Senn (N.)

FRACTURES OF THE NECK OF THE FEMUR,

WITH SPECIAL REFERENCE TO BONY UNION AFTER INTRA-CAPSULAR FRACTURE.

BY

N. SENN, M.D.,

OF MILWAUKEE, WISCONSIN.

Extracted from the
Transactions of the American Surgical Association,
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PHILADELPHIA:
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TO

GEHEIMERATH von NUSSBAUM,

This Monograph

IS DEDICATED

IN ADMIRATION OF HIS SUCCESS AS A TEACHER,

AND OF

HIS ABILITY AND SKILL AS A SURGEON,

BY HIS

FRIEND AND FORMER PUPIL,

THE AUTHOR.

FRACTURES OF THE NECK OF THE FEMUR,

With Special Reference to Bony Union after Intra-capsular Fracture.

I. *Experiments on Animals.*

These experiments were undertaken with a view of obtaining information concerning the following questions: 1st. What is the mode of repair after non-impacted intra-capsular fracture of the neck of the femur? 2d. What becomes of a bone or metallic nail when driven into the neck of the femur and retained permanently? 3d. What is the effect of such a nail upon the adjacent bone tissue? 4th. Can we, in cases of intra-capsular fractures of the neck of the femur, by immediate or direct measures, as by nailing the fragments together, obtain such accurate coaptation and retention as to secure union by bone?

A great many difficulties were encountered in performing these experiments, prominent among them I will enumerate shortness of the femoral neck, difficulty in carrying out the antiseptic treatment, and in providing additional means for securing immobility of the fractured bone, and the great danger to life in using anæsthetics. After I had lost a number of animals from the administration of chloroform and sulphuric ether I relied exclusively on hypodermic injections of morphia in preventing pain during the operation. The experiments were made on cats, dogs, and rabbits, embracing in all thirty-three operations upon thirty animals. In the first thirteen operations the capsule of the hip-joint was exposed by a small posterior

incision, and the neck was rendered more accessible by forcibly rotating the thigh inward; the bone was perforated a sufficient number of times with a small drill close to the head, and usually fractured by forcible abduction and rotation outward of the limb. The fracture usually took place with a distinct snap, and was followed by all the characteristic symptoms of fracture through the neck; preternatural mobility, shortening, and crepitus. The incision was closed with catgut sutures, and the wound covered with iodoform and salicylated cotton. In all of these cases the fractured bone was replaced as nearly as possible in the normal position, and a plaster-of-Paris dressing applied, which included the pelvis and both extremities. Two of these animals died of pyæmia, and in not a single instance out of the whole number could be found the slightest attempt at bony union at the post-mortem examination. In one instance (a young Newfoundland dog) the hip-joint presented evidences of severe inflammation without suppuration; the head of the femur, having necrosed, was found completely detached in the acetabulum. In some cases ligamentous union had taken place, while in others the fractured surfaces were covered with healthy granulations. In all the specimens the lower fragment had become shortened. Having satisfied myself that the antiseptic treatment could not be followed with sufficient accuracy in these cases to protect the animals against infection, I determined to fracture the neck subcutaneously. In the next six cases, after shaving and disinfecting the hip, and rotating the thigh inward and sliding the skin forward, I made a puncture down to the neck of the femur from behind with a narrow tenotome, and inserting the drill into the passage made, divided and fractured the neck as before. The skin retracting made the operation entirely subcutaneous. A plaster-of-Paris dressing was applied in the same manner as in the first series of experiments. No inflammation or febrile reaction followed these operations, and the post-mortem examinations showed evidence of ligamentous repair. In the absence of bony union, the functional result in several cases appeared remarkable. With few exceptions, all of the fractures produced

so far were proved to be purely intra-capsular at the post-mortem examinations.

In Experiment No. 21 the neck was fractured subcutaneously and no retaining dressing applied. The animal was killed five weeks after the operation, and an examination of the hip-joint showed that a firm and short ligamentous union had taken place. After the first three weeks little or no lameness could be detected.

Having failed in all cases so far in obtaining union by bone I determined to secure immediate and direct coaptation by nailing the fragments together.

The fracture was produced subcutaneously in the same way as in the preceding series of cases, and, after replacing the limb in its natural position and sliding the opening in the skin to a point corresponding with the centre of the base of the femoral neck, the drill was introduced, and a perforation made in the direction of the centre of the femoral head, and a wire-nail or bone-peg of proper length was driven into the opening made by the drill so that the outer extremity of the nail should not project beyond the surface of the bone.

The first two animals progressed very favorably after the operation and appeared to suffer but little pain, but unfortunately escaped before an examination could be made to ascertain the result.

Experiment No. 24.—Young cat; fractured the right femoral neck subcutaneously, and nailed the fragments with a bone-nail. Animal killed ten weeks after operation. Neck of femur almost entirely absorbed; capsular ligament thickened; vertical section through head, neck, and upper portion of shaft shows that the head is almost in contact with the trochanteric portion of the femur; posterior portion of neck shows line of fracture near the head, and fractured surfaces in close contact, but movable upon each other; anterior portion firmly united by a dense compact callus, the upper fragment apparently impacted into the lower; no trace of the bone-peg can be found. The perforation in the trochanter major can be followed to a distance of about two mm. In this specimen the lower fragment appears to have become almost completely absorbed, as the upper fragment remains unchanged, and appears to be almost

in direct contact with the trochanteric portion of the femur. Ligamentum teres normal.

Experiment No. 25.—Adult cat; subcutaneous fracture of neck of right femur; direct transfixion of fragments with wire-nail. Animal killed eighteen weeks after operation. Fracture within capsule close to the head; fragments in close contact, slightly movable upon each other, but united by a very short ligament. Nail had slipped outward, and projected from the trochanteric surface about one-third of an inch, and could be felt as a sharp point immediately under the skin. The projecting portion of the nail is invested by a firm, dense, fibrous capsule, while the implanted portion is firmly and immovably fixed in the bone. Vertical section through the head, neck, and trochanteric portion shows that almost the entire neck has disappeared by interstitial absorption, the upper fragment being almost in contact with the trochanteric portion. The trochanteric portion has almost entirely lost its cancellated structure, its interior being filled with compact tissue; this change is conspicuous more particularly in that portion traversed by the nail. Capsular ligament thickened; ligamentum teres normal.

Experiment No. 26.—Adult, large Maltese cat; subcutaneous fracture of right femoral neck; direct coaptation of fragments with wire-nail. Animal killed ten weeks after operation. Neck of femur shortened; capsular ligament thickened; ligamentum teres normal; vertical section through the upper portion of the femur shows line of fracture within capsule, with impaction of upper fragment into lower; fragments movable upon each other, but broken surfaces in immediate contact. A new compact layer of bone was formed on the outer surface of the compacta in the region of the lesser trochanter. Nail firmly imbedded in bone, outer extremity on a level with compact layer of trochanter major; it is seen to traverse the trochanteric portion in a backward direction, entering the cavity of the hip-joint, and being in close contact with the posterior surface of the femoral neck; its sharp point being on a level with the highest point of the head. No inflammation in the hip-joint. During life the function of the joint appeared to be perfect. As the point of the nail was firmly fixed in the capsular ligament, and impaction had taken place during the nailing process, immobility was tolerably

well attained, and there is every reason to believe that bony union would ultimately have taken place.

Experiment No. 27.—Adult Maltese cat; subcutaneous fracture of left femoral neck; fixation of fragments by means of bone-peg made from compacta of tibia of an ox. Animal killed fourteen weeks after operation. Neck of femur only slightly shortened; capsular ligament nearly normal; ligamentum teres normal; vertical section shows a slight curve in the upper portion of the neck, the head being slightly depressed. Perfect and complete bony union, the spongiosa being restored nearly to its normal condition. Bone-peg has disappeared completely.

Experiment No. 28.—Old Maltese cat; subcutaneous fracture of left femoral neck; direct adjustment of fragments by bone-peg. Cat died of fatty degeneration of liver and kidneys five weeks after operation. Vertical section through upper portion of femur reveals line of fracture partly within and partly without the capsule; no union; fragments in good apposition; outer extremity of bone-nail beneath the compacta, direction of nail downward and inward, the point terminating a little beyond the line of fracture in the lower portion of the neck. The saw has divided the nail obliquely at the juncture of the outer with the middle third. No evidences of inflammation or repair.

Experiment No. 29.—Adult cat; fractured neck of left femur subcutaneously, and used bone-peg for nailing fragments together. Animal died of pyæmia twelve days after operation. Hip-joint filled with pus; fracture intra-capsular; outer extremity of nail on a level with compacta, its point was in the cavity of the joint on a level with the foveola of the head. A piece of the posterior portion of the head is split off, an accident which occurred either by the drill or driving in of the nail.

Experiment No. 30.—Adult cat; subcutaneous fracture of right femoral neck, and direct transfixion of fragments by wire-nail. Animal died, four weeks after operation, of pneumonia. No inflammation of joint; fracture intra-capsular; fragments slightly separated but well transfixed by nail; no callus.

Experiment No. 32.—Young cat; subcutaneous fracture of neck of right femur; direct fixation of fragments with bone-peg. Animal killed four months after operation. During life function of the joint was perfect; vertical section through the head, neck, and upper portion of shaft, shows that the line of fracture must have been entirely within the capsule, as no thickening of bone or ligament could be seen; capsular ligament normal. Accurate measurement shows only an appreciable shortening of neck; compact tissue within neck more abundant than in the opposite bone. Spongiosa restored to nearly its natural perfection. No trace of track of perforation or bone-nail.

In no case did I feel crepitation more perfectly than in this case, and the sudden giving way of the bone the moment it was fractured was well marked, and heard by several witnesses, and as the post-mortem examination shows a most perfect restoration of the continuity of the bone, I am convinced that this case represents a typical and perfect recovery of union by bone after intra-capsular fracture of the neck of the femur.

In all cases, twenty-one in number, where no direct means of fixation were used, there was not the slightest evidence of bony union, the best result attained was a short ligamentous band. In Experiment No. 21, no retention dressing was applied, and the result was equally good, if not better, than in the cases where the plaster-of-Paris dressing was used.

In all of these cases the tendency to shortening was not as well marked as in man, while eversion occurred seldom, and only to a slight degree.

The weight of the limb evidently counteracted muscular action, while the conditions which produce eversion in man are absent in animals. The results obtained by immediate transfixion of the fragments stand in direct contrast to those treated by external fixation. Bony union, or union by short ligament, was the rule, non-union the exception.

These experiments would also tend to prove that aseptic metallic nails, when implanted subcutaneously into living bone, remain firmly in its substance for an indefinite period of time without giving rise to suppuration, and from one of the experi-

ments it will be seen that the point of the nail was within the cavity of the joint for many weeks without materially interfering with the normal function of the joint, or producing more than a slight synovitis.

Iron- and bone-nails, if driven into living bone, produce osteo-plastic inflammation, and are, on this account, not only useful in the treatment of pseud-arthrosis, but are equally beneficial in accelerating the reparative process in recent fractures. Bone-nails are completely absorbed, the time required for absorption to take place depends upon the vascularity of the tissues, which are in immediate contact with the nail.

According to Gurlt, the time required for bony union to take place is proportionate to the diameter of the fractured bone, being much shorter in case of slender bones as compared with those of greater diameter.

It appears that the shortest time for the slender neck of the femur in cats to unite by bone is at least two months; hence in man the time required for bony consolidation of fracture of the femoral neck must be at least from one hundred to one hundred and twenty days. As in two of the specimens, well-marked impaction occurred during the nailing process, the question arises if the same desirable conditions could not be obtained in man by using sufficient lateral force at the time direct coaptation is attempted; in other words, would it not be prudent to use sufficient force to produce artificial impaction.

