a synovial arthritis were found.

The painful shoulders without restriction of mobility did not show any increase in bone turnover suggesting a different pathophysiology.

There seems to be no condition which quite resembles the frozen shoulder.

B. FACTORS CONTRIBUTING TO THE PRODUCTION OF FROZEN SHOULDER

With respect to age the risk of Primary F.S. is tremendously increased between 40 and 60 which indicates that the disease is almost entirely restricted to middle-aged persons. Therefore F.S. is not related to ageing *per se* or to age-related degenerative changes in joints or periarticular tissue.

In the secondary cases trauma and forced inactivity after trauma must be taken into consideration as possible contributing factors in spite of the fact that many cases with identical injuries did not develop the syndrome. A support for the theory of inactivity as a contributing factor is the preponderance for the left shoulder in women. However, it must be stressed

that both inactivity and over-activity and strain are offered as explanations for this disease.

With regard to endogenous factors the only symptom which coincided with Primary F.S. more often than could be expected was cervical pain. However, certain diseases may also to some extent contribute as trigger mechanisms for the F.S.

The fact that bilateral involvement is more common than may be expected from chance only, suggests a *sui generis* disease which points to the existence of a constitutional factor.

The morbidity of Primary F.S. outside a given age range is very low and this suggests that the constitutional factor alone is insufficient and that the age requirement will have to be fulfilled. The logistics of the suggested interaction between age, contributing factors and constitutional factors are shown in Figure 18.

In this study it has not been possible to describe the constitutional factor by any known variable although the data suggest that it exists.

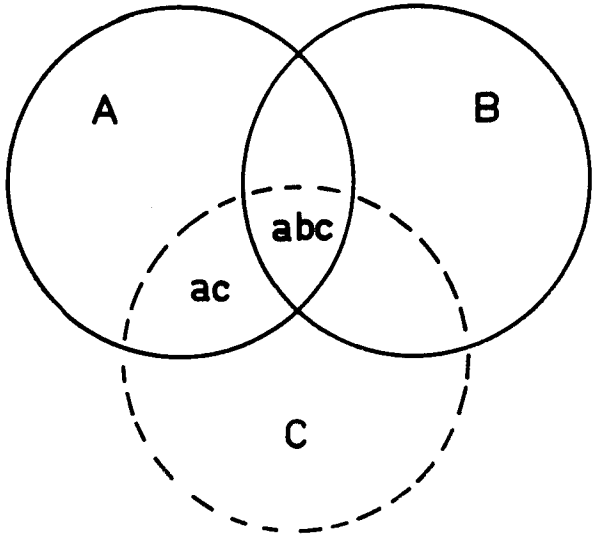


Fig. 18

Diagram demonstrating the interaction of age, contributing factors and constitutional factors.

A: Age

B: Contributing factors

C: Constitutional factors

With the most generous interpretation of the role of contributing conditions the portion of primary F.S. with such influence (abc) was 57 %, the subset (ac), 43 % were healthy, middle-aged people.

C. ASPECTS ON THE TREATMENT OF THE FROZEN SHOULDER

The F.S. is a self-limiting disease. All the primary cases of this study restored eventually their free range of motion, although the duration of symptoms varied considerably. Therefore, manipulation is an optional procedure and the physician has a free choice of treatment.

Manipulation has been recommended with varying degrees of enthusiasm (WITHERS 1949, QUIGLEY 1956, HARMON 1958, BLOCH and FISCHER 1958, LLOYD-ROBERTS and FRENCH 1959, NEVIASER 1963). Discourageing results of this procedure, on the other hand, have been reported by LIPPMANN (1944), DEPALMA (1952), MCLAUGHLIN (1961) and WATSON-JONES (1963).

In the present study the main advantage of manipulation in Primary F.S. has been found to be a shortening of the time during which the range of motion is extensively decreased. The selection of cases for manipulation is difficult. From the data, however, it appears that patients with the stiffer shoulders have more to gain than the patients with an initially less decreased range of motion. Open manipulation offered no advantage, on the contrary the speed of restoration decreased.

The main cause of unsatisfactory therapeutic results appears to be that the capsule heals in the original state of retraction. Adjuvant therapy consisting of intensive physiotherapy appears, to a large extent, to prevent such relapse by promoting regeneration of the synovial tissue to a more normal state.

In some instances, particularly in cases with completely stiff shoulders, the relief from pain is the immediate objective of the treatment. CHARNLEY (1959) stressed the pain relieving effect of manipulation. In the present study the effect on pain has not been investigated as the variable is difficult to evaluate. However, the impression of the investigator is that the relieving effect on pain, particularly in severe cases is considerable. There are no serious complications of manipulation if some caution is exercised. It should be kept in mind that all shoulders can not be mobilized to a full range of motion.

