Valvular mechanisms in juxta-articular cysts

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Quadriceps contraction normally produces sub-atmospheric or small positive pressures within the knee, but in the presence of arthritis and with effusions, high positive pressures are developed (Jayson and Dixon, 1970b). Pressures of this magnitude may well damage the articular surfaces, but it would also seem possible that they could 'blow out' the capsule at points of weakness, so producing cysts.

Adams (1840) first drew attention to an enlarged bursa developing beneath the medial head of the gastrocnemius muscle in association with 'chronic rheumatic arthritis of the knee joint', and a further description was made by Foucher (1856) before the definitive paper of Baker (1877). In a further study, Baker (1885) recorded similar cysts in association with diseases of other joints. Since then there have been many descriptions of popliteal and calf cysts in association with rheumatoid arthritis of the knee (Meyerdig and VanDemark, 1943; Kersley, Barber, Cregan, and Gibson, 1954; Burleson, Bickel, and Dahlin, 1956; Beatty, 1959; Harvey and Corcos, 1960; Maudsley and Arden, 1961; Good, 1964; Litwin, Lister, and Rotstein, 1964; Kogstad, 1965; Hall and Scott, 1966; Perri, Rodnan, and Mankin, 1968). Cysts have also been reported in association with other inflammatory joint diseases, such as brucellosis (Harris, 1943), gout, tuberculosis, and non-specific synovitis (Burleson and others, 1956), and polymyalgia rheumatica with knee effusions (Kogstad, 1965). They have also been found in association with osteoarthritis of the knee (Wilson, Eyre-Brook, and Francis, 1938; Meyerdig and VanDemark, 1943; Burleson and others, 1956) and with Charcot's disease (Wilson and others, 1938).

A study of the physiological relationships between the knee joints and the cysts was performed in order to elucidate the mechanisms by which these cysts develop.

Clinical material

Twelve patients with definite or classical rheumatoid arthritis (Ropes, Bennett, Cobb, Jacox, and Jessar, 1959) with easily palpable popliteal or calf cysts agreed to these investigations after detailed explanations. In two, cysts were present bilaterally and they agreed to the studies being performed on both knees.

Little effusion or none was found in those knees associated with cysts. Examination usually revealed the cysts to be very tense when the knees were extended although it was difficult to quantify this finding. The cysts became softer with knee flexion. They could not be reduced when the knee was extended but, in two, reduction into the knee could suddenly occur with flexion and manipulation.

Methods

Arthrograms were performed on all knees by aspirating any effusion, replacing it with 20 ml. 60 per cent. meglumine iothalamate (Conray 280), and obtaining appropriate radiographs before and after exercise.

The intra-articular and intracystic pressures were measured with external transducers via separate Braun size 2 cannulae which were passed through small skin incisions under local anaesthesia (Fig. 1). Readings were obtained with the knee in the extended position and with the heel elevated on a small block so that the calf was not compressed. In some subjects the knee was then passively flexed to 45° and 90° and further recordings were made in each of these positions.

The knee was aspirated to dryness and the effusion volume was measured. A simulated effusion (4.3 per cent. dextrose 0.18 per cent. sodium chloride) was then used to redistend the joint. The cyst was squeezed manually and records were made of the cyst and knee pressures. The distended knee joint was then squeezed, avoiding joint movement and tension in the tissues as far as possible, and records were made again. The subject was also asked to perform quadriceps setting while records were simultaneously made. At the end of the study, all fluid was aspirated from the knee and as much as possible from the cyst. However, it did not generally prove possible to remove significant quantities from the cysts because, although their contents were partly fluid, they also contained large quantities of semi-solid fibrin which obstructed the cannulae as soon as suction was applied.

FIG. 1 *Knee with cannulae for simultaneous recording of intra-articular and intracystic pressures.*

After-effects

Neither arthrography nor the pressure measurements produced any complications.

Results

On arthrography the radio-opaque dye always passed from the knees into the cysts, demonstrating direct connections between them. Fig. 2 shows a typical appearance of a popliteal cyst with a long narrow neck connecting with the knee, and Fig. 3 (opposite) demonstrates an unusual finding, in

FIG. 2 *Arthrogram, showing a typical popliteal cyst joined to the knee by a narrow neck.*

which the cyst commenced on the lateral side of the joint and tracked obliquely round the back of the tibia to present on its antero-medial surface.