In nearly all the specimens the upper fragment underwent but little change, while the lower fragment always, without exception, suffered a diminution in length from osteo-porotic inflammation and interstitial absorption.

Interstitial absorption, as the consequence of inflammatory osteo-porosis, takes place to a greater or less extent in every case of fracture through the femoral neck, and precedes and accompanies the reparative process. In all cases of bony union the posterior attachment of the cervical portion of capsular ligament was displaced outward, an occurrence which can only be explained satisfactorily by assuming that during the osteo-porotic inflammation, the periosteal investment of the femoral neck is

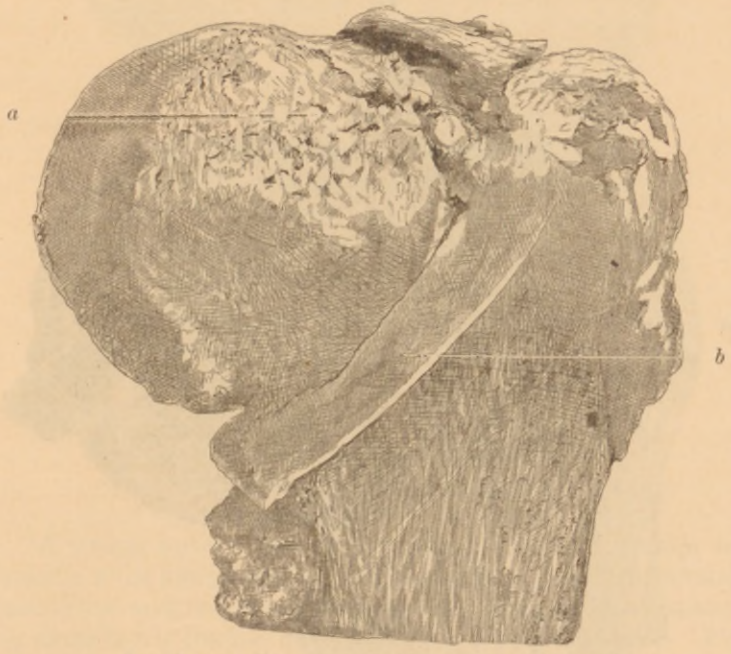
loosened and transplanted toward the femoral shaft, carrying with it the femoral insertion of the capsular ligament. These experiments also illustrate the difficulty of transfixing the upper fragment in the process of nailing, a circumstance largely due to the diminutive size of the bone, the incomplete anæsthesia, and the want of fixation of the parts in their relative normal positions previous to the operation.

II. *A Case of Bony Union after Impacted Intra-capsular Fracture of the Neck of the Femur.*

At our last meeting I presented a specimen of bony union after an intra-capsular fracture of the neck of the femur, and gave a full description of the case and specimen (see page 167). In the discussion which followed, it became not only evident that in the opinion of the speakers the specimen was not what I had claimed for it, but that such a favorable occurrence was not possible, and that a well-authenticated case had never been observed. These criticisms induced me to look up the literature on the subject with care and impartiality, and to resort to experiment to verify my position. I will ask the Fellows to examine the specimen once more, and will call their attention to a few prominent points in the case. The patient was a female, aged seventy-five years, and was under my observation at the Milwaukee Hospital. She was in good health at the time of the accident, hence there can be no possibility that the extensive changes in the neck of the femur were the result of senile coxitis or interstitial absorption. The fracture was produced by direct violence by a fall upon the greater trochanter. Fractures of the neck produced in this manner are very apt to be impacted. Loss of function was complete immediately after the injury, and remained so for several months. The patient suffered great pain in the groin and the region of the trochanter minor, a symptom which is always indicative of injury within the capsular ligament. For the purpose of excluding asymmetry of the bones, all the long bones of both legs were measured separately, and on comparing the measurements

the injured limb was found shortened one-half of an inch. The limb was strongly everted. Gentle traction had no effect on the length of the limb. On comparing the movements of the trochanter major on both sides by rotating the limbs it was found that the neck of the femur on the affected side was perceptibly shorter. No crepitation could be felt. As the impaction appeared to be firm no treatment was employed, except rest in bed on a smooth even mattress, and the limb supported on each side with sand-bags. In this position the patient remained for three months; at the expiration of this time she was allowed to walk on crutches. After the third week the shortening gradually increased until it reached an inch and a half, when the treatment was suspended. The secondary shortening I attributed to inflammatory osteo-porosis and interstitial absorption in the lower

Fig. 1.



Bony Union after Intra-capsular Fracture. (Anterior view.)

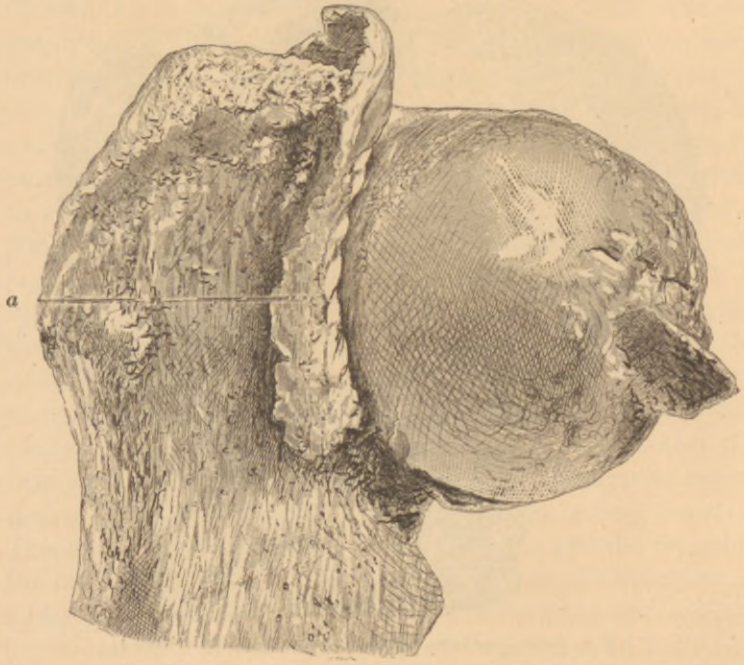
a.—Line of Fracture.

b.—Capsular Ligament.

fragment. The patient eventually was able to walk quite well with the aid of a cane. Two years after the accident she died of pneumonia. The post-mortem appearances I will quote from the former report:—

"The capsule of the joint, especially the upper portion, was thickened and firm, and bridges of fibrous bands connected the line of fracture with the anterior portion of the ligament. On the anterior surface of the neck the direction of the fracture could be clearly traced from below upward, and from within outward, but not extending beyond the insertion of the capsular ligament. The line of fracture is elevated, and presents a serrated appearance. Posteriorly the head of the bone was in close proximity to the posterior inter-trochanteric ridge. A slight depression on the articular cartilage marked the point of contact with the inner surface of the capsular ligament. Impaction had evidently taken place at

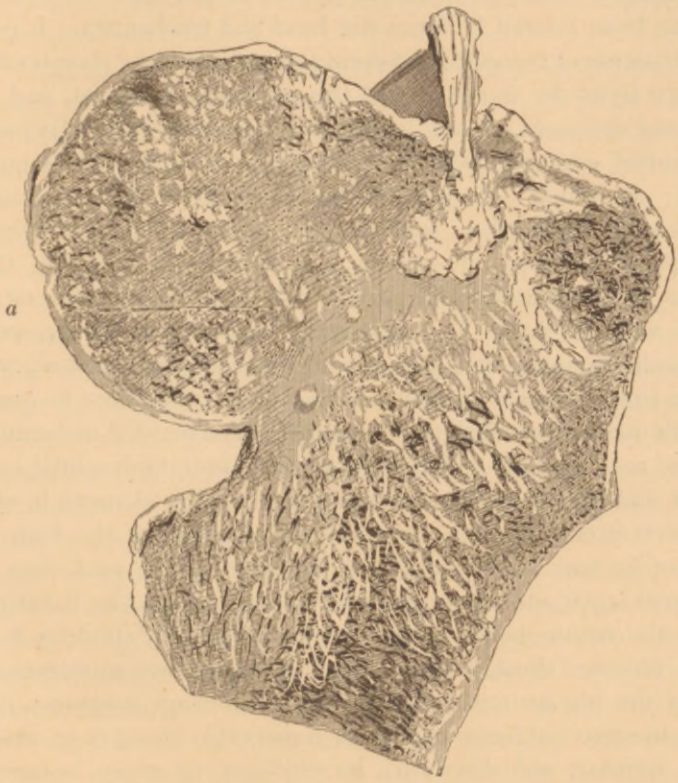
Fig. 2.



Bony Union after Intra-capsular Fracture. (Posterior view.)
a.—Capsular Ligament.

the expense of the posterior compact portion of the neck. A portion of Adam's arch, which had been implanted into the lower fragment, could be distinctly seen in the spongiosa, on making a vertical section (Figs. 1, 2, 3).

Fig. 3.



Bony Union after Intra-capsular Fracture. (Vertical section.)
a —Compact Plate of Bone.

"A vertical section through the neck, head, and trochanter revealed a white line of very compact bone traversing the cancellous tissue of the neck near the shaft in an oblique direction, corresponding to the line of fracture on the anterior surface of the neck. The anterior half of the specimen has been submitted to the boiling test without affecting the union of the fragments, hence there can be no doubt as to the union by bone.

"The bone outside of the capsular ligament presents no sign of callus or any other evidences of injury or disease."

III. *Anatomy of the Neck of the Femur.*

The neck of the femur is that portion of the upper extremity of the bone located between the head and trochanters. It is a continuation of the shaft, and springs from an oblong rhomboidal surface from the inner side of the trochanteric region, and is directed obliquely upward, inward, and a little forward. Its base is limited anteriorly and posteriorly by the inter-trochanteric lines; above and behind it reaches the summit of the greater trochanter, while below and in front it extends to the upper margin of the lesser trochanter. In animals the neck of the femur is exceedingly short, and usually set almost at a right angle with the shaft. The great length and obliquity of the neck is peculiar to man. It is this which gives elasticity, freedom, and grace to the motions of the body, but at the same time its great length increases the liability to fracture. The decided inclination of the neck forward naturally turns the lower limb a little outward, and constitutes an important determining element in the production of posterior impaction and eversion of the limb in case of fracture. The length and obliquity of the neck vary at different ages and under different circumstances, in harmony with the requirements of age or conditions. In children it is very oblique, short, and slender, and the bony prominences about the hip are not well defined. As old age advances, the neck in some instances undergoes remarkable changes in structure, contour, and direction; its obliquity in many instances diminishes to such an extent that the head descends below the level of the superior border of the greater trochanter, at the same time its length is greatly diminished. During adult life, when the femur represents the most perfect degree of development and maximum power of resistance, the neck forms an obtuse angle with the shaft varying in degree from 120° to 130°.[1]

[1] Fr. Merkel, Betrachtungen über das os femur. Virchow's Archiv f. Pathol. Anat. Band 50, Heft. II.

Viewed from the front or from behind, it is seen that the neck is widest at its base or trochanteric portion, gradually becoming narrower until its most contracted part near the head is reached, when it abruptly expands into the corona of the head. The posterior surface is smooth for the play of muscles, especially the obturator externus; convex in the vertical and concave in the longitudinal direction.

