TRAUMATIC INTRAMUSCULAR OSSIFICATION:

ITS PATHOLOGY AND TREATMENT BY EXCISION AND AUTOGENOUS GRAFTING OF FASCIA.

A CLINICAL AND EXPERIMENTAL STUDY.

[With Special Plate.]

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THE condition dealt with in this paper is usually known as myositis ossificans traumatica, but the name is objectionable as implying a theory of its pathology, for which, as I hope to show, there is little foundation. The condition to be described follows the infliction of a single severe contusion, and must be distinguished clearly from two other types of intramuscular ossification—namely, (1) myositis ossificans progressiva, which starts early in life, usually in the muscles of the back, and ultimately causes death from respiratory failure; and (2) ossification into tendons, the result of slight, repeated mechanical irritation, such as "rider's bone."

THEORIES OF CAUSATION.

After a severe, blunt, subcutaneous injury to a limb, usually the thigh or upper arm, a mass of bone develops in the contused muscles. Various theories have been entertained as to the origin and nature of this bony growth, a full discussion of which is given by Lapointe in a recent paper.¹

Briefly, the theories fall into three main groups, namely:

1. Tumour formation.
2. Metaplastic inflammation of muscular connective tissue.
3. Mechanical.

1. *Tumour Formation.*—All authorities are agreed that traumatic intramuscular ossification is not of the nature of a malignant growth. It shows no tendency to infiltration of any tissue but muscle (if one excepts the ligaments when "ossifying peri-arthritis" occurs in addition), nor does it ever give rise to metastases. Only one case is recorded in the literature, by Coley,² of a sarcomatous change supervening on this condition. Nor can it be held that the bony mass is a true osteoma, or benign tumour, on account of its natural history. In the early stages the growth of bone into the damaged muscle suggests true tumour formation in that it is progressive and unrestrained by the laws that limit normal growth of bone, and to some extent mechanically injurious. But after several weeks or months not only does the growth cease, but a tendency to reabsorption is seen, which may in some cases go on to almost complete disappearance.

2. *Inflammation.*—According to some, the change set up in the muscle is an interstitial myositis with transformation into bone of the intramuscular fibrous tissue; that is to say, the growth is not derived from bone, and any attachment to bone is only secondary and accidental. Lapointe¹ gives his support to this view. He points out that while in some cases the bony growth is attached to the underlying bone, in others it is free from the bone, which may be found at operation to be completely covered by periosteum. Since both types of growth, free and attached to bone, are identical macroscopically and microscopically, Lapointe very properly insists that their manner of production is probably identical. His next inference, however, that the unattached bony masses cannot have originated in bone or periosteum and that therefore both types must arise by metaplasia of the intramuscular connective tissue, is unconvincing, since a temporary breach in the periosteum might allow of escape of osteoblasts. I do not contend that metaplasia of fibrous tissue into bone never occurs. In a case shown recently in Manchester by Professor G. A. Wright, a large plate of bone developed in the scar of an abdominal wound after gastro-enterostomy, and similar cases are reported in the literature (Lapointe). But I am unable to agree with Lapointe that, because in exceedingly rare cases such metaplasia may occur, therefore it must be invoked to explain the relatively common condition of

traumatic intramuscular ossification. As I shall show, a simpler and more credible explanation is available. That the process is inflammatory, in the sense that it is a reaction of the tissues to injury, is obvious. There is, however, no evidence of any constitutional infection such as syphilis in these cases. The Wassermann reaction in the case reported below was negative.

3. *Mechanical.*—The truth of the mechanical view of its causation is suggested by certain facts concerning the incidence of the condition. Of a series of 233 cases collected from the records of the German Army in ten years by Schultz,³ all but 3 were situated in the quadriceps or brachialis anticus. The patients are usually young adult or adolescent males. The type of injury is always a severe subcutaneous contusion, and it is remarkable, on looking through the literature, how many cases are due to a kick on the front of the thigh or a blow with a fist on the front of the upper arm. Now in both these situations we have a broad, smooth, convex area of bone, covered by periosteum that is loosely attached and readily stripped off owing to the absence of tendinous insertions. This point has impressed many observers, and has given rise to the view that the lacerated muscle fibres may retract, carrying torn fragments of periosteum away from the bone, and that these fragments act as grafts producing bone. Others hold that as a result of trauma the cells of the deep layer of the periosteum are stimulated to proliferate. These views must be abandoned, however, since they are based on an erroneous conception of the function of the periosteum. The work of Macewen⁴ has shown conclusively that the periosteum does not act as a bone producer, but as a limiting membrane to the growth of osteoblasts. Working on dogs, he showed that the so-called osteogenetic layer of the periosteum is really a subperiosteal layer of areolar tissue which normally contains osteoblasts in the growing bone only; that in healthy adult bone this subperiosteal areolar space contains few osteoblasts or none, so that transplanted periosteum does not produce bone; and that subperiosteal deposits of bone produced by irritation are due to the pouring out of osteoblasts into the subperiosteal space from the deeper parts of the bone via the Haversian canals.