In every study (Table I), the intra-articular pressure was lower than the intra-cystic pressure, and when a statistical comparison was made between

Table I *Intra-articular and intra-cystic pressures*

Patient no.	Side	Initial knee effusion (ml.)	Pressure (mm. Hg)	
			Knee	Cyst
1	Right	0	25	40
2	Left	15	20	45
3	Right	0	6	21
4	Right	0	0	40
5	Left	5	8	87
	Right	10	17	88
6	Left	0	7	78
7	Left	0	5	220
	Right	0	11	18
8	Left	0	60	82
9	Right	0	17	125
10	Left	9	— 2	9
11	Right	10	11	67
12	Right	2	6	91
Mean		3·6	13·6	72·2
Standard deviation		5·2	15·3	54·0
Student's 't'			3·90	
P			<0·001

FIG. 3 Arthrogram, showing a cyst commencing on the postero-lateral aspect of the knee and tracking obliquely round the back of the tibia to present on its antero-medial surface.

their means, the difference was highly significant ($P < 0.001$).

The mean effusion volume at initial joint puncture in the knees with popliteal cysts was 3.6 ± 5.2 ml., and this was compared with that in the fourteen rheumatoid knees without cysts studied by Jayson and Dixon (1970a). The latter had a higher mean effusion volume of 23.6 ± 21.4 ml. and the difference was statistically significant ($t = 3.40$; $P < 0.01$).

In five knees (Table II), passive flexion by 45° considerably reduced the intra-cystic pressure, but further passive flexion to 90° produced little further change. On straightening the knee again, approximately the same pressures were found as previously recorded in the extended position.

Table II Effect of passive knee flexion on cyst pressure

Patient no.	Cyst pressure (mm. Hg)			Knee re- extension
	Knee flexion			
	0°	45°	90°	
1	40	15	20	40
7	220 18	30 8	30 17	225 20
8	82	29	6	82
12	91	20	24	90

In all subjects cyst squeezing did not significantly alter the pressure within the knee joint. Despite rises of several hundred mm. Hg within the cyst, the knee pressure increases were never greater than

10 mm. Hg. The manoeuvres were repeated many times with many different volumes of knee effusion and similar results were obtained.

Squeezing the knee and quadriceps setting, however, produced very variable and bizarre results. This was because it proved very difficult to perform either manoeuvre without altering the angulation of the joint slightly and particularly without tensing the soft tissues behind the knee. The cysts were very sensitive to these and even small changes produced considerable increases in intra-cystic pressure often to values higher than those reached in the knee. After the manoeuvres the two pressures fell to approximately their previous levels. It seemed likely that the recorded pressures were therefore due to artefacts rather than to direct transmission from the joint.

However, in one subject (Case 9), it was possible to demonstrate convincingly a valvular mechanism between knee and cyst (Figs 4 and 5). At the beginning of the study the cyst pressure was 125 mm.

FIG. 4 Simultaneous recordings of knee (K) and Baker's cyst (BC) pressures. On increasing the cyst pressure by direct squeezing, there was no change in knee pressure.

Hg and knee pressure 17 mm. Hg. There was no knee effusion. Pressure on the cyst (Fig. 4*) produced a large increase in the intra-cystic pressure (BC) but no change in that within the knee (K). A 40-ml. simulated effusion was added to the knee, raising its pressure to 145 mm. Hg. Squeezing the knee (Fig. 5*) produced a sharp rise in the intra-articular pressure (K) to 375 mm. Hg. While constant squeezing was maintained, the intra-articular pressure gradually fell. At the same time the cyst pressure (BC) slowly rose to meet the knee pressure at 320 mm. Hg. On releasing the knee the intra-articular pressure fell to well below its original level to 105 mm. Hg, whereas the cyst pressure fell only slightly (to 250 mm. Hg) and remained higher than before knee squeezing. Only 20 ml. fluid could then be withdrawn from the knee, suggesting that squeezing had pushed the other 20 ml. into the cyst. Similar results were obtained several times in this subject.

FIG. 5 Simultaneous recordings of knee (K) and Baker's cyst (BC) pressures. On squeezing the distended knee, there was a sharp increase in intra-articular pressure. During constant squeezing the intra-articular pressure slowly fell and the cyst pressure rose to meet it. When the knee was released the knee pressure fell below its initial value, and the cyst pressure fell only slightly to a level above its initial value. The tracings should be read from right to left.

Discussion

Clinical examination revealed tense cysts which, with the knees in the extended position, could not be reduced into the joints. In two it was possible, by manipulating the knee into various positions, for this reduction to occur. However, arthrography demonstrated a connection between knee and cyst in all. This implied that there must have been some form of valvular mechanism, allowing intra-articular fluid to pass into the cyst but preventing it from returning. In all subjects, the cyst pressures in the extended position were significantly higher than in the knees and further increases were not communicated back into the joint. This confirmed the clinical finding of tense cysts and difficulty in reduction and again indicated a valvular connection.

* The traces run from right to left.

It was, however, possible to demonstrate this valve in only one knee on joint squeezing.

