Intra-articular pressure and rheumatoid geodes (bone 'cysts')

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In continental Europe the name 'geode' (which is borrowed from a geological term meaning a rounded pocket of gas in a mineral specimen) is used to describe the radiological appearance of a cyst or cystic erosion in a bone end, so commonly seen in many forms of chronic joint disease. The word is to be preferred as it does not imply (as does 'cyst') that the area is full of fluid—commonly it is not.

In the course of rheumatoid arthritis large geodes may develop. Castillo, El Sallab, and Scott (1965) have shown that the size and extent of geode formation in affected hands is related to the type of work in which the patient is engaged. The largest geodes are found in those doing the hardest manual work.

Many geodes are small and difficult to puncture. However, two patients with rheumatoid arthritis and large geodes volunteered for investigations and allowed studies of the intra-articular pressures and of how they were altered by changes in the pressures within the corresponding joints. Animal experiments were also performed to determine the manner in

which changes in intra-articular pressure were transmitted across the articular cortex and whether they were associated with compensating changes on the epiphysal side of the surface.

Patient 1

A 64 year old housewife gave a 14-year history of classical (Ropes, Bennett, Cobb, Jacox, and Jessar, 1959) nodular sero-positive rheumatoid arthritis, previously treated with prednisone (7.5 to 15 mg. per day), injections of sodium aurothiomalate, and arthrodesis of the left knee. Examination showed that the right knee contained a small effusion and flexion was limited to 90°. X rays (Figs 1A, B) showed loss of joint space, particularly on the medial side. On the antero-posterior view a large geode was seen in the supero-lateral pole of the patella, and a lateral x ray showed this to be in the upper third and almost reaching the anterior surface of the bone. There appeared to be a break in the articular surface of the patella beneath it.

The exact surface marking of the geode was identified using metal markers and x rays and, after skin steriliza-

FIGS 1A AND 1B Antero-posterior and lateral x rays of knee of Patient 1, showing patellar geode.

tion, a fluid-filled Gillette Scimitar Serum II needle was passed directly into it under local anaesthesia. No difficulty was encountered in passing through the patellar cortex as this consisted of periosteum only. The needle was connected to a sterile Statham P23Gb pressure transducer so that the intrageodal pressure could be recorded. The intra-articular pressure was measured by way of a Braun Size 2 cannula and a second transducer as described by Jayson and Dixon (1970a). Simultaneous records of the geode and knee pressures were thus obtained.

A 10-ml. effusion was aspirated from the joint. During constant monitoring the knee was squeezed over its medial and lateral surfaces and over the suprapatellar pouch, but direct patellar-squeezing was avoided. The patient was also asked to perform quadriceps-setting. A 10-ml. simulated effusion (4.3 per cent. dextrose 0.18 per cent. sodium chloride) was then injected into the knee and both manoeuvres were repeated.

After the study all fluid was aspirated and the cannula and needle removed.

Patient 2

A 47-year-old labourer gave a 9 year history of classical (Ropes and others, 1959) nodular sero-positive rheumatoid arthritis. Despite the disease he continued to perform heavy manual work.

Examination of the right forearm showed swelling of the distal end of the radius and typical rheumatoid deformities of the hands. X rays of the hands showed multiple geodes with a large geode in the distal end of the radius (Figs 2A, B).

Using markers, a Gillette Scimitar Serum II needle was passed directly into the radial geode as before. The pressure in the geode was recorded and the patient was asked to clench his fist and then to relax. The wrist pressure was also increased by an observer squeezing the joint but pressure on the radius was avoided. Each manoeuvre was repeated several times before removing the needle.

No after-effects developed in either of these patients.

FIGS 2A AND B Antero-posterior and lateral x rays of right wrist, showing large geode in the distal end of the radius

Animal studies

Experiments were performed on both knees of two anaesthetized large mongrel dogs. The intra-articular pressure was measured with an external Statheon P23Gb pressure transducer of volume displacement 0.01 cu. mm./100 mm. Hg by way of a plastic cannula. This was passed into the joint lumen through an incision on the lateral side of the patellar ligament. The epiphyseal pressure was recorded with a second transducer through a modification of the bone needle described by Helal (1967) screwed into the upper end of the tibia under x-ray control, so that the open end lay just beneath the articular surface. Free communication between marrow and needle was confirmed by observing blood passing freely back through the needle, by being able to freely inject saline through the needle, and by injecting radio-opaque dye and obtaining x rays (Fig. 3).

FIG. 3 Radiograph demonstrating free communication between bone needle and marrow. Radio-opaque dye injected through the needle rapidly spreads throughout the epiphysis and into the veins.

