MECHANISM CAUSING FRACTURE DISLOCATION OF THE SEMILUNAR CARTILAGES.

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In 1784 William Hey wrote his paper "On Internal Derangements of the Knee Joint." Therein he states: "The complaint which I have described may be brought on, I apprehend, by any such alteration in the state of the joint, as will prevent the condyles of the os femoris from moving truly in the hollow formed by the semilunar cartilages and the articular depressions of the tibia. An unequal tension of the lateral or cross ligaments of the joint, or some slight derangement of the semilunar cartilages may probably be sufficient to bring on the complaint." Since then many explanations have been put forward as to the mechanism causing fracture and dislocation of the semilunar cartilages. In every text book of surgery, and every paper which has been written on the subject, a different opinion is expressed. These opinions differ, so extensively that even the common custom of copying a statement from one text book to another has not been adopted.

To illustrate this it will be sufficient to quote a few only of the many opinions which have been expressed.

(1) Surls, J. K., and Osgood, R. B., in their paper on "Internal Derangements of the Knee Joint" (Journal Bone and Joint Surg., 1923/5, 635-697), quote Alwyn Smith as follows:—"Dislocation or fracture of the internal semilunar cartilage is the most common lesion found in the derangements. It is produced by strong internal rotation of femur on tibia when the knee is in a flexed position. When this rotation takes place, the semilunars first slide internally over the tibial surface, as far as their small range of motion will allow. (All normal rotation of the knee takes place between semilunars and tibia.) If this rotation continues to an abnormal degree the deep fibres of the internal lateral ligament are torn, usually at one extremity and more often at the tibial than the femoral. They may bring a fragment of bone away with them, producing a "sprain fracture." Further rotation involves a tearing loose of the internal semilunar at its periphery or extremities, or a fracture of the cartilage in a longitudinal or transverse direction.

DETAILS OF THE PATHOLOGY OF THE SEMILUNAR CARTILAGE AND MECHANISM OF PRODUCTION.—Reports vary regarding the type of internal semilunar injury seen most frequently at operation, but it seems to lie between a fracture, a longitudinal splitting of the cartilage, and a dislocation, a tearing loose of the anterior end. The other prominent type of fractured cartilage is the transverse, occurring opposite the internal lateral ligament, or in the anterior third.

With a partial tearing loose of the periphery of the cartilage from the capsule, attempted extension of the knee no longer draws the semilunar sufficiently far towards the periphery, for the connection between capsule and semilunar has been partially severed, and hence locking is apt to occur. This peripheral separation of the cartilage is probably the most frequent of all lesions of the internal semilunar (Barker, Vulpius), but is not the one most frequently seen at operation, because of the comparative mildness of the symptoms. In other words, a patient sustaining this degree of semilunar injury is not seriously disabled. Locking, if present, is only momentary. The patient does

*In the case of a sprain fracture, the femoral extremity is involved more often than the tibial. X-ray shows a small bony film separated from the femur in the vicinity of the adductor tubercle. If the tibial end is involved, the bony fragment is apt to include part of the articular surface.
not receive adequate treatment, and healing takes place with the semi-
lunar in this relaxed position and pulled centrally by its extremities.
Hence a second injury, similar to the first (i.e., inward torsion with
the knee flexed), may cause a severe catching of the cartilage between
the joint surfaces, with a consequent fracture or tearing loose of one of
the extremities. It is after this or subsequent lockings that operation
is performed.

The longitudinal fracture referred to above is probably the result
of one of these secondary injuries. The semilunar, because of its
relaxed condition, becomes caught between the articulating surfaces.
Encouraging torsion pulls on its periphery, while the pressure of the femoral
trochlea, especially upon its central fibres, holds it back. The result is
a longitudinal split beginning near its anterior extremity, between the
peripheral fibres, which are continuous with the transverse ligament and
the central fibres, which are attached separately to the tibia. This
anatomical point was first brought out by Billington. If the cartilage
is torn longitudinally, the inner portion generally slips centrally, but
remains attached at its extremities. It thus roughly resembles an old-
-fashioned bucket-handle and the type is so designated.