Little effusion or none was found within knees associated with cysts, and these volumes were significantly lower than in rheumatoid knees without cysts. The former group had previously undergone aspiration of the joint contents and arthrography, but these had been performed several days or weeks before the pressure measurements and would have been unlikely significantly to alter the volumes of fluid found. It would seem that the valvular mechanism allowed fluid to be pumped from the knees into the cysts but not to return, so that the volumes of joint effusion were significantly reduced. As the pressure increase with quadriceps contraction and knee flexion is directly related to the effusion volume (Jayson and Dixon, 1970b), reduction of joint contents would limit any pressure increase and therefore protect the joint against damage. The physiological consequences of these results are that, if an operation is indicated on a knee associated with a popliteal or calf cyst and this is limited to excision of the cyst, then there will be an increase in size of the knee effusion, higher pressures will be produced on joint use, and the synovial cyst may be expected to recur. On the other hand, if production of the effusion is reduced by an anterior synovectomy, then the synovial cyst may disappear. Therefore, if an operation is to be performed, synovectomy to the knee is to be preferred and should be undertaken first.

The fluid contents of the cyst could be readily absorbed through the lining membrane, whereas the large solid clumps of fibrin would have difficulty in crossing this barrier. Because of this, dense concentrations of fibrin could accumulate in the cyst, making the contents difficult to aspirate (Fig. 6).

FIG. 6 Joint effusion is pumped from the knee into the cyst. Fluid can be readily absorbed leaving dense concentrations of fibrin.

Adams (1840), in the first paper on popliteal cysts, suggested that they were connected with the joint 'by a species of valvular opening', and Baker (1877) pointed out that, although cross-fluctuation might not be detectable between the cyst and the

knee, a connection could still exist. Fullerton (1916) showed that the semimembranosus bursa often communicates with the knee. Infective matter can be pumped from the joint into the cyst but not in the reverse direction because of a valve-like communication. Wilson and others, (1938) likewise found that it was not usually possible to empty fluid cyst contents back into the knee, although air, injected into a cyst, passed promptly into the joint.

Evidence against a valvular connection has been provided by Haggart (1938), who thought that fluid could pass back and forth more readily depending upon the particular mechanics of the opening, by Beatty (1959), and by Maudsley and Arden (1961), who showed that contrast medium and radioactive yttrium could pass from a cyst into the joint space.

The type of valvular connection is not certain. It could be a ball valve with a narrow channel through which fluid could be pumped from the knee into the cyst. When higher pressure develops in the reverse direction the large quantities of fibrin within the cyst plug the opening. Alternatively, the valve may be of the Bunsen type, consisting of a narrow curved passage, the walls of which collapse under direct cyst pressure (Fig. 7).

FIG. 7 Suggested types of valvular connection.

The intracystic pressure varied with position, being considerably reduced by flexing the knee. This was not due to any reduction in cyst contents because reduced pressure was not found on restraightening the limb. Alterations with knee position must have been due to altered squeezing by neighbouring structures.

The development of these cysts has been subject to some controversy. Billroth (1875) and Lewin (1952) thought that they were true herniations through the posterior wall of the joint capsule, whereas Adams (1840), Baker (1877), Fullerton

(1916), Wilson and others (1938), Harvey and Corcos (1960), and Gristina and Wilson (1964) thought that they occurred *via* the distension of a communicating gastrocnemius/semimembranosus bursa. Other authors (Haggart, 1938; Meyerding and VanDemark, 1943; Burleson and others, 1956; Kogstad, 1965; Perri and others, 1968) thought that either of these routes might be responsible. Tait, Bach, and Dixon (1965) and Fairbank (1969) thought it possible that, after acute joint rupture with release of knee effusion into the soft tissues of the limb, the extruded fluid might develop into chronic cysts. Kersley and others, (1954) suggested that they might be due to breaking down of rheumatoid nodules with central necrosis or, alternatively, to synovial proliferation in non-communicating bursae.

In all the present studies, the cysts communicated directly with the knees, a fact which is consistent with either hernial protrusion or distension of communicating bursae. The majority of the arthrograms showed the cysts arising from the medial side of the posterior surface of the knee joint, which would be the site of the gastrocnemius/semimembranosus bursa.

Summary

Studies were performed on fourteen rheumatoid knees with popliteal or calf cysts. Clinical examination in the extended position revealed tense cysts which were not reducible into the joints but, on arthrography, dye always passed from the knees into the cysts. Measurements showed that the cyst pressures were significantly higher than those within the knee joints. Cyst squeezing did not produce any change in the intra-articular pressure, but knee squeezing on one occasion convincingly demonstrated the one-way passage of fluid into the cyst. The mean effusion volume within these knees was significantly lower than in a series of rheumatoid knees without cysts.

These results demonstrated valvular connections allowing effusions to be pumped from the knees into the cysts but not to return. This limited the intra-articular pressure rise during joint use.