Even in the more successfully treated, hospitalized cases the effect of manipulation on the total duration of symptoms was less pronounced than the immediate effect on the range of motion. Although, in the non-hospitalized series manipulation could be demonstrated to increase the speed of restoration of mobility there was no effect on the total duration of the disease. From the point when 160° of total elevation is attained, the symptoms, including a slightly decreased mobility, may exist far out in time. The total duration probably reflects the course of the disease itself which is less influenced by therapeutic measures.

XII. SUMMARY

Clinical, radiological, morphological and biochemical information was collected in cases of frozen shoulder.

1. The disease was somewhat more common in women.

2. The age at onset of the disease was lower in women than in men.

3. The disease occurred almost always in middle-aged individuals and within a rather narrow age range.

4. There was a preponderance for involvement of the left shoulder in women.

5. Relapse of the disease in the contralateral shoulder was more common than could be expected from chance only.

6. Relapse of the disease in the same shoulder was not observed.

7. The disease could not be proven to be related to menopause in women.

8. The disease occurred with a seasonal variation, the frequency being lower in the spring.

9. There was no conclusive evidence that, in cases of primary frozen shoulder, inactivity, strain or minor trauma contributed to the production of the disease.

10. Of various concomitant conditions examined, only cervical pain appeared to coincide with the onset of the disease more often than could be expected.

11. Manipulation under general anesthesia increased the speed at which the range of motion was restored.

12. The effect was appreciable only in cases with highly restricted range of motion.

13. Manipulation did not shorten the total duration of the disease.

14. Joint distension increased somewhat but not significantly the speed of restoration of the range of motion. It did not change the total duration of the disease.

15. Intensive physical therapy after manipulation further increased the speed of restoration and also shortened the total duration of the disease.

16. The manipulation procedure demonstrated the importance of the restricting changes in the joint in that a brisement was required for full range of motion.

17. Relapse of stiffness after manipulation is probably caused by healing of the rupture in an original state of retraction.

18. Retraction of the capsule was frequently confirmed by arthrography. The arthrographic degree of retraction was related to the range of motion.

19. Arthrographies simultaneous with manipulation showed rupture of the joint capsule.

20. There was no indication that rupture of the rotator cuff is a frequent complication to manipulation, nor were any other harmful effects established.

21. The capacity of the joint, evaluated from volumetric injections, was related to the range of motion.

22. Surgical exposure verified the retracted condition of the joint capsule and rupture of the capsule when the shoulder was being manipulated.

23. Histological examination revealed fibrosis and fibroplasia of the fibrous layers of the joint capsule. There were no obvious changes in the synovial lining.

24. Electron-microscopy in a few cases did not reveal any obvious changes in the ultrastructure of the collagen of the joint capsule.

25. Analysis of the glycosaminoglycans in joint capsules from frozen shoulders revealed an increase in the amount of hexosamines. The increase was confined to the glycosaminoglycans, heparan sulfate and chondroitin sulfates, whereas the hyaluronic acid was decreased.

26. The mineral content in the head of the humerus was decreased by half in cases of frozen shoulder. There were no signs of restoration of the mineral during the time of observation.

27. The turnover rate of mineral evaluated from the uptake of ^{85}Sr was increased by a factor of almost 2 in frozen shoulders but not in painful shoulders with a normal range of motion.

28. Secondary frozen shoulders differed from the primary cases in many respects but the capsular retraction and the immediate effect of manipulation were the same in both groups.

XIII. BIBLIOGRAPHY

AKESON, W. H., AMIEL D. and LA VIOLETTE, D.: The connective-tissue response to immobility: A study of the chondroitin-4 and 6-sulfate and dermatan sulfate changes in periarticular connective tissue of control and immobilized knees of dogs. Clin. Orthop. 51: 183, 1967.

ALFFRAM, P. A.: An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. Acta orthop. scand. Suppl. 65, 1964.

ANDRÉN, L. and LUNDBERG, B. J.: Treatment of rigid shoulders by joint distension during arthrography. Acta orthop. scand. 36: 45, 1965.

ANTONOPOULUS, C. A., GARDELL, S., SZIRMAI, J. A. & DE TYSSONSK, E. R.: Determination of glycosaminoglycans (mucopolysaccharides) from tissues on the microgram scale. Biochim. biophys. Acta. 83: 1, 1964.

ASK-UPMARK, E.: Correlations between heart and arm. Nord. Med. 21: 434, 1944.

BALAZS, E. A. and JEANLOZ, R.: The amino sugars: The chemistry and biology of compounds containing amino sugars, vol. II A, ed. by E. A. Balazs and R. Jeanloz, Academic Press, New York, 1965.

BERENSON, G. S. and DALFERES, E. R.: Identification of acid mucopolysaccharides from granulation tissue in rats. Brit. J. exp. Path. 41: 422, 1960.

BLOCH, J. and FISCHER, F. K.: Probleme der Schultersteife ("Frozen shoulder"), Documenta rheumatologica, Geigy, nr 15, 1958.

Board of malpractice investigation, Läk.-Tidn. 65: 4814, 1968.