The anterior surface is rough, flat from above downward, and slightly concave from without inward. On account of the direction of the neck forward the anterior surface is somewhat shorter than the posterior. According to Heppner this difference amounts to two and two-and-a-half lines.[1]

The under surface is smooth and forms with the inner side of the shaft a well-marked curve or arch nearly three inches in length, the upper surface is rough and only half the length of the lower.

The thin compact layer of bone on the anterior and upper surface is perforated by numerous foramina for the passage of nutrient vessels. Seen from above, the neck appears much narrower than from an anterior or posterior view. The proportion of the diameter of the neck from above downwards, and from before backwards, at the trochanteric portion is as two to one. From the general anatomical description, it becomes apparent that the neck of the femur is constructed strictly on purely mechanical principles, in order to resist the greatest amount of vertical pressure, but this becomes more evident if we study the inner architecture of the upper portion of the femur, and more particularly the neck. On making a vertical section through the head, neck, and upper part of the shaft of the femur, it may be seen that the thick compact layer of the shaft, as it approaches the trochanteric region, gives off from its inner surface cancelli at regular intervals, which build up the interior or spongy tissue of the bone. As the spongy tissue is formed at the expense of the compact layer, the latter gradually becomes thinner as it approaches the head, which it supplies with a delicate layer of

[1] C. L. Heppner, Beobachtungen u. Untersuchungen über eingekeilte Schenkelhalsbrueche. Med. Jahrb. Band XVIII. p. 106.

uniform thickness. The most important part of the cortical layer in relation to fractures of the neck is the lower and inner portion, which, from the support it gives to the head and neck has been called Adam's arch, or femoral brace. It is a continuation of the cortical layer of the inner portion of the shaft, preserving its thickness and strength to a level with the upper margin of the trochanter minor, where it is gradually broken up into spongy tissue, until at the corona it is lost in the thin cortical layer surrounding the head. The trochanter major is surrounded by a thin layer of compact tissue. Transverse sections made through the neck at different depths show that while the anterior and posterior layers are of the same thickness in the upper part of the neck, the posterior wall gradually loses in thickness, until near the lower surface it is reduced to the thinness of paper, while the anterior wall becomes of great thickness and strength.[1] The direction of the neck, the concavity of the posterior surface, and the thinness of the posterior compact wall as compared with the anterior, afford abundant and satisfactory explanations concerning the frequency of posterior impaction in fractures of the neck, and outward rotation of the limb in the non-impacted form.

Of great interest to the surgeon is the arrangement of the cancelli of the spongy tissue in the upper part of the femur. It is true that some of the peculiarities of the structure of the spongiosa in this locality were known to surgeons for a long time, still the credit is due to H. Meyer of having first, in 1867, called attention to the regularity of its construction, and out of this deduced distinct and positive laws governing its mechanical construction.[2]

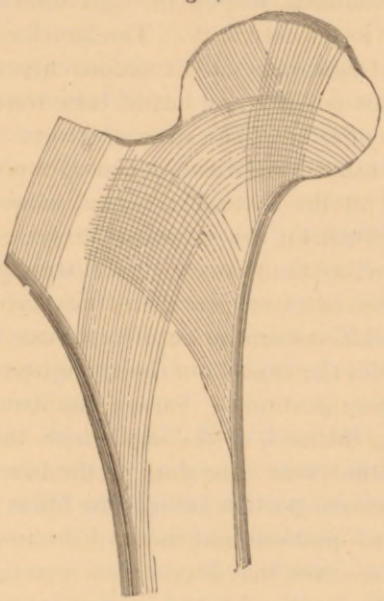
He describes three distinct systems of cancelli which traverse the neck in different directions. The first begins on a level with the lesser trochanter, and reaches in parallel curves the lower segment of the head of the femur. The second system

[1] H. J. Bigelow, M.D., The True Neck of the Femur, its Structure and Pathology. Boston Med. and Surg. Journ., Jan. 7, 1875.

[2] H. Meyer, die Architectur der Spongiosa, Archiv f. Anatomie, von Reichert und Du Bois-Reymond, 1867, p. 624.

commences on the opposite side on the same level, and traverses towards the outer side of the trochanter major, and in such a way that the points of intersection of the curves form a series of arches. The third system springs from the commencement of

Fig. 4.



Meyer's Pressure and Fraction Curves. (Meyer.)

the femoral brace, and extends to the upper and inner circumference of the head of the femur, is the strongest, and transfers the weight of the body at once upon the femoral brace on the inner and lower side of the neck. According to Meyer's description and drawings, a triangle exists between the curves of the first and second systems, the apex of which corresponds to the base of the neck. This triangular space is occupied by an irregular network of cancellated tissue, or by curves from the second or third system. This space, however, does not exist in all specimens, but is usually present in the bones of aged people, where the spongiosa has undergone rarefaction.

In specimens from adults the interior of the bone is filled with

arches from the inner and outer compact layer for some distance below the point indicated by Meyer. In another paper[1] Meyer dwells at length on the mechanical function of these curves, which he calls pressure and traction curves. It seems as though the compact layer is gradually lost in the spongiosa. This is well seen in a horizontal section through the long bones, more especially of the lower extremity. The lamellæ are so arranged as to correspond to pressure and traction curves, a construction by which the least possible amount of bone tissue can resist the greatest amount of force. The spaces between these curves are filled with loose cancellated tissue, which does not add materially to the strength of the bone, but serves more the purpose of forming a framework for the medullary tissue. The spongiosa appears, therefore, as the primary typical structure of bone, and the compact tissue as an accidental modification of the spongiosa constructed by local concentration of resistance curves.

Heppner divides the cancelli of the spongiosa into two strong and two less dense portions. Among the first he includes the fibres connecting the neck of the femur with the femoral brace, and from the other side extending to the base of the femoral neck. To the second portion belong the fibres in the space between the first two portions and those of the trochanter major.

About the same time that Meyer was investigating this subject, Dr. J. H. Packard published a very interesting paper on "Fractures of the Neck of the Femur,"[2] in which he calls attention to the architecture of the interior of the neck of the femur, and accurately describes and delineates the arching fibres passing from the femoral brace to the upper segment of the head of the femur. He says: "A careful examination of vertical sections of the head and neck of the femur shows, as several writers have pointed out, that a number of the cancellous columns, beginning at the upper end of the inner wall of the shaft of the bone, diverge upward to the concavity of the thin articular lamella of compact substances of the head, so as to receive the weight of the body

[1] Die Statik u. Mechanik des menschlichen Knochengerüstes, 1873.

[2] On some Points relating to Fractures of the Neck of the Femur, by John H. Packard, M.D., Amer. Journ. of Med. Sciences, Oct. 1867, p. 379.

upon their extremities. Another series of columns are found to run outward from the same point, and from a line running upward from it, to meet other columns running up inward from the outer wall of the shaft; and these two sets of columns form a series of groined arches culminating at the upper wall of the neck of the bone, a little to the inner side of the greater trochanter.

"By this arrangement the shifting of the weight towards the outer or upper portion of the head of the bone is provided for, the pressure coming in greater degree on the outer wall of the shaft, the inner wall, however, receiving its share through the inner columns of the arches. The remainder of the cancelli run in various directions, not capriciously or at random, but so as to afford in the aggregate a very strong support to the solid wall of the bone. Sometimes it may be clearly seen that they are so placed as to run as nearly as possible in the line of muscular traction; an arrangement, the mechanical advantage of which must be at once evident."

In 1870, Julius Wolff[1] published the result of his studies of the spongiosa, which he considered as standing in the closest relation to the static and dynamic forces of the bones. In his researches he made use of the mathematical calculations of Culmann, showing that interior braces intended to aid supporting a weight upon the end of a cylinder, curved like the femur, or like a crane or derrick, should be placed, in order to act to the advantage, precisely where the trabeculæ of the spongy tissue of this bone actually exist.

"Nature," says Wolff, "has built the spongy bones as an engineer would construct a truss bridge, mathematically."

A compact plate of bone (Schenkelsporn, septum) is usually found imbedded in the cancellous tissue of the neck, and to it an important function has been assigned by Merkel and Bigelow.

Merkel[2] described a structure in the interior of the neck of the femur which he called "Schenkelsporn." It consists of a wedge-

[1] Julius Wolff, Ueber die innere Architectur der Knochen und ihre Bedeutung für die Frage von Knochenwachsthum. Archiv f. Path. Anat. u. Phys. Band 50.

[2] Der Schenkelsporn. Centralbl. f. d. Med. Wissensch. No. 27, 1873.

shaped solid projection of the cortical layer, which springs from its inner surface on a level with the trochanter minor towards the median line, and penetrates into the interior of the spongiosa to the depth of 1 cm., and is lost immediately under the head of the femur on the anterior surface of the neck. It is not found in the fœtus, is fully developed in the adult, and again disappears completely during old age.

Bigelow, after describing the necessary manipulations for exposing it, says: "The septum will then be distinctly seen, as a thin dense plate of bone continuous with the back of the neck, and reinforcing it, plunging beneath the inter-trochanteric ridge in an endeavor to reach the opposite and outer side of the shaft. At its lower extremity it curves a little forward, so as to take its origin, when on a level with, from the centre, instead of the back, of the cylindrical cavity; a disposition easily seen in a transverse section of the shaft just above the trochanter minor. Or it may be said that the posterior wall of the neck forks before reaching the inter-trochanteric line, one layer being seen upon the surface, while the other dives beneath the inter-trochanteric ridge in a vain attempt to reach the outer wall of the shaft. If these views be correct, the inter-trochanteric ridge is simply a buttress erected for the insertion of muscles upon and over the true neck, by the impaction of which it is in fact often split off and detached in a mass; the force exerted by the true neck, though slight, being nevertheless an effort to resist such impaction."

The importance of this septum, when in a perfect state, becomes evident as the same author continues: "The true neck is often, at best, but an ineffectual attempt to bridge the interval beneath the trochanters, as seen in Merkel's figures, while, in the latter half of life, it degenerates into papery plates, radiating downward from a point near the lesser trochanter. Weakened in this way, both by its own tenuity and by its own slender union to the trochanteric ridge, the true neck has great practical interest for the surgeon. Even the adult femur is generally defective in construction at this point; and here occurs the most common form of fracture, namely, the posterior impacted fracture of the base of the neck."

Bigelow looks upon the septum as a continuation of the "True Neck," while Merkel has described the same structure as a projection of a portion of the posterior and inner compact wall into the spongiosa; hence, he has called it Calcar femoral or Schenkelsporn.

The relation of the septum to the trochanter minor is such as to isolate its spongy tissue, and on that account Wolff alludes to it as "the compact tissue upon which the trochanter minor rests."

The importance of this structure in preventing and determining the location of fractures has, undoubtedly, been over-estimated. It is absent in children, and is subject to the same degenerative changes as the remaining portions of the cortical layer and the spongiosa.

In conclusion it may be stated that the spongiosa of the upper extremity of the femur is derived directly from, and at the expense of, the compact layer, that it is constructed upon a definite plan in a series of arches arranged in such a manner as to resist the greatest amount of vertical pressure according to well-established architectural laws; at the same time by expanding the bone it furnishes a more extensive surface for muscular attachments, and imparts to it a greater degree of elasticity.

The exact point of insertion of the capsular ligament into the femoral neck has been a frequent source of dispute among anatomists and surgeons to decide the location of fractures in this locality. Great discrepancies on this point may be found in our anatomical text-books.