In the light of these facts, and of the investigations I now record, I consider the pathology of traumatic intramuscular ossification to be as follows: A severe blunt injury at once subcutaneously strips off and destroys the periosteum, and crushes the muscles in contact with the bone. Bleeding occurs from the surface of the denuded bone, and, with the blood, osteoblasts in a free and possibly amoeboid condition escape into the pulped muscle tissue and blood, and there produce a growth of bone. As Macewen has shown, healthy muscles left in contact with denuded bone form protective fibrous adhesions from their interstitial connective tissue, and so take on the limiting function of the periosteum. My own investigations show that severely contused muscle tissue mixed with blood, so far from restraining the migration and growth of osteoblasts, provides a very favourable pabulum for them.

CASE.

The following case affords a clear demonstration of the truth of these views:

A strong, healthy young man, aged 20, a greengrocer's assistant, was admitted to the Ancoats Hospital, Manchester, under my care on January 2nd, 1913, complaining of sudden swelling of the left thigh. He gave the following history. On December 11th, 1912, three weeks before admission, he was thrown out of a cart which he was driving, and the wheel ran over the front of his left thigh. There was a good deal of bruising, for which he massaged it, and he was off work for three days. He then returned to work, and noticed nothing wrong but slight difficulty in flexing the knee, and pain on attempting to do so. On the evening before admission, while sitting down at home, he bent his knee a little more than usual and felt a sudden pain in front of the lower third of the thigh. Almost immediately he noticed that the thigh was swelling, and he felt with the swelling a "buzzing sensation" in his muscles. In a few minutes the thigh had swelled up very considerably, and felt distended. His friends made matters worse meanwhile by vigorous massage. Early next morning he came to hospital.

On Admission.—The left thigh was greatly swollen, chiefly on the antero-lateral aspect of the femur about its centre. On palpation the swelling was only slightly tender. It was partly fluctuant, but gave a sense of the presence of a solid element as well as fluid. It was obviously a case of spontaneous haematoma under the quadriceps, and naturally gave rise to the

suspicion of sarcoma resulting from the trauma. A skiagram taken the same day by Dr. Bythell showed "a faint subperiosteal deposit of bone, irregular in shape, that might be due to a periosteal sarcoma." The Wassermann reaction, tested by Dr. Arnold Renshaw, was negative. It was decided to explore in order to establish the diagnosis. Accordingly on January 3rd, the day after admission, under ether anaesthesia, an incision 8 in. long was made on the front and outer aspect of the thigh. The rectus femoris and vastus externus having been separated, a large haematoma was evacuated lying under and in the crureus muscle. At the bottom of the cavity of the haematoma was the femur, covered by an irregular layer of new bony growth, about 2 cm. thick on the average. Blunt spikes and bars of bone were projecting into the surrounding muscular tissue and into the cavity of the haematoma in an irregular manner, and two or three bars of similar hard material were felt on the outer (superficial) aspect of the haematoma cavity, widely separated from the rest and embedded in muscle tissue. The new bone was soft and easily gouged away, and presented just the appearance of three weeks old callus. The surface of the mass where it projected into the haematoma cavity was smooth and covered by what appeared to be embryonic or myxomatous connective tissue. The case was plainly one of intramuscular ossification, and not malignant. Accordingly I gouged out the mass as completely as possible. It covered an area on the front of the femur roughly 8 x 4 cm. When the soft young spongy bone was removed the underlying compact bone of the shaft of the femur was left smooth and of normal appearance, but there was no trace of periosteum between femur and new bone. I also removed the bars of bone felt in the muscle on the superficial aspect of the blood cavity, for microscopical examination, taking care to excise some of the adherent muscle with them. The wound was then sutured, and the patient put to bed with the leg bandaged in extension. Healing was by first intention, and he left the hospital ten days later with no swelling of the thigh, but slight limitation of flexion of the knee, and was instructed to attend as an out-patient.

