

from one another. Still the compact tissue of the extremity of the fragments is red; if we detach the periosteum for a certain distance above and below, we find the compact tissue pink and its vascular canaliculi enlarged. We have then here the anatomical characteristics of non-suppurating osteitis of the compact tissue. I give the name *plastic* to that osteitis under the influence of which the exudation destined to repair is poured out, by opposition to the osteitis in which there is formation of pus with or without a concomitant reparatory process.

The anatomical modifications of this period in a fracture set end to end may then be resumed in this: periosteum thick, fibro-cartilaginous, with beginning of ossification; marrow dense, fibro-cellular, soon becoming cartilaginous, but without bony deposit; no sign of interfragmentary callus; osteitis on the surface and in the thickness of the compact tissue of the fragments. In a word, repair by means of the periosteum and the muscles more advanced than repair by the other tissues.

II. We have now to see what has taken place in this second period (from the eighth to the fifteenth day) in overriding fractures. You still find here the fibro-cartilaginous condition of the periosteum and the deep muscular layer, with beginning of ossification. But as the periosteal capsule is incomplete that part of the work of repair which is performed by this capsule is necessarily less solid than in the preceding case. As to the marrow, it is grayish and thick as when the fragments are end to end; but that of the upper and that of the lower fragments no longer correspond on account of the overriding; consequently this thickening of the medullary substance does not help the consolidation. But between the fragments there is a fibro-cellular, partly cartilaginous substance which aids in keeping them together. This is the beginning of an interfragmentary callus. But it is furnished exclusively neither by the marrow nor by the compact tissue; it evidently has its origin in all the surfaces which are brought into contact with one another by the overlapping. Such are the outer face of the periosteum and a part of the compact edge of the fragments. There, in a word, we must not seek circular repair in the periosteum nor in the interfragmentary compact tissue, still less in the marrow which contributes nothing to it since its two divided surfaces are removed from one another. A mixed lateral interfragmentary callus is produced, the materials of which are formed by the muscles and by the outer surface of the periosteum, without its being possible to prove that this latter is thickened and transformed, and without our being able to admit anything else than the effusion from it, as well as from the surrounding cellular and muscular tissues, of plastic juices which are ultimately transformed. But we must not expect to find regularity of the phenomena which we observed in the end-to-end fractures, and which the authors have erroneously indicated as occurring indiscriminately in all fractures.

3d period.—During the third period, which lasts from the fortieth to the sixtieth day, new anatomical modifications ensue in the fibro-cartilaginous substance which was formed during the second. The

most important is the formation of the bony substance, that is, the deposit of calcareous matter, and the more abundant deposit of osteoplastes or bone corpuscles. As for these latter, we may again ask ourselves if they are the result of a transformation of the cartilaginous cells or of a substitution. This is a point which histological observation has not been able to clear up, and upon which only suppositions are permissible. You know that I lean toward the theory of substitution.

Let us see what observation has taught us concerning the succession of the phenomena in the different portions of the fracture; and here let us distinguish again between an end-to-end and an overlapping fracture. The observations have always been made upon the end-to-end fracture only. They have formed what I show you here upon this guinea-pig's femur, the lesion of which has reached the sixtieth day; a very large external bony ferrule; a bony mass, a sort of internal ferrule, within the medullary canal, but an intermediate substance between the fragments which is not yet quite ossified, and the greater part of which remains fibro-cartilaginous. In other words, you see here what Dupuytren described under the name *provisional callus*, and Miescher under the name *primitive callus*. By these names these authors wished to indicate that the periosteal and medullary portions of the bony callus were destined in great part to disappear by absorption, and that the true callus was formed by what was left of these and by the bony substance which ultimately formed between the fragments. But there was an exaggeration on the part of these surgeons in the expression of their thought in this way, first, that all is not provisional in the periosteal and medullary calluses, since a part is to remain; and secondly that, as I shall presently explain, the theory given by them as a general one, is not applicable to overriding fractures.