To Dr. Geo. K. Smith much credit is due for the light he has thrown on this subject.[1] By injecting the capsule of the hip-joint with air or plaster of Paris he was enabled to make very careful dissections, and by measuring accurately the distance between the corona of the head and the insertion of the ligament, and from this point to the inter-trochanteric lines, he could locate the exact point of insertion. After preparing and

[1] The Insertion of the Capsular Ligament of the Hip-joint, and its Relation to Intra-capsular Fracture. New York, 1862.

measuring sixty-one specimens in this manner he came to the following important conclusions:—

"1st. That scarcely any two specimens of the normal capsule, taken from different subjects, are alike in their insertion into the neck of the bone; consequently no definite description of its insertion can be given.

"2d. That the normal capsules of the opposite femurs of the same subject are alike in their insertion. Having measured twenty-four pairs I have yet to see a single variation from this rule. Moreover, it is just what we must expect to find in obedience to that law of symmetrical conformation which pervades the animal economy."

Morris[1] locates the femoral insertion of the capsular ligament as follows: "At the femur the capsule is fixed to the anterior portion of the upper border of the great trochanter, and to the tubercle of the femur close to the insertion of the gluteus minimus and the origin of the vastus externus, with slips from each of which it is blended. Thence it runs along the upper and outer part of the anterior inter-trochanteric line, but it soon gets below it, and at the inner border of the femur is on the level of the lower surface of the small trochanter. It is then inclined upward and backward along an oblique line, two-thirds of an inch in front of the small trochanter, to reach the back of the neck; here it is attached above the posterior inter-trochanteric line at a distance varying from half an inch, at the lower and upper ends, to over two-thirds of an inch opposite the middle of that line. . . . After laying open the capsule it is seen that some of the deeper fibres of this ligament are reflected upward along the neck, so as to be attached to the femur much nearer its head. These reflected fibres occur at three places, one corresponding in position to the middle of the ilio-femoral ligament, another to the pectineo-femoral, and the third on the upper and back part of the neck. A thin fold of synovial membrane stretches between the reflected and the unreflected fibres of the capsule."

These strong bands of reflected fibres have been called reti-

[1] The Anatomy of the Joints of Man. Philadelphia, 1879, p. 322.

nacula by Weitbrecht. Packard, in his paper previously alluded to, has called attention to the existence of pockets, usually three in number, between the reflected fibres.

Rüdinger,[1] in speaking of the fibrous capsule of the hip-joint, says: "Its attachment to the lateral portions of the neck is in such a manner, that anteriorly it reaches the anterior inter-trochanteric line; posteriorly, on the other hand, it reaches only as far as the middle of the neck."

Practically, we can safely say, that the anterior portion of the capsular ligament, as a rule, is inserted into the anterior inter-trochanteric line, reaching its lowest level on the lower surface of the lesser trochanter, while the posterior portion is usually inserted at or near the middle of the femoral neck. A close inspection of the posterior segment of the capsular ligament will usually reveal the existence of more or less fibres running from the insertion of the ligament proper towards the inter-trochanteric ridge. For our purpose it is also proper to mention that the largest nutrient vessels to the neck pass beneath the reflected portions of the ligament.

The ligamentum teres will receive mention only as far as it serves as a carrier of bloodvessels to the head of the femur. In infants it contains a number of bloodvessels which enter the head of the femur at the point of insertion of the ligament in the fovea. That the blood supply from this source is not essential for the growth and development of the upper extremity of the thigh-bone, is apparent from the fact that it is wanting in many animals, as the Bradypus, Echidna, Cholaepus, elephant, rhinoceros, and others. According to Savory, two hip-joints were examined at the St. Bartholomew's Hospital, where no trace of this ligament could be found, but the head of the femur presented a depression, not covered with cartilage, at the usual point of insertion of this ligament. There can be no doubt that in infants the vessels of this ligament penetrate the bone and furnish material for ossification to the epiphysis of the femur. After the growth of the bone has been completed, the vessels

[1] Topographisch-chirurgische Anatomie des Menschen, Stuttgart, 1873, p. 142.

diminish in size with advancing age, and disappear entirely at their point of entrance into the bone in a certain percentage of cases. Hyrtl has asserted that the vessels from the capsule which pass along the ligamentum teres to the surface of the head do not communicate with the vessels of the medullary substance, but return in the form of loops.

In one-third of the specimens examined by Welcker,[1] no foramina nutritia could be found in the fovea capitis; hence, he concluded that the round ligament is not destined to act as a carrier for nutrient vessels. Sappey, on the other hand, attributes to the ligamentum teres the function of protecting the vessels and nerves that nourish the head of the femur.

Langer[2] has made careful injections of the vessels of the hip-joint, and has observed that not all of the vessels of the ligamentum teres return in loops on reaching the bone, as described by Hyrtl, but that some of them penetrate into the spongiosa of the head of the femur. I have examined a number of specimens with reference to this point, and have been able to detect with the naked eye nutrient foramina in the fovea capitis in more than one-half of them. When the foramina were of considerable size, I have been able to trace them for some distance into the bone. In such specimens there can be no doubt as to the presence of bloodvessels from the round ligament in the interior of the spongy tissue of the head of the femur, and in this the vessels from the round ligament enter into anastomosis with vessels from the bone, and render material assistance in maintaining the circulation in the head of the femur. In some specimens the foramina may be so small as to elude detection with the naked eye, but may nevertheless admit small vessels which may be of some importance in furnishing material for nutrition in the bone. The absence or destruction of the vessels of the ligamentum teres may not interfere with the growth and development of the bone as long as the normal supply through the neck of the femur is not impaired; but in case of fracture of the

[1] Virchow u. Hirsch's Jahresbericht, 1875, vol. i. p. 9.

[2] Rüdinger, op. cit., p. 144.

neck they are of great importance, and assume a compensating function in harmony with similar processes in other parts of the body. Rudimentary small vessels may assume vicarious action for the purpose of answering an increased demand, and thus supply a sufficient amount of blood, not only for maintaining the vitality of the upper fragment, but likewise to furnish material for repair.

IV. *Classification of Fractures of the Neck of the Femur.*

Since the teachings of Sir Astley Cooper on this subject, it has been customary to classify fractures of the cervix femoris according to the relative position the capsular ligament bears to the seat of fracture, into the intra-capsular and extra-capsular fractures, to which has been added a third variety, fractures partly within and partly without the capsular ligament. The mixed variety has given rise to a good deal of confusion, as some have included it among intra-capsular fractures, while others class it with extra-capsular fractures. Since it has been ascertained that many of the fractures of the neck of the femur are impacted, those who have placed great prognostic and therapeutic importance upon this condition, have made impaction the basis for a new classification, and speak of impacted and non-impacted fractures of the neck of the femur. Among those who favored this classification may be enumerated Cloquet, Josselin, Duplay, Bigelow, Bryant, Hueter, and Lossen.

The distinction into impacted and non-impacted fractures is important in a clinical, diagnostic, prognostic, and therapeutic sense, while the division into intra-capsular and extra-capsular fractures has a very important pathological significance. Fractures of the neck of the femur with impaction will unite by bony union irrespective of the situation of the capsular ligament, provided the impaction is maintained for a sufficient length of time. Fractures, impacted or non-impacted, outside of the capsular ligament will unite in the same manner as fractures in any other locality, if the fractured ends are kept in apposition and immobilized for the necessary length of time. Fractures at the narrow

part of the neck, and entirely within the capsule, can only unite by bone, if the penetration is such as to secure apposition for a number of weeks, or if the same degree of apposition and immobilization is affected by surgical procedures. The frequency with which impaction occurs in the femoral neck, and the important part it performs in the reparative process, entitle it to a permanent place as a basis for classification.

When we are able to diagnosticate the existence of an impacted fracture of the neck of the femur all efforts to locate the exact seat of fracture are perfectly useless, as it could have no influence in selecting therapeutic measures, and might eventuate disastrously by abolishing the most favorable conditions for a fortunate issue. If we adopt the proposition, that fractures of the femoral neck with penetration can, and often do, unite by bone, irrespective of their relative position to the capsular ligament, then the distinction between fractures within and without the capsular ligament can only find a practical application in the examination of specimens to prove or disprove the correctness of the proposition. This holds the more true as, *in vivo*, all known diagnostic means have proved unreliable in locating the exact point of fracture. The sooner the profession can be convinced that intra-capsular fractures also unite by bony union under certain favorable conditions, the better will it be to abandon the old classification, which has proved to be incorrect anatomically, and unwarranted by pathological facts. Practically, then, it is always important to ascertain the presence of impaction, and not to interfere with it when found; theoretically, and for the purpose of adopting therapeutic measures, it is desirable in non-impacted fractures to locate as nearly as possible the seat of fracture without inflicting unnecessary violence.

In the light of recent anatomical investigation and pathological research, and for the purpose of avoiding unnecessary confusion, it would be advisable to limit the term intra-capsular to all fractures that do not extend beyond the insertion of the capsular ligament, and include among the extra-capsular fractures the so-called mixed and purely extra-capsular fractures. Remembering the attachment of the anterior portion of the capsular ligament

we would naturally infer that purely extra-capsular fractures, without further injury to the shaft of the femur, if possible at all, must be exceedingly rare. The greatest number of extra-capsular fractures, as described by our text-books, have belonged to the mixed variety; intra-capsular in front, extra-capsular behind. In speaking of extra-capsular fractures, Dr. R. W. Smith says: "All extra-capsular fractures are, in the first instance, also impacted fractures, and all impacted fractures are necessarily accompanied by a fracture traversing some part of the trochanteric region. I have omitted no opportunity of investigating this point, and have now examined here and elsewhere upwards of one hundred specimens of the extra-capsular fracture, and have found in all, without a single exception, a second fracture traversing some portion of the inter-trochanteric space."

In commenting upon the paper of Dr. G. K. Smith,[1] Dr. Post suggested to substitute the terms intra-cervical and extra-cervical for intra-capsular and extra-capsular, the latter designation to indicate an impacted fracture at the base of the neck with more or less injury of the femoral shaft. As under this classification intra-cervical fractures would include intra-capsular and mixed fractures, and the term extra-cervical would imply the existence of a fracture rather beyond than in the cervix itself, these terms do not convey sufficiently accurate anatomico-pathological precision to recommend themselves for general adoption, although they are full of practical significance. Inasmuch as the principal object in writing this paper has been to prove that bony union after intra-capsular fractures can take place, the terms intra-capsular and extra-capsular have been retained, but will be applied in the sense previously suggested.

V. *Relative Number of Intra- and Extra-capsular Fractures.*

The inability to accurately locate the fracture during life, the existing confusion and uncertainty as to the meaning and application of the terms intra- and extra-capsular in the description

[1] Op. cit., p. 35.

of specimens have rendered the statistics on this point unsatisfactory and unreliable. Although the cervix femoris may be broken at any point between the head of the femur and the inter-trochanteric ridges, there are certain points where it is more liable to give way. The exact location of the fracture is determined to a great extent by the seat and degree of senile osteo-porosis, and the direction of the fracturing force. Senile osteo-porosis, as we have seen, begins in the spongiosa and reaches its maximum degree soonest at the contracted portion of the neck; hence fracture nearest the head is most likely to take place in decrepit old people. Fractures at this point are exceedingly rare in persons less than fifty years of age; only a very few well-authenticated cases being on record. Rodet, in a series of experiments on the femur and on plaster-of-Paris casts of the upper extremity of this bone, has demonstrated the important fact, that the situation and direction of a fracture of the neck of the femur may be predicted to almost a certainty by a knowledge of the direction in which the force was applied. Thus, a force acting vertically will produce an oblique intra-capsular fracture; a force acting from before backward a transverse intra-capsular fracture; one from behind forward a fracture partly within and partly without the capsule; and a force applied transversely a fracture entirely without the capsule. Clinical evidence has repeatedly verified the correctness of these observations. The traction fractures described by Linhart, Riedinger, and Hueter, from the powerful traction of the ilio-femoral ligament, when the thigh is over-extended and adducted, invariably fall outside of the limits of the capsule.