In the case of a free extremity, the locking is most likely due to a
slipping: centrally or buckling over of the injured part.

Bizarre forms of the above lesions occur, such as the nodular type
of loosened anterior extremity. The cartilage in general may show
different degrees of alteration due to long-continued trauma or other
causes, and cases have been found in which the cartilage has disappeared
entirely. (Jones.)

2. Timbrell Fisher states:—"Sudden rotation inwards of the
femur upon the fixed tibia with the knee partly flexed, combined usually
with abduction, may act in two ways:

(a) The internal lateral ligament and the attachment of the semi-
lunar (internal) to its posterior part remain intact, but the
attachment of the anterior horn or the weak coronary attach-
ment thereof, or both are ruptured. The anterior portion of
the cartilage itself may be torn, or every variety of tranverse
or oblique tear may take place opposite the fixed part of
the cartilage. The anterior portion of the cartilage is displaced
usually towards the interior of the joint, and its normal
elasticity being interfered with, it is often unable to retrace; its
steps, so that when extension takes place it is nipped between
the condyles of the femur and tibia, and may be thereby
further damaged.

(b) In more severe rotatory movements the cartilage may be even
torn from its attachment to the internal lateral ligament, or if
abduction is a marked feature, the latter may be severely
stretched or even ruptured. Thus the middle portion of the
cartilage may slip into the interior of the joint, and when
extension occurs, is apt to be split longitudinally, producing a
typical "bucket-handle" type of lesion."

3. Thomson and Miles.—"Combined flexion and abduction of the
knee opens up the medial side of the joint by separating the medial
condyles of femur and tibia, and the medial meniscus, in its movement
backwards during flexion, slips under the femoral condyle and is caught
between it and the tibia. It may even slip past the condyle into the
intercondylar notch and come to lie against the crucial ligaments. The
mechanism by which this lesion is produced doubtless explains the
greater frequency with which the left knee is affected, as most sudden
movements are made from right to left, thus throwing the strain upon
the left knee.
The medial meniscus exhibits undue mobility much more frequently than the lateral, and the condition is usually met with in adult males who engage in athletics, or who follow an employment which entails working in a kneeling or squatting position for long periods, with the toes turned out, e.g., Coal miners. The tibial collateral ligament, and through it the coronary ligaments, are thus gradually stretched, so that the cartilage becomes less securely anchored, and is rendered liable to be displaced towards the centre of the joint during some sudden movement which combines flexion of the knee with medial rotation of the femur upon the tibia, as, for example, in rising quickly from a squatting position or turning rapidly and pushing off with the foot in the course of some game such as tennis or football. It may occur also from tripping on a loose stone or slipping off the kerbstone.

If flexion and abduction of the knee are essential in the mechanism, I fail to see how a sudden movement from right to left could render the left internal semilunar cartilage more liable to injury. In such a case the femur would be rotated outwards and, the foot being fixed on the ground, the tibia will tend to rotate in the opposite direction, and abduction then becomes a mechanical impossibility.

If undue mobility of the cartilage contributed in any way, the external semilunar cartilage ought to be fractured much more frequently than it is. The comparative immunity to damage of the external semilunar cartilage is entirely due to this abnormal or undue mobility.

Anatomy.—Before discussing the mechanism I wish to draw attention to the following points in the Anatomy of the semilunar cartilages.

FIG. I.

The internal semilunar cartilage is firmly attached, by its anterior horn, to the top of the tibia, and to a lesser extent, to the external semilunar cartilage through the transverse ligament, the latter being a continuation of the more peripherally placed fibres. Along the periphery it is attached to the capsule of the knee joint, the attachment being specially firm to the internal lateral ligament, and to the anterior part of the capsule, which is here formed mainly by the fibrous expansion of the vastus internus muscle. Posteriorly the periphery is attached to the capsule by some loose areolar tissue. The synovial membrane, covering part of the periphery both above and below, is continued over this areolar tissue before being reflected on to the capsule. In some cases a distinct mesentery is formed between the periphery and the capsule. The posterior end is the most moveable part of the internal semilunar cartilage. During extension of the knee joint the anterior part of the semilunar cartilage is pulled forward by the vastus internus muscle.