I ask you to notice, in passing, upon this human tibia, in which chance has permitted us to study a callus at the sixty-fifth day, that at the level of, above, and below the fracture, which is not an overlapping one, the compact tissue has become very vascular, very dense, and enlarged; that it offers, in short, the characteristics ascribed by Gerdy to condensing osteitis. When I shall study the clinical phenomena of fractures in detail I shall recur to this habitual intervention of hyperostosis after fractures of the long bones. But here, while studying the question anatomically, I am justified in telling you that the work of consolidation of fractures is dependent upon a modification of the vitality of the fragments which we can ascribe to nothing else than osteitis, and that the variety of osteitis which here intervenes is that which Gerdy named *condensing osteitis*. I go even further. In diaphysary fractures of long bones the intervention of this condensing form of osteitis seems to be necessary. When there is lack of consolidation and pseudarthrosis, rarefying osteitis has intervened. Fortunately that is much more rare, and that is why we so rarely see pseudarthrosis follow simple fracture of the shaft of long bones.

Now let us look at overlapping fractures. We have here an

example in the femur of a guinea-pig. I have sawn it longitudinally, and you can see that the new ossification, or, if you prefer, the calcification and production of osteoplastes, have taken place between the two bony surfaces in contact, there where the fibro-cartilaginous callus already existed, but that there is no mention to be made here of a medullary bony callus. It is true that the marrow at the line of the fracture is in great part ossified. But you see that this ossification is of no use to the callus and does not contribute to the consolidation, since that of the upper and that of the lower fragment are not in continuity as they were in the end-to-end fracture.

Nor is there any question of an interfragmentary callus formed by the compact tissue. Consequently, we have no longer to speak of provisional callus and definitive callus. Say, if you please, that the lateral interfragmentary callus is perhaps larger to day than it would have been six or eight months hence. But do not think that Dupuytren's and Miescher's ideas are applicable to cases of this kind, which are the most frequent in man. I have also to point out the same hyperostosis consecutive to the condensing osteitis, as that of which I spoke in end-to-end fractures.

4th period.—For the fourth period, which extends from the sixtieth to the one hundred and twentieth day, and sometimes beyond, I have but few anatomical details to point out: the callus becomes denser and diminishes in size, the medullary canal generally remains filled by the interior ossification, and the shaft of the bone remains a little larger than is normal.

I have further to mention lesions which I can show you only imperfectly in animals, and of which I have at this moment no specimen belonging to man. But we often notice the consequences in the living. I refer to—

- 1st. Obliteration of the veins;
- 2d. Synovitis of neighbouring tendons and articulations;
- 3d. Muscular atrophy.

1st. Obliteration of the large veins near the fracture is quite a common lesion. Are we to explain it by a phlebitis due to the propagation to the interior of the veins of the phlegmasia which arises at the point of fracture, or is it due to simple coagulation of the blood without preceding inflammation of the internal membrane of the veins? The pathological anatomists are still discussing these two theories. As for myself, I hold the first opinion. In most cases, and especially in those in which this lesion occurs in the course of a fracture, I attribute the coagulation of the blood in the veins to a phlebitis by propagation. I even ask myself (but I shall never be able to answer the question by positive facts) if this phlebitis is not due to the passage into the large veins of irritating materials coming from the inflamed marrow or osteomyelitis. But, leaving aside the theoretical question, I point out to you this spontaneous coagulation and the resultant obliteration as the cause of a complication which is not dangerous, but is troublesome and lasts a long time, œdema of the limb about and below the point of fracture.

2d. Synovitis of the tendons and joints is not so frequent in frac-

tures of the shaft as in those of the extremities of the long bones. Nevertheless, after one of the former you often see one of the neighbouring joints inflame and preserve for a long time a more or less painful rigidity, which is explained by the loss of extensibility and of suppleness of the synovial membrane and the connective tissue which lines it. This is particularly common in the knee after fracture of the shaft of the femur, and in the ankle-joint after fracture of the leg.