Bonnet believed that the line of fracture was almost always without the capsule, and Nélaton contended that in the great majority of cases he made the same observation; while many authors, equally competent, among them Sir Astley Cooper, Ashhurst, and Druitt, claim that intra-capsular fracture occurs more frequently in persons above fifty years of age. Of twelve specimens examined in the museum of St. Bartholomew's Hospital by Stanley, six were supposed to be intra-capsular, and six extra-capsular.

Malgaigne[1] examined one hundred and three specimens from different sources to determine the relative frequency of these fractures, and found that sixty-one belonged to the intra-capsular to forty-two of the extra-capsular variety.

M. Mercier, at Bicêtre, found in eight autopsies three intra-capsular to four extra-capsular fractures, and one below the trochanters; while Malgaigne himself, in the same hospital, found in eight other autopsies one fracture below the trochanters, five within the capsule, and only two outside of it. Stimson[2] made a post-mortem examination in six cases, and ascertained that in two of them the fracture was purely intra-capsular, and in four the fracture was at the junction of the neck and shaft.

Heppner[3] gives a description of five cases of impacted fractures of the neck of the femur, of which number three were extra-capsular and two intra-capsular. Of twenty-three specimens of fracture of the neck of the femur, in the Museums of the College of Physicians, Philadelphia, and the University of Pennsylvania, examined by Agnew,[4] ten were within and thirteen without the capsular ligament.

Mussey's collection contains twelve examples of fracture of the femur without the capsule, and ten within. The above statistics embrace one hundred and eighty-five post-mortem specimens, of which number ninety-nine were fractures within, and eighty-six without the capsular ligament; figures which would tend to prove that intra-capsular fractures are more frequent than fractures without the capsule. It must, however, be remembered that many of these specimens were collected for a special purpose, and on that account the numbers do not represent the true proportion as it actually exists. If the statistics obtained by the examination of post-mortem specimens are not reliable in ascertaining the relative frequency with which these fractures occur, the information derived from clinical observation

[1] Treatise on Fractures. Translated by J. H. Packard, M.D., 1859, p. 533.

[2] A Treatise on Fractures, 1883, p. 491.

[3] Beobachtungen u. Untersuchungen über die Schenkelhalsbrueche. Oestr. Med. Jahrb. Heft. 3 u. 4, 1870.

[4] Principles and Practice of Surgery, 1878, vol. i. p. 931.

must prove still less satisfactory in deciding this question, as the symptoms during life are not sufficiently well marked to enable the surgeon to locate with certainty the exact seat of fracture.

Billroth[1] refers to twenty-seven cases of fracture of the neck of the femur, of which number thirteen were diagnosticated as intra-capsular, and fourteen extra-capsular. In Dr. Hyde's table of three hundred and twenty-one cases of fracture of the femur, we find that the neck was involved thirty-one times, these were supposed to be located fourteen times within and seventeen times without the capsule.

Hamilton[2] has recorded eighty-four cases of fracture of the femoral neck from his own personal observation; of these, forty were believed to be without the capsule, and thirty were believed to be within, the remainder were undetermined. These statistics furnish one hundred and twenty-eight cases with fifty-seven intra-capsular, and seventy-one extra-capsular fractures, a majority in favor of the extra-capsular variety.

Combining the figures from the museum specimens and those taken from bedside observation we obtain three hundred and thirteen cases of fracture of the neck of the femur, of which number one hundred and fifty-six were supposed to be located within, and one hundred and fifty-seven without the capsular ligament.

VI. *Incomplete Fractures of the Neck of the Femur.*

The structure of the neck of the femur in the aged furnishes conditions unusually favorable for the occurrence of partial or incomplete fracture. Although this form of fracture has received but little attention on the part of surgical writers, receiving at the best only brief mention, it would appear from the cases reported during the last few years, that the accident is not as rare as has been supposed. Colles[3] was the first to call attention to this variety of fractures as it occurs in the neck of the femur, and described

[1] Chirurgische Klinik. Wien, 1879.

[2] A Practical Treatise on Fractures and Dislocations, 1880, p. 393.

[3] Dublin Hospital Reports, vol. ii.

three cases. Dr. J. B. S. Jackson, of Boston, described a case of incomplete fracture (fissure), the line of fracture extending from the junction of the upper border of the neck with the head downward to within a quarter of an inch of the inferior and internal wall of the bone. Gurlt[1] mentions three cases. In Tournel's case the infraction took place at the upper portion of the base of the neck, the line of fracture running from the digital fossa downward.

In the case reported by P. Wilkinson King, the line of fracture was near the head of the femur, a bridge of compact tissue on the anterior and upper portion of the neck, one-third the circumference of the compacta remained intact. The third described he found in the Pathological Museum in Giessen. The transverse infraction affects the entire posterior half of the femoral neck about its middle, while the anterior wall is not affected. The margins of the fractured surfaces are in immediate contact. Koenig[2] described two specimens. In the first specimen the line of fracture occurred on the upper and posterior surface of the neck, near the head, with impaction of the cervical portion into the head, while the compact tissue on the anterior and inferior surface remained entire. In the second specimen, the line of infraction took place at the lower surface of the neck, at the most constricted portion, with penetration of the apex of Adams's arch into the interior of the head, while the upper portion of the neck had yielded without being broken. (Figs. 5 and 6.) These two varieties Koenig considers as representing typical forms of this fracture, the mechanism of their production being the same as in complete fractures of the neck. In the first variety from the direction of the impaction the limb is rotated outward, while in the second form the foot remains in its natural position but the limb is shortened in proportion to the extent of the impaction. Koenig is of the opinion that many of the cases of complete recovery after supposed intra-capsular fractures, were cases of incomplete fracture with impaction. At the

[1] Knochenbrueche, vol. i. p. 31.

[2] Verhandlungen der Deutschen Gesellschaft f. Chirurgie, 1877, p. 131.

same meeting, Billroth reported two cases where he made the diagnosis of incomplete fracture during life, in both instances recovery was imperfect.

Fig. 5.

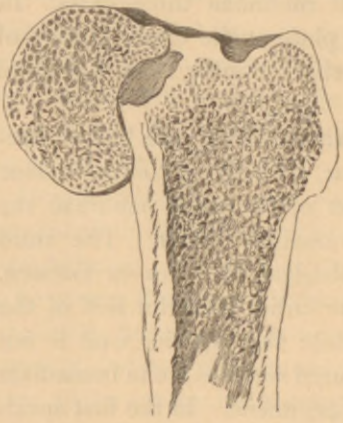
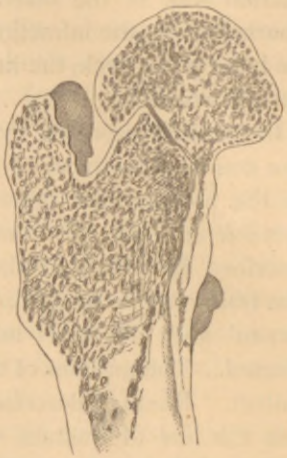


Fig. 6.



Partial Fracture of Neck of Femur. (Koenig.)

Incomplete fractures of the neck of the femur, as well as of other bones, consist of a loss of continuity of a certain number of cancelli, forming the substance of bone. It may exist in every degree from a fracture almost complete to one in which the number of severed cancelli is so small as to elude detection by the naked eye. The location and direction of the line of infraction, as in complete fractures, must necessarily vary according to the direction in which the force is applied which produces the fracture. Stimson[1] says: "The line of fracture is transverse and upon the concave side, and is produced by crushing, not by overbending." Incomplete fractures are repaired by the formation of intermediate callus between the fractured surfaces which restores the continuity of the bone. The unbroken portion of the bone and periosteum serve as a perfect splint, which secures complete rest and apposition until the injury is repaired. The de-

[1] A Treatise on Fractures, 1883, p. 41.

formity attending this accident is necessarily always very slight, and as the symptoms at the same time are not pronounced, the diagnosis must always remain uncertain. The cases are most likely to be mistaken for contusion of the hip; hence, we should always examine the severer injuries about the hip with unusual care, and if any doubt exists, give the patient the benefit of such doubt, and treat the case as one of incomplete or complete fracture with impaction.

VII. *Impacted Fractures of the Neck of the Femur.*

Impaction, penetration, implantation, and incuneation, are synonymous terms, which are used to describe a fracture when one fractured end is driven into the other, an occurrence which secures perfect coaptation and fixation. In some instances impaction is mutual. Impaction may be complete or incomplete, according to the tissue-structure at the seat of the fracture, or the direction and intensity of the fracturing force. Impacted fractures are most frequently met with in the spongy portions of the long bones, and in persons suffering from osteo-porosis from any cause. These fractures have only quite recently become the object of special investigation, and are at the present time receiving the attention their importance merits.

Robert was the first to give a good description of impacted fracture of the neck of the femur and explain its mechanism. He specified the following conditions which must be present for penetration to take place. In the first place the penetrating bone must have a conical shape, and must be placed opposite a spongy section of bone, and must have been broken off close to the insertion of the same. The impacting force must be applied in the direction of the long axis of the incuneated bone. All these conditions are presented in fractures through the neck of the femur. Adams regarded the inner and lower compact tissue of the neck of the femur as the principal element of impaction; the direction of the fracture through the neck being oblique from above downward fractures the arch in such a way that the apex, sharp and pointed, is placed opposite the loosely

cancellated tissue of the shaft into which it is driven by the same force which fractured the bone.

Streubel looked upon senile osteo-porosis as the main cause of impaction. It is necessary, however, that the compacta of the fractured neck retains sufficient firmness to penetrate the bone without being comminuted. Some authors assert that impaction follows fracture in such a way that the neck of the femur gives way to indirect violence from a fall upon the foot or knee, the impaction following by the patient falling upon the trochanter. Heppner assumes that the relation existing between the neck of the femur and the trochanteric portion of the femur is the cause of impaction, and takes into special consideration the spongiosa in which he distinguishes two distinct layers, of which the one possesses a greater degree of density than the other. He believes fracture at the base of the neck with impaction is always the result of force applied to the trochanter major, which expends itself at the origin of the femoral brace, and fractures the entire base of the cervix. Aside from the diminution in the obliquity of the cervix, and the presence of senile osteo-porosis, he finds another cause for this fracture in the general atrophy of the aged, rendering the trochanter major more prominent and thus more directly exposed to external violence.

This last assertion, however, is not in accord with experience, as corpulent aged females furnish the largest number of fractures of the femoral neck. Streubel made some experiments on cadavers to determine the seat of fracture on the application of direct and indirect violence. To test the effect of violence applied in the axis of the femur, he amputated the thigh and applied the force directly to the sawed surface of the femur, and succeeded only in one instance in producing an intra-capsular fracture. By applying the force to the trochanter major he produced one extra-capsular impacted fracture, while in all other cases the trochanter major was fractured. Heppner repeated these experiments with the same results. He then reversed the direction of the force. Taking a femur, stripped of its soft parts, and resting the outer surface of the trochanter major upon a

table, he struck the head of the femur with an axe, and produced in every instance a fracture of the neck resembling an impacted fracture. He repeated the experiment thirty times, and in five of the cases the impaction was typical. From these experiments he has drawn the deduction, that the fracture is produced by contre-coup, whether the force is applied to the trochanter major or through the axis of the femur.

