

**POST-TRAUMATIC PAINFUL OSTEOPOROSIS**  
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THE fact that the osseous frame-work of the body undergoes rapid and extensive physico-chemical changes under the influence of the circulatory disturbances that frequently follow traumatization of an extremity, emphasizes that the bones are not inert supporting structures with a fixed and unchangeable constitution, but that they are able to react in exactly the same way as the other tissues of the body.

After an extensive study of the post-traumatic vasomotor syndromes of the extremities, made over a period of many years, Professor Leriche has demonstrated the great importance of one special variety of the syndrome which is characterized by constant severe pain associated with stiffness of the neighboring joint or joints. This variety is relatively common, it causes marked disability and it greatly prolongs the convalescence of the patient. It is our purpose to give a complete study of this post-traumatic painful osteoporosis and to show some of the striking benefits that have been obtained in such cases by operations upon the sympathetic nervous system.

*Historical review.*—In 1900 Sudeck described acute reflex atrophy of bone and established it as a clinical entity. His first report concerned the type of acute atrophy that follows inflammatory processes of the articulations, but later he described a type which he called post-traumatic reflex atrophy of bone. He clearly differentiated between the type following fractures of bones, trauma to articulations, and simple torsion of the joint. He compared the reflex atrophy with the type described previously by Virchow, Charcot, Chambers, and others in relation to certain nervous diseases, especially tabes dorsalis and syringomyelia.

As early as 1877 Wolff described trophic changes in the extremities of adults and disturbances of growth and trophic changes in children following infectious arthritis or resection of a joint. A critical analysis of these cases by Cassirer in 1912 seems to show that the changes observed by Wolff were actually the end-results of bone atrophy.

In 1901 Kienböck added further to the clinical description of the disease entity and he gave an accurate description of the röntgenological changes that are characteristic of it. Both Sudeck and Kienböck showed that inactivity could not account for the severe degree of atrophy, that it appeared much earlier than the atrophy of disuse and that in many cases the atrophy of the bone came on while the extremity was still in use.

Exner (1902) made an accurate gross and microscopic study of the atrophic bones. Nonne (1902) described similar atrophy of bones associated with pathological lesions of the peripheral nerves. Imbert and Gagnière

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(1903) and Destot (1904) also added to the clinical description and röntgenologic picture of this disease. Benkwitz (1906), Ziesche (1907), Bibergeil (1911) and Brandes (1913) reported many interesting clinical studies in Germany, while Bienfait (1907), Delherm (1911), Moreau-Gimelli (1912) and Halipré (1914) made the disease entity known in France. In 1919 Hitschmann and Wachtel described typical cases of osteoporosis following severe frost bites. Dubs (1921) reported extensive osteoporosis following burns, but he emphasized that the extent or severity of the osteoporosis bore no relation to the extent or degree of the burns. Osteoporosis was only initiated by the burns as it continued long after the burns had healed.

Legg (1908) made a study of the atrophy of bone that resulted from infectious arthritis which he produced experimentally. The experimental work of Grey and Carr (1915) and of Allison and Brooks (1921) concerning the atrophy of bone which follows injuries of the large nerves of the extremity, that which occurs after changes in the vascularization of the part, and that type which follows prolonged immobilization, has added much to our knowledge concerning the factors which are responsible for this disturbance.

Turner (1924) reported osteoporosis following Colles' fracture and he pointed out the possibility of sensory nerve involvement. He observed that osteoporosis was more marked on the ulnar side of the hand; consequently he felt that injury of the dorsal interosseus nerve or the dorsal cutaneous branch of the ulnar nerve might have played a part in bringing about the atrophy of the bones.

*Theories concerning etiology.*—In all the recent work there has been no evidence that the disease is of an inflammatory nature as Sudeck originally supposed it to be. Vialleton (1922) failed to find any evidence of cellular infiltration of an inflammatory nature in any of the specimens of porotic bone which he examined histologically.

At the present there are two main hypotheses concerning the etiology of post-traumatic osteoporosis. The first is that the disease is the direct result of the trauma and that the changes in the bone are brought about by reflex action upon the trophicity or the vascularity of the bone. The second theory is that osteoporosis comes on indirectly and that it is due to inactivity or loss of functional stimulation.

Sudeck showed that the atrophy of inactivity was able to reach a very pronounced degree in amputation stumps, but both Sudeck and Kienböck felt that true osteoporosis comes on much more rapidly than could be explained on the basis of inactivity alone.

In 1913 Brandes studied this problem experimentally. He resected the tendon Achilles in order to immobilize the foot and then studied the density of the calcaneus at regular intervals after complete fixation of the foot by a plaster-of-Paris bandage. He showed that the atrophy of inactivity came on very early—just opposite to the findings of Sudeck and Kienböck. Brandes' results were similar to those obtained by Pillet in 1906.

In 1915 Grey and Carr made similar experiments, and they also showed that the atrophy of inactivity came on early. They concluded, however, that the atrophy was due to an absence or deficiency of the necessary functional excitation to the nutrition.

Allison and Brooks (1921) obtained similar results. The röntgenological pictures of the atrophy of bone which they produced in animals by inactivity showed the same characteristics as the atrophy of bone in man. They demonstrated the characteristic changes in the trabeculae of the epiphysis of the bones, and they pointed out that the degree of atrophy was in direct proportion to the length of time of immobilization. The histological structure of the bones of experimentally produced osteoporosis was identical with that found in the porotic bones from man.

Guarini (1918) explained such osteoporosis on the loss of functional activity with the resulting state of anæmia of the member and a deficit in the calcium salts that were being brought to the bone by the blood-stream. The reports of Delorme (1916) concerning the condition of the bones of seven soldiers in whom severe shrapnel wounds necessitated the ligation of the principal artery of one extremity fail to substantiate that theory, since no röntgenological evidence of atrophy of the bones was ever noted in any of these patients. Allison and Brooks were unable to produce atrophy of bone experimentally by ligation of the principal artery of the extremity. Attempts have also been made to produce atrophy of bone experimentally by local venous congestion, but these experiments have also been unsuccessful.

The remaining theory concerning the etiology is that attributed to the lack of functional excitation of the bone. Dauriac (1919) states that the absence of axial thrust is able to bring about a rarefaction about the ends of fractured bones. In extreme cases he states that this rarefaction goes on to the production of a pseudoarthrosis. In final analysis it is difficult to determine the exact nature of this "axial thrust" or "functional excitation."

It is quite probable that trauma of the peri-articular tissues has, in some cases at least, played a definite rôle in the production of the rarefaction which was attributed to the immobilization by the plaster case. It is true that simple immobilization does not always produce an extensive atrophy of the bones so, perhaps, there are still other factors which play a part in bringing about the rarefaction in such instances. Clinically it is well known that extensive osteoporosis frequently comes on in patients whose extremities had never been immobilized.

Osteoporosis is relatively rare after fractures of the diaphysis of bones and quite common after trauma, with or without fracture, of the peri-articular or juxta-articular regions. Marked vasomotor changes of an extremity have been produced experimentally by Albert (1924) and by us (1927) after various kinds of injury to the peri-articular tissues. The fact that osteoporosis is still more frequent after trauma to the poly-articular regions such as the ankle or the wrist, is suggestive evidence that stimulation of the nu-

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merous articular and peri-articular nerves brings about the vasomotor changes that are ultimately responsible for the production of the osteoporosis.

The oscillometric studies made by Professor Leriche in 1917 show that, in man also, peri-articular trauma is followed by a marked vasomotor disturbance in the extremity. Slight trauma to the poly-articular regions usually produces a very marked vaso-dilatation, but it may, on the contrary, produce a vaso-constriction. Leriche and Fontaine (1929) have shown that the traumatization frequently causes a block in the local circulation at the site of the injury. This block of the circulation may be caused either by marked vaso-dilatation or by marked vaso-constriction. It is this difference in the local reaction to the trauma that determines the various clinical pictures of this disease. It is generally thought that osteoporosis appears only after violent trauma, fracture of a bone, or some severe contusion of a joint. However, recent extensive studies have convinced us that marked osteoporosis may follow a very slight trauma to the soft tissues around a joint. The peripheral vascular disturbances associated with spasm of the surrounding muscles which was originally described by Babinski and Froment (1917) as "physiopathic troubles" has recently been shown to give rise to osteoporosis in the great majority of the cases.

In the early stages of osteoporosis there is always a local hypervascularization as shown clinically by the increased local temperature and the increase of the oscillometric index. The phenomena of vaso-constriction are uniformly found in the late stages of the disease. Leriche and Policard have studied the problem in detail, and they have shown that hyperæmia is a necessary factor for the absorption of bone.

We are of the opinion that true osteoporosis is the direct result of the hyperæmia produced by vasomotor changes that result from reflexes which originate in the traumatized area.

*Site and frequency.*—Osteoporosis is most frequently found in the short bones of the hands and feet. Next in order of frequency is the epiphysis of metatarsals, metacarpals and phalanges, and then the epiphysis of long bones. The diaphysis of long bones is rarely involved. The flat bones of the skull may also be the seat of similar rarefaction. Recently Schüller (1929) reported typical examples of post-traumatic osteoporosis of the skull.

Moreau-Gimelli (1912) and Delorme (1917) analyzed a total of 7400 röntgenograms which had been taken because of trauma to one or more of the extremities, and they found only 115 cases (1.5 per cent.) of atrophy of the bones. During the World War, Delorme reported sixty-two cases of osteoporosis from a series of 178 cases of trauma to bones, and later he analyzed 1350 additional röntgenograms of the same type. He concluded from these series of cases that osteoporosis existed in 50 per cent. of the cases where the trauma affected the small bones of the hands or feet; 20 per cent. after trauma to the distal phalanges and 50 per cent. of the cases in which both bones of the leg were fractured. In the cases of fracture of the bones of the forearm he concluded that one-third of the cases of fracture

of one bone and two-thirds of the cases in which both bones were fractured developed true osteoporosis. Guarini (1918) came to the same conclusions after studying a large series of röntgenograms. Such statistics, however, only show the number of cases which showed decalcification of the bones in the röntgenograms, and they do not take into consideration the equally important clinical signs of the disease.

*Clinical forms.*—In order to avoid all confusion with atrophy of inactivity or disuse we shall always refer to the bone atrophy that is associated with pain and vasomotor disturbances as the true osteoporosis. We distinguish four main forms of painful osteoporosis, namely: (a) The post-traumatic form. (b) The post-infectious form. (c) The form associated with nervous disorders. (d) The dystrophic form associated with disturbances of ovarian function.

In this paper we shall limit our discussion to the post-traumatic form. Sudeck differentiated between the reflex atrophy and the atrophy of inactivity, but since that time many investigators have referred to the two forms of bone atrophy as being identical.

True osteoporosis is always characterized by (a) *loss of motor function of the extremity*, (b) *characteristic changes in the röntgenograms*, (c) *the constant coëxistence of vasomotor disturbances*, and (d) *great pain*. The disturbances of the function are always more extensive than could be explained on the basis of the trauma alone, and the severe acute pain is greatly out of proportion with the local signs of injury to the tissues. If we disregard the local effect of the trauma we are still impressed by the great loss of motor function; the extreme constant pain and the marked vasomotor disturbances. Another almost pathognomonic symptom is that the pain is not relieved by immobilization, while the pain associated with simple trauma, fracture of one of the bones, or even tuberculous osteo-arthritis is definitely relieved by proper immobilization.

A very common clinical form of the disease of osteoporosis is frequently seen after fractures of the bones of the wrist or ankle which have been properly reduced. After the removal of the bandage at the end of two or three weeks the extremity is found to be swollen and discolored. Slight active or passive motion of the joint causes the patient great pain. Mechanotherapy, baking and massage make the pain more severe and the loss of function of the extremity continues to become worse. Such a clinical history is typical of true osteoporosis.

From the clinical point of view the extension of the functional disturbances beyond the area of traumatization and accompanied by constant pain which cannot be relieved by immobilization or physiotherapy is indicative of true post-traumatic osteoporosis. When the osteoporosis is limited to the bones of the foot the patient suffers very little pain while he is in bed, but he constantly complains that he is unable to bear weight on his foot because of pain.

*Vasomotor disturbances.*—The vasomotor and trophic disturbances ac-

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companying osteoporosis were described by Sudeck. The association of osteoporosis with cyanosis; subjective and objective sensations of cold; œdema and trophic disturbances such as ulcerations, hyperkeratosis, atrophy of the skin and hypertrichosis; and constant pain have been repeatedly pointed out. Most of our cases have shown marked muscular atrophy, cyanosis of the extremity which is accentuated when the limb is placed in the dependent position, marked œdema and a thinning of the skin with a disappearance of all of the surface markings giving it a "glossy skin" appearance.

