THE PAIN IN PRIMARY OSTEOARTHRITIS OF THE KNEE

ITS CAUSES AND TREATMENT BY OSTEOTOMY

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MUCH of the pathology of primary osteoarthritis has been unravelled. The present study was carried out in an attempt to answer two questions:

What produces the pain in osteoarthritis? and Why is the pain so often relieved by osteotomy?

I believe that the answers to these questions shed light on the ætiology of primary osteoarthritis.

The knee joint was selected for this investigation because it is affected by primary osteoarthritis more frequently than any other joint (Kellgren, Lawrence, Aitken and Swan, 1957). Indeed, a study of human remains of the archaic period of Egyptian civilization (3000 BC) reveals that, even then, the knee was the joint most frequently damaged by osteoarthritis. (Ruffer, 1921).

Clinical Material

The investigation is based on 116 patients with primary osteoarthritis of the knee. These patients were collected from the David Lewis Northern Hospital, Liverpool, and the Rowley Bristow Orthopaedic Hospital, Pyrford. Their ages range from 39 to 86. 65 (56%) were female and 51 (44%) were male.

The investigation

In the history-taking special regard was paid to the evolution of symptoms and to the earliest signs noticed by the patients. In addition to the clinical examination and routine X-rays, intraosseous venography was carried out on all those patients who agreed to this test after the procedure and its purpose had been explained to them.

An analysis of the findings revealed several features of interest. I will concentrate upon two in this paper.

Pain

This was the leading symptom and was present in all the cases. Three distinct types of pain were described.

I have termed these "muscular", "capsular" and "venous".

All three types could occur together.

Muscular. This was a cramp-like pain felt in the quadriceps mass during activity and continuing for a few moments after stopping exercise. This was the most trivial pain of the three described and complaint about it was elicited only by cross examination. This pain could be elicited by static exercise of the quadriceps in those patients who suffered from it.

Capsular. A sharp pain usually felt on the inner side or the back of the knee upon moving the joint. This could be reproduced by forced extension, flexion, or sometimes by rotation of the affected knee, and temporarily relieved by injections of local anæsthetic into the capsule and ligaments of the joint.

Venous. A dull aching or throbbing pain felt diffusely around the knee, usually worse towards the end of the day and persisting for a while after retiring to bed. In the early stages of osteoarthritis this pain was felt only when the subject was tired; later in the disease it was aggravated by fatigue. This pain could be reproduced by artificially raising the intramedullary pressure in the bones adjacent to the affected joint (*vide infra*).

THE INCIDENCE OF THE VARIETIES OF PAIN

Combined muscular, capsular and venous:	4 patients
Capsular and venous:	59 patients
Capsular only:	47 patients
Venous only:	6 patients

Of 15 patients in this series requiring surgery for their osteoarthritic knees, 14 had the "venous" element of pain.

Venous Varicosity

There was a striking association between lower limb varicosities and osteoarthritis of the knee (Fig. 1).

In this series 48 patients had marked superficial varicosities and 35 had had symptoms from these. All but two of these 48 patients had had the "venous" element of pain associated with their osteoarthritic knees. That is, no less than 67% of patients with osteoarthritis

and the venous variety of pain also had varicose veins. Also of considerable interest was the fact that in 21 patients with unilateral osteoarthritis, the varicose veins were either confined to or were worse on the osteoarthritic side (Fig. 1).

The history of vein disease always predated the osteoarthritic symptoms by 3 to 18 years.

To draw a comparison with the incidence of lower limb varicose veins in a similar age group 100 outpatients attending for complaints not referable to the lower limbs, were examined. 22 had varicose veins. Cockett and Dodd (1956) quote a 26% incidence of varicose vein disease in their survey of the general population.

Intraosseous Venography

This technique is now well established and has been employed for over twenty years, notably by Schobinger (1960) who used it to display the deep venous system. I employ the method primarily to display the intraosseous venous sinusoids. Provided precautions are taken to guard against iodine sensitivity, the procedure is without hazard and no complications have occurred.

Technique:

A routine iodine patch test is done. If this is negative, 1 ml. of 45% hypaque is given intravenously 6 hours before venography to confirm the absence of sensitivity. The venography is performed in the operating theatre under aseptic conditions. Local or light general anaesthetic is used. It has been found that the best position is with a 20° foot-down table tilt.

A special self-tapping needle with a screw end has been developed (Fig. 2). When this is screwed into the medulla of the bone, the threads help to prevent leak-back of dye. After making sure there is a free flow of blood from the medulla 45% hypaque is injected. 5 ml. is usually adequate to display the pattern of medullary veins, sinusoids, and the adjacent deep veins. A total of 40 ml. of hypaque has been used with no ill-effect. An X-ray is taken as the dye is being injected.