The joint was distended with a simulated effusion (4.3 per cent. dextrose, 0.18 per cent. sodium chloride) and was manually compressed over its medial and lateral surfaces, avoiding squeezing the tibia and fibula. The changes in knee and marrow pressures were recorded. Measurements were obtained with a wide range of effusion volumes and squeezing was controlled to produce intra-articular pressure changes of the magnitudes found during quadriceps-contraction in the human knee.

After these manoeuvres a further series of traces was obtained with manual squeezing of the quadriceps muscle.

Results

Some typical results obtained from Patient 1 are shown in Table I. During both manoeuvres and with the knee joint empty and with a 10-ml. simulated effusion, the resting pressures in the geode and knee were virtually identical and increases in the intra-articular pressure produced identical changes in the geode. Fig. 4* illustrates the recorded pressures during quadriceps-setting with no effusion

Table I Patient 1 Changes in intra-articular and intrageodal pressures

Effusion volume (ml.)	Manoeuvre	Pressure (mm. Hg)			
		Knee		Geode	
		R	M	R	M
0	KS	15	55	18	55
		15	65	17	65
	QS	12	245	13	255
		15	230	15	225
10	KS	35	155	40	155
	QS	35	390	35	380

R = Resting pressure
M = Pressure during manoeuvre
KS = Knee-squeezing
QS = Quadriceps-setting

FIG. 4 Patient 1. 0 ml. effusion. Quadriceps-setting produces identical changes in knee (K) and patellar geodal (PG) pressures

and with the baselines of the traces of the knee (K) and patellar geode (PG) pressures superimposed; Fig. 5* shows the effect of knee-squeezing with a

FIG. 5 Patient 1. 10 ml. effusion. Knee-squeezing produces identical changes in knee (K) and patellar geodal (PG) pressures.

* These experimental traces run from right to left.

10-ml. effusion, but on this occasion with the two base lines separated.

In Patient 2, fist-clenching and wrist-squeezing produced sharp rises in the intrageodal pressure (Table II) and typical traces are shown in Figs 6* and 7*. On some occasions after the manoeuvres the pressures fell only slowly back to the base lines so that the next results were obtained with higher preceding resting pressures.

The dog epiphyseal marrow pressures varied widely (Table III) and in one knee showed a pulsation synchronous with the arterial pulse of 70/55 mm. Hg which increased to 105/90 mm. Hg with

Table II Patient 2 Changes in intrageodal pressure

Manoeuvre	Pressure (mm. Hg)	
	R	M
Fist-clenching	18	36
	24	38
Wrist-squeezing	40	65
	65	90

R = Resting pressure
M = Pressure during manoeuvre

FIG. 6 Patient 2. Fist-clenching produces sharp increases in pressure within radial geode.

FIG. 7 Patient 2. Wrist-squeezing produces sharp increase in pressure within radial geode.

Table III Effect of knee-squeezing

Dog no.	Side	Effusion vol. (ml.)	Pressure (mm. Hg)			
			Intra-articular		Marrow	
			Resting	Squeezing	Resting	Squeezing
1	Right	20	115	175	15	15
			85	215	15	15
	Left	18	125	220	0	15
			100	190	5	18
2	Right	18	155	200	25	25
			145	250	25	25
	Left	16	125	210	70/55	70/55
			70	145	105/90	115/100

slight bone needle movement. Altering the volume and therefore the pressure of the intra-articular effusion did not produce any recordable change in the bone marrow pressure. When further large increases of the intra-articular pressure were induced by squeezing the joint, there was either a very small increase in the marrow pressure or none (Fig. 8). In each study knee-squeezing was repeated many times with varying volumes of effusion and similar results

FIG. 8 Simultaneous recordings of pressures within the dog knee (K) and Marrow (M) of tibial epiphysis. Increase of intra-articular pressure on knee-squeezing produces virtually no change in marrow pressure.

were obtained. Typical examples are shown in Table III.

No pressure change occurred in the tibial epiphysis on quadriceps-squeezing and some typical results are shown in Table IV.

Discussion

The marrow pressure in the cat femur varies widely (McPherson and Juhasz, 1965) and in the present study in dogs it would appear that the recorded pressures were related to the position of the bone needle within the marrow. The arterial pulsation observed in one experiment presumably indicated that the needle tip was close to an artery.