When the osteoporosis was limited to the bones of the hand most of our patients showed a hyperthermia of the affected side and occasionally this hyperthermia was very marked. In one case of osteoporosis of the bones of the shoulder the temperature of the dorsum of the hand on the affected side was  $29.5^{\circ}\text{C}$ ., while that of the normal side was  $28.5^{\circ}\text{C}$ . The measurements were made with a sensitive thermo-couple. The temperature of the affected shoulder was  $34.2^{\circ}\text{C}$ . and only  $33.1^{\circ}\text{C}$ . on the normal shoulder. In other cases, however, a slight hypothermia was found.

The oscillometric index is of great value in determining the existence of the vasomotor disturbances. In seven cases of osteoporosis of the bones of the wrist the oscillations were six times stronger in the affected forearm than at the same level in the normal forearm. In one case there was no difference between the two sides. In the upper arm the difference in the oscillations is usually less marked. In many cases where a definite difference in the oscillations existed in the forearms there was little or no difference in the upper arms.

Out of six cases of osteoporosis of the bones of the ankle we found a marked increase in the oscillations in the lower third of the affected leg in five cases. The difference in the oscillations in the thighs was always very small. In the other case of osteoporosis of the bones of the ankle the oscillations in the corresponding extremities were about equal.

In six cases of osteoporosis of the bones of the shoulder we found four cases with diminished oscillations in the forearm and arm of the affected side. One case showed a marked increase in the oscillations of both the arm and forearm of the affected side. The other case showed an increase in the forearm and a decrease in the upper arm of the affected side.

In osteoporosis there is always a stage in which there are local signs of vaso-dilatation (hyperæmia and increase in the oscillations). Later in the evolution of the disease these vasomotor disturbances may disappear or become modified in the opposite direction.

*Röntgenological aspects.*—Two main forms of osteoporosis have been described as showing constant and characteristic changes in the röntgenograms. Sudeck named these apparently distinct stages in the evolution of the disease the (a) acute form and (b) the chronic form.

(a) The so-called acute form is characterized by a mottled appearance of the bone due to the irregular rarefied areas in the spongiosa. This mottling is usually most marked in the carpal and tarsal bones and in the heads of the metacarpal and metatarsal bones. In advanced cases the cortex of the small

bones becomes very thin and the outline of the individual bones is frequently lost. The lamellæ fade into one another and produce an ill-defined or homogeneous shadow in the röntgenogram.

(*b*) In the so-called chronic form the trabeculæ of the bone are very fine and sometimes difficult to recognize. The limits of the individual bones again become demonstrable, but there still remains a general loss of calcium salts. The patchy areas of rarefaction are not present. The increased strength of the bone is due to a thickening of the longitudinal lamellæ since the horizontal lamellæ remain very thin.

In cases of osteoporosis of the short bones, especially the carpal and the tarsal bones, we recognize three stages in the evolution of the disease. These three stages are (*a*) the onset; (*b*) the height of the disease; and (*c*) the reorganization. We believe that each of these three stages present characteristic röntgenological changes. The evolution of the disease from the standpoint of röntgenological changes can best be portrayed as follows: In the period of onset, which Sudeck called the acute form of the disease, there is a general mottled appearance of bones in the röntgenogram. The outlines of the bones are still easily discernible. The rarefaction continues to become more marked and more extensive. The irregular areas of rarefaction soon disappear and the bones become uniformly permeable to the Röntgen-rays. This stage of diffuse and marked decalcification marks the height of the disease. The absorption of the bone seems to spread to the neighboring bones and thus involves the heads of the metacarpals or metatarsals, then the phalanges and finally the adjoining ends of the radius and ulna or the tibia and fibula as the case may be. Marked thinning of the cortex of the bones has taken place and longitudinal streaks have made their appearance in the thinned cortex. In the region of the carpal and tarsal bones this thinning of the cortex of the bones results in the disappearance of the limits of the bones and thus transforms the entire area into a homogeneous mass which is very permeable to the Röntgen-rays. It is at this stage that a diagnosis of tuberculous osteo-arthritis is frequently made. During the period of reconstruction there is a slow reappearance of the calcium in the bones. In most cases complete recalcification never takes place. Röntgenograms taken during this stage show that the limits of the small bones have again become visible and the longitudinal lamellæ have become thickened.

The duration of each of these stages is very variable. The factor of time seems to be of little importance. In general, however, the first two stages are relatively rapid in their evolution, while the third or reconstructive stage is usually extremely slow. Professor Leriche has observed one case in which the rarefaction of the bones of the foot persisted for more than fourteen years after the initial trauma. (Fig. 1.) It is certain that after a bone becomes rarefied to any great extent it rarely regains its original density; consequently the process of reconstruction must usually be considered as incomplete. Complete anatomical restoration of the density of the bone, however, is not necessary for complete symptomatic relief.

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In cases of osteoporosis of the epiphysis of long bones the first stage of evolution passes rapidly and it is unusual to observe the patient early enough to find the typical mottled appearance of the bones in the röntgenogram. There is usually a marked thinning of the cortex and a diffuse rarefaction of the entire bone demonstrable in the röntgenogram.

Post-traumatic osteoporosis of the flat bones of the skull is rare. We have observed one case in which the mottled appearance of the bones was marked. We have not observed thinning of the cortex of the bones of the skull comparable to that which we have described for the short and long bones of the body.

*Clinical evolution.*—It is commonly thought that osteoporosis is a self-limited disease and that after a few weeks or months recalcification takes place without leaving any deformities. Vialleton and others have expressed such views. Sudeck states that favorable evolution is only occasionally seen, and it is not the usual end-result of this disease. Kienböck (1902) and Hofmann (1916) have expressed the same opinion.

It has been our experience that after the disease has reached the climax or stage of complete decalcification, the process of recalcification begins spontaneously. Years later, however, the röntgenograms still show the thinning of the cortex of the bones and the thin lamellæ containing irregular areas of recalcification. From these facts one might get the impression that the disease heals spontaneously since it is also well known that all the vasomotor disturbances and pain frequently disappear without treatment. In the untreated cases, however, the recovery of function of the extremity requires many years and frequently during the stage of recalcification extensive fusion of the carpal or tarsal bones takes place. This ankylosis may cause great economic loss to the patient.

The following case history is presented as a typical example of the end result of osteoporosis of the bones of the foot which was allowed to continue untreated.

CASE I.—A single, white woman, aged thirty-seven years, was seen in consultation by Professor Leriche in July, 1928, because of constant dull, aching pains in the left foot and an inability to bear weight on that foot. In 1914, about fourteen years previously, she "sprained" her left ankle while on a hunting expedition. The injury was apparently not very severe since she continued to walk throughout the day without much discomfort. During the night that followed she complained of moderately severe throbbing pains in the ankle-joint but no attempt was made to immobilize the extremity. She continued to walk about without aid but the pain in the ankle caused her to limp most of the time. For years after the accident she said her ankle remained "sensitive." Slight trauma to the ankle always caused great pain. During the subsequent fourteen years she consulted several physicians and almost invariably she was told she had tuberculous osteo-arthritis of the ankle. No methodic treatment had ever been instituted as she had always refused the proposed surgical form of treatment.

Physical examination in 1928 showed the patient in good general health. Local examination of the feet showed no evidence of vasomotor disturbances. There was a slight swelling of the left ankle with some tenderness to pressure over the tarsus-



metatarsal joints. There was a subastragaloid ankylosis with the left foot in the talipes equinus position. Röntgenograms showed a diffuse rarefaction of all the small bones of the left foot. There was a fusion of the calcaneus and the cuboid; and between the scaphoid and the cuneiform bones. (Fig. 1.)

In this patient the osteoporosis of the bones of the foot evolved over a period of fourteen years and without ever having had the foot immobilized. During the entire time the patient suffered almost continuous pain and she was considerably incapacitated. Examples of this type are not rare. The knowledge of the slow evolution of osteoporosis

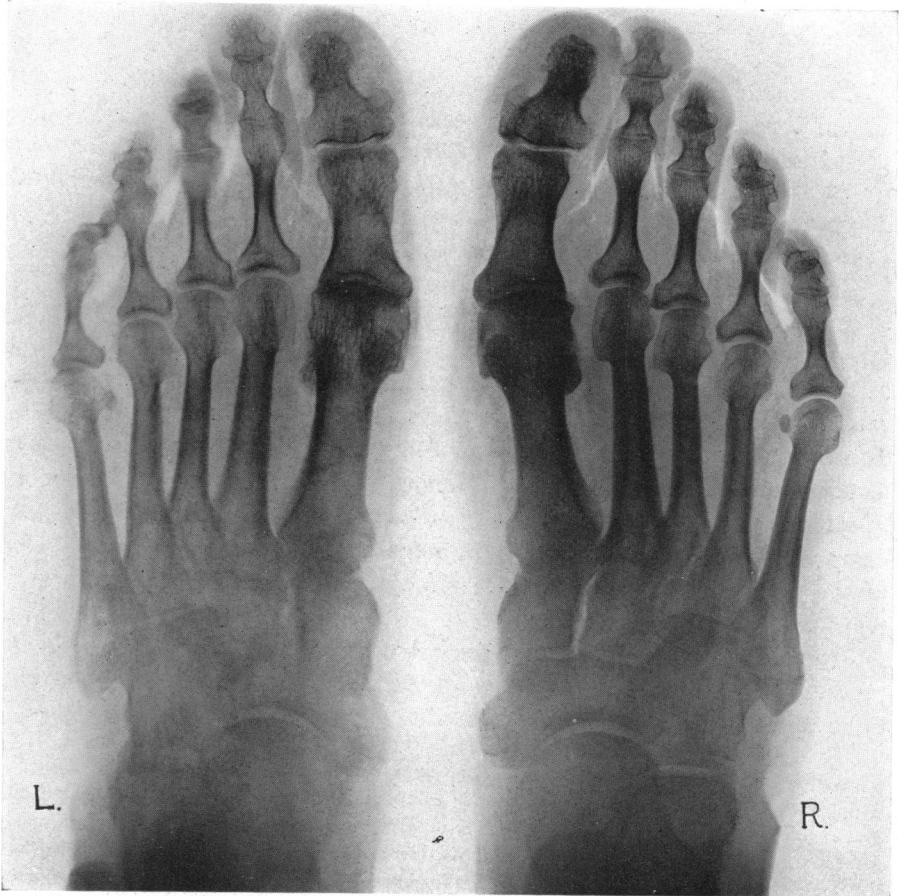


FIG. 1.—Röntgenogram showing post-traumatic osteoporosis which had evolved over a period of fourteen years. (Case 1.) Destruction of the joint surfaces between the tarsal bones and between the tarsal and metatarsal bones can be seen.

and the extensive ankylosis that frequently results should constitute an added indication for the prompt and thorough treatment of this disease.

*Diagnosis.*—In general painful osteoporosis can be divided into three main clinical groups depending upon the type of trauma which precipitated the disturbance. The differential diagnosis is somewhat different in each of these groups since the clinical course of the disease is frequently altered by the in-

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tensity of the trauma and the extent of the injury to the bones or to the articulations.

In the case of osteoporosis which follows slight or moderate trauma to one of the poly-articular regions, wrist or ankle, little importance is usually attached to the original trauma. Gradually, over a period of weeks, the patient develops pain on moving the extremity and vasomotor disturbances of the entire extremity slowly make their appearance. Limitation of motion in the neighboring joints then becomes the outstanding symptom. The functional disability increases in severity and the pain is made worse by immobilization of the affected part. The differential diagnosis between osteoporosis and tuberculous osteo-arthritis must then be made. The röntgenological evidence of a diffuse decalcification without the slightest evidence of a specific focus is against a diagnosis of tuberculosis. However, the great majority of our cases had had a diagnosis, at one time or another, of tuberculous osteitis or arthritis.

In the second group, namely those in which the injury of the articular or peri-articular tissues is associated with a fracture of one or more of the bones of that extremity, the trauma is immediately considered as the major cause for the pain and local vasomotor changes. Since such injuries are regularly treated by complete immobilization in splints or plaster-of-Paris cases one must always consider the possibility of atrophy of inactivity. Whenever an extremity continues to show evidence of vasomotor disturbances associated with limitation of motion and pain in the neighboring or involved joints after the proper reduction of the fracture the most probable cause for such a disturbance is a diffuse osteoporosis and röntgenograms should be taken at once to establish the correct diagnosis.