3d. The muscular atrophy consecutive to fractures which I have studied for several years, and which I made known in a thesis of Dr. Lejeune¹ based upon my lectures at the Hôpital Cochin, and a little later in my work upon *irreducibility and the consecutive deformities of long bones*,² is a phenomenon, if not constant, at least very frequent. We often see examples in living patients. The diminution in size of the limbs, the diminution of strength, are easily recognized. In three guinea-pigs whose muscles I here show you, this lesion is very evident. The muscles of the thigh which was broken a few months ago are a little paler and smaller than those of the opposite side. I weighed the muscles of the thighs of one of the animals and found on the healthy side 142 grains, and on the fractured one 117.

Dr. Lejeune weighed separately the muscles of both limbs of a patient who died at the Hôpital Cochin, and found a notable difference in each one.

According to these results, you may consider it an incontestable fact that the muscles diminish in size after a fracture, and I have ascertained that this diminution is permanent, and not temporary.

I have sought³ for what might be the cause of this slight atrophy, and reached this conclusion, that it should be attributed neither to the compression nor to the immobility, and that it was doubtless due to a change in the distribution of the nutritive materials which is the consequence of the process of consolidation. Not only does the fracture draw towards itself a greater quantity of these materials, but the callus itself, when once formed, and after its completion the hyperostosis, require a greater proportion for their nourishment. This seems to me to be proved by the difference in weight between the fractured and the opposite healthy bone of the same subject. For example, look at these two femurs of a guinea-pig. The right, which was broken forty-three days ago and which is consolidated, weighs 19.8 grains, the left, 15.75 grains. Is it not probable that the right has taken, and would have continued to take, if the animal had lived, more material from the blood, and that consequently there would have been less left for the muscles?

Whatever may be the explanation, the anatomical fact exists and accounts for the persistent weakness so long complained of by patients in limbs which have been broken. I admit that in many patients the diminution of strength is not great, and is scarcely

¹ Lejeune, Thèses de Paris, 1858.

² Gosselin, Mémoire sur l'Irréductibilité et les Déformations consécutives des Os longs. (Gaz. Hebdomadaire de Méd. et de Chirurgie, Paris 1859.)

³ Gosselin, loc. cit.

appreciable. That is because the innervation is not affected, and the muscles receive from the nerves a stimulus sufficient to diminish the physiological results of the atrophy. It is no longer the same when the nerves have been wounded at the same time as the bone. There may then be paralysis as well as atrophy, and the functional troubles are much more marked.

§ 2. PHENOMENA OF CONSOLIDATION IN THE EXTREMITIES OF LONG BONES.

In the extremities of long bones, as in their shafts, we have a first period, called inflammatory, during which the blood and the plastic lymph are effused between the fragments, and at the same time the adjoining connective tissue is swollen for a certain distance above and below the solution of continuity. The beginning of consolidation has not been so well studied here as upon the shaft, for the fractures are so difficult to produce, that experimental study has not been possible, and on the other hand, occasions upon men are rare. We know, however, that the fragments are almost never entirely separated from each other, and that consequently we have not to make a separate study for the end-to-end and for the overlapping fractures. They are almost always end to end, with a more or less marked displacement according to thickness and sometimes according to direction. On the other hand, there is no medullary cavity, and consequently no internal ferrule. The repair is periosteal and interfragmentary, and in this first period, the solution of continuity of the periosteum begins its repair at all the points where its borders are a little separated. But in general the periosteum does not thicken as much as it does on the shaft, and does not form from the beginning this thick ferrule of which we have spoken. No consolidation yet takes place between the fragments; we find there only extravasated blood.

During the second period the new periosteal portion becomes fibro-cartilaginous. At the same time the interfragmentary consolidation commences by the production, probably through the transformation of the exuded lymph, of a fibro-cartilaginous substance. But here several varieties must be pointed out.