In regard to impaction of intra-capsular fractures he could find nothing in the literature on the subject of fractures of the femoral neck. Vollemier speaks of them at length, but only for the purpose of denying their occurrence. But, inasmuch, as he relates having seen several specimens where the end of Adams's arch was found to terminate in the interior of the spongy portion of the head of the femur, he contradicts himself, as the description corresponds with impaction of the lower wall of the femoral arch into the head. The question at issue is not the degree of impaction, but whether it can secure mutual fixation of the fragments. In most cases only the lower edge of the outer fragment is impacted, but the contrary may take place, as is evident from the description given by Koenig under the head of partial fractures.

For one of the best contributions to our knowledge of impacted fractures of the neck of the femur we are indebted to Riedinger.[1] He has studied this subject by way of experiments and examination of museum specimens. In speaking of intra-capsular fractures, he says that, as a rule, the lower and more particularly the posterior wall of the lower fragment is driven into the spongiosa of the head. As a necessary consequence of this form of impaction, the head of the femur is depressed and inclines backward sometimes to such an extent as to come in contact with the posterior inter-trochanteric line. The cortical portion of the lower fragment can often be traced into the interior of the head to a distance of two centimetres. At the anterior line of fracture the denticulated margins retain such a firm grasp as to add materially to the firmness of the impaction. At the base of the

[1] Studien über Grund und Einkeilung der Schenkelhalsbrueche, Würtzburg, 1874.

neck of the femur the conditions for impaction are most favorable. If sufficient force is applied over the trochanter major, the neck fractures in such a way that the femoral brace is detached near its origin, and constitutes a sharp projection, which, when slightly dislocated, is placed *vis-à-vis* to the spongy tissue of the outer fragment, and is implanted into the same by the fracturing force. The upper portion of the inner fragment, although not possessed of an analogous dense structure as the femoral brace, follows in the penetrating process the more readily as the whole inner fragment is wedge-shaped. The spongiosa between the cortical layers forms a somewhat sharp projection. Impaction of the base of the neck is carried to its fullest extent in case the fracturing force is sufficient to fracture also the trochanteric portion of the femur. In such instances the apex of the inner fragment splits the shaft of the femur sometimes into a number of fragments, and presents itself on the outer surface of the bone beneath the soft parts.

Mr. Bryant[1] has published a table of fourteen cases of impacted fracture of the neck of the femur, and from an analytical study of these cases he draws the following conclusions:—

"1. That in all the cases the injury to the hip-joint was communicated through the great trochanter.

"2. That, as a result of the injury, there was more or less loss of power in the limb; in some cases it was complete, in as many the patient could rotate the limb slightly on the couch; and in two cases partial flexion of the thigh could be performed.

"3. That in all the cases immediate shortening of the injured limb was the direct result of the accident; and that this shortening was about an inch or less, and it was irremediable by extension.

"4. That the foot of the injured extremity was either straight or slightly everted, although in several cases this eversion was less marked on the injured than on the sound side.

"5. That the great trochanter was placed nearer the median line of the body, and also nearer the anterior superior spinous process of the crest of the ilium than on the sound side.

[1] Medical Times and Gazette, April 17 and May 1, 1869.

"6. That the head of the femur could be made to rotate smoothly in the acetabulum, and the great trochanter moved with it.

"7. That crepitus was either absent or indistinct in all cases.

"8. That all the cases, with one exception, occurred in patients past middle age."

Bardeleben[1] maintains that, in intra-capsular fractures, longitudinal displacement is opposed by the untorn portions of the capsular ligament.

In this fracture the ends of the fragments are often interlocked in such a manner as to prevent dislocation, and may even enable the patient to walk on the limb for a few hours, or for several days.

The more important elements in retaining the fragments are, however, the presence of impaction, and the untorn portions of the reflected capsule, the retinacula of Weitbrecht.

S. D. Gross[2] believes that impaction is rare, and, when present, it is almost exclusively extra-capsular. The distance of penetration varies from a few lines to one-half or three-quarters of an inch.

Hueter[3] places great importance in recognizing the presence of impaction. He regards the schenkelsporn as the most important agent in the process of impaction. Anatomically he distinguishes two varieties: either the upper end of the lower fragment is displaced inward, so that the termination of the schenkelsporn penetrates the soft tissues below the upper fragment, or the lower fragment is displaced outward in such a manner that the schenkelsporn is driven into the spongiosa of the neck. Impacted fractures are not so frequent as non-impacted fractures, but they are sufficiently common to render them of the greatest importance in diagnosis, prognosis, and treatment of fractures of the neck of the femur.

H. H. Smith[4] believes that in the majority of cases the neck

[1] Lehrbuch der Chirurgie, 1871. Band II. S. 473.

[2] System of Surgery, 1864, vol. i. p. 965.

[3] Grundriss der Chirurgie, 1882. B. II. S. 883.

[4] The Principles and Practice of Surgery, 1863.

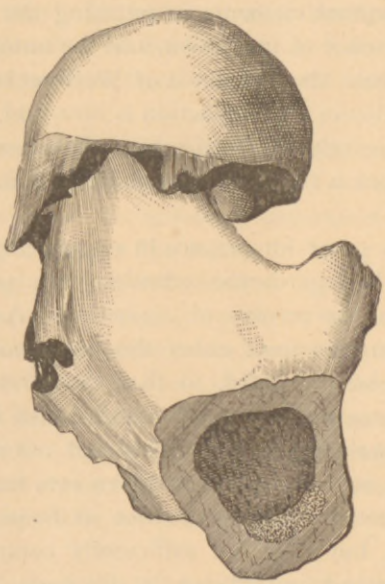
of the femur is fractured by indirect violence, impaction following subsequently by a fall upon the trochanter major.

R. W. Smith says: "That all extra-capsular fractures are, in the first instance, also impacted fractures."

Robert[1] was of the opinion that fractures of the neck of the femur were nearly always impacted, and as such should be disturbed as little as possible to obtain the best results, as the impaction furnishes the best possible conditions for bony union to take place.

MacNamara[2] affirms that fractures of the neck of the femur are usually impacted, the fragments being jammed into one

Fig. 7.



Posterior Impaction of Femoral Neck. (Bigelow.)

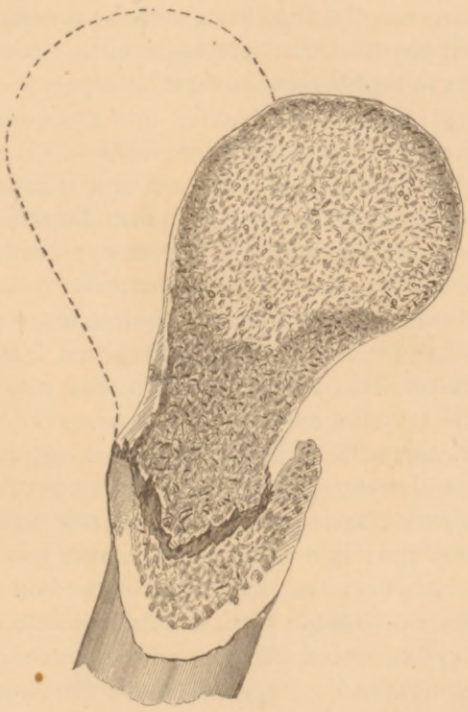
another; the smashed cancellated tissue must be removed, rendering the process of repair tedious.

[1] Mémoire sur les Fract. du col de Fémer, 1845.

[2] Diseases of Bones and Joints, 1881.

Bigelow,[1] who has devoted a great deal of time and attention to the subject of injuries about the hip-joint, from the views he entertains as to the architecture of the femoral neck, is convinced that fracture takes place most frequently at the base of the neck, and is usually accompanied by impaction of its posterior wall. (Figs. 7 and 8.) These cases present outward rotation of the limb, and slight shortening, and may be followed by complete repair without lameness.

Fig. 8.



Posterior Impaction of Femoral Neck. (Bigelow.) Transverse Section.

Impaction at the constricted portion of the neck is not frequent. Impaction of the entire base of the neck with inward

[1] The True Neck of the Femur, Boston Med. and Surg. Journ., Jan. 7, 1875.

rotation of the limb is very rare, and is hardly possible without fracture of the trochanters.

The same author, at a meeting of the Boston Society for Medical Improvement, held November 23, 1874, exhibited a specimen of a fracture within the capsular ligament with imperfect impaction, which, during life, had simulated impaction at the base of the neck, and induced him to express a favorable prognosis. "The autopsy showed that the fracture was not through the base of the neck, but through the neck itself, close to the head, and that the fragments were 'rabbeted' together. There was motion enough to have worn away the thin walls of the neck, and to show that any bony union, had the patient lived, was not to be hoped for. In this respect it differed from Dr. Gay's case of impacted fracture into the head, where the patient, on the day of his death from pneumonia, a week or two after the accident, lifted up his leg and said that as far as that went, he was getting well. Had that man lived, he would undoubtedly have had bony union and a serviceable leg. The rabbeting of the fragments was shown here very well in the present specimen. It was due to a conical mass of comparatively dense bony tissue projecting from the head fragment, which was driven into the loose cancellated structure of the portion of the neck in the shaft fragment. This dovetailing, although sufficient while the fragments were surrounded by the capsule and soft parts to prevent crepitus, and to cause the neck and head to rotate in the socket as a whole, did not prevent such attrition of the fragments as would hinder bony union."

Koenig[1] locates fractures of the neck of the femur either near the head or the trochanteric portion, localities which correspond to intra- and extra-capsular fractures. From anatomical reasons, after a fall upon the trochanter major, the anterior wall of the neck (the convex side) fractures first, and the fractured end of the neck is directed forward. In most, if not in all cases, the wedge-shaped end of the inner fragment is implanted into the trochanteric portion, producing impaction.

[1] Lehrbuch der Speciellen Chirurgie, 1879. B. II. S. 837.

Adams's arch, the densest and strongest portion of the neck, penetrates the deepest. The greater the inclination of the inner fragment forward the more extensive the impaction. As a necessary result of this impaction, the head of the femur descends and approaches the posterior inter-trochanteric line, the dislocation of the head in these directions satisfactorily accounts for the shortening and outward rotation of the limb.

Accurate statistics as to the frequency with which impacted fractures occur as compared with non-impacted fractures, are still wanting. The individual experiences of surgeons are so widely at variance on this point, that a final decision can only be rendered after the accumulation of more positive knowledge from accurate bedside observation and post-mortem examinations.

From a study of the literature on this subject it is apparent, however, that the more recent authors advance the opinion that it is of frequent occurrence. It is also evident that impaction is not limited to any particular part of the femoral neck, but that it can follow any fracture, although the most favorable conditions for its occurrence are found at either extremity of the femoral neck. The direction and extent of impaction depend on the density of the tissues which are penetrated, and on the direction and intensity of the fracturing force. Impacted fractures within the capsule may occur from the application of indirect violence, as the capsular ligament will offer the necessary resistance; on the other hand, impacted fractures without the capsular ligament can only take place from direct violence. It is also possible in cases of this kind, as suggested by several authors, that a simple fracture is produced in the first place by force applied through the axis of the femur, and impaction takes place subsequently by a fall upon the trochanter major. Impaction from indirect violence would necessarily take place at the lower portion of the constricted portion of the neck by the apex of the femoral brace penetrating the soft spongiosa of the head, while if produced by a fall upon the trochanter major, the compacta of the posterior surface is also implanted into the head. Impaction outside of the capsule, from the normal position of the neck

and the direction of the fracturing force, always takes place at the expense of the posterior portion of the neck, except in cases where the fracturing force is so severe as to drive the entire neck wedge-like into the upper portion of the femoral shaft, splitting the latter into two or more fragments. Impaction implies the destruction or crushing of more or less of bone tissue; and, in case the fragments are unlocked, a vacuum is formed, which must be filled by the interposition of fluids or the adjacent soft tissues. It is well known that intra-capsular fractures are often produced by very slight injuries, and it is equally certain that these are the cases which furnish the most unfavorable prospects for a good result, and the question might naturally arise, had the violence been sufficient to produce deep penetration, would it not have enhanced the prospects for a more favorable issue? In fractures of the neck of the femur the prospects for a favorable result are better if the exciting cause acts with sufficient intensity to produce impaction, as this condition is the most favorable for repair by bony union.