In the third group, namely those in which the trauma is slight and limited to the soft parts around the joint one must rule out the possibility of a low-grade myositis or chronic teno-synovitis as the cause for the constant pain since spasm of the muscles of the extremity, slight tenderness of the muscles or tenderness in the region of the joint may be the only physical evidence of disease. In cases of osteoporosis the patient complains of great pain on motion of the extremity. The röntgenogram may confirm the diagnosis for osteoporosis in this stage of evolution shows a very definite diffuse mottling of the bones of the extremity. In this type of case the vasomotor disturbances are very slight if present at all. We believe this mild form of osteoporosis should be treated in the same manner as the more severe forms of this disease.

*Pathology.*—Gross examination of the porotic bones show them to have a very thin, brittle cortex and a medulla that is almost completely replaced by adipose tissue. In the later stages of the disease the vascularization is markedly reduced.

Comparatively few studies of the microscopic structure of the porotic bones have been made. Vialleton (1922) has reported histological examinations of the bones in two cases of osteoporosis. He examined the metatarsals

and the astragalus and found a disappearance of all the transverse striæ of the bones with a diminution of the longitudinal striæ (lamellæ). The atrophy was not uniform. In very late cases only a few dense, irregular acellular areas remain within the large medullary spaces. The Haversian canals become greatly enlarged without causing corrosion of the lacunæ. The cortex becomes very thin and the vessels undergo marked thickening which results in a diminished vascularization of the bone.

The mechanism of this absorption of bone has been described by Volkmann as being brought about in two different ways. First, removal by the so-called osteoclasts and, secondly, by the process of halisteresis or osteolysis of Kilian.

The first method of osteoclasia is dependent upon the phagocytic action of special cells called "osteoclasts" by Kölliker. In the cases examined by Vialleton and in our own cases, these specific phagocytes were not seen in any of the preparations which were examined.

The second method of osteolysis is based on the discovery that the disappearance of osseous tissue may take place without the apparent intervention of cellular elements. The progressive diminution of the spongy medullary bone; the enlargement of the Haversian canals; and the thinning of the cortex of bones without the presence of osteoclasts seems, to us at least, to represent more accurately the mechanism of the production of osteoporosis.

The exact chemical phenomena which bring about this disappearance of osseous tissue are still unknown. Professor Leriche has presented the various theories regarding the resorption of bone in his recent work on the normal and pathological physiology of bone which was done in corroboration with Professor Policard. The chemical examinations made by Pech (1920) and Pradal (1921) show that the mineral content of porotic bone is relatively the same as that of normal bone; consequently they conclude that there is a uniform loss of bony substance in osteoporosis and not merely a depletion of the mineral salts of the bones.

From the standpoint of the pathological picture it has been shown by Grynfeldt (1921) and again by Vialleton (1922) that the "fatty osteoporosis" described by Cornil and Ranvier is identical with the post-traumatic osteoporosis.

*Treatment.*—The treatment of osteoporosis has, until recently, been symptomatic and preventative rather than curative in nature. Sudeck recommended minimum immobilization and then active movement in most of his cases. Nobel and Hauser (1926) recommended heat to the point of tolerance either in the form of radiant heat or paraffin baths. They also advised massage and voluntary motion of the joints in spite of a little pain, but they emphasized that forceful manipulation under anæsthesia was definitely contra-indicated. Any form of fixation with plaster-of-Paris casts or orthopædic apparatus causes increased pain to the patient. Delorme recommended treatment by thyroid and para-thyroid extracts and Pech advised heliotherapy.

All of these forms of therapy still left much to be desired. The course of

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the disease was only slightly shortened and the unfavorable sequelæ were about as frequent as when the process was left untreated.

In 1924 Heyman performed the first peri-arterial sympathectomy for osteoporosis. About the same time Professor Leriche also performed a peri-arterial sympathectomy as the surgical treatment of osteoporosis. The therapeutic result was striking.

It is difficult to explain the mechanism by which this improvement is brought about since the operation of sympathectomy should be contra-indicated in a disease which is caused by hypervascularity of the extremity. The sympathectomy produces an added vasodilatation and hyperæmia. The clinical fact remains, however, that improvement can be obtained equally well in cases of osteoporosis with vaso-dilatation as well as those with vaso-constriction as the dominant clinical sign.

Since 1924 all cases of osteoporosis admitted to the clinic of Professor Leriche have been treated by sympathectomy and the results have been so gratifying that we feel that the method with our complete results is worthy of being placed on record.

REPORT OF CASES.—The first two cases of this series are especially interesting because we had an opportunity of studying the histological changes that took place in the protic bone after the sympathectomy.

CASE II.—G. M., married, white, farmer, aged fifty-seven years, was admitted to hospital August 21, 1929, because of a swollen, painful, discolored right hand. All the joints of the right hand were stiff. The past history showed that on April 29, 1929, a cow stepped on the patient's hand. The hand became swollen and remained so in spite of vigorous medical treatment. After a few weeks the joints of the hand became stiff and a constant dull pain in the hand and wrist made its appearance. Vasomotor disturbances in the form of cyanosis and more œdema gradually came on over the entire right hand and wrist. There was an average difference of one centimetre between the circumference of corresponding fingers on the two hands. The affected hand was two centimetres greater in circumference than the normal hand. Slight motion of the thumb remained while all the other joints of the right hand were immovable. There was no evidence of fractures in any of the bones in the röntgenogram but there was a marked diffuse, irregular or patchy decalcification of the bones. (Fig. 2.) Oscillations were increased in the right forearm.

On August 23, 1929, the stellate (cervico-thoracic sympathetic ganglion) together with the intermediate ganglion of the right side were removed. Examination made several hours after the operation showed that the œdema had completely disappeared, the hand was very warm and the skin was of the normal pink color. The movements of the fingers were free and the motion was not painful. Moderate motion of the wrist. Examination on the following day showed some diminution of the movements of the fingers and wrist. During the next two days the cyanosis returned and the movements of the fingers again became limited; consequently on August 27 a peri-arterial sympathectomy of the right brachial artery was performed. This operation was followed by a return of the movements of the fingers associated with moderate hyperæmia of the entire hand and arm. The following day the patient developed an acute alcoholic psychosis and had to be transferred to the psychopathic ward. He died in acute delirium tremens about three weeks later.

At autopsy several of the carpal bones were removed from each wrist for histological examination. There were gross and microscopic changes in the bones from the right

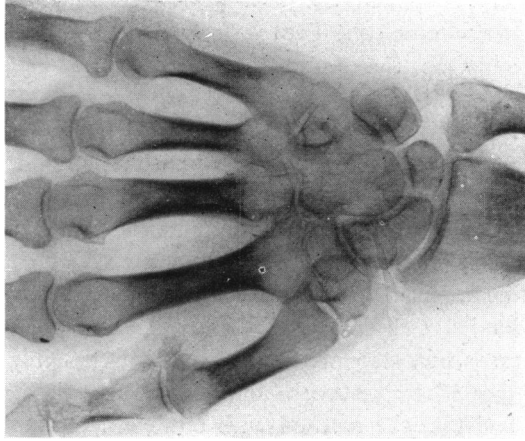


FIG. 4.



FIG. 3.

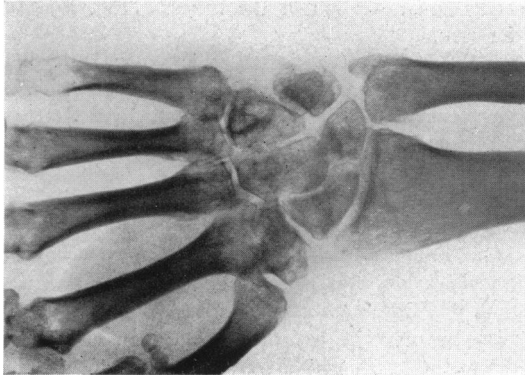


FIG. 2.

FIG. 2.—Röntgenogram taken four months after an injury of the right hand. The patchy decalcification of the bones is characteristic of the early stage in the evolution of post-traumatic osteoporosis. (Case II.)  
FIG. 3.—Photomicrograph showing the histological structure of the carpal bones during the stage when the patchy decalcification is so marked as in Fig. 2. (Case II.) (X 200.)  
FIG. 4.—Röntgenogram taken six months after an extensive injury to the right shoulder. The diffuse and uniform decalcification is characteristic of the fully developed post-traumatic osteoporosis. (Case III.)

## POST-TRAUMATIC OSTEOPOROSIS

hand. The lamellæ were fairly thick. (Fig. 3.) Osteoblasts were present along the lamellæ. A few osteoclasts were found in small lacunæ in the lamellæ. Evidences of construction of bone seemed to dominate the picture. The bone marrow was very fatty and poor in myelogenous elements. Very thin-walled blood vessels were grouped around the masses of myeloid tissue. There were several islands of fibrous tissue between the lamellæ and separated from the bone by a layer of osteoblasts. It is, of course, impossible to directly attribute all of these changes toward the construction of bone to the sympathectomy. The circumstantial evidence is striking and it remains for us to carry out similar studies on a large series of cases in order to determine the exact changes brought about by the sympathectomy.

CASE III.—O. K., married, white, laborer, aged fifty-seven years, was admitted to the hospital January 15, 1930, because of a swollen, painful and discolored right hand. His past history showed that on October 31, 1929, during the course of his work, he received a severe blow on the right shoulder. Fracture of the right scapula, clavicle and several ribs resulted from that trauma. About three weeks after the accident he noticed a burning sensation in the fourth and fifth fingers of the right hand. These pains were relieved by immersing the hand in cold water. The pains gradually spread to the entire right hand, forearm and shoulder. At the same time there developed stiffness of all the joints of that extremity.

Physical examination showed a slight Claude Bernard-Horner syndrome on the right side. Moderate atrophy of the muscles of the right arm. The right hand and forearm were cyanotic and oedematous. The skin of the hand was smooth and shiny. Slight increase in the local skin temperature of the right hand. Manipulation of the slightest degree of the hand or arm caused severe pains in the entire arm and shoulder. All movements of the extremity were markedly restricted. Only slight abduction of the right shoulder was possible. Complete extension of the right elbow was impossible and motion, active or passive, of the elbow-joint was very painful to the patient. Slight flexion and extension of the wrist. Pronation and supination greatly limited. Slight movements of the fingers were possible but painful. The oscillations as recorded by the Pachon oscillometer were much greater in the right than in the left forearm. Röntgenograms showed well-consolidated fractures of the right clavicle and scapula. There was a marked decalcification of the head of the humerus; of the epiphyses of the bones in the region of the elbow; and of both bones of the forearm. The rarefaction of the carpal and metacarpal bones was still more marked. (Fig. 4.)

January 18, 1930, Professor Leriche attempted to perform a resection of the stellate ganglion and the inferior part of the cervical sympathetic chain. There was an extensive sclerosis of the tissues at the base of the neck which was probably the result of the organization of an old and extensive hæmatoma. The vertebral artery was identified but it was found impossible to dissect out and identify either the sympathetic chain or the stellate ganglion. A small mass of tissue was removed from behind the vertebral artery. Histologically this tissue showed some nerve fibres with ganglion cells imbedded in a mass of dense fibrous tissue. Because of the incompleteness of this operation Professor Leriche performed a peri-arterial sympathectomy of the right brachial artery on January 21, 1930.

After the second sympathectomy the pain in the hand and elbow disappeared but the pain in the shoulder remained unchanged. The mobility of the fingers and wrist was greatly improved but the limitation of motion in the shoulder-joint remained the same.

Since the pain persisted in the right shoulder Professor Leriche felt that it was advisable to attempt the removal of the superior part of the dorsal sympathetic chain on the right side. The posterior approach was used and the second rib and part of the first rib were removed. The same dense fibrous tissue was found in the region of the dorsal sympathetic chain. It was impossible to identify the individual ganglia; consequently only section of the sympathetic chain could be done with any degree of accuracy.

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Histologically the tissue which was removed showed many nerve fibres and a few scattered ganglion cells imbedded in dense fibrous tissue.

Following this operation there was considerable improvement in the mobility of the shoulder-joint and a diminution of the pain in the shoulder and in the upper arm. At the time of discharge from the hospital on April 23, 1930, there was fairly good motion of the fingers and elbow but only slight motion in the shoulder-joint. The patient still complained of moderate pain in the right shoulder and upper arm.

In July, 1930, the patient returned to the hospital because of a bilateral empyema which had apparently come on after a severe upper respiratory infection. Surgical drainage was instituted, but the patient continued to become worse and finally died.