In the first, the fragments, composed almost exclusively of cancellous tissue, have not been crushed; they offer neither the reciprocal penetration so well described by M. Voillemier¹ for fracture of the lower extremity of the radius, nor the reduction into small fragments, sometimes into dust, of a portion of this bony tissue which is broken by the mechanism of crushing. In such cases the blood is absorbed, and the fibro-cartilaginous substance, the beginning of the interfragmentary callus, is formed.

In a second variety, which is often found in fractures of the lower extremity of the radius the pieces are in contact, but are reduced by crushing into a certain number of fragments, some of which are very small, almost pulverized. In such cases, especially when there is penetration, the work of consolidation is preceded by the absorption

¹ Voillemier, Clinique Chirurgicale, Paris, 1861.

of a part or of the whole of the fragmentary portions. Nothing in the clinical symptoms indicates this absorption, but as, after fractures long consolidated, we find a shortening which cannot be explained by overriding, and which we can attribute only to this absorption, I presume that it takes place during the first few days at the same time as that of the blood infiltrated between the fragments.

In a third variety, of which the intra-capsular fractures of the neck of the femur and of the humerus give us quite frequent examples, the fragments are in contact but do not penetrate one another; the interposed blood is reabsorbed, and so too is the bone dust. But no intermediate fibro-cartilage is produced, and this absence of the first rudiments of a callus is the indication of non-consolidation which has been pointed out by all the modern authors as frequent in fractures of this kind.

To what cause must we attribute this unfortunate result? It has been claimed to be due to the shortness of the upper fragment, the insufficiency of vessels, and therefore of nutritive materials, in this fragment, and consequently the necessity for the lower fragment to do the whole work of repair, a task which it is unable to perform properly.

I would here say that if this were the only cause, or even the principal one, all fractures of the extremities would be exposed to non-consolidation. Now some of these, those of the lower extremity of the radius for example, consolidate very well.

In those which consolidate rarely I see the intervention of a condition which ought in great part to explain it; I refer to the free communication between the seat of the lesion and the articular cavity, such as exists in intra-capsular fractures of the neck of the femur. I suppose that, as it has been claimed for fractures of the patella, the blood and plastic lymph flow into the articulation, and not enough of the latter remains between the fragments to ultimately produce the fibro-cartilaginous substance.

In the third period, absorption of the pieces goes on if the conditions of the fracture are favourable thereto; the periosteal callus ossifies without becoming thick enough to form a ferrule comparable to that of fracture of the shaft. The interfragmentary callus is completed and assumes a greater and greater importance through the ossification of the fibro-cartilaginous substance, according to the same mechanism, and in the same mysterious conditions which I indicated above. This intermediary callus is often very thick and very resisting, especially at the lower extremity of the radius; but sometimes, and in particular at the neck of the femur, it remains fibrous and more or less dense, almost always dense enough to allow the patient to walk with crutches without inflection or rupture of the callus.

In any case, the capital difference to which I wish to call attention between the callus of the shaft and that of the extremities is that, at the beginning, the former is much more peripheral than interfragmentary; that if it is interfragmentary in overlapping fractures, it is at the same time lateral and periosteal; while the second is interfragmentary in the most rigorous sense of the word, that is, it is formed

in great part or in totality by the spongy tissue through which the solution of continuity was made. And the result of this comparative study is to show that all the constituent parts of the bone, spongy tissue, compact tissue, periosteum, contribute to repair fractures of the bone, that even the layers of muscular tissue and the surrounding cellular tissue contribute also to it, and that, finally, the authors erroneously attributed a much too large part to the periosteum in this reparatory function. Furthermore, the same conclusion will be drawn from the study of the consolidation of simple fractures of flat bones and short bones.