A bursa between the internal lateral ligament, and the internal semilunar cartilage has often been noted. This bursa is very frequently present in natives; I found it present in all of the 7 knee joints dissected for the purpose. This point will be referred to again later.

The external semilunar cartilage forms a larger arc of a smaller circle. Its peripheral attachment resembles that of the internal, with the exception that it is separated from the external lateral ligament by the tendon of the popliteus, which is not attached to the cartilage, but is separated from it by a synovial lined space.

The presence of this space or bursa and that between the internal lateral ligament and the internal semilunar cartilage permits that part of the periphery of the cartilage to move towards the interior of the knee joint when the anterior and posterior ends are separated from each other. In other words, it allows of both cartilages being converted into a smaller arc of a larger circle.
The semilunar cartilages are attached to the tibia and not to the femur except through the long coronary ligaments. Both cartilages move with the tibia and not with the femur as it is sometimes stated. (See Figure 1.)

The mechanism which I am now putting forward was first suggested to me in the following manner:—

A patient, already anaesthetised and on the operating table, was to be operated on for a fracture dislocation of the left internal semilunar cartilage. When the operation field had been toweled off it was found that the patient was not sufficiently far down on the table to allow of flexing the knee to a right angle. The upper part of the back of the calf was resting against the edge of the table with the knee flexed to about 60 degrees. Instead of having the patient pushed downwards, I applied pressure on his foot and ankle with the object of pulling him down by using the leg as a lever. A fair amount of force was necessary, but even before the patient’s body began to move a distinct clicking, heard all over the theatre, was produced in the knee. I tried to straighten the knee, but experienced a distinct obstruction when nearing complete extension. By manipulation, as for displaced semilunar cartilage, the obstruction was overcome. The knee joint was then opened, just sufficiently to allow of a view being obtained of its interior. The patient’s leg was then placed in the same position as before, viz., with the upper part of the calf against the edge of the table, and the leg again used as a lever to move the patient farther down on the table. After a few attempts I succeeded in producing the same loud click, and on looking into the joint saw a fracture dislocation of the internal semilunar cartilage of the "bucket-handle" type, with the handle of the bucket lying between the femoral and tibial condyles, and acting as a definite
mechanical block to extension. The fractured cartilage was reduced by manipulation, and it was found that by rotating the foot outwards and abducting the knee the cartilage could be displaced at will, while the knee was in the above position and the leg used as a lever.

The essential factors appeared to be flexion and abduction of the knee, rotation of the tibia outwards and pushing, or pulling, the upper end of the tibia forward in relation to the femoral condyles.

MECHANISM.—The accident which results in a fracture dislocation of the internal semilunar cartilage happens when the knee is partly flexed, the femur rotated inwards, the tibia rotated outwards, and the foot fixed on the ground. The force, the body weight, acting from above downwards, and from without inwards, tends to open up the joint on the inner side, i.e., produce abduction. The knee in this position, one not voluntarily assumed, is unstable, incapable of supporting the body weight, and the individual is liable to fall. To prevent this the quadriceps extensor group is brought suddenly into violent contraction in an effort to straighten the knee. The mechanical condition of the joint, however, is such as will not allow of normal extension, so that the contraction of the quadriceps will result in:

1. The upper end of the tibia being pulled forward in relation to the femoral condyles.
2. The femoral condyles being pushed backwards in relation to the upper end of the tibia.
3. Or a combination of these.

FIG. 2.

The external rotation of the tibia and the internal rotation of the femur have brought the posterior end of the internal semilunar cartilage forward in relation to the medial femoral condyle, a condition which is further accentuated by the forward pull of the upper end of the tibia and the backward push of the femoral condyles just mentioned. To straighten the knee under these conditions the medial femoral condyle must either override the posterior end of the semilunar cartilage, or push it bodily backwards. The latter is the usual result because the ligaments, cruciate and lateral, will not permit of sufficient separation between the tibial and femoral condyles to allow of the former alternative. In other words, straightening of the knee is only possible by increasing the distance between the anterior and posterior ends of the cartilage, i.e., the distance between the points A and C (Fig. 1). This can be done in one or other of the following ways:

1. It has already been pointed out that the internal semilunar cartilage forms the arc of a circle—that it is fixed in front to the capsule (at this point formed mainly by the expansion of the tendon of the vastus internus)—that it is firmly attached to the internal lateral ligament. We thus have a semilunar structure, composed of fibres running mainly in a longitudinal direction from before backwards, the anterior end pulled forward by the quadriceps, the posterior end pushed forcibly backwards by the medial femoral condyle, and the periphery firmly held by the internal lateral ligament. It follows from this that the distance between A and C can be increased only by converting the arc A B C (Fig. 1) or part of it into a straight line, or into a smaller arc of a larger circle. As the fibres forming the inner part of the cartilage are naturally shorter than those nearer the periphery, it is the inner part of the cartilage that usually gives way, and the most obvious manner to do so is by a longitudinal split in an antero-posterior direction. The inner part is broken off and separated from the outer by being displaced inwards, thus allowing of the necessary increase in the distance between the points A and C. The mechanical conditions are now more favourable for extension, but before this can be completed
the inner broken off portion of the cartilage has slipped in between the femoral and tibial condyles, producing a true mechanical block. At this stage the patient falls down, experiences acute pain in the knee, which is locked in extension. This explains the most typical symptom of a fracture dislocation of the internal cartilage, viz., "locking." This type is usually called the "Bucket Handle" type, and is the one most frequently found at operations. (Fig. 3A.)
(2) Detachment of the anterior horn with a longitudinal split backwards—the split beginning at the junction of the transverse ligament with the anterior horn. (Fig. 3B.)

(3) Transverse fracture alone or combined with a longitudinal split backwards or forwards or both. (Fig. 3C a,b,d.)

This type depends upon the proportion and strength of the transverse fibres present.

(4) A combination of these (Fig. 3D). A combination of "bucket handle" type with transverse fractures.

It is possible, when the patient is anaesthetised, to displace a fractured cartilage at will by following the mechanism just described. It was demonstrated to students a few weeks ago while operating on a case of the "bucket handle" type. Further, the mechanism will usually demonstrate a fracture should there be any difficulty in finding it after the knee joint has been opened.

The bursa between the internal lateral ligament and the periphery of the cartilage permits the cartilage to move inwards. In other words, it allows of sufficient separation of the points A and C without doing damage to the cartilage. This explains why damage to the internal semilunar cartilage is hardly ever seen in a native. I have not seen a single case in the Native Hospital, nor have I heard of a case in any of the Mine Hospitals.

Fracture dislocation of the external semilunar cartilage is comparatively rare. It is stated that the percentage compared with the internal is from 2%-5%. Personally I have seen it in the proportion of 1 in 30. The mechanism is the reverse of that for the internal semilunar, i.e., internal rotation of the tibia, external rotation of the femur, and adduction of the knee.

The comparative immunity to damage which it enjoys is due to:

(1) The larger range of mobility as the result of the popliteus tendon separating the periphery from the external lateral ligament and capsule.

(2) The comparative rarity of torsion from within outwards. When this does take place the free leg can always be thrown over the other to take the body weight.

Surles and Osgood, in their paper, give a similar explanation.

An anatomical explanation has been offered for the great preponderance of internal semilunar injuries over those of the external. This is the small range of motion possible in the former, when compared with the latter. The internal cartilage is attached more extensively at the periphery, and its extremities lie farther from each other than those of the external. On this account, there is less "give" when violence is applied to the internal, and its factor of safety is smaller.—(Jones, Lancet, 1914.)

But there is also a physiological feature which helps to explain this situation—the preponderance of torsions inward over torsions outward on the part of the athlete or worker. The athlete turning suddenly in running and the miner turning to throw a shovelful of coal into a car, both turn towards the opposite side and throw the body weight to the other leg. If the individual turns towards the same side, he must throw his free leg across the other, in order to keep his balance. The latter method of turning must, of course, be used at times, but it is awkward and is not the motion of choice. We know that it is internal torsion rather than external which produces internal semilunar injuries. Assuming that a corresponding torsion, i.e., external, produces external semilunar injuries, we thus have an additional explanation for the comparatively small number of these lesions.