At autopsy a bilateral confluent broncho-pneumonia was found in addition to the extensive subacute empyema. We were especially interested in the condition of the

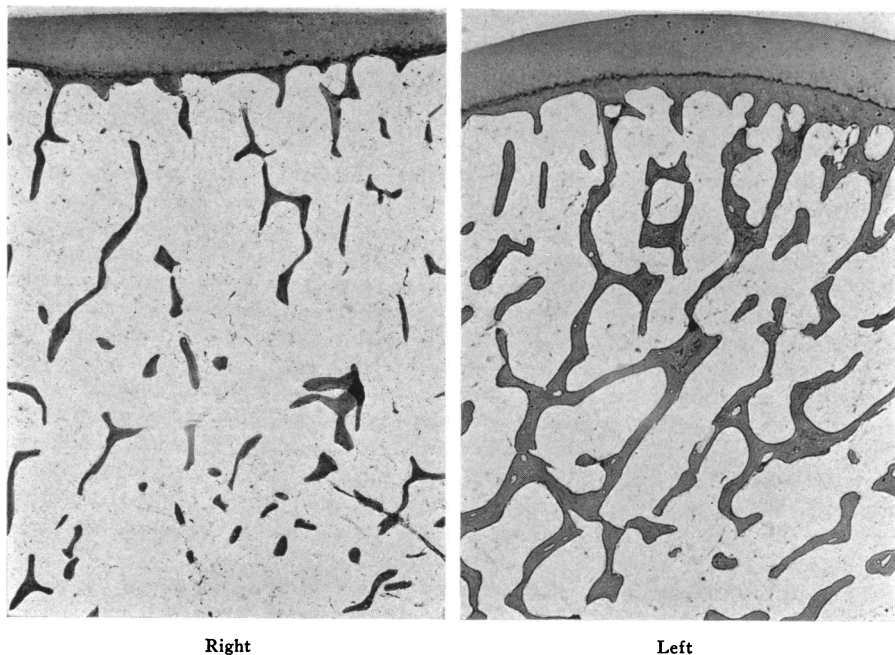


FIG. 5.—Photomicrographs showing the difference in the histological structure of a carpal bone from the right hand, in which there was röntgenological evidence of fully developed osteoporosis, and the histological structure of the corresponding carpal bone from the opposite hand. (Case III.) Compare with Fig. 3. (x 100.)

bones in the right arm and hand; consequently the head of the humerus and several carpal bones were removed from each side for histological study. The bones of the right hand showed extensive and marked osteoporosis. The histological preparations showed fewer and thinner bony lamellæ in the bones of the right hand. (Fig. 5.) The bone marrow was almost entirely made up of adipose tissue. There was no evidence of hypervascularization in this case probably because this was a late stage of the disease. The process of osteoporosis in this case appeared to be one of pure osteolysis. Very little evidence of repair was found in any of the preparations which we examined. The lack of signs of reconstruction of bone might be attributed to the fact that complete sympathectomy was impossible due to the extensive sclerosis in the region of the sympathetic ganglia.

*Osteoporosis of the bones of the hand and wrist following simple trauma*

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to the peri-articular or juxta-articular tissues. In this series of cases the trauma was not severe enough to cause a fracture of any of the bones.

CASE IV.—J. F., single, white, laborer, aged seventeen years, entered the hospital November 11, 1924, because of a painful swelling of his left hand with marked limitation of motion in the wrist-joint. The past history showed that during the six months prior to admission he had noticed that his left arm became fatigued after slight exertion. Two weeks before admission to the hospital he was suddenly taken with a severe pain in his left wrist while he was attempting to lift a block of iron. Motion of the wrist remained painful and he noticed moderate swelling of the dorsum of his hand.

Examination at the time of entry to the hospital showed a marked œdema of the entire left hand with almost complete fixation of the wrist-joint. There was marked

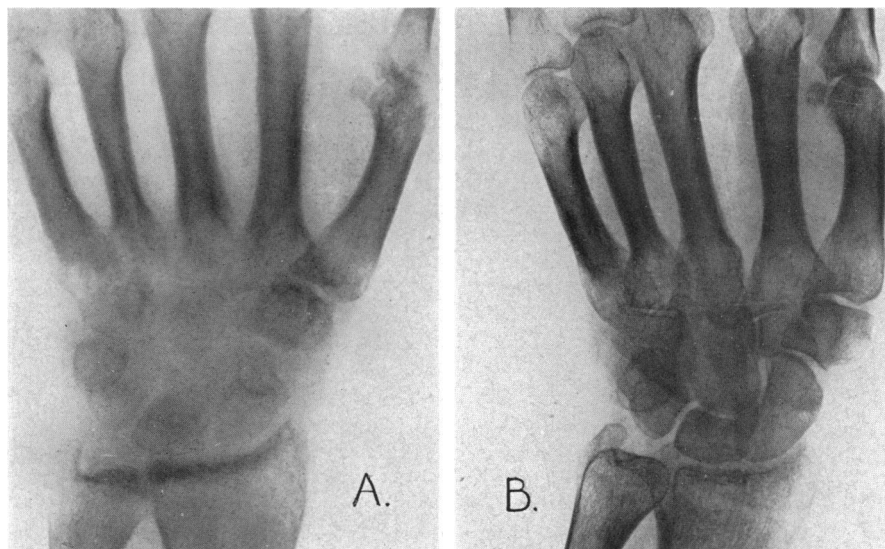


FIG. 6.—Röntgenograms showing the condition of the carpal bones before and after peri-arterial sympathectomy in a case of diffuse post-traumatic osteoporosis. (Case IV.)

A—One month after injury of the left hand.

B—Two and one-half months after the sympathectomy.

tenderness of the carpal bones to light palpation. There was a pronounced atrophy of all the muscles of the forearm. The röntgenogram showed an irregular rarefaction of all of the carpal bones causing a loss of the outline of some of the carpal bones. (Fig. 6A.) A diagnosis of tuberculous osteo-arthritis was made and the extremity was immobilized in a plaster-of-Paris case. This fixation made the pain and swelling so much greater that the case had to be removed. In December, 1924, Professor Leriche examined the patient and found that there was an increase in the vascularization of the left forearm and hand. The oscillations were greater in the left forearm than in the right. (Fig. 7.) After these examinations he felt that the entire clinical picture together with the röntgenological findings was characteristic of post-traumatic osteoporosis.

December 10, 1924, a peri-arterial sympathectomy of the left brachial artery was performed. A plaster case was then applied to the forearm. The pain disappeared soon after the operation. December 25 the case was removed and the patient was able to move his wrist freely without pain. The œdema had also disappeared. A new plaster-of-Paris case was applied and the patient was discharged from the hospital. A short time later the patient removed the case without consulting his family physician.

Follow-up examination of February 20, 1925, showed him to be entirely free from



pain or swelling of the wrist. The movements of the left wrist were normal. The atrophy of the muscles of the left forearm remained unchanged. Röntgenogram taken February 23 showed considerable recalcification of all of the carpal bones of the left

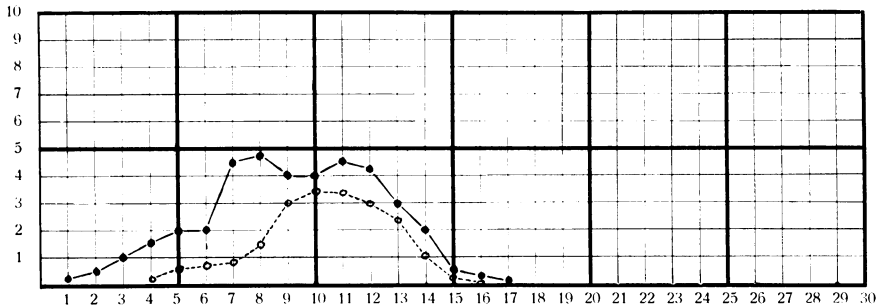


FIG. 7.—Comparison of the oscillometric readings from the forearms. (Case IV.) Readings from the left forearm are represented by a solid line while those from the right forearm are shown by the interrupted line.

wrist. (Fig. 6B.) April 20 he reported that he had been working regularly without the slightest pain or feeling of fatigue in his left arm or hand. He enlisted in the French Marine Corps April 25, 1925. In March, 1928, he reported that he was well and had no trouble with his arm or wrist.

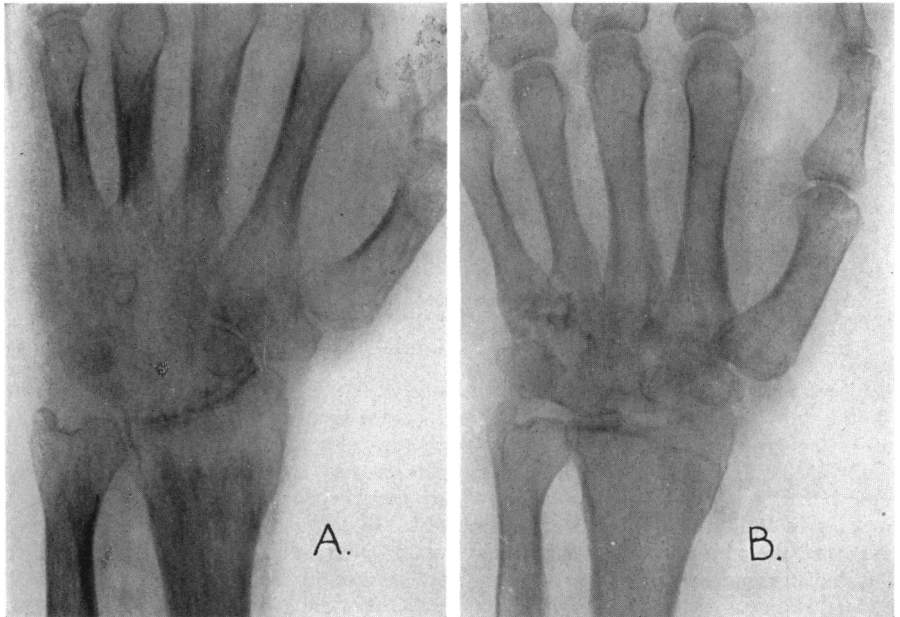


FIG. 8.—Röntgenograms showing unfavorable evolution of the osteoporosis in spite of sympathectomy. Complete ankylosis of the wrist-joint with only partial recalcification of the bones was the ultimate result. (Case V.)

A—Marked osteoporosis six months after the trauma.

B—Ultimate anatomical result five years after the trauma.

CASE V.—F. W., married, white, laborer, aged forty-seven years, entered the hospital September 11, 1924, because of painful swelling of his left hand. The past history showed that June 2, 1924, he slipped and struck his left hand against a wagon.

## POST-TRAUMATIC OSTEOPOROSIS

Immediately after this accident he began to have severe pains in the left wrist and hand. Swelling of the hand gradually came on and within two days all motion in the wrist-joint was lost. Rest, massage and hot baths failed to give relief from the pain.

On admission to the hospital about three months after the accident there was marked swelling of the wrist and cyanosis of the forearm and hand. Only slight flexion and extension of the wrist was possible. Motion of the wrist-joint was painful. Movements of the fingers were limited and the muscles of the forearm and arm were atrophied. Röntgenogram showed marked decalcification of all the bones of the left hand. The limits of the individual carpal bones could no longer be made out. (Fig. 8A.) A diagnosis of tuberculous arthritis was made and on September 24, 1924, the arm was immobilized in a plaster-of-Paris case. This immobilization made the pain much worse; consequently the case was removed. Oscillations were increased in the left forearm. (Fig. 9.) Professor Leriche was asked to see the patient. After a complete examination he felt that the clinical findings together with the röntgenological changes in the bones were typical of post-traumatic osteoporosis and he, therefore, advised a peri-arterial sympathectomy as the treatment.

November 21, 1924, a peri-arterial sympathectomy of the left brachial artery was performed. There was a marked diminution of the swelling within the first forty-eight hours after the operation. The pain on motion of the wrist disappeared. December 9,

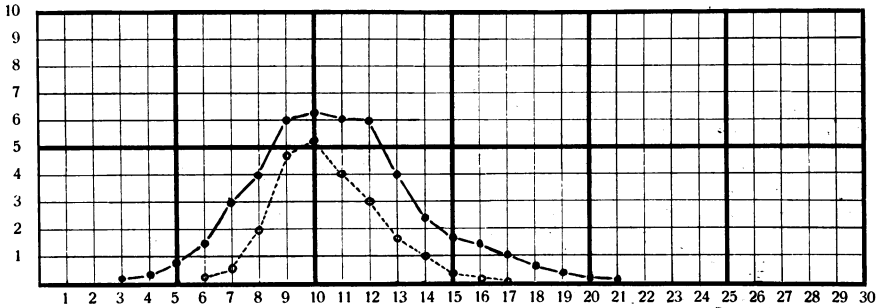


FIG. 9.—Curves showing the oscillometric readings in the right and left forearms. (Case V.) Solid line represents the left forearm.