In the fourth period, the patients are tormented by the consequences of articular and tendinous synovites, and so much the more so because these fractures being near a joint or synovial grooves, and often even in communication with them, the inflammation has spread to the latter and left behind it the dryness and stiffness which in the joints, characterize plastic chronic arthritis and dry arthritis. These consequences are so much the more marked and rebellious because the patients affected with these lesions of the extremities are almost always advanced in age, for the predisposing cause of fracture with crushing is rarefaction of the cancellous tissue, rarefaction which, in consequence of inexplicable modifications of nutrition, is a very common consequence of age. Now it is also the case that in old people traumatic arthritis and synovitis, although they do not go on to suppuration, are very slow to end and often pass to that condition of incurability which causes dry arthritis. Finally, muscular atrophy occurs after these fractures as well as after those of the shaft.

§ 3. ANATOMICAL PHENOMENA IN FRACTURES OF THE FLAT BONES AND SHORT BONES.

I have not much to say on this subject; nature uses the same resources in the consolidation of these two kinds of bone as in that of long bones. The muscles, the periosteum, and the whole fractured surface furnish the materials, and the same ulterior modifications of these materials cause the formation of the callus. But in the flat bones, and especially in those which have no diploë, or only a very thin one, the periosteum is the chief agent where it has been preserved, and it must not be forgotten that if it has been divided, which very commonly happens, it begins by repairing itself, and the material which it supplies to the callus comes as much from its cicatricial portion as from that which remained intact about the fracture. Further, no matter how thin the bone may be at the place of fracture, it can still furnish the materials needed for repair. I had occasion, in 1871, to trepan for intra-cranial suppuration following gunshot fracture of the right parietal bone, a young man twenty-four years old, who was employed in the museum of natural history, and had been brought to the ambulance of that establishment after the battle of Buzenval, where he had been wounded. Not only did he survive the operation, but a bony growth formed all around the opening and advanced towards the centre, so that this sort of flattened callus

closed entirely the hole made by the crown of the trepan. Larrey has reported similar cases, in which, as in mine, the calluses were formed during suppurative osteitis, but I wish to mention them here in order to show you once more the power and the multiplicity of means which the organism possesses to repair not only solutions of continuity but also losses of substance in the bone.

LECTURE X.

PHENOMENA OF CONSOLIDATION AFTER COMPOUND SUPPURATING FRACTURES.

1st Variety: Consolidation after benign and superficial suppurating osteitis. 2d Variety: Consolidation after deep osteitis or non-putrid suppurative osteomyelitis. 3d Variety: Death before consolidation by putrid osteomyelitis and purulent infection.

GENTLEMEN: Do not lose sight of a first point which is capital in the history of fractures complicated by wounds; they may get well, exactly like simple fractures, but on one condition, which you should always bear in mind when you are called upon to treat such a case, on condition, I repeat, that the bone does not suppurate.

When the broken bone suppurates, and unfortunately all the efforts which you have made and should have made to prevent it do not always succeed, the clinical and anatomical phenomena of consolidation are peculiarly modified, sometimes hindered by this new complication which I shall study especially in the long bones.

Moreover, we have differences depending upon whether the suppurating osteitis occupies the superficies or the entire thickness of the bone, and according to its greater or less intensity. Let me explain these two points.

1. In a first variety, which I call *benign and superficial suppurating osteitis*, the patient has no general symptoms and consequently no fever. The swelling of the limb is moderate, suppuration is established the fourth or the fifth day in the wound itself. The eschars begin to be eliminated, and if you probe the wound gently, you feel the bone denuded superficially. Suppuration becomes a little more abundant after the eighth or ninth day, but the pus is laudable, not fetid, and the apyrexia continues. Things go on in this way for twenty or thirty days; the suppuration continues rather scanty, with no burrowing of the pus, no indication of a deep collection. Mobility of the fragments begins to diminish; in short, except for the superficial suppuration and denudation, the fracture resembles a simple one that has reached this period. But the denudation continues and the fracture goes on to the sixtieth, sixty-fifth day; about the seventieth