BOSWORTH, D.: An analysis of 28 consecutive cases of incapacitating shoulder lesions, radically explored and repaired. J. Bone Jt. Surg. 22: 369, 1940.

BRIMBERG, S.: Om skulder-armsmärtor. Diss. Ejnar Munksgaard, Köpenhamn, 1952.

CHARNLEY, J.: Periarthritis of the shoulder. Postgrad. med. J. 35: 384, 1959.

CODMAN, E. A.: The shoulder. The author, Boston, 1934.

DANIELSSON, L. G.: Incidence and prognosis of coxarthrosis. Acta orthop. scand., Suppl. 66, 1964.

DEPALMA, A. F.: Loss of scapulohumeral motion (Frozen shoulder). Ann. Surg. 135: 193, 1952.

DICKSON, J. A. and CROSBY, E. H.: Periarthritis of the shoulder. J. Amer. med. Ass. 99: 2252, 1932.

DUPLAY, S.: De la péri-arthrite scapulo-humérale et des raideurs de l'épaule qui en sont la conséquence. Arch. gén. Méd. 20: 513, 1872.

ENNEVAARA, K.: Painful shoulder joint in rheumatoid arthritis. Acta rheum. scand. Suppl. 11, 1967.

FRANSSON, L. Å. and RODÉN, J.: II Characterization of products obtained by hyaluronidase digestion of dermatan sulfate. J. biol. Chem. 242: 4170, 1967.

HARMON, P. H.: Methods and results in the treatment of 2,580 painful shoulders. Amer. J. Surg., 95: 527, 1958.

HEINEGÅRD, D., HERNBORG, J. and LUNDBERG, B. J.: The glycosaminoglycans of the human joint capsule. Isolation and characterisation. Arthr. and Rheum. 11: 787, 1968.

HULTH, A. and OLERUD, S.: Disuse of extremities II. Acta chir. scand. 120: 388, 1961.

HULT, L.: Cervical, dorsal and lumbar spinal syndromes. Acta orthop. scand. Suppl. 17, 1954.

JOHNSON, J. T. H.: Frozen-shoulder syndrome in patients with pulmonary tuberculosis. J. Bone Jt. Surg. 41 A: 877, 1959.

KESSEL, A. W. L.: Arthrography of the shoulder-joint. Proc. roy. Soc. Med. 43: 418, 1950.

KLAMI, P.: Periarthrosis calcarea of the shoulder joint. Acta radiol. (Stockh.) Suppl. 215, 1962.

KLAPP, R.: Die operative Erweiterung der Schultergelenkkapsel. Eine Methode zur blutigen Mobilisierung von Schultersteifigkeiten. Zbl. Chir. 43: 137, 1916.

LIDSTRÖM, A.: Den "frusna skuldran". Nord. Med. 5: 125, 1963.

LIPPMANN, R. K.: Frozen shoulder; periarthritis; bicipital tenosynovitis. Arch. Surg. 47: 283, 1943.

— Bicipital tenosynovitis. N.Y. St. J. Med. 44: 2235, 1944.

— The frozen shoulder. Surg. Clin. N. Amer. 31: 367, 1951.

LORENZ, T. H. and MUSSER, M. J.: Life stress, emotions and painful stiff shoulder. Ann. intern. Med. 37: 1232, 1952.

LLOYD-ROBERTS, G. C. and FRENCH, P. R.: Periarthritis of the shoulder. Brit. med. J. 20: 1569, 1959.

LUNDBERG, B. J.: Arthrography and manipulation in rigidity of the shoulder joint. Acta orthop. scand. 36: 35, 1965.

— Mobiliseringsresultat vid axelrigiditet. Nord. Med. 77: 168, 1967.

LUNDBERG, B. J. and NILSSON, B. E. R.: Osteopenia in the frozen shoulder. Clin. orthop. 60: 187, 1968.

LUNDBERG, B. J.: Disappearance of ^{22}NaCl and ^{131}I-Hippuran from immobilized joints in rabbits. To be published in Acta rheum. scand. 15: 1969.

— The glycosaminoglycans of the normal and frozen shoulder joint capsule. In preparation.

MCLAUGHLIN, H. L.: On "Frozen" shoulder. Bull. Hosp. Jt. Dis. (N.Y.) 12: 383, 1951.

— The "Frozen shoulder". Clin. orthop. 20: 126, 1961.

MILLONIG, G.: Further observations on a phosphate buffer for osmium solutions in fixation. V Internat. Congr. EM. Philadelphia. 2: 8, 1962.

MOBERG, E.: The shoulder-hand-finger syndrom as a whole. Acta chir. scand. 109: 284, 1955.

MOSELEY, H. F.: Shoulder lesions, Springfield Ill., Charles C. Thomas, Publisher, 1945.

NELSON, D. H.: Arthrography of the shoulder. Brit. J. Radiol. 25: 134, 1952.

NEVIASER, J. S.: Adhesive capsulitis of the shoulder. J. Bone Jt. Surg. 27: 211, 1945.