1924, the movements of the fingers were normal, but the motion of the wrist remained limited. Another plaster-of-Paris case was applied and immobilization was continued for three months longer. At the end of that time the range of motion of the fingers was normal. No improvement in the motion in the wrist-joint. The surface temperature of the left hand was greater than that of the right. Röntgenograms showed that recalcification was taking place slowly but there was also evidence of destruction of several of the carpal bones with extensive fusion of the bones of the wrist. (Fig. 8B.) The patient was seen at fairly regular intervals over a period of more than five years after the operation. The motion of the fingers remained normal. No œdema of the hand, vasomotor disturbances of the extremity nor pain on motion of any of the joints had ever appeared since the sympathectomy. He has been able to continue his work as a laborer without interruption since the removal of the plaster-of-Paris case three months after the sympathectomy.

CASE VI.—M. MO., married, white, housewife, aged fifty-four years. This patient entered the hospital on January 11, 1928, because of painful swelling of her right wrist. The past history showed that on October 22, 1927, while at work in the fields, she twisted her right wrist. This caused severe pain in the entire right hand associated with numbness of all the fingers. She left her work immediately and in spite of complete rest and hydrotherapy the functional difficulties increased in severity. A short time later she noticed a marked increase in the swelling of the hand with progressive stiffness of the wrist.

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On entrance to the surgical dispensary (polyclinic) about five weeks after the accident examination showed an atrophy of all of the muscles of the right arm. The right wrist was swollen and deeply cyanotic. Röntgenograms showed a marked decalcification of all the carpal bones with some involvement of the distal ends of the radius and ulna and the proximal ends of the metacarpals. There was a loss of the inter-articular spaces between the carpal bones. (Fig. 10A.) A diagnosis of tuberculous arthritis was made and a plaster-of-Paris case was applied to the arm and hand. The immobilization was continued for about six weeks in spite of the fact that the pain was made worse by the plaster bandage.

January 11, 1928, Professor Leriche examined the patient and in view of the circulatory disturbances, changes in the bones as shown by the röntgenograms and the clinical course of the disease he felt that a diagnosis of post-traumatic osteoporosis should be made.

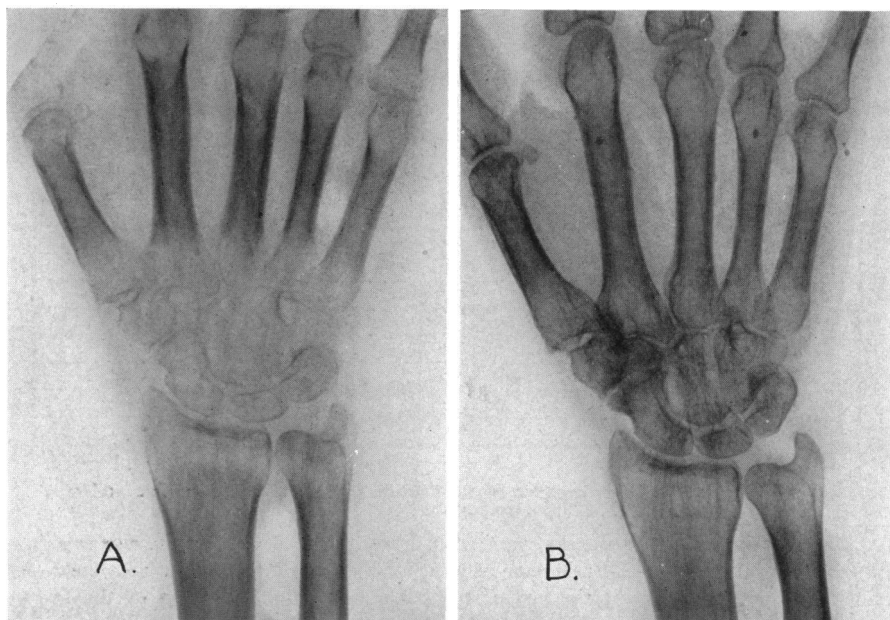


FIG. 10.—Röntgenograms showing the effect of peri-arterial sympathectomy upon post-traumatic osteoporosis which had already reached the height of the disease. (Case VI.) Recalcification has taken place very slowly.

A—Three months after simple torsion of the right wrist.  
B—Two years after peri-arterial sympathectomy.

January 14, 1928, a peri-arterial sympathectomy of the right brachial artery was performed. Immobilization by plaster was continued after the operation. The pain disappeared immediately. Examination after the removal of the plaster on the fifteenth post-operative day showed an absence of the œdema and a marked increase in the motion of the fingers and wrist.

Follow-up examination April 4, 1928 (six months after the sympathectomy) showed only slight limitation of motion of the fingers and wrist. No circulatory disturbances nor œdema present. Considerable recalcification of the bones of the wrist had already taken place. February 26, 1930, twenty-five months after the sympathectomy, examination showed normal range of motion of the fingers and wrist. No pain on movement of the joints and no evidence of circulatory disturbances. Röntgenograms showed more recalcification but the process was still not complete. (Fig. 10B.) This case shows that complete recalcification is not necessary for complete symptomatic relief to the patient.

## POST-TRAUMATIC OSTEOPOROSIS

*Osteoporosis of the bones of the hand* following trauma which was of sufficient intensity to cause a fracture of one or more of the bones in the vicinity of the wrist-point.

CASE VII.—M. E., married, white, housewife, aged fifty-nine years, was referred to the hospital October 1, 1928, because of painful swelling of the right hand and wrist. The past history showed that on July 20, 1928, the patient fell on the outstretched arm causing a typical Colles' fracture. Immediately reduction under anæsthesia put the bones in perfect anatomical position. The entire extremity was immobilized for five weeks. Massage and "electrical treatment" were then instituted. In spite of all treatment the hand remained swollen, discolored and stiff. Röntgenograms showed a diffuse mottling of all the carpal bones with some rarefaction of the distal ends of the radius and ulna and

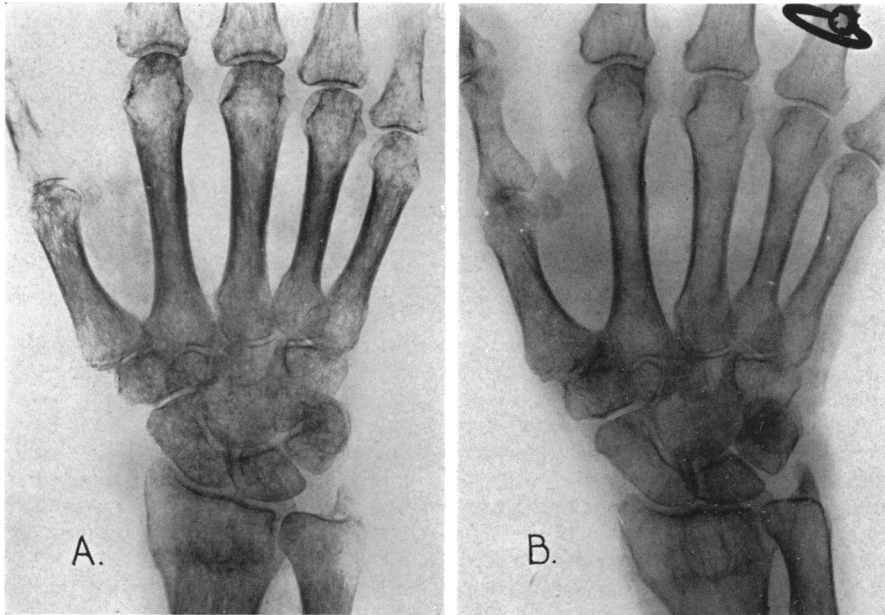


FIG. 11.—Röntgenograms showing the effect of peri-arterial sympathectomy upon post-traumatic osteoporosis which was still in the early stage of evolution. (Case VII.)

A—One month after the Colles' fracture.

B—Two months after the peri-arterial sympathectomy.

moderate mottling in the heads of the metacarpals. (Fig. 11A.) The oscillations were increased in the right forearm.

The patient was referred to Professor Leriche and he performed a peri-arterial sympathectomy of the right subclavian artery October 3, 1928. The post-operative course was uneventful. During the four weeks that followed there was a noticeable increase in range of motion of the fingers. The cyanosis and œdema had disappeared.

Repeated follow-up examinations have shown a constant improvement in the movements of the fingers. Six months after the sympathectomy, examination showed full range of motion of the fingers and the wrist. No pain on motion of any of the joints. She stated that the strength of her right hand was still below normal nevertheless she was able to do all her housework without difficulty or fatigue. Röntgenograms taken at that time showed almost complete recalcification of the bones of the right hand and wrist. (Fig. 11B.)

CASE VIII.—M. T̄e., married, white, housewife, aged sixty-five years, entered the

hospital November 8, 1928, because of severe pain in the right forearm associated with swelling and discoloration of the right hand. September 3, 1928, she had sustained a Colles' fracture (Fig. 12A). Reduction was done under anæsthesia and fair alignment of the fragments was obtained. The first plaster-of-Paris bandage was removed after five days and the hand was put up in abduction and extension. When this case was removed after two weeks it was found that the patient could not move her wrist or her fingers. Pronation and supination of the hand was also impossible. The patient then began to have violent, shooting pains which started in the fourth and fifth fingers and radiated to the elbow. Massage, "electrical treatments," and the application of moist heat failed to give any relief. This loss of function could not be explained on the basis of a poor reduction of the fractured bones. Slight adduction and abduction of the thumb could be done with difficulty. The entire hand and forearm were cyanotic. There was increased local heat associated with pitting œdema of the dorsum of the right hand. Oscillations were increased in the right forearm (Fig. 13). Röntgenograms showed an extensive osteoporosis of the carpal bones, the radius and ulna and the metacarpal bones. There was a marked thinning of the cortex of all of these bones. (Fig. 12B.)

November 8, 1928, a peri-arterial sympathectomy of the right brachial artery was performed. The fractured bones were manipulated slightly and then immobilized by plaster-of-Paris. The pain disappeared immediately. When the plaster case was changed November 17 the movements of the fingers was found to be much better and the œdema and cyanosis had also disappeared.

Follow-up examination March 17, 1929, over four months after the sympathectomy, showed a normal range of motion in the wrist and in the joints of the fingers. Moderate degree of pronation and supination possible. No pain on motion of any of the joints. Röntgenograms showed that the recalcification of the bones of the hand was taking place slowly. (Fig. 12C.)

CASE IX.—M. R., married, white, housewife, aged forty-one years. This patient entered the hospital November 26, 1927, because of constant severe pains in her right wrist associated with œdema and cyanosis of the hand and forearm. The past history showed that October 1, 1927, she fell down a stairway and fractured the distal end of the right radius. The fracture was reduced immediately. After four weeks of immobilization in plaster-of-Paris the callus did not appear to be very firm; consequently further immobilization by a crinoline bandage was carried out. About one week later the patient began to complain of pain in the right wrist. During the subsequent two weeks the pain gradually increased in severity.

Examination at the time of admission to the hospital showed an enormous swelling of the right hand and forearm. All the joints of the fingers were stiff. Oscillations were increased in the upper third of the right forearm. Surface temperature of the dosum of the right hand was 33.4° C. as compared with 30° C. on the left. Röntgenograms showed the fractured bones to be in good position and well consolidated but there was an extensive osteoporosis of all of the carpal bones.

On November 23, 1927, a peri-arterial sympathectomy of the right brachial artery was performed by Professor Leriche. Immediately after this operation the pain in the wrist disappeared, and the œdema slowly diminished. There was a rapid return of the motion in the wrist and joints of the fingers.

Follow-up examination May 10, 1928, over five months after the sympathectomy, showed that the clinical improvement was lasting. No further pain or œdema and all circulatory disturbances had disappeared. There remained only slight limitation of pronation. Recalcification of the wrist and hand was taking place slowly.

*Osteoporosis of the bones of the hand and wrist* associated with vasomotor disturbances and marked spasm of all of the muscles of that extremity following trauma of slight or moderate intensity.