The investigation has been carried out on 22 patients in the above series. It has also been carried out on patients with normal limbs, with Paget's disease and with secondary osteoarthritis.

At various times the dye has been injected into bone at the upper and lower ends of both tibia and femur and into the olecranon.

Results

Pressure and Pain:

When venography has been performed under local anaesthetic it was found that a rise in the intramedullary pressure always caused pain, whose intensity rose in proportion to the pressure at which the fluid was injected. Similar observations have been made by Robson and Van Miert (1962). Presumably the pain is due

to deformation of the sinusoids which stimulates the vaso-sensory endings described by Bazett and McGlone (1928) and by Seguiria (1958). Two patients from the series with primary osteoarthritis of the knee elected to have the venography carried out under local anaesthetic. The pain was described as identical with the dull, diffuse aching pain from which they were suffering.

Three patients with normal limbs subjected to this manoeuvre experienced pain of the same character.

One patient with Paget's disease of the tibia complained of pain similar to that which she normally felt throughout the bone. The venograph in this case showed the dye to be filling the whole of the medulla.

Substitution of saline for hypaque in these cases produced no change in the pain response.

Only in those patients with osteoarthritis and congestive pain have the following characteristics been observed:

1. The medullary sinusoids are dilated. This is most noticeable in the subchondral zone. Adjacent to a normal joint this area of bone remains free of dye (Fig. 1).

2. In this group of patients there is distension of the deep veins as compared with the opposite side, when this is normal. The distension of the deep veins may occur in the absence of superficial venous varicosities.

3. The insertion of the needle is consistently easier in the bones with congested sinusoids than in normal bones; this would suggest that the bones with engorged venous sinusoids are softer.

The Relief of Pain by Osteotomy

Richard Volkmann in 1875 was the first to use osteotomy to correct tibial deformity. There is no record in the literature of tibial osteotomy being performed for osteoarthritis of the knee until Jackson and Waugh published their series of 10 cases in 1961. Their results were encouraging and were confirmed by Wardle (1962) who had followed up his cases for 16 years.

In 1962, during a routine Out-Patient Clinic, I saw a patient who had been operated on by Professor McMurray in 1943. The leg had been osteotomised for osteoarthritis of the knee with deformity. (Although there was no "record in the literature", osteotomy was being performed for osteoarthritis). The patient was currently attending with a traumatic effusion, having slipped on an icy patch and fallen on to his knee. It was obvious from the series of radiographs that there had been complete loss of

FIG. 1.—Only the right knee is painful. There is both superficial and intraosseous venous engorgement. The left knee shows a striking absence of dye in the subarticular area.

FIG. 1.—Right Knee

FIG. 1.—Left Knee.

FIG. 2.—A self-tapping needle with a screw end is used in intraosseous injections.

the correction before union of the osteotomy. Despite "malunion" of the osteotomy, the patient's knee had been completely painless throughout the intervening 19 years.

Another patient, a dock labourer, had bilateral tibio-fibular osteotomies for osteoarthritis 8 years previously. Despite non-union of the osteotomy on one side, both knees had become and had remained free of pain; each had a range of movement from 170°—80°.

The success of osteotomy is usually explained by the mechanical advantages it produces (Osborne and Fahrni, 1950). In the two cases described, the relief of symptoms must be due to some factor other than a correction of deformity.

Venographic studies were made on 3 post-osteotomy patients. The oldest osteotomy had been carried out 3 years before and his X-rays show (Fig. 3 a, b):

1. decongestion of the bone sinusoids adjacent to the joint.
2. the persistence of a vascular disconnection at osteotomy level by what Wardle has aptly termed a "medullary plug".

The Acrylic Plug

In view of the findings described above, it was felt that a permanent artificial medullary

A

This patient had the usual triad—varicose veins, congestive pain and intraosseous vein dilatation.

B

After osteotomy dilatation is reduced and the congestive pain relieved.

C

Similarly after acrylic plugging.

D

FIG. 3.

plug might prove an effective alternative to osteotomy. (Fig. 3c, d). This plugging operation has been done in selected cases of osteoarthritis of the knee and hip. The patients selected were those with "venous" pain, sinusoidal engorgement displayed by venography and some contra-indication to osteotomy such as immobilisation in bed or in plaster of Paris.