— Arthrography of the shoulder joint, J. Bone Jt. Surg. 44 A: 1321, 1962.

— Musculoskeletal disorders causing cervicobrachial pain. Surg. Clin. N. Amer. 43: 1703, 1963.

NILSSON, B. E. R.: Post-traumatic osteopenia. Acta orthop. scand. Suppl. 91, 1966.

NILSSON, B. E. R. and WESTLIN, N. E.: Muscle dysfunction and osteopenia following injury to the semilunar cartilage. To be published.

NORDÉN, J. G.: Personal Communication, 1969.

PASILA, M.: Periarthritis glenohumeralis. (Thesis, Helsinki) Duodecim, Suppl. 44, 1965.

PAYR, E.: Gelenk-"Sperren" und "Ankylosen"; über die "Schultersteifen" verschiedener Ursache und die sogenannte "Periarthritis humero-scapularis", ihre Behandlung. Zbl. Chir. 58: 3, 2993, 1931.

QUIGLEY, T. B.: Treatment of checkrein shoulder by use of manipulation and cortisone. J. Amer. med. Ass. 161: 9, 850, 1956.

REEVES, B.: Arthrography of the shoulder. J. Bone Jt. Surg. 48 B: 424, 1966.

REYNOLDS, E. S.: The use of lead citrate at high pH as an electronopaque stain in electron microscopy. J. Cell. Biol. 17: 208, 1963.

RIEDEL, R.: Die Versteifung des Schultergelenks durch Hängelassen des Armes. Münch. med. Wschr. 63: 1397, 1916.

RINGERTZ, N. R. and REICHARD, P.: Chromatography on ECTEOLA of sulfate containing mucopolysaccharides. Acta chem. scand. 14: 303, 1960.

SAMILSON, R. L. et al.: Arthrography of the shoulder joint. Clin. orthop. 20: 21, 1961.

SAMUELSSON, S.: Menarche, Menopause und Reproduktionszeit des Weibes. Acta obstet. gynec. scand. 22: 33, 1942.

SCHAER, H.: Die Ätiologie der Periarthritis humeroscapularis. Ergebn. Chir. Orthop. 29: 11, 1936.

SCOTT, J.: Aliphatic ammonium salts in the assey of acidic polysaccharides from tissues. Meth. biochem. Anal. 8: 145, 1960.

SÈZE, S. DE, RYCKEWAERT, A., WELFLING, J., RENIER, J.-C., HUBAULT, A., CAROIT, M. et POINSARD, G., Études sur l'épaule douloureuse (périarthrite scapulo-humérale). Les lésions anatomiques de l'épaule bloquée. Rev. Rhumat. 27: 323, 1960.

SÈZE, S. DE, RYCKEWAERT, A., RENIER, J.-C., HUBAULT, A., WELFLING, M., CAROIT, M., et POINSARD, G.: Études sur l'épaule douloureuse (périarthrite scapulo-humérale) L'arthrographie de l'épaule bloquée. Rev. Rhumat. 28: 279, 1961.

SILWER, M.: Incidence of diabetes mellitus in a Swedish county. Acta med. scand. Suppl. 385, 1958.

SYLVÈN, B.: Über das Vorkommen von hochmolekylaren Esterschwefelsäuren im Granulationsgewebe und bei der Epithelregeneration. Acta chir. scand. 86. Suppl. 66, 1941.

THUNELL, S.: Procedures for the microscale investigation of vessel wall glycosaminoglycans. Acta univ. Lund. II, n:o 9, 1967.

WENDEBERG, B.: Mineral metabolism of fractures of the tibia in man studied with external counting of ^{85}Sr. Acta orthop. scand. Suppl. 52, 1961.

WATSON-JONES, R.: Simple treatment of the stiff shoulder. J. Bone Jt. Surg. 45 B: 207, 1963.

VIALLA, M., SIMON, L. et CAILLENS, J. P.: Intérêt des mesures de pression intra-articulaire au cours de l'arthrographie de l'épaule. J. Radiol. Electr. 45: 836, 1964.

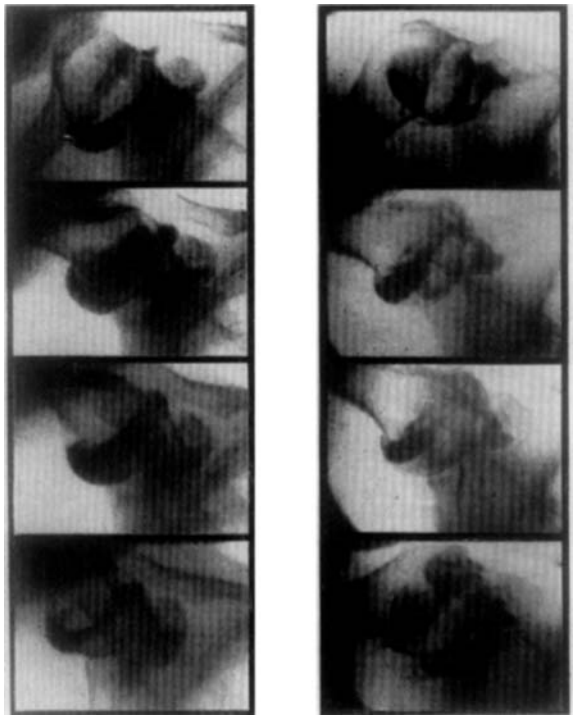
VINOGRADOV, V. V.: Mucopolysaccharide histochemistry in the healing of skin wounds. Arkh. Pat. 28: 53, 1966.