The limitation of flexion became gradually worse during the next month, and he complained of inability to walk up steps in consequence, and a tendency to fall down owing to his toe catching. Examined three weeks after the operation a distinct, irregular, hard swelling in the same position as before was apparent. A radiogram showed a definite recurrence a good deal larger in extent than at the first operation. No pain was felt, but he could not flex the left knee to a right angle, and asked for further operation, since he would be quite unable to get up into his cart in this condition.

As expectant treatment offered the prospect under the most favourable circumstances of months of inability to work, and possibly of permanent limitation of flexion, and since I had now come to the conclusion that the cause of the recurrence was the destruction of periosteum and loss of its function as a limiting membrane for the osteoblasts, I considered how best that function might be replaced. Staige Davis⁵ has shown experimentally in dogs the feasibility of transplanting layers of fascia or aponeurosis to remedy defects in the abdominal wall, skull, and in a wide variety of situations. Accordingly I decided to remove the recurrent bone, and perform an autogenous transplantation of fascia on to the denuded bone, and to use for this purpose a piece of the patient's ilio-tibial band. This I hoped would fulfil the double function of preventing further recurrence, and preventing adhesions of muscle to the denuded bone.

The patient was readmitted on February 20th, 1913, seven weeks after the first operation. The last skiagram, taken on February 11th, had shown a slight further extension of the growth. An incision to the outer side of the former one was made, slightly curved outwards, and a flap of skin and subcutaneous tissue raised, leaving the ilio-tibial band exposed. The fascia was incised, the muscles separated, and the new bone growing in the crureus thoroughly excised, leaving the femur bare. A piece of ilio-tibial band and fascia lata at least 10 by 5 cm. in size, was then cut out, care being taken not to divide the whole width of the band, lest the muscles inserted into it should be weakened. It was placed on the denuded bone with the outer, subcutaneous surface next to the bone, and the inner surface, less calculated, as I considered, to form adhesions, in contact with the muscle. In this position it was fixed by six sutures of fine catgut, so as completely to cover the

denuded area. The wound was then closed, and the limb put up in flexion on a double inclined plane.

Healing was by first intention. Movement was commenced after the first two days. There was a little weakness of the quadriceps at first, owing to slight injury to some of its motor fibres, but at the end of three weeks this had recovered. A month after operation there was full flexion at the knee, and the patient could walk and perform all movements without the least inconvenience. Skiagrams taken four and eight weeks after operation showed complete freedom from recurrence.

EXPERIMENTAL CONFIRMATION.

By the kindness of Professor Boycott I have been able to perform experiments on rabbits in the pathological laboratories of Manchester University. These investigations are not yet complete, and will form the subject of a subsequent communication. It may be stated as a preliminary report, however, that intramuscular ossification essentially similar to the condition that occurs in man may be produced by curetting off the periosteum from the front of a rabbit's femur, and crushing the adjacent muscles. Ossification occurs by the migration of osteoblasts into the crushed muscles and blood clots lying in contact with the denuded bone. A specimen produced in this way in a rabbit is shown in Fig. 6, with a normal bone for comparison. The corresponding skiagram is shown in Fig. 7, and a microscopic preparation from another rabbit in Fig. 4. That devitalization of the muscles by crushing is an essential factor is shown by the fact that when the periosteum is removed, and the muscles are not crushed, little, if any, exuberant growth of bone occurs. This fact agrees with the observations of Macewen.

HISTOLOGY.

For microscopical examination a bar of bone, some 3 cm. long, removed at the first operation, was chosen. It was cylindrical in shape, with a diameter of 0.5 cm. at its widest part, and was almost completely surrounded by fibres of the muscle, in which it was growing parallel to their long axis. This piece of bone was

decalcified, and transverse and longitudinal sections cut and stained with haematoxylin and eosin (Figs. 1, 2, and 3).