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References

- ADAMS, R. (1840) *Dublin J. med. Sci.*, 17, 520 (Chronic rheumatic arthritis of the knee joint).
- BAKER, W. M. (1877) *St. Bart. Hosp. Rep.*, 13, 245 (On the formation of synovial cysts in the leg in connection with disease of the knee-joint).
- (1885) *Ibid.*, 21, 177 (The formation of abnormal synovial cysts in connection with the joints).

- BEATTY, D. C. (1959) *Proc. roy. Soc. Med.*, **52**, 1106 (Rheumatoid cysts of the calf).
- BILLROTH, T. (1875) 'General Surgical Pathology and Therapeutics', trans. C. E. Hackley. Lewis, London.
- BURLESON, R. J., BICKEL, W. H., AND DAHLIN, D. C. (1956) *J. Bone Jt Surg.*, **38A**, 1265 (Popliteal cyst).
- FAIRBANK, T. J. (1969) *Brit. med. J.*, **3**, 220 (Examination of the knee joint).
- FOUCHER, E. (1856) *Arch. gén. Méd.*, 5th sér., **8**, 313, 425 (Mémoire sur les kystes de la région poplitée).
- FULLERTON, A. (1916) *Brit. J. Surg.*, **4**, 191 (The surgical anatomy of the synovial membrane of the knee-joint).
- GOOD, A. E. (1964) *Arthr. and Rheum.*, **7**, 56 (Rheumatoid arthritis, Baker's cyst, and 'thrombophlebitis').
- GRISTINA, A. G., AND WILSON, P. D. (1964) *Arch. Surg.*, **88**, 357 (Popliteal cysts in adults and children).
- HAGGART, G. E. (1938) *J. Bone Jt Surg.*, **20**, 363 (Posterior hernia of the knee joint. A cause of internal derangement of the knee).
- HALL, A. P., AND SCOTT, J. T. (1966) *Ann. rheum. Dis.*, **25**, 32 (Synovial cysts and rupture of the knee joint in rheumatoid arthritis. An arthrographic study).
- HARRIS, H. J. (1943) *J. Amer. med. Ass.*, **122**, 1204 (Swelling of popliteal bursae in brucellosis).
- HARVEY, J. P., AND CORCOS, J. (1960) *Arthr. and Rheum.*, **3**, 218 (Large cysts in lower leg originating in the knee occurring in patients with rheumatoid arthritis).
- JAYSON, M. I. V., AND DIXON, A. ST J. (1970a) *Ann. rheum. Dis.*, **29**, 261 (Intra-articular pressure in rheumatoid arthritis of the knee. I. Pressure changes during passive joint distension).
- , —, (1970b) *Ibid.*, **29**, 401 (Intra-articular pressure in rheumatoid arthritis of the knee. III. Pressure changes during joint use).
- KERSLEY, G. D., BARBER, H. S., CREGAN, J. C. F., AND GIBSON, H. J. (1954) *J. Bone Jt Surg.*, **36B**, 238 (Degenerative rheumatoid changes).
- KOGSTAD, O. (1965) *Acta rheum. scand.*, **11**, 194 (Baker's cyst).
- LEWIN, P. (1952) 'The Knee and Related Structures'. Kimpton, London.
- LITWIN, S. D., LISTER, J., AND ROTSTEIN, J. (1964) *N. Y. St. J. Med.*, **64**, 2107 (Bilateral popliteal cysts in a patient with rheumatoid arthritis).
- MAUDSLEY, R. H., AND ARDEN, G. P. (1961) *J. Bone Jt Surg.*, **43B**, 87 (Rheumatoid cysts of the calf and their relation to Baker's cysts of the knee).
- MEYERDING, H. W., AND VANDEMARK, R. E. (1943) *J. Amer. med. Ass.*, **122**, 858 (Posterior hernia of the knee).
- PERRI, J. A., RODNAN, G. P., AND MANKIN, H. J. (1968) *J. Bone Jt Surg.*, **50A**, 709 (Giant synovial cysts of the calf in patients with rheumatoid arthritis).
- ROPES, M. W., BENNETT, G. A., COBB, S., JACOX, R., AND JESSAR, R. A. (1959) *Ann. rheum. Dis.*, **18**, 49 (Diagnostic criteria for rheumatoid arthritis. 1958 revision).
- TAIT, G. B. W., BACH, F., AND DIXON, A. ST J. (1965) *Ibid.*, **24**, 273 (Acute synovial rupture).
- WILSON, P. D., EYRE-BROOK, A. L., AND FRANCIS, J. D. (1938) *J. Bone Jt Surg.*, **20**, 963 (A clinical and anatomical study of the semimembranosus bursa in relation to popliteal cyst).