WITHERS, R. I. W.: The painful shoulder. J. Bone Jt. Surg. 31 B: 414, 1949.

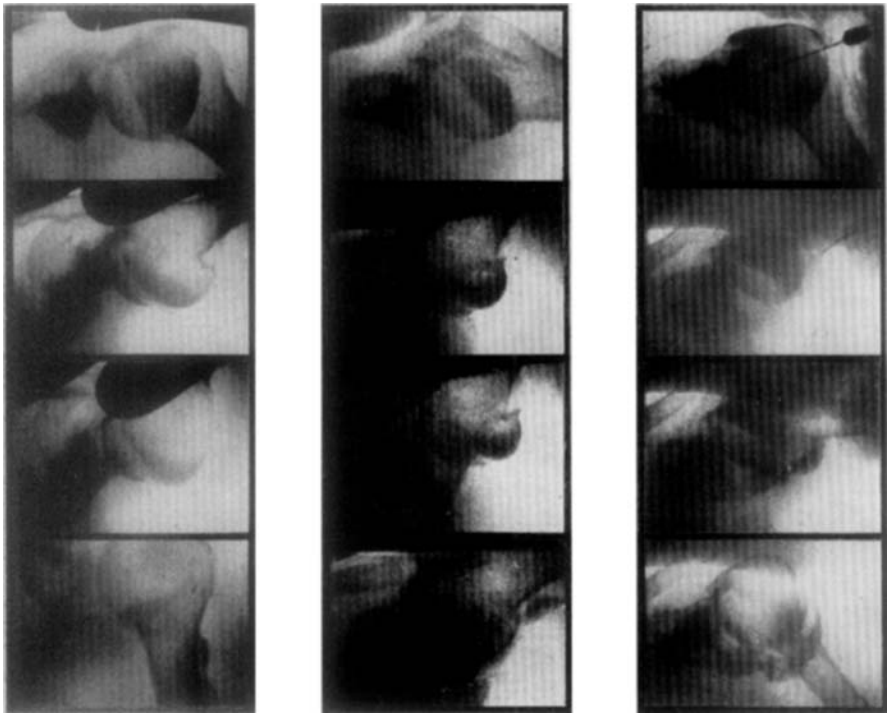
YOUNG, J. H. and PEARSON, A. T.: The shoulder-hand syndrome. Med. J. Aust. 1: 776, 1952.