Technique:

A slot is cut in the cortex, usually the lateral surface of the tibia, at tibial tubercle level (or, for the hip, the lateral surface of the femur at intertrochanteric level). All cancellous bone is removed and acrylic cement is used to plug the medulla.

The only complication was delayed healing of the wound in the first case due to inadvertent burning of the skin by the exothermic reaction of the acrylic while this was setting.

Results

This procedure has been carried out in 9 patients for osteoarthritis of the knee. The longest follow up is eighteen months. All the patients have had maintained relief from "venous" pain. None has so far required any further treatment. A more detailed appraisal of the method awaits more cases and a longer follow up period.

Discussion

Three questions in particular arise out of the above findings and demand further explanation:

1. Why should bone venous sinusoids become distended?

2. Why, for example, is the knee joint, which is placed at the proximal end of the tibia, so liable to osteoarthritis whilst the ankle joint, placed at the other extreme, is spared?

3. Why does osteotomy result in decongestion of previously distended bone sinusoids as well as the relief of pain and arrest of the progress of osteoarthritis?

1. The first point to be established is the reason for distension of the sinusoids. Normally the medulla can discharge a large influx of blood without difficulty. Dickerson and Duthrie (1963) have anastomosed arteries to the bone medulla; the bone effluents were apparently able to cope with the increased intake of blood without any disturbance of anatomy or physiology. Hulth (1958), in venographic studies on the hip saw pooling of dye in the intramedullary veins and no filling of the deep veins and suggested that there was an "obstruction" to the outflow of blood from the medulla. This impression can be obtained because dye is rapidly cleared from the deep veins, especially if the subject is horizontal or in some head-

down tilt, or if there is any delay between the injection and the X-ray. It is also evident that to accommodate dye placed in a rigid medullary chamber an equivalent volume of blood must be displaced. I have not encountered any resistance to the outflow of blood from bone during the venogram procedure.

To emphasise the fact that there is no shortage of effluents and no "obstruction" to the evacuation of dye from the medulla of bones adjacent to osteoarthritic joints, the following experiment was performed:

A cannula was inserted into each of a pair of cadaveric tibiae. The first had normal joints, the second an osteoarthritic knee (with typical enlarged sinusoids). A pint of fluid was allowed to run through each of these bones under identical conditions. It flowed out of the abnormal tibia more rapidly. This experiment was repeated on a second pair of tibiae with the same result.

It seems reasonable to conclude that the effluent channels are larger than normal in bone adjacent to these osteoarthritic joints and that there is no obstruction to the outflow of blood from such bones, therefore distension of the bone sinusoids follows upon increased pressure in the extrasosseous deep veins.

2. To understand the reason for the immunity of the ankle joint from osteoarthritis an investigation of the effluent patterns of the tibia and other bones was done. I have found that the pattern of venous channels emerging from the medulla of a bone is constant for a specific bone, but varies with different bones.

Effluent patterns are shown for cadaver tibiae and a femur (Fig. 4 a, b, c). It can be seen that venous blood flow in the tibia is proximal—it is evacuated at the upper end. As the medullary system is valveless this upward flow is simply due to the comparatively large transcortical veins at the proximal end of the tibia.

It seems clear that an increase in venous pressure is transmitted to sinusoids in the bone medulla, particularly in a situation like the upper end of the tibia where there is a concentration of effluents. An explanation for the immunity of subarticular bone of the ankle joint may be that because of small transcortical veins, the sinusoids near the ankle joint are spared the turbulence that occurs in the upper tibia.

3. It is my opinion that osteotomy may relieve pain in two ways:

(a) by taking stress off the capsule of a joint when deformity is corrected and

A

B

C

FIG. 4.—Vertically held cadaver bones. Dye injected into the medullae at mid shaft level.

- A. This proximal flow of dye is constant in the tibia.
- B. Three 7/64" holes had to be drilled at the lower end before the dye would flow distally. The proximal flow is entirely due to the concentrate of transcortical effluents at the top end.
- C. The femoral pattern is quite different.

- (b) by producing the decongestion of adjacent sinusoids and a partition of the bone medulla, as demonstrated by venography (*vide supra*).

The features described in (b) prompted an enquiry into the way blood is evacuated from bone.

A series of medullary pressure measurements were made on patients at the time of venography. Pressures were found to be markedly labile and great fluctuations were produced by a large number of factors, mainly those which had an effect on the general systemic venous pressure.

One finding which I believe is of great significance was obtained in this manner:

A simple tube manometer is allowed to fill with tibial medullary blood until steady and then this is followed by a sustained voluntary contraction of the calf muscle. There is a small initial rise of pressure followed by a rapid and large fall in pressure which then slowly returns to its original level.