POST-TRAUMATIC OSTEOPOROSIS

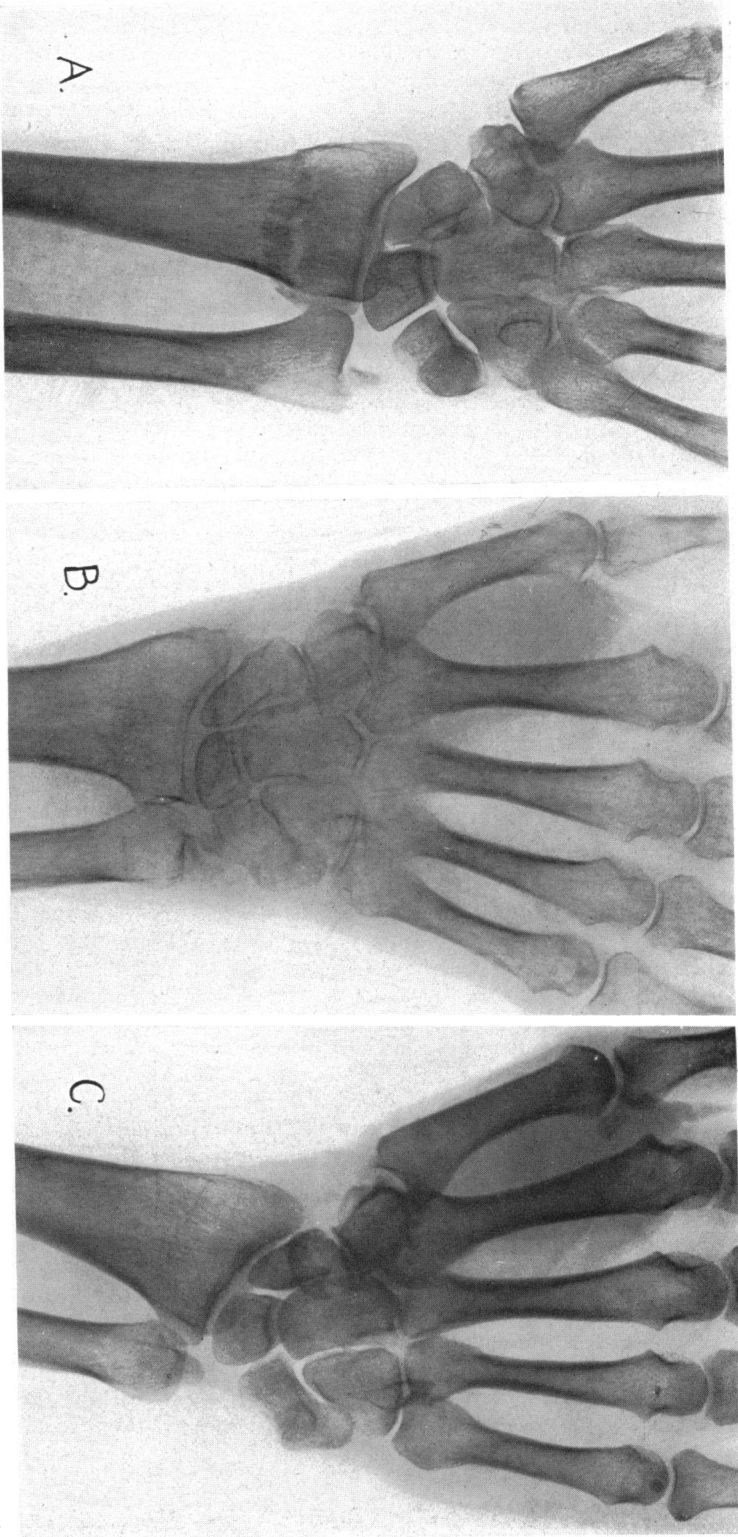


FIG. 12.—Röntgenograms from Case VIII showing the fracture produced by the trauma, the diffuse osteoporosis that developed subsequently, and finally the rapid

recalcification that followed the peri-articular sympathectomy.  
A—Colles' fracture resulting from a fall (September 3, 1928).  
B—Marked osteoporosis of all the bones of the hand two months later.  
C—Recalcification almost complete four months after the sympathectomy.

CASE X.—L. S., married, white, housewife, aged sixty-five years, entered the hospital June 15, 1925, because of stiffness of the left shoulder and elbow-joints associated with attacks of pain in the entire left arm. Five months previously she was knocked down by a bicyclist. The only physical evidence of injury from the fall was a small, superficial wound on the dorsum of the left hand. This wound healed promptly without showing any signs of infection. About one month after the accident she noticed stiffness of the joints of the fingers of the left hand. This stiffness grew progressively worse and soon after there was noticeable stiffness of the wrist-joint, elbow-joint and finally shoulder-joint. The patient then began to complain of sharp pains in the left hand and arm.

At the time of admission to the hospital there was a marked spasm of all of the muscles of the arm and moderate atrophy of the scapular group of muscles. The scapulo-humeral joint was immovable, and attempts at passive motion of the upper arm caused excruciating pain to the patient. Movement of the scapula permitted the arm to be raised a slight amount. Complete extension of the elbow-joint was impossible. The joints of the fingers were so stiff that the patient could not close her hand. Complete neurological examination was normal. Electrical stimulation of the nerves and muscles of the left arm gave normal reactions. Professor Leriche felt that in view of the negative neurological examination and the positive röntgenological evidence of decalcification of the bones of the left arm that a diagnosis of diffuse osteoporosis due to axone reflexes of

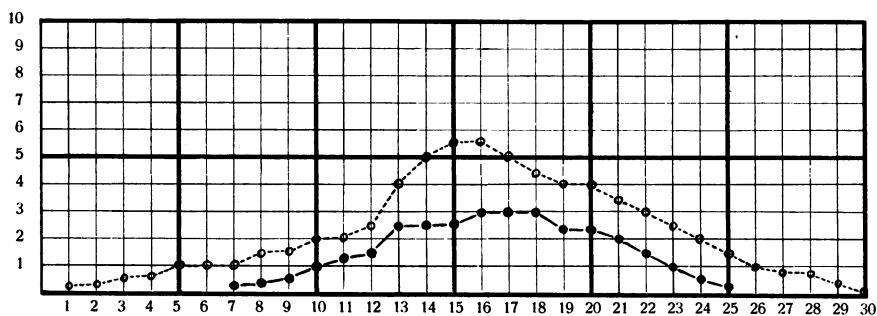


FIG. 13.—Curves showing the oscillometric readings in the right and left forearms. (Case VIII.) Solid line represents the left forearm.

traumatic origin was justifiable. He suggested cervical ramisection as the treatment of choice.

June 19, 1925, Professor Leriche exposed the cervical sympathetic chain through an incision at the base of the neck just above the left clavicle (novocaine anæsthesia). The four rami communicantes of the stellate (cervico-thoracic ganglion) were then isolated, identified and finally sectioned. That evening the constriction of the left pupil and enophthalmos of the left eyes were very marked. The surface temperature of the dorsum of the left hand was 1.9° C. higher than that on the opposite hand. The pain in the arm had disappeared. Movements of the fingers were improved. Increase range of motion in the left elbow-joint. June 28, nine days after the cervical ramisection, complete extension of the forearm was possible without pain. The left hand could be closed. Passive motion of the upper arm produced no pain but the scapulo-humeral joint remained almost completely fixed.

Repeated follow-up examinations showed a constant improvement in the mobility of the shoulder, elbow, wrist and interphalangeal joints. In December, 1930, five and one-half years after the operation, examination showed that the patient had regained the full range of motion in the shoulder-joint. The hand could be closed tightly and she had been free from all pain or discomfort in the left arm. The recovery was complete. Röntgenograms showed considerable recalcification yet all of the bones of the left arm and hand remained less dense than the corresponding bones of the opposite side.

## POST-TRAUMATIC OSTEOPOROSIS

*Osteoporosis of the bones of the foot and ankle* which appeared after simple trauma to the peri-articular or juxta-articular tissues. In this series of cases the trauma was not sufficient to produce a fracture of any of the bones.

CASE XI.—J. Ko., married, white, coal-miner, aged forty-five years, was brought into the hospital November 28, 1925, because of an injury to the left foot. Examination showed an extensive contusion of the left ankle but no physical or röntgenological evidence of fracture of any of the bones. The entire leg was immobilized in a splint and the patient was kept in bed. After three weeks he attempted to bear weight on the left foot. This caused so much pain that it was necessary to immobilize the foot again. The condition of the foot remained about the same and he was unable to walk for many months. He slowly improved sufficiently to bear weight on the foot. He was discharged from the hospital May 10, 1926.

He was unable to return to work because his left leg would become completely fatigued after short walks or after standing for some time. Some time later he began to have dull aching pains in the left ankle and foot. Sometime in September, 1926, he was referred to a private hospital where a peri-arterial sympathectomy of the left formal artery was supposed to have been done. Following this operation the pains in the foot and ankle grew worse and he was finally referred back to the University Hospital.

On the second admission to the surgical clinic on November 20, 1926, he complained of violent pains in the left ankle and radiating along the inner aspect of the leg. Pains were aggravated by walking. The muscles of the left leg were atrophied. There was marked cyanosis of the left foot and leg. Röntgenograms showed an extensive osteoporosis of all the bones of the left foot and ankle.

November 22, 1926, about one year after the original injury, Professor Leriche performed a left lumbar sympathetic ramisection by the extraperitoneal route. An intense hyperæmia of the left leg and foot followed this operation. The pains disappeared immediately. Within a few days the œdema and cyanosis had also disappeared. On the sixteenth post-operative day the patient walked without aid and without pain. Gradual improvement followed and he was discharged from the hospital on the twenty-first post-operative day.

Follow-up examination three months later showed complete return of the movements of the leg and ankle and no pain. Recalcification of the bones of the ankle was almost complete at that time. March 28, 1927, four months after the ramisection, the patient stated that he had no further pain and that he had returned to his regular work in the coal mines.

CASE XII.—G. K., married, white, laborer, aged twenty-seven years, was admitted to the hospital April 13, 1928, because of severe pains in the left ankle associated with marked swelling of the entire foot. On March 21, 1928, he had fallen from a roof and landed on the heel of his left foot. The foot became swollen immediately. Four days later he noticed a "black and blue" discoloration of the skin over the entire left ankle and extending a short distance up the leg. The œdema of the foot slowly diminished but he was unable to bear weight on the foot because of the violent pains in the ankle.

Examination showed moderate œdema of the dorsum of the left foot. The muscles of the left leg were slightly atrophied. Slight limitation of extension of the left foot. Pressure over the tarsal bones and over the heads of the metatarsals caused great pain. Röntgenograms showed marked osteoporosis of tarsal bones and the heads of the metatarsals. Oscillations were strong on both sides.

April 21, 1928, a peri-arterial sympathectomy of the left femoral artery was done. The pain disappeared almost immediately. Follow-up examination about six months later showed that the patient was able to walk normally and without the slightest pain. Röntgenograms showed almost complete recalcification of the bones of the ankle and foot.

CASE XIII.—E. Tr., married, white, laborer, aged twenty-five years, was referred to



the hospital October 8, 1929, because of swelling of the left ankle and an inability to walk because of pain in the left foot. In August, 1929, a beam of wood fell on his left foot. The foot became swollen and painful immediately but he was able to continue his work. About two weeks before admission to the hospital he suddenly noticed sharp pains in the left ankle. That evening on leaving the street-car he twisted his ankle and following this slight accident he was unable to bear weight on that foot. The next morning his foot was greatly swollen and very painful. Medical treatment failed to give relief so he was sent to the hospital.

On admission to the hospital there was marked oedema and cyanosis of the left foot and lower leg. The foot was warm and the oscillations were increased in the left lower leg. Pressure over the third tarso-metatarsal joint was painful. Röntgenograms showed irregular zones of rarefaction in the heads of the third and fourth metatarsal and in the cuneiform bones. A diagnosis of tuberculous osteitis was made and the foot was immobilized in a boot-type plaster-of-Paris case. The pain was not relieved by this immobilization. Rarefaction of the tarsal bones continued until the limits of these bones could no longer be seen. A diagnosis of osteoporosis was finally made.

December 12, 1929, a peri-arterial sympathectomy of the femoral artery was performed. The oedema and cyanosis disappeared very quickly. By the following day all the pain had disappeared. The movements of the toes were free and painless. Röntgenograms taken at the end of January, 1929, showed a moderate amount of recalcification.

Follow-up examination in April, 1930, four months after the sympathectomy, showed no signs of oedema or cyanosis of the left foot. The movements of the ankle were normal and painless and the patient was able to walk normally.