APPENDIX

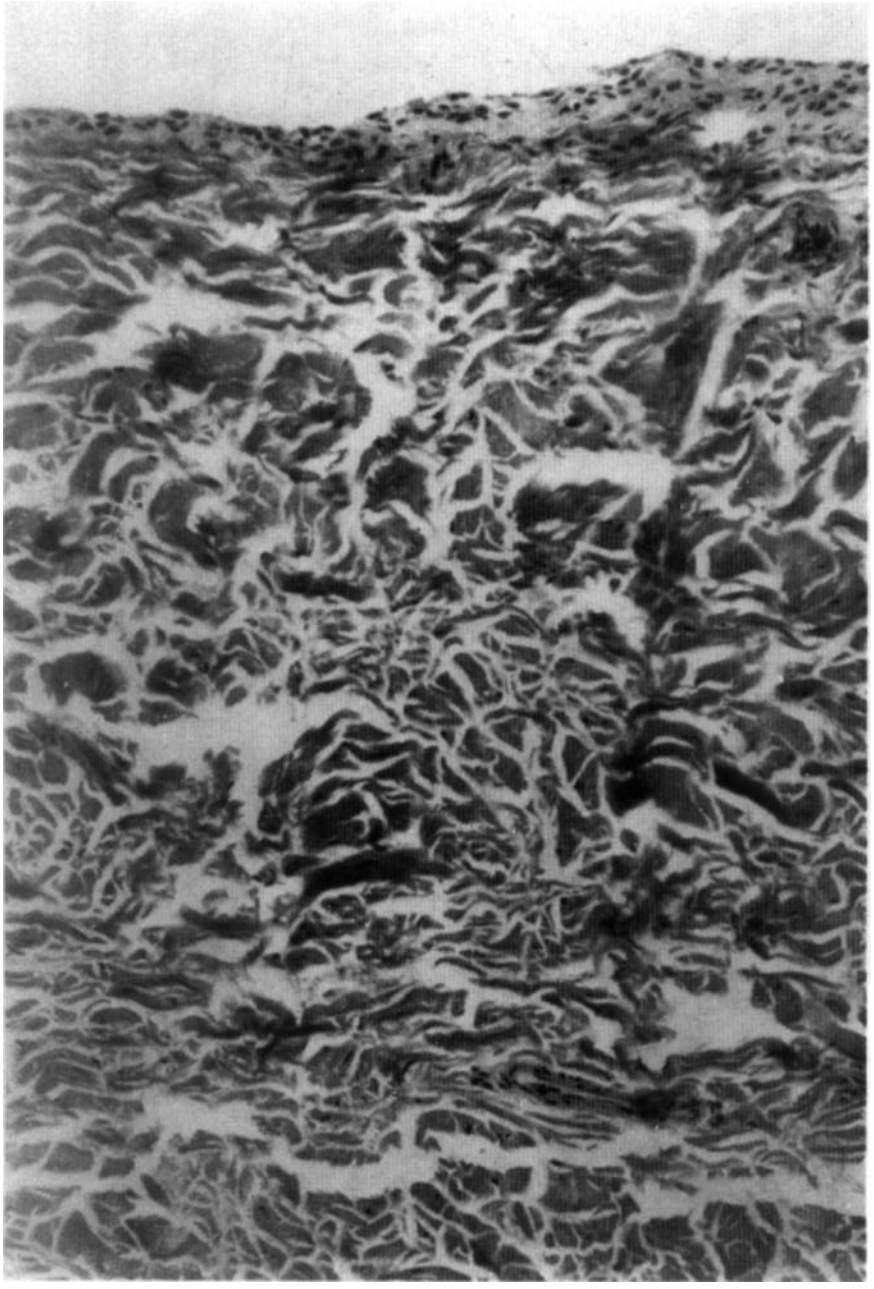
A. REPRODUCTIONS OF RADIOGRAMS AND MICROSCOPY PHOTOGRAPHS



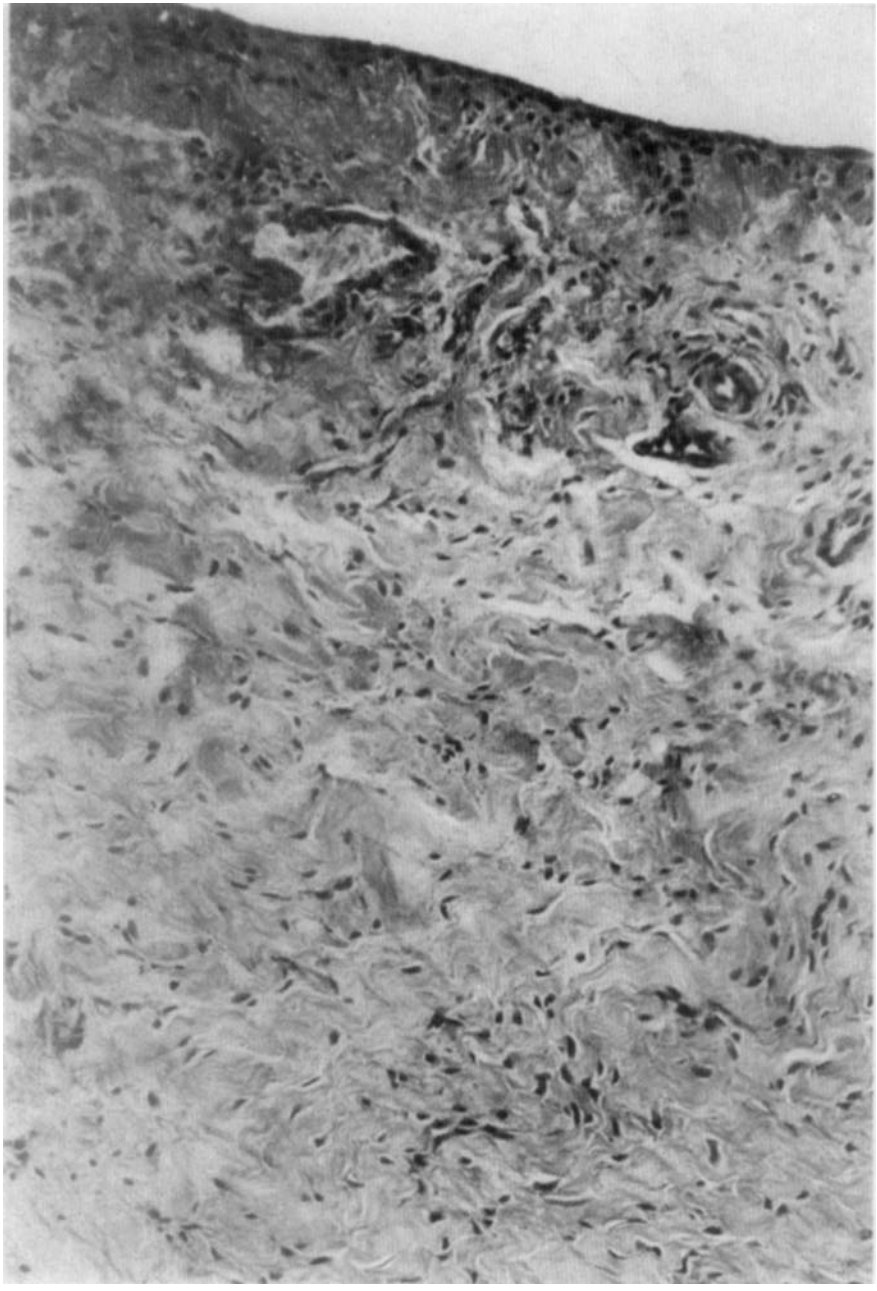
Appendix A 1
Discontinuous pictures from cinearthrography of one normal (left), three primary frozen quality of the copies is inherent in the method. The first frames of frozen shoulders show by manipulation and in the last frames extraarticular contrast is more or less visible.