VIII. *Predisposing Causes.*

Fractures of the neck of the femur is one of the rarest accidents during childhood and adult life, while after the fiftieth year they constitute a high percentage of all fractures. Between the twenty-first and thirtieth year they constitute $\frac{1}{91}$ of all fractures; between thirty and forty $\frac{1}{74}$;[1] between fifty and sixty nearly $\frac{1}{10}$, and over seventy $\frac{1}{3}$. Their frequency increases steadily with the advance of old age. A number of explanations have been advanced to explain this clinical fact. Thus, Richter[2] mentions the following predisposing causes: 1. Spongy texture of neck, and diminution in thickness of compact layer. 2. Diminution in the obliquity of the neck. 3. Prominence of trochanter major by which the fracturing force is transmitted directly to the neck.

Walther[3] assigns to syphilis an important part. Sex has also

[1] Gurlt, Handbuch der Lehre von den Knochenbrueche, 1862, vol. i. p. 30.

[2] Lehrbuch von den Bruechen, etc., 1833.

[3] System der Chirurgie, 1852. B. VI. S. 348.

been mentioned as a predisposing cause; aged females furnish a greater number of fractures, and it was claimed that this could be explained by the more horizontal position of the neck in the former than in the latter. As the strength of the femoral neck is derived from the peculiar architectural arrangement of the spongiosa, the simple diminution of its angle would not render it more liable to fracture, as Julius Wolff has shown that, even in fractures that have healed with considerable deformity, the structure of the spongiosa is perfectly restored in accordance with the original plan. If the neck is placed at a right angle to the shaft, it would give way more easily at the constricted portion on the application of indirect violence, while from a mechanical standpoint it ought to resist force more advantageously in case it is applied in the direction of the axis of the neck. The predisposing cause is intrinsic—inherent in the bone itself—a degeneration or diminution of bone-tissue. All influences which affect nutrition, and that of bone in particular, as insufficient or improper food, wasting diseases, prolonged confinement in bed, etc., hasten the degeneration of bone, consequent upon senile marasmus. Senile osteo-porosis then is the only known predisposing cause; an assertion which is abundantly confirmed by clinical experience.

IX. *Exciting Causes.*

Fractures of the neck of the femur are produced by—

1. Force applied in a vertical direction through the axis of the femur.

2. Force applied in a horizontal direction over the trochanter major in the axis of the femoral neck.

3. Traction force transmitted through the capsular ligament when the limb is forcibly hyper-extended and adducted and rotated outwards.

A fall upon the foot or knee, as a rule, will fracture the neck at its narrowest portion; and, if the fracture is complete, no impaction will take place, unless it follows as a secondary occurrence from transmission of force through the trochanter major.

Most authorities who believe that intra-capsular fractures are the most frequent, assert that indirect violence is the most frequent exciting cause.

Experiments and clinical observation have shown that the majority of fractures of the neck are produced by force applied in the direction of the axis of the neck by falls upon the trochanter major. It is also an established fact that in most instances of this kind the neck gives way at its trochanteric portion, and that the posterior wall is crushed or fractured first. Impaction takes place more frequently from direct force with deeper penetration of the posterior than the anterior wall of the neck.

Of thirty cases of fracture of the neck examined by Desault[1] for the purpose of learning the exciting cause, twenty-four were produced by a fall upon the trochanter major. All the cases reported by Sabatier appear to have been produced in a similar manner. Sabatier ascribed to the prominence of the greater trochanter an important part in the production of fracture, and believed that fracture of the femoral neck does not occur in children on account of the imperfect development of the upper extremity of the femur.

Although direct force through the axis of the neck generally expends itself near the femoral shaft, causing a fracture of the expanded portion of the neck with posterior impaction, there are a number of cases recorded where the fracture occurred within the capsule. Intra-capsular fractures produced in this manner are often impacted.

The last manner in which a fracture may be produced of the femoral neck is by forcible hyper-extension and rotation outward of the limb, movements by which the ilio-femoral ligament is put upon its utmost stretch; and, when this bone has become so fragile that it is unable to resist the traction of this powerful ligament, a fracture, the so-called traction fracture, takes place at the junction of the neck with the femoral shaft. This fracture

[1] A Treatise on Fractures, etc., 1817.

is always extra-capsular, and was first described by Linhart, and subsequently experimentally studied by Rüdinger.[1] Rüdinger believes the fracture takes place before the patient falls upon the ground; comminution of the trochanter major and impaction may subsequently result from direct violence.

X. *Senile Osteo-porosis.*

Senile osteo-porosis is an affection of the bones in the aged, characterized by diminished elasticity and increased fragility as compared with healthy bones. It is an excentric atrophy of bone, due to impairment of the physiological functions which preside over digestion and assimilation. During the incipient stages the bone retains its volume, but loses in density and weight, owing to an actual loss of bone-tissue, which necessarily results in increased porosity. This affection appears first in the spongiosa of the head and neck of the femur, and it is here where its most advanced stages are observed. In the upper end of the femur this senile degeneration weakens the support to vertical pressure, allowing the head gradually to descend in some instances below the summit of the great trochanter, at the same time diminishing the oblique angle of the neck to almost a right angle with the shaft. Senile, in connection with this subject, however, is a relative term, as this condition of the bones may be found in comparatively young people, provided atrophic changes peculiar to old age, the senile marasmus, from any cause manifests itself; and, on the other hand, even very old people, when otherwise in good health, may remain exempt from this form of senile degeneration. I have in my possession a femur, taken from a gypsy 104 years of age at the time of his death, which illustrates this assertion. The neck of the bone retains the normal obliquity, the compact layer is firm and thick, while the spongiosa, although somewhat more porous, presents the different systems of arches in a degree of perfection unsurpassed at any age. Senile atrophy of bone, and the diminution in the

[1] Studien über Grund u. Einkeilung d. Schenkelhalsbrueche, 1874, p. 63.

obliquity of the neck of the femur resulting from it, have justly received so much attention on the part of pathologists and surgeons, to explain the frequency of fracture, that I may be pardoned for entering more fully into a consideration of this subject.

All authorities agree in assigning to the structural degeneration of the neck of the femur an important, if not the only predisposing cause in the production of fractures in this locality in the aged. The increased brittleness of bones during advanced age has been explained in different ways. Bichat attributed it to an excess of the inorganic constituents of the bone with a corresponding decrease of the organic matter. This view found almost universal acceptance among surgeons, and is still taught in many of our text-books on surgery.

Henle was among the first to assert that the fragility is not caused by a disproportion of the earthy and organic constituents of bone, but that it is the result of an actual loss of bone tissue, a genuine atrophy of bone. Ribbert[1] has made special inquiries into the pathology of senile atrophy of bone, and from the prevalence of this affection along the lower regions of the Rhine, he has been enabled to study this process under the most favorable circumstances. On examining sections of osteo-porotic bone stained with carmine he invariably found an osteoid red zone upon the surface of the lamella varying in size, extent, and number in proportion to the severity of the process. These zones presented very delicate parallel lines, and bone-cells with very fine or spindle-shaped projections. The margins of the osteoid layers towards the unchanged portion of the lamella are not very irregular, and usually devoid of lacunæ. The medulla, as a rule, is pulpy, hyperæmic, and often infiltrated with blood, the medullary spaces dilated, and the lamellæ correspondingly reduced in thickness. In one case he found the latter completely destroyed and converted into osteoid tissue, forming cyst-like cavities filled with pulpy medullary tissue. Ribbert regards the process as being due to an impairment of nutrition, which of

[1] Ueber senile Osteo-malacia u. Knochenré-orption im Allgemeinen. Archiv. f. Path. Anat., LXXX. S. 436.

necessity is attended by chemical changes of the basis substance of bone, which is followed again by a separation of the earthy phosphates from the basis substance. The earthy salts are rendered soluble by acids (perhaps carbonic acid) contained in the fluids of the body. As an evidence that the earthy phosphates are separated from the organic tissues, the author mentions that he has seen a granular opacity at the junction of the osteoid spaces with the normal bone, which cleared up on the application of an acid.

Insufficient or improper food has an important influence in impairing the nutrition of bone, as has been abundantly shown by reliable observations. Roloff[1] made experiments on animals for the purpose of studying the pathology of fragility of bones. He was able to produce this condition artificially by depriving the animals of all food containing phosphate of lime. He ascribes the condition primarily to a diminution of the earthy constituents of bone, and during the more advanced stages of decalcification a metamorphosis of osteoid into myeloid tissue takes place. The walls of the canaliculi appear more transparent and wider, and present the appearance of light stripes with dark edges. The walls of the bone-cells or spaces become translucent. During the further progress of the metamorphosis the appearances are such as would indicate that the bony tissue over greater or less areas had been entirely destroyed, and its space filled up with new myeloid cells from the adjacent myeloid spaces. A close examination, however, showed that the myeloid cells originated from the bone-cells.

Maresch observed an epidemic of fragility of bones among cattle and pigs in Bohemia, which lasted for three years, and was attributable to a prolonged drouth, and consequent upon it poor quality of food. He invariably found that the disease showed a predilection for the extremities of the long bones, which were softened to such an extent that they could be readily cut with the knife. The interior of the spongiosa was filled with a white pultaceous mass, while the compacta was reduced to a thin shell.

[1] Ueber Osteo-malacia u. Rachitis. Virchow's Archiv, B. XXXVII. Hft. 4, S. 434.

M. Mercier observed that in all specimens of senile atrophy the alveolar spaces were enlarged, rendering the tissue more porous.

Kölliker[1] believes that giant-cells are the agents which produce absorption of bone in normal and pathological conditions. These cells, when found in bone, he calls osteo-klasts. They originate from osteo-blasts, and are found on the surface and in the interior of the lacunæ.

Humphry,[2] in mentioning the causes of fracture of the femoral cervix, alludes to the subject as follows: "In the aged the arrangement of the cancelli, which in the young and middle aged are so admirably adapted to support superimposed weight, becomes imperfect from senile degeneration, a process which begins earliest in the upper end of the femur."

Herman Meyer[3] advanced the idea that senile osteo-porosis appears under the form of a non-suppurating periostitis, the product of which as yet remains unknown.

Gurlt's[4] description of senile osteo-porosis may be condensed as follows: The medullary canal is enlarged, the cortical layer very thin or entirely absent, and the spongiosa exceedingly porous, the meshes being filled with myeloid tissue of a dark color.

Kassowitz[5] affirms that absorption of bone takes place as a consequence of increased vascularization, the loss of bone-tissue being the direct result of absorption.

G. Pommer[6] has studied the process of resorption in diseased bones with a view to determine the formation of Howship's depressions and the function of the osteo-klasts. His observations, based upon thirty cases of bone atrophy, due either to old age or pressure from any cause, has induced him to accept Kölliker's views as mentioned above.