This suggests an active evacuation of blood from the medulla. This is similar to the evacuation of the superficial system of veins (Walker and Longland, 1956). Stannard (1963) suggests that the hydrostatic means by which this is accomplished is the so-called Venturi effect—that is a suction effect produced by fluid in motion. This vacuum effect is exerted by the deep veins on the medullary effluents. With the medullary chamber partitioned following osteotomy or acrylic plugging its size is reduced. A more efficient active withdrawal of blood from the smaller compartment therefore takes place. This, together with the fact that some blood destined for evacuation through this smaller compartment is diverted by the partition formed at the osteotomy site, will result in a mean fall in the medullary pressure.

The sequelæ are:

1. loss of the "venous" element of pain,
2. an improved circulation especially to subchondral bone and its overlying cartilage, which will then enjoy a better nutrition.

Conclusion

The findings in this study strongly suggest a link between a specific symptom ("venous" pain) and the presence of distended bone sinusoids in patients with primary osteoarthritis. Many of these patients have associated superficial varicose veins. An explanation is offered for the dilatation of the sinusoids in bone (*vide supra*).

After osteotomy a partition forms in the medulla of the bone at the osteotomy site. The previously distended bone sinusoids return to normal size, and venous pain is relieved.

In discussions of the ætiology of osteoarthritis a good deal of attention has focussed upon the changes in arterial patterns in bone. Harrison, Schajowicz and Trueta (1953) studied the histology of injected postmortem femoral heads and femoral heads excised at operation. They commented in particular upon the change in arteriolar patterns and believe that much of the pathology is a result of this arteriolar response to damaged tissue. This, they felt, was nature's overzealous attempt at repair. Their preparations (Figs. 40-43, p. 619 of their paper) also show distended sinusoids, especially in regions of bone cavitation.

Altogether scant attention has been directed to the venous changes in the bone adjacent to osteoarthritic joints. (Bernstein (1933) reported experiments on dogs in which obstruction to the venous drainage resulted in osteoarthritis). The close association between lower limb superficial varicose veins and a subgroup of primary osteoarthritic knees is, I think, significant particularly as the venous disorders constantly antedate the arthritis.

It may well be that the venous changes are not merely the source of much of the pain in osteoarthritis but in some cases may even be the primary cause of primary osteoarthritis.

I therefore venture to suggest a different train of events which may lead to osteoarthritis.

Man's upright posture, a comparatively late acquisition in his evolution (Darwin, 1888), imposes great stress on the venous system of his lower limbs. This stress is further aggravated by any rise in intrathoracic or intra-abdominal pressure. The increased venous pressure is transmitted to the sinusoids in the bone medulla, particularly where there is a concentration of effluents, as at the upper end of the tibia. As pressure rises in, for example, the proximal tibial sinusoids, they distend at the expense of the adjacent trabeculæ. The overlying cartilage suffers as venous stasis robs it of some of its nutrition, and trabecular erosion disturbs its uniform bony support. (Fig. 5 a, b).

After, for example, tibial osteotomy a partition forms which results in diversion of blood destined for evacuation at the upper end of the tibia and there is also a more efficient active withdrawal of blood from the smaller compartment so formed. A mean fall of medullary pressure occurs and an improved circulation results. The long-term consequences are that

FIG. 5.—A. Shows the normal arcades of bone at osteochondral junction.
B. The trabecular distortion in osteoarthritis.

Diagrammatic Representation of Fig. 5.

the sinusoids become less distended and, with the improved circulation, the subchondral bone and the overlying cartilage enjoy better nutrition. Restoration of lost trabeculae occurs as the sinusoids decrease in size. Thus the steps along one of the paths leading to osteoarthritis are retraced: a degenerative process is reversed.

Summary

1. Some results of a clinical investigation of patients with osteoarthritis of the knee are described.
2. The different varieties of pain which occur in osteoarthritis are detailed.
3. A sub-group of patients with primary

osteoarthritis of the knee is described. In this group "venous" pain predominated; the venographic appearances are typical, and in a large proportion of cases the veins outside the bone are manifestly abnormal.

4. It is suggested that venous congestion within the bone results from extra-osseous vein disturbances, and leads to congestive bone pain and to progressive joint degeneration.

5. The mechanism by which osteotomy produces relief of pain is analysed and discussed.

6. A simple procedure which reproduces some of the benefits of osteotomy is described.

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The work was continued at the Rowley Bristow Orthopaedic Hospital.

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