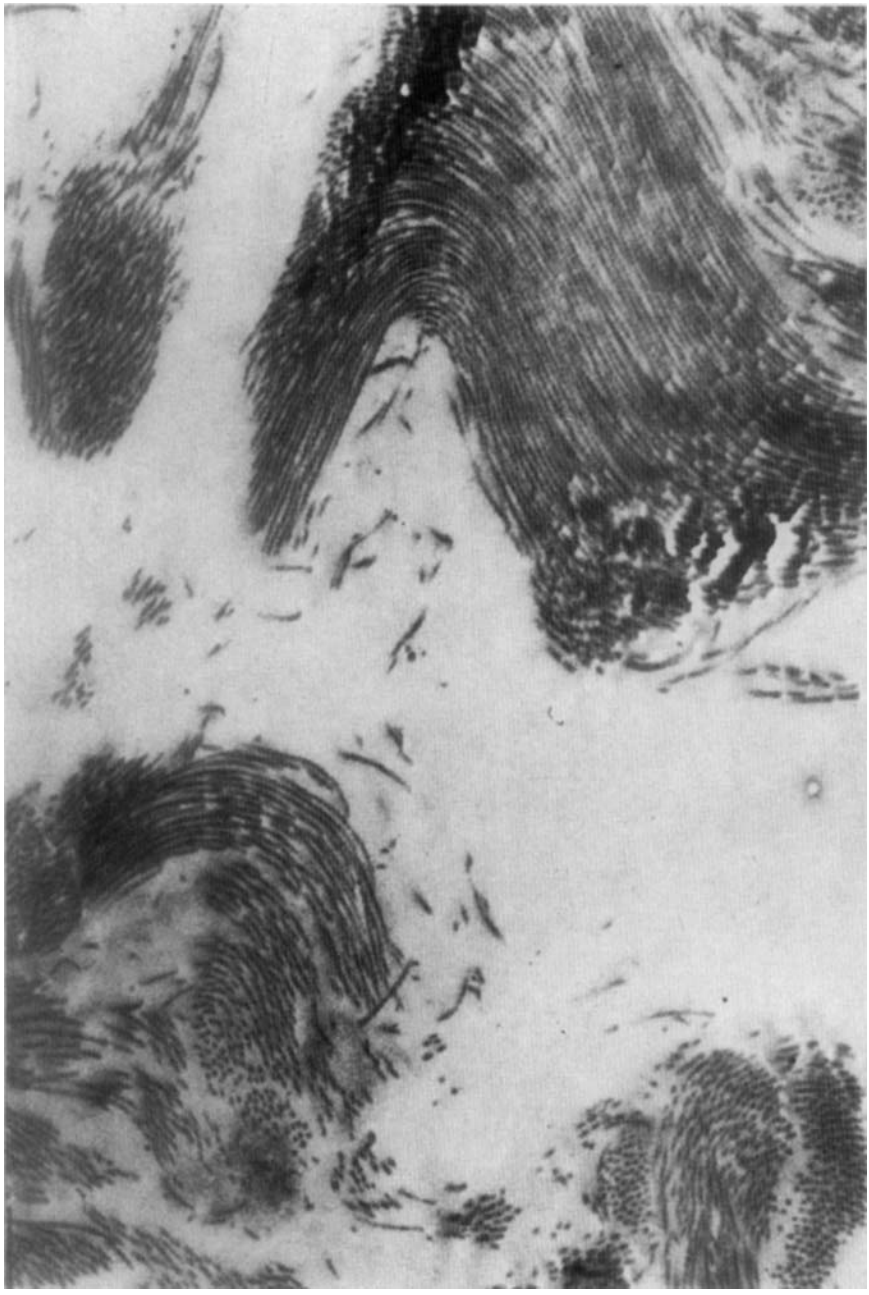
shoulders and one secondary to fracture of the neck of the humerus (right). The varying joint obliteration. Between the second and the third frames the joint has been released