The blood vessels supplying synovial tissue in the joint capsule communicate with those in the periosteum and bone ends (Barnett, Davies, and Mac-

Table IV *Effect of quadriceps squeezing*

Dog no.	Side	Marrow pressure (mm. Hg)	
		Resting	Squeezing
1	Right	15	15
	Left	3	3
2	Right	30	30
	Left	65/55	70/55

Conaill, 1961; Brånemark, Ekholm, Goldie, and Lindström, 1967). This could theoretically equalize the intra-articular and intraosseus pressures. However, increases in intra-articular pressure were not passively transmitted across the articular cortex. Muscle contraction or squeezing normally increases the pressure in underlying bone (McPherson, Scales, and Gordon, 1961; Shaw, 1964; Trueta, 1968), but quadriceps-squeezing also failed to alter the pressure within the tibial epiphysis. Use of the normal knee joint produces subatmospheric or small positive intra-articular pressures but, in the presence of disease and of effusions, very high pressures may develop (Jayson and Dixon, 1970b). There appeared to be no direct compensatory mechanism raising the pressure on the epiphysal side of the cortex so that in rheumatoid arthritis of the knee the normal pressure gradient from the marrow into the joint would be reversed by a steep gradient in the other direction.

Normal bone is probably strong enough to withstand these stresses and the articulating part of the surface normally meets much greater forces (Walker, Dowson, Longfield, and Wright, 1968). However, in rheumatoid arthritis, the bone is often weakened by osteoporosis and erosion by rheumatoid granulation tissue. In these circumstances fluid under high pressure may well burst through an area of surface weakness into the underlying marrow.

The nature of rheumatoid geodes has been studied and opinion has been divided whether they arise from primary damage within the bone or by extension from the joint space. Fletcher and Rowley (1952) obtained detailed radiological studies and concluded that in a number of cases the geodes were enclosed within an intact bony cortex. Soila (1963) similarly obtained stereomicroradiographs and showed changes in trabeculae not connected with the bone surface. These produced small defects which when larger gave rise to the appearances of closed cystic defects with no connection with the joint space. The results suggested that nutritional, vascular, or metabolic injury primarily caused destruction of the subcortical bone.

On the other hand, Freund (1940), Cruickshank, Macleod, and Shearer (1954), and Bywaters (1964)

FIG. 9 Section through a rheumatoid geode, demonstrating continuity of pannus between its lumen and the joint space. $\times 25$.

thought that the geodes communicated with the lumen of the joint, although it was sometimes difficult to demonstrate this histologically. The geodes sometimes contained fluid, granulation tissue, and pieces of detached cartilage and bone that must have come from within the joint lumen. Fig. 9 shows extrusion of synovial tissue into a subchondral geode. On macrotomography, Kersley, Ross, Fowles, and Johnson (1954) found a connection between geodes in small joints and the articular surface.

The present study has demonstrated that changes in the intra-articular pressure were directly communicated to two typical rheumatoid geodes so that there must have been hydrostatic continuity with the joint space.

The occasional failure of the pressure to fall back to the initial value after fist-clenching or wrist-squeezing in Patient 2 was presumably due to blocking of the channel between geode and joint space by a plug of geodal contents when the former was at the higher pressure. This may well occur during normal joint use so that the geode is subjected to a constant high pressure. Over-use of the joint will produce recurrent high pressures and encourage the development and enlargement of these geodes.

Several studies have suggested that cartilage derives at least part of its nutrition from the underlying bone (Ingelmark and Sääf, 1948; Holmdahl and Ingelmark, 1950; Ekholm, 1951; Ekholm, 1955; McKibbin and Holdsworth, 1966; Greenwald and Haynes, 1969), and that this is increased by joint use (Ingelmark and Ekholm, 1948; Ingelmark and Sääf,

1948; Ekholm and Ingelmark, 1952). This may well be due to the subatmospheric intra-articular pressure and the pressure gradient normally developed from the marrow to the joint space. The replacement of this gradient by a steeper one in the reverse direction might therefore be potentially harmful to the nutrition of articular cartilage.

Summary

Simultaneous measurements showed that increases in pressure within the dog knee joint were not transmitted into the tibial epiphysis. Squeezing the quadriceps muscle also failed to alter the epiphysal pressure. Studies were made in one patient of the pressures within a rheumatoid knee and an associated patellar bone 'cyst' or geode. Increases in the intra-articular pressures were communicated directly to the geode. In another patient with rheumatoid arthritis and a geode in the radius, raising the wrist pressure by direct squeezing or by wrist-clenching increased the intrageodal pressure.

The results suggest that joint use in rheumatoid arthritis produces a pressure gradient across the articular cortex in the reverse of the normal direction. This could lead to disruption of the surface and to geode formation.

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