Transverse sections (Figs. 1 and 2) show a definite formation of spongy bone arranged in irregular trabeculae, with large vascular medullary spaces between, in which a few multi-nucleated cells and many oval cells of embryonic connective tissue type are seen. The osseous matrix takes on a definite pink with the eosin. In the centre of the bone is an area of hyaline cartilage, avascular, and merging into bone at its periphery. The cartilage is distinguished from the osseous tissue by the non-staining character of its hyaline matrix, by large cell spaces, and round nuclei, faintly stained with blue. It appears to be undergoing rapid cell division. The periphery of the bony mass is nowhere in immediate contact with muscle fibres, but is surrounded by and merges into a layer of primitive fibrous tissue containing many oval nuclei. It is evident that these embryonic connective tissue cells are actively infiltrating the muscle and destroying its fibres. Here and there isolated and degenerate muscle fibres are seen surrounded by this tissue, and a little further from the bone it is seen to be invading the muscle substance by infiltration between its fibres. There is a general increase of the intramuscular fibrous tissue.

Longitudinal sections show particularly well this process of infiltration and destruction of muscle tissue by these indifferent connective tissue cells (Fig. 3).

Interpretation.

The first point of interest is the nature and origin of the cells that are infiltrating the muscle fibres and paving the way for the growth of true bone. Do they originate in the intramuscular connective tissue or in bone? A minute

DESCRIPTION OF SPECIAL PLATE.

Fig. 1.—Traumatic intramuscular ossification of three weeks' growth in man. From case described in text. Transverse section. B=bone, c=hyaline cartilage, m=muscle, p=preosseous tissue ($\frac{1}{2}$ in. objective).

Fig. 2. Same under high power ($\frac{1}{2}$ in.), showing transition from bone into cartilage.

Fig. 3.—Same in longitudinal section, showing infiltration of muscle fibres by preosseous tissue ($\frac{1}{2}$ in. objective).

Fig. 4.—Section of traumatic intramuscular ossification of four weeks' growth produced experimentally in rabbit, showing infiltration of muscle (m) by preosseous tissue (p); similar to Fig. 3.

Fig. 5.—Old-standing traumatic "myositis ossificans," showing incomplete reabsorption and transformation into dense bone. (Museum specimen.)

Fig. 6.—Traumatic intramuscular ossification produced experimentally in rabbit. Normal femur of rabbit for comparison.

Fig. 7.—Radiogram of specimens shown in Fig. 6.

FIG. 1.

FIG. 2.

FIG. 4.

FIG. 3.

FIG. 5.

FIG. 6.

FIG. 7.

examination of a number of these sections under a high power lens convinces me that they are simply osteoblasts in an actively dividing preosseous stage. The outer margin of the definite bony tissue passes by insensible degrees into this embryonic fibrous tissue, which here and there takes on faintly the pink stain seen in the fully developed osseous matrix. Similarly cells can everywhere be seen in every stage of transition between the mature osteoblast and these indifferent connective tissue cells. This conclusion is, of course, supported by the experimental evidence given above.

The sections show further in a striking manner that the cartilage cells are also identical with the osteoblasts, though in a different matrix, for between these again all stages of transition are seen. The importance of this conception of the essential unity of the osteoblast and chondroblast is obvious in connexion with our ideas on the growth of bone. There is now a very general feeling of scepticism towards the classical description of ossification in cartilage. Macewen holds that the osteoblast and chondroblast are the same cell in different guise. Wingate Todd,⁶ as the result of extensive histological investigations, concludes that "osteoblasts are fibroblasts or connective tissue cells which have undergone certain characteristic modifications, and may or may not have passed through a chondroblast stage." With these authorities I am in entire agreement. The explanation of the presence of cartilage here is not so simple. The cartilage plainly originated from bone, and would probably have been transformed in course of time into bony tissue. I am inclined to think that the presence of cartilage in the centre of the bar of bone is to be explained by its lower vascularity, since we know that an essential difference between bone and cartilage is that the former is vascular, the latter avascular.

DIFFERENTIAL DIAGNOSIS.

One condition only is likely to give rise to serious trouble in diagnosis, and that is sarcoma. In my own case the spontaneous haemorrhage occurring three weeks after the causal injury (so far as I know a unique complication) gave rise to the suspicion of sarcoma. More commonly it is the bony swelling that first arouses this suspicion, and there is no doubt that before the simple nature of "myositis ossificans" was generally recognized many limbs were needlessly sacrificed by this error in diagnosis. A careful x-ray examination, and if there is the least doubt exploration by open operation, should be undertaken in every case. A recent paper by Coley² deals very fully with this difficulty in diagnosis.

PROGNOSIS AND TREATMENT.