CASE XIV.—C. H., married, housewife, aged thirty-nine years, was admitted to the hospital October 15, 1930, because of pain, swelling and limitation of motion of the right ankle-joint. In June, 1930, she injured her right heel by jumping from a chair to the floor. The ankle became swollen and painful. Röntgenograms failed to show any evidence of fracture of the bones of the ankle or foot. The swelling and tenderness of the ankle persisted; consequently she was referred into the hospital.

On examination there was oedema and cyanosis of the entire right foot. Tenderness over the entire heel of the right foot. Röntgenogram showed a small "spur" of the calcaneus which had formed since the accident. The foot was immobilized for two weeks but no relief from the pain was obtained. In November, 1930, examination showed limitation of the movements of the ankle. Cyanosis was still present. All movements of the foot were painful. Oscillations were strong in both legs and greater in the right thigh than in the left. Röntgenograms taken at this time showed a mottling of all of the bones of the right foot and ankle and a diffuse decalcification of the calcaneus. (Fig. 14A.)

November 15, 1930, a peri-arterial sympathectomy of the right femoral artery was done. Marked hyperthermia of the leg and foot followed that operation. The pain was diminished in intensity but not completely relieved. The patient was able to bear her weight on the foot several days after the operation. On the fifteenth post-operative day she was able to walk unaided but she still complained of pain in the foot. Röntgenograms showed very little evidence of recalcification.

Follow-up examination in April, 1931, showed that the movements of the right foot were normal and the patient walked normally and without pain. Only slight recalcification of the bones has taken place during these five months since the operation. (Fig. 14B.)

CASE XV.—S. W., married, white, housewife, aged twenty-seven years, was admitted to the hospital June 1, 1926, because of severe pains in her right foot. Several months previously she had had a slight trauma to the right ankle but not sufficient to cause any severe pain or inconvenience at the time. Patient denied any history of venereal diseases.

Examination showed moderate oedema of the right ankle and foot with an extreme blanching of the entire distal part of that extremity. Pressure over the tarsal bones caused severe pain. Röntgenograms showed a diffuse osteoporosis of all of the bones of

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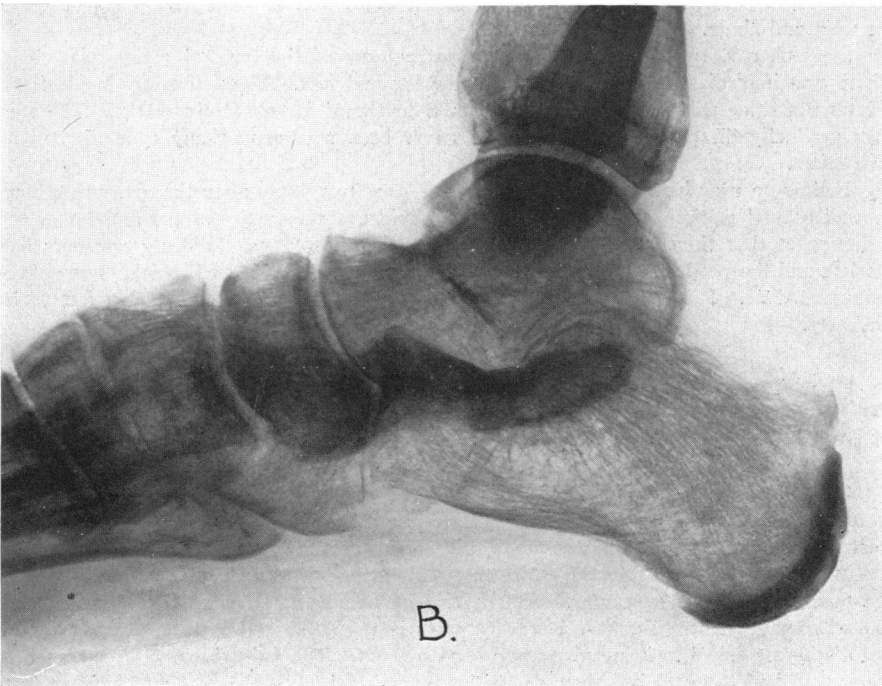
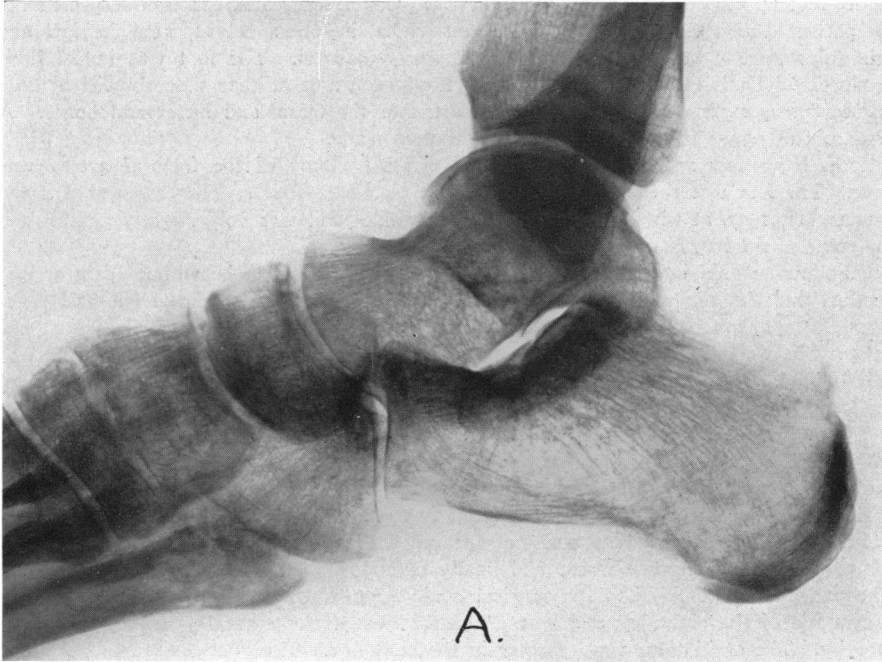


FIG. 14.—Röntgenograms showing moderate decalcification of the bones of the right foot following simple trauma to the ankle. (Case XIV.)  
A—Four months after the injury.  
B—Five months after the peri-arterial sympathectomy.

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ankle, foot and inferior third of the right leg. Gonorrhœal arthritis was suspected but the patient denied all signs of an acute gonorrhœal infection and repeated cervical and urethral smears were negative for intra-cellular diplococci. The foot was immobilized in plaster-of-Paris until November, 1926. Röntgenograms at that time showed a more diffuse osteoporosis with thinning of the cortex of the tarsal and metatarsal bones. A diagnosis of post-traumatic osteoporosis was then made.

On November 20, 1926, a peri-arterial sympathectomy of the femoral artery was done. The foot was then again immobilized in plaster-of-Paris. The case was changed January 18, 1927, at which time motion of the ankle-joint was only slightly painful and the color of the foot had returned to normal.

Follow-up examination May 26, 1927, showed the patient to be without pain or discomfort and she was able to walk normally. In April, 1930, three and one-half years after the sympathectomy, examination showed no signs of the former disease of the ankle. She walked normally and without pain or fatigue. Motion of the ankle-joint was still limited. Röntgenograms showed moderate recalcification and fusion of several of the tarsal bones.

CASE XVI.—J. B., married, laborer, aged thirty-eight years, was operated upon in May, 1926, because of an ingrown toe-nail of the right great toe. The wound became badly infected and suppuration continued for many weeks. When the wound finally healed the patient began to have sharp pains in the heel and on the lateral aspect of the right foot. Hot soaks, baking and massage failed to relieve the pain. On the contrary the pain gradually became worse and finally extended up the leg as high as the knee. The patient was admitted to the surgical clinic August 27, 1926. Examination showed a cyanosis of the right leg and foot. The muscles of the right leg showed moderate atrophy. The oscillations were greater in the right leg. The röntgenograms showed a diffuse decalcification of all of the bones of the right foot including the lower ends of the tibia and fibula.

September 2, 1926, a peri-arterial sympathectomy of the femoral artery was done. There was immediate relief of the pain in the leg and foot. The following day brought a return of some pain and this slight dull pain continued for about six weeks. The pain then gradually disappeared and there has never been a return of any type of pain or discomfort.

Follow-up examination November 14, 1928, over two years after the sympathectomy, showed normal motion of the ankle-joint. No evidence of atrophy of the muscles of the right leg at that time. Gait was normal. The right foot was decidedly warmer than the left and the oscillations were still slightly greater on the side where the sympathectomy was done. Röntgenograms showed the density of the bones of the two feet to be the same.

*Osteoporosis of the bones of the foot and ankle* following trauma which was of sufficient intensity to cause a fracture of one or more of the bones in the region of the angle-joint.

CASE XVII.—P. Vo., married, white, housewife, aged thirty-one years. On January 11, 1928, the patient fell and twisted her ankle in such a way as to cause a typical Pott's fracture on the left. There was no displacement of the fragments according to the röntgenograms; consequently the entire foot and leg was immobilized in plaster-of-Paris. No manipulation was necessary. At the end of five weeks the plaster was removed. She was unable to walk because of severe pains in the ankle and foot. Baking, massage and diathermy failed to bring about any improvement. The pains became so severe that the patient had to go to bed since the pain was relieved when the foot was kept at rest. In attempting to walk she struck the left great toe on a chair and caused a fracture of the distal phalanx. The röntgenograms taken on April 8, 1928, showed a very patchy decalcification of the small bones of the left foot. (Fig. 15A.) A diagnosis of tubercu-

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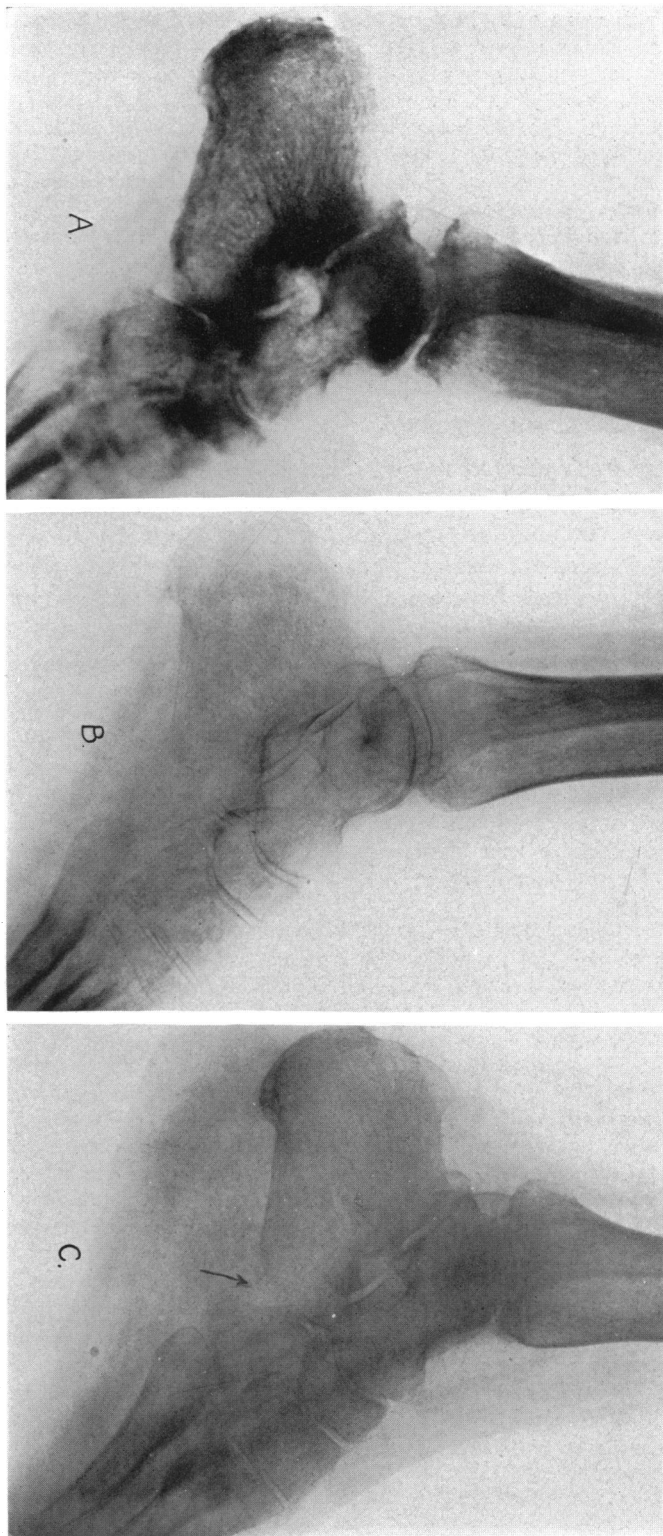


FIG. 15.—Röntgenograms showing the evolution of post-traumatic osteoporosis before and after peri-arterial sympathectomy. (Case XVII.)  
A—Three months after a Pott's fracture.  
B—Four months after the fracture and just before sympathectomy.  
C—Seven and one-half months after the sympathectomy.

lous arthritis was made. Professor Leriche<sup>45</sup> was asked to see the patient in consultation. Examination showed a slight œdema of the left foot, limitation of motion in the ankle-joint and limitation of motion of the toes. Passive motion of the sub-astragaloid joint caused great pain. The röntgenograms taken in May, 1928, showed extreme decalcification of all of the bones of the left ankle. The cortex of the bones was greatly thinned but the limits of the individual bones could still be made out. (Fig. 15B.)