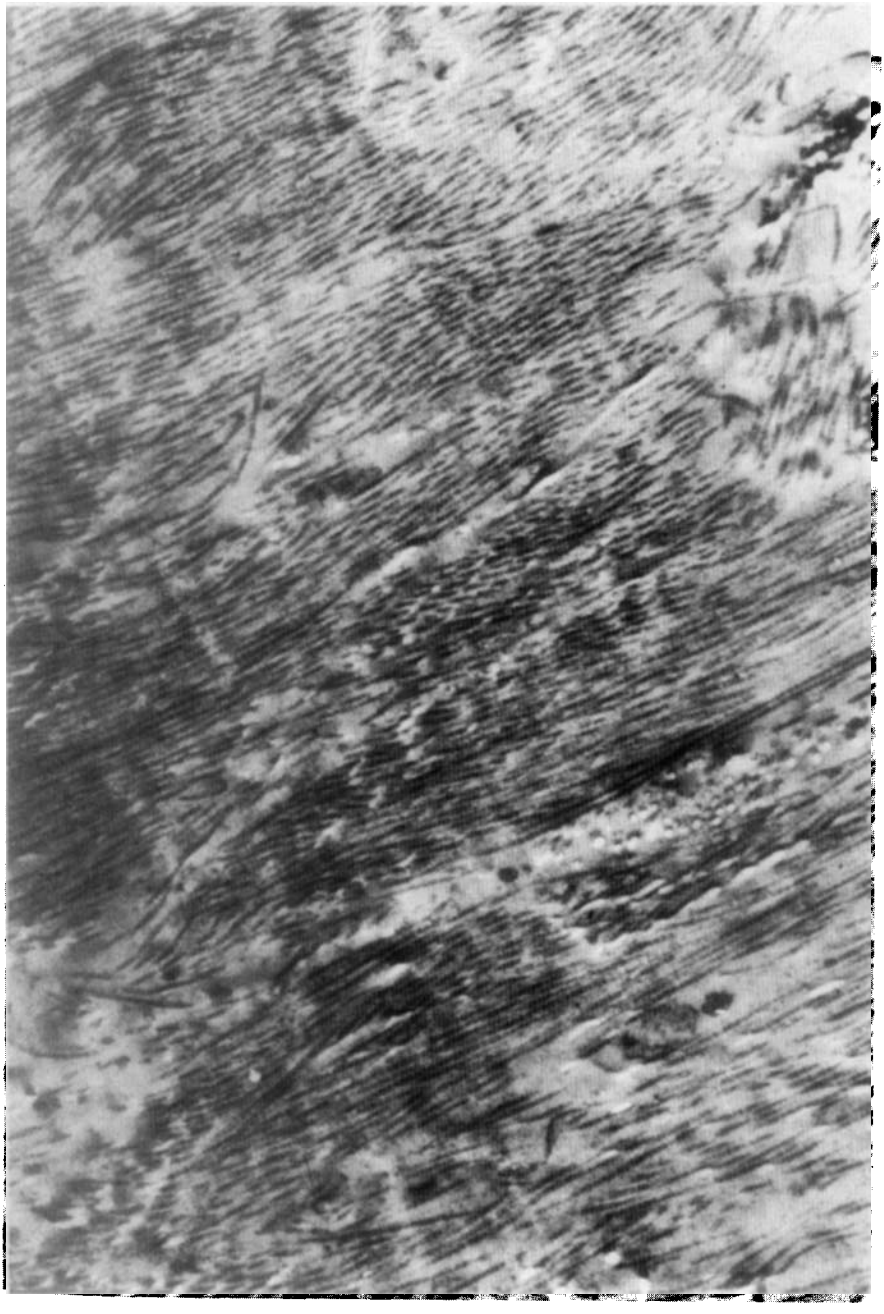
Appendix A 2
Histological sections of a normal (left) and a frozen shoulder joint capsule (right). Synovial in the pathological case. (Htx-eosin $\times 300$.)



lining on top in the figures. Note fibroplasia, denseness and vascularity of the fibrous layer



Appendix A 3
Electron-microscopy in most aspects representative of the findings in a normal (left) bundles in the latter specimen their are no visible changes in the ultrastructure of the



and a frozen shoulder joint capsule (right). Except for a more compact arrangement of the collagen. (×16,000.)

B. STATISTICAL METHODS

For comparison of frequencies the method of Chi-square with Yates' correction was used.

For comparison between sets of numerical data and between paired data the method of t-test was used, differences in variance in the sets being taken into consideration. Skewed distributions were also compared using the geometric means and standard deviations.

If interaction from variables other than the tested could be expected, analysis of covariance was used with the interacting variable as the covariant factor even if no significant correlation was found between the two variables.

Correlation was calculated as the linear correlation coefficient.

Differences and correlations have been referred to as "significant" when the level of probability was less than 5 %.

The central tendency and the scatter of the data were represented as arithmetic Average$\pm$Standard Deviation unless otherwise stated.