The extent to which the bony mass will grow, apart from treatment, cannot be predicted with any accuracy, though it doubtless bears some relation to the severity of the injury to muscles and the area of bone denuded. In some cases recorded almost the whole quadriceps, or brachialis anticus, has been infiltrated with bone. Most observers have noticed a natural tendency to cessation of growth after some months, and a variable degree of reabsorption. That this reabsorption is not always complete is shown by an x-ray plate of Coley's taken five years after the onset, and by two specimens in the pathological museum of Manchester University that are obviously of very old standing (Fig. 5). In these specimens the partial reabsorption has been accompanied by a condensation of the outer layer of the new-formed bone into very dense, compact tissue. The degree of disability produced depends on the mechanical embarrassment of muscles and joints. By reabsorption of bone and stretching of muscles with exercise this disability will tend slowly to improve. Ultimately, in many cases, perfect function will be restored, though this will take many months, as a rule, and may take years. There is also no doubt that simple excision is followed as a rule, though not invariably (Lapointe) by recurrence.

The tendency of late years has been towards conservative treatment. Robert Jones, who formerly advocated excision, has latterly⁷ advised an expectant course in view of the disappointing results of operation. Makins and others, at the discussion in 1911 before the Royal Society of Medicine,⁸ also advocated conservative treatment.

Lapointe admits the frequency of recurrence, but considers that excision is worth trying.

The main purpose of this paper is to advocate excision with grafting of a stout layer of deep fascia or aponeurosis on to the denuded bone. As stated above, the result in my own case was a complete success, and has saved the patient at the least many months of incapacity for work. In the case of the femur the fascia is most conveniently taken from the ilio-tibial band, taking care not to divide that structure completely, lest weakness of the gluteus maximus and tensor fasciae femoris, and, through them, of the knee-joint, should result. In the upper arm a strip of the investing layer of deep fascia would prove sufficiently tough to act as a limiting membrane. It is not enough simply to lay the fascia on the denuded bone, as it would crumple up. It must be sutured in place by a few catgut stitches passed on a curved needle through the neighbouring periosteum and muscular tissue. Early movement is advisable to aid in the prevention of adhesions. Extremely scrupulous aseptic precautions are necessary.

I am greatly indebted to Professor Boycott for allowing me to carry out the experimental work in the Manchester University Pathological Department, and to Drs. Bythell and Barclay for producing the radiograms.

CONCLUSIONS.

1. Traumatic intramuscular ossification ("myositis ossificans") is due to migration of osteoblasts into adjacent contused muscle and blood clot, after destruction of the periosteum and loss of its function as limiting membrane to the growth of bone. It is essentially the same process as callus formation.
2. The condition may be produced experimentally in animals by reproducing the same mechanical conditions by an aseptic open operation.
3. In a case of difficulty in diagnosis from sarcoma open exploration is advisable.
4. Simple excision is usually, though not invariably, followed by recurrence.
5. Conservative treatment condemns the patient to a long period of disability, which may occasionally be permanent.
6. Excision combined with grafting of deep fascia on to the denuded surface of bone gives the best prospect of rapid and complete recovery, and is urged for all cases not complicated by ossifying peri-arthritis.
7. Osteoblasts and chondroblasts are the same cells under different conditions of nutrition.

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- ⁴ Macewen, *The Growth of Bone*, 1912.
- ⁵ Staige Davis, *Ann. of Surg.*, 1911, ii, 734.
- ⁶ Wingate Todd, *The Development and Growth of Bone*, *Journ. Anat. and Phys.*, xlvii, 1913, 177.
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THE usual monthly meeting of the executive committee of the Medical Sickness and Accident Society took place on November 21st at 429, Strand, W.C., Dr. F. J. Allan in the chair. The claim account showed a decided reduction, and was not above the expectation. New business was well above the number for the corresponding month in preceding years. The increasing interest taken by the profession in the society and the many inquiries received at the head office in Chancery Lane prove that the solid business basis on which it is conducted and the fairness with which claims are met is much appreciated. For thirty years now the society has steadily progressed, and from quite a small concern has gradually developed into one of some prominence in the insurance world, with invested reserves of over £260,000. The committee at this meeting discussed some changes of the rules which are to be submitted to the members at the annual meeting next year. It has been thought advisable to give greater facilities for dealing with sundry matters which arise from time to time. The basis of the quinquennial valuation was approved, and it was resolved that this should be carried out by the actuary to the society as before. It is confidently hoped that the bonuses paid to members insured for sickness benefit on their attaining age 65 may be maintained during the next quinquennium. Prospectus and all further information may be had on application to the Secretary, Mr. Bertram Sutton, 33, Chancery Lane, W.C.