May 5, 1928, Professor Leriche performed a peri-arterial sympathectomy of the left femoral artery. The œdema and pain disappeared very rapidly. The movements of the foot were much freer and entirely painless at the time of discharge from the hospital May 19.

Follow-up examination July 16, 1928, about two and one-half months after the sympathectomy, showed that the patient was able to walk without aid but she still had slight pain in the left ankle-joint. Recalcification was taking place slowly but by December 18, 1928, the recalcification was nearly complete. (Fig. 15C.) The patient was again seen in July, 1929, at which time she was able to walk normally but slight pain in the ankle-joint still persisted.

*Osteoporosis of the bones of the shoulder.*—This variety usually presents the clinical picture of traumatic arthritis. The changes in density of the head of the humerus are much more difficult to recognize. Professor Leriche has shown that extensive changes in the articulations may take place after trauma and the subsequent hyperæmia. The results following sympathectomy are usually very striking in these cases; consequently we wish to present the following typical cases and the results which we have obtained by this method of treatment.

CASE XVIII.—C. Pf., single, white, laborer, aged fifty-six years, entered the hospital October 22, 1927, because of constant pain in the right shoulder with almost complete fixation of the shoulder-joint. In May, 1926, he was struck on the right shoulder by a heavy block of lead which fell from a height of about six feet. He continued to work in spite of considerable pain in the entire shoulder. About three weeks later the pain suddenly became worse and he noticed a constant decrease of the motion in the shoulder-joint.

At the time of admission to the hospital all movements of the right arm were extremely painful. There was a slight atrophy of the muscles of the right shoulder. Loss of strength of the right hand and forearm. Only slight voluntary motion in the right shoulder-joint possible. The oscillations were greatly increased in the right upper arm. Röntgenograms showed definite decalcification in the head of the right humerus.

On October 31, 1926, Professor Leriche<sup>46</sup> performed a peri-arterial sympathectomy of the right subclavian artery together with an exploration of the shoulder-joint. The joint capsule was greatly thickened. The synovial membrane was villous and the cartilage of the head of the humerus was slightly roughened and a few irregular reddened areas were found in the cartilage. Biopsy of the cartilage and synovium was made.

The improvement was rapid and by November 3 most of the pain in the shoulder had disappeared and the patient was able to raise his right arm to the horizontal position without great pain. He was discharged from the hospital November 12, 1926.

Follow-up examination on December 20, 1926, showed that he was able to raise his arm to the vertical position without pain. He returned to work in December, 1926. Frequent examinations after that time showed no return of the former symptoms. He has continued to work without interruption.

CASE XIX.—C. Fr., married, white, laborer, aged fifty-seven years, entered the hospital April 17, 1928, because of severe pain in the right shoulder associated with marked restriction of motion of the shoulder-joint. In 1923 the patient fell from a

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bicycle and dislocated the head of the right humerus. The dislocation was reduced immediately after the accident. No further trouble until March 24, 1928, when he fell from a lumber wagon and again injured the right shoulder. The upper part of the right arm and the entire shoulder became swollen and motion in the shoulder-joint became greatly restricted. The functional disturbances gradually became worse.

Examination showed marked limitation of all the movements of the shoulder-joint. Passive rotation of the right arm was extremely painful. There was slight oedema of the right shoulder but there were no signs of vasomotor disturbances present. Röntgenograms showed no evidence of fracture of any of the bones in the region of the shoulder but there was a slight decalcification of the head of the right humerus.

Treatment by diathermy was carried out for several weeks but the symptoms continued to become worse in spite of the treatment. A few days later vasomotor disturbances were present in the upper part of the right arm. The cyanosis soon involved the forearm and hand also. There was a slight increase in surface temperature of the right forearm. The oscillations were increased in the right forearm but decreased in the upper arm. Surgical treatment by sympathectomy was proposed but the patient refused the operation and left the hospital.

June 26, 1928, the patient returned to the hospital because the pain and stiffness of the shoulder-joint had gradually but progressively grown worse. A periarterial sympathectomy of the right subclavian artery was performed on June 30, 1928. There was an immediate partial relief of the pain with considerable improvement in the motion of the right upper arm. The patient was discharged from the hospital July 12, 1928. The movements of the right arm were greatly improved but the patient still complained of moderate pain in the shoulder.

Follow-up examination in August, 1928, showed that all the former signs and symptoms had returned. In July, 1929, the pains in the right shoulder and the limitation of motion in the shoulder-joint were about the same as before the operation. In this case only moderate temporary relief was obtained from the peri-arterial sympathectomy.

CASE XX.—L. J., married, white, wood-chopper, aged fifty-one years, entered the hospital January 14, 1928, because of pain in the left shoulder with limitation of motion of the left upper arm. In 1914 he injured his left shoulder. Following that accident he had constant pain in that shoulder for over three months. The pain then disappeared slowly without treatment. He remained well until December 10, 1927, when he was struck on the left side of his body by a falling tree. Two ribs of the left side of the chest were fractured by this blow and the left shoulder was badly contused. After three weeks' rest in bed he began to have sharp pains in the left shoulder. Immobilization of the arm and shoulder aggravated the pain. Marked limitation of motion of the arm gradually took place. Pressure over the peri-articular tissues of the left shoulder-joint caused severe pain to the patient. Cyanosis of the left arm and shoulder then developed. The oscillations were diminished in the upper arm on the left side. Röntgenograms showed no evidence of fracture of any of the bones in the region of the left shoulder-joint. There was a marked rarefaction of the head of the left humerus.

January 16, 1928, Professor Leriche<sup>45</sup> performed a peri-arterial sympathectomy of the left subclavian artery. The pains in the left shoulder disappeared immediately and the range of motion in the shoulder-joint was greatly increased. Three weeks after this operation the patient returned to his work as a wood-chopper.

Follow-up examination May 16, 1928, four months after the operation, showed no limitation of motion in the left shoulder-joint and no pain. The patient had been working regularly.

CASE XXI.—C. Kr., married, white, farmer, aged thirty years, was admitted to the hospital June 17, 1929, because of severe pain in the left arm and shoulder associated with marked cyanosis of the entire extremity. February 14, 1929, he was caught between two wagons and a crushing injury of the left shoulder and chest resulted. The patient spat up blood-tinged sputum for about ten days. The pain in the left shoulder increased

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in severity and the motion in the shoulder-joint became progressively more limited. The pain became so severe that he was unable to sleep. Treatment by baking, massage and diathermy was carried out for over four months without much relief of the pain or stiffness in the joint.

At the time of admission to the hospital there was atrophy of all of the muscles of the left shoulder and arm. Intense cyanosis of the entire left arm was present. The oscillations were diminished in the left upper arm. The left arm could only be raised to the horizontal position. Rotation of the arm was impossible. Passive motion of the arm caused great pain to the patient. Röntgenograms showed no evidence of fracture of any of the bones in the region of the left shoulder-joint. There was moderate rarefaction in the head of the left humerus.

June 28, 1929, a peri-arterial sympathectomy of the left subclavian artery was done by Doctor Fontaine. Intense hyperæmia of the hand and arm resulted but there was no improvement in the movements of the arm. The pain remained unchanged. Repeated follow-up examination showed no improvement followed the operation in this case.

CASE XXII.—L. M., married, white, laborer, aged thirty-five years, was referred to the surgical clinic from the neurological clinic on June 3, 1929, because of severe pain of the causalgic type in the scar of a war-wound in the right fronto-temporal region, together with severe pains in the right shoulder and limitation of motion of the right upper arm. In 1918 he was wounded by a shrapnel. The wound was in the right fronto-temporal region and it extended down to and included the right eye. The eye was removed immediately. Suppuration of the wound lasted for months but finally healing took place and a large irregular scar remained.

In March, 1929, he fell from a wagon and injured his right shoulder. Following that injury he gradually developed pain in the shoulder and arm with progressive limitation of the motion in the shoulder-joint. At about the same time he began to have pain in the scar on the side of his head. The pains in the scar increased in severity very rapidly and by June, 1929, they were so severe that he was unable to sleep.

Examination showed a marked cyanosis of the right arm and hand. Active rotation of the right upper arm was impossible. All active or passive motion of the right arm caused great pain to the patient. The oscillations were diminished in the right forearm.

Because of the intolerable pain in the scar on the side of the head it was felt advisable to treat that disturbance first; consequently on June 13, 1929, the right superior cervical sympathetic ganglion was removed by Doctor Fontaine. The pains in the scar ceased immediately after the operation. The pains in the right shoulder seemed to have been made worse by this operation upon the cervical sympathetic chain. Röntgenograms of the shoulder showed no evidence of fracture of any of the bones but there was a marked rarefaction of the head of the right humerus.

June 30, 1929, a peri-arterial sympathectomy of the right subclavian artery was performed by Doctor Fontaine. Following this operation the pain disappeared immediately but there was only slight improvement in the motion of the right upper arm.

Follow-up examination on January 10, 1930, showed no further improvement in the motion of the right arm but all the pain in the arm, shoulder and scar on the side of the head had been completely relieved by the operations. In spite of the limitation of motion of the right upper arm the patient was able to return to work.

### SUMMARY

After an analysis of the results obtained in all of the cases of post-traumatic osteoporosis admitted to the surgical clinic of Professor Leriche since 1924, it is evident that the sympathectomy has added greatly to the comfort of the patient as well as having brought about the restoration of function much quicker than could possibly have taken place without the

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operation. However, in cases in which there is an advanced stage of the disease, the sympathectomy frequently gives only partial relief of the pain and little or no improvement in functional disturbances.

In the group of osteoporosis of the bones of the wrist we have reported nine cases. Two of these cases died from other causes shortly after the operation. Six of the remaining seven patients were completely relieved of all symptoms and functional disturbances. In one case of extensive osteoporosis of long standing the sympathectomy relieved the pain, but almost complete ankylosis of the wrist-joint was the ultimate anatomical result.

In the group of osteoporosis of the bones of the ankle we have reported seven cases. Four of these cases showed prompt and complete recovery. Two of the cases showed marked improvement in the function of the extremity, but a slight amount of pain persisted after the sympathectomy. One case has been operated upon recently; consequently no comment as to the end-result can be made at this time.

In the group of osteoporosis of the bones in the vicinity of the shoulder-joint we have reported five cases. Two of these cases showed prompt and complete relief after the sympathectomy, while the other two cases showed only slight improvement following the operation. One patient was completely relieved of the pain, but the stiffness of the shoulder-joint remained unchanged.

The type of operation upon the sympathetic nervous system that is to be used is determined entirely by the extent of the osteoporosis. In cases where the disease is limited to the bones of the ankle or wrist simple peri-arterial sympathectomy of the brachial or femoral artery, as the case may be, is sufficient. However, when all of these bones of an extremity are involved, the operation of sympathetic ramisection or ganglionectomy should be done. The surgical technic for these various operations is now well established.

### CONCLUSIONS

(1) Post-traumatic osteoporosis is a disease entity with characteristic röntgenological changes in the three main stages in the evolution of the disease.

(2) Post-traumatic osteoporosis which is left untreated usually results in an ankylosis of one or more of the joints in the region of the porotic bones.

(3) Operations upon the sympathetic nervous system offer a rational and effective surgical treatment for this disease entity.

(4) Cases of post-traumatic osteoporosis treated by sympathectomy during the initial stages of the disease respond quickly and the undesirable sequelæ of the disease are prevented.

(5) Peri-arterial sympathectomy is usually sufficient for cases of post-traumatic osteoporosis which is limited to the distal part of the extremities. Cervical and lumbar sympathetic ramisection should be reserved for the extensive forms of the disease.



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