[1] Die Verbreitung und Bedentung d. vielkernigen Zellen d. Knochen u. Zaehne. Virchow u. Hirsch Jahresb., 1872, vol. i. p. 21.

[2] Treatise on the Human Skeleton, 1871, p. 471. [3] Op. cit.

[4] Handbuch von der Lehre der Knochenbruechen, 1861, vol. i.

[5] Virchow u. Hirsch's Jahresbericht, 1881, vol. i. p. 262.

[6] Ueber die lacunaere Resorption im erkrankten Knochen, Wiener Sitzungsbericht. B. 83, Abth. III. S. 17.

Morisane has made histological examinations to ascertain the minute processes which take place in the destruction and absorption of bone in cases of rarifying osteitis. He believes that the normal exudation which takes place from the minute vessels in bone in a state of health, is destined to perform the essential part in the production of bone, but when inflammation is present, chemical changes take place in the exuded material, which annihilate the bone producing properties of the cells. He distinguishes an acute and chronic form of the disease. In the chronic form the destruction of the compact tissue is the result of a progressive diminution of its earthy phosphates, during which the basis substance is reduced to fibrillæ, which unite with the connective tissue of the marrow spaces, and undoubtedly materially assist in the formation of the connective tissue framework of these spaces. In the acute form, where nutrition is seriously impaired, the stroma undergoes rapid granular degeneration, while the earthy salts are absorbed, the bone-cells are destroyed instead of being converted into connective tissue, as is the case in the chronic form. In the chronic as well as the acute variety of rarefying osteitis, the death and absorption of bone-tissue is dependent in an intimate manner on the numerical increase and degree of dilatation of the small vessels; and, to a certain extent, it also results from a chemical change which the products of exudation have undergone; to this latter must be assigned an important rôle as a dissolving agent.

I have called attention to inflammatory osteo-porosis of bone under the head of senile osteo-porosis, in order to explain the rapid absorption which takes place after fracture of the neck of the femur. In all of these cases, and more particularly in the intra-capsular variety, more or less of the neck is removed by absorption, in some instances almost the entire neck disappears. This process of absorption after fracture expends itself more on the lower than the upper fragment, and more upon the posterior than the anterior portion of the neck. Interstitial absorption of the neck of the femur in young adults, as described by Gulliver,[1]

[1] Interstitial Absorption of Neck of Femur without Fracture, Medico-Chirurgical Review, vol. xvii. p. 543.

can only be explained on the hypothesis that inflammatory softening and absorption were induced by traumatism. Only in two cases of the four reported by Gulliver was the diagnosis verified by the autopsy. Both were young men who had suffered contusion of the hip on the affected side, in both the neck was shortened, and almost at a right angle with the shaft; in one of them the cancellated tissue of the neck was more compact, and some adventitious bony material on its surface near the shaft; while in the other case, "the cancelli of the neck were filled with caseous matter, in some nearly colorless, in others tinged with dark grumous blood."

Similar specimens have been brought forward as cases of bony union after intra-capsular fracture; there is, however, in all of these cases a symmetrical atrophy of the anterior and posterior portion of the neck of the femur, while in cases of intra-capsular fracture with bony union, there is almost without exception a greater loss of substance of the posterior than of the anterior portion of the neck.

Interstitial absorption of the neck in young adults is always the result of rarefying osteitis, which eventuates in loss of bone-tissue, but after the disease has subsided regeneration takes place, the spongiosa becomes more dense by deposit of new bone, while the same process takes place beneath the periosteum, giving rise to adventitious bone, which might easily be mistaken for callus, as in Case III. described by Gulliver; in other instances the process of destruction is not followed by repair, the products of inflammation remain in the cancelli, as in Case IV., mentioned by the same author:

There has been considerable difference of opinion in regard to the particular structure which is the primary or most important seat of senile osteo-porosis. Authors have located it in the structures which, in accordance with the views they entertained, were supposed to furnish the principal support to vertical pressure; thus Meyer found it in the spongiosa, Merkel in the calcar femoral, Bigelow in the compact tissue of the neck. Senile degeneration, in preference, affects the spongy bones, and the spongy portions of the long bones; hence, there can be no doubt

that it first attacks the spongiosa in the interior of the head and neck of the femur, from where it gradually invades the different parts of the compact tissue. With a view to prove this assertion I have examined a number of sections of the upper extremity of the femur from persons advanced in years, and have repeatedly observed the spongiosa atrophic and porous, while the femoral brace and the calcar femoral retained their normal strength. During the advanced stage of the affection the compacta may be reduced to the thinness of paper, or disappear entirely, the periosteum coming in contact with the spongiosa; in such cases, fracture takes place on the slightest application of force, and the bone can be readily cut with a knife. The myeloid spaces are the starting points of the process of degeneration; they are enlarged and become distended by the accumulation of myeloid cells and granulation tissue; the cancelli are broken down, and thus spaces of considerable size are created at the expense of the regular system of arches which make up the structure of the spongiosa. Giant cells and granulation tissue possess the property to disintegrate and absorb bone, they are the destructive agents, while the broken-down tissue is removed by the bloodvessels. When sections of a bone, the seat of senile atrophy, are examined during the earlier stages of the process, they present a vascular and red appearance, on account of increased vascularization and an abundant deposit of red marrow. When degeneration has progressed to the highest degree, the compacta has disappeared almost completely, the spongiosa is exceedingly porous, the alveoli large and filled with fat, the bone presents a yellow appearance, imparted by the free fat derived from the fatty degeneration of the histological elements.

As long as the bone is supplied with an abundance of myeloid tissue and bloodvessels, its bone-producing capacity is not impaired; on the other hand, it is said to be increased, irrespective of the degree of softening and fragility; but if fatty degeneration has progressed to the extent just mentioned, and the vascular supply is greatly diminished, as is the case in the most aggravated forms of senile osteo-porosis, no attempt at production of bone can reasonably be expected in the event of fracture. We

are then justified from a consideration of the foregoing remarks in adopting the following conclusions:—

1. Senile osteo-porosis is the only predisposing cause of fractures of the neck of the femur in the aged.

2. Senile osteo-porosis, except in the most advanced stages of fatty infiltration, does not impair, but hastens the production of myeloid, or permanent callus.

XI. *Symptoms of Fracture of the Neck of the Femur.*

As the very best authorities are forced to admit that during life it is impossible to locate accurately the precise seat of fracture, there exists no longer the necessity of considering the symptoms separately under the head of intra- and extra-capsular fracture. In practice, the greatest care should be exercised to ascertain the presence of impaction; but even impacted fractures present the most important symptoms in common with non-impacted fractures; and they may be conveniently, and I think profitably, grouped together to prevent unnecessary repetition.

The symptoms presented by a fracture through the neck of the femur, as in any other fracture, are: 1. Subjective; 2. Objective.

The subjective symptoms are: 1. Pain; 2. Loss or impairment of function.

1. *Pain.*—The pain is due either to the immediate effects of the traumatism, laceration of the contiguous soft tissues, irritation produced by the movements of the fractured ends, or the inflammation of the bone or surrounding tissues succeeding the injury. The pain is variable, almost absent, and of short duration in some cases, excruciating and continuous for months and sometimes years in others. If the fracture is located in the narrow portion of the neck, the pain is usually referred to the groin about the insertion of the ilio-psoas muscle; if at or near its base, it is more diffuse, and referred to the seat of injury.

There has been considerable discrepancy of opinion as to the severity of the pain in fractures within, as compared with fractures without the capsule. Sir Astley Cooper maintained that

it is less severe in the former variety, while Malgaigne claimed that the reverse was true. As fractures of the narrow portion of the neck are the result of less violence than when they occur near the shaft, it is undoubtedly true that the pain attending them immediately after the traumatism is less than in the latter class of injuries, while the reverse may be true during the subsequent history of the case. In impacted fractures, where the favorable conditions for bony union are not disturbed, and the process of repair is initiated at once, and progresses uninterruptedly, the pain, as a symptom, is referable only to the traumatism; and as such, as a rule, is more severe in fractures where the greatest amount of tissue has been lacerated, that is, in extracapsular fractures.

In cases of non-impacted fractures within the capsule, with motion of the fragments upon each other, a certain amount of inflammation springs up, which is always attended by its most prominent symptom—pain. When pain, the result of inflammation, is present, it assumes the characteristic features as witnessed in coxitis independent of fracture. It is then no longer a symptom of fracture, but indicates the accession of traumatic coxitis. The presence of no inconsiderable amount of inflammation has repeatedly been verified at post-mortem examinations, in the form of thickening of the capsule, adhesions, and destruction of the synovial membrane and cartilage. Any attempt at motion or pressure against the trochanter major aggravates the pain. In some old inveterate cases the pain assumes a neuralgic type, which would indicate that some of the nerves about the hip-joint were encroached upon by the displaced fragments, or exuberant callus, or the products of inflammation.

2. *Loss or Impairment of Function.*—This symptom is present in all fractures of the femoral neck. As a general rule, it may be stated, it is prominent as a symptom in proportion to the degree of separation of the fragments. In impacted fractures the patients are often not only able to move the limb, but even walk for hours and sometimes days. The impairment of voluntary movements does not depend alone on the direct loss of support, but is also influenced by the pain incident to such

movements; hence, this symptom will present itself in the highest degree in nervous, excitable patients. Laceration of the soft parts, the periosteum, and capsule, in the absence of impaction, will also counteract voluntary motion, not only by allowing a greater degree of disjunction of the fragments, but likewise by increasing the pain on any attempt at motion.

In the great majority of cases the patient, as he lies in bed, is unable to raise or move the limb in any direction, it remains perfectly helpless in the position it was left after the accident, or in which it has been left by the displacing elements. In some cases where interlocking of the fragments exist, or where a slight amount of impaction has taken place, the patient has control over a certain amount of voluntary movements for a number of days, or until disjunction of the fragments takes place as a result of injudicious examination or inflammatory osteo-porosis, when the limb is placed in the same conditions as if no impaction had taken place.

The objective symptoms are: 1. Swelling and deformity at the hip. 2. Suggillation about the hip. 3. Eversion of limb. 4. Shortening. 5. Change of position of trochanter major. 6. Either increased or diminished mobility of the hip-joint. 7. Loss of tension of fascia lata between the trochanter major and the crest of the ilium.

1. *Swelling and Deformity.*—In all cases there is an appreciable fulness in the fold of the groin corresponding to the seat of fracture. This swelling is caused by the hinge-like projection of the anterior portion of the neck, effusion of blood or inflammatory products, and, lastly, by the over-riding or impaction of the fragments. When impaction takes place at the base of the neck, the trochanteric portion of the femur is enlarged from implantation of the upper fragment. The swelling is larger when the fracture is located without the capsule from the more extensive bone injury and the more copious effusion of blood.

2. Suggillation appears earlier and more constantly the nearer the fracture is seated to the femoral shaft. As this symptom is the result of the presence of blood at the point of fracture, it is more extensive if the hemorrhage has been considerable and

outside of the capsule. If the hemorrhage has been within the capsule, and the capsule is ruptured at some point, the discoloration will usually show itself along the inner side of the thigh. The same force which produced the fracture may also contuse the soft parts sufficiently to give rise to superficial discoloration independent of the fracture.

3. *Eversion.*—The lower limb in a natural condition is slightly everted on account of the forward obliquity of the femoral neck. This normal eversion is increased during sleep when the muscles are at rest, or when they have been completely relaxed by an anæsthetic, or when their action has been permanently suspended by paralysis. In the normal condition, then, the weight of the limb effects outward rotation until arrested by muscular action, or the resistance offered by the ligament of the hip-joint. As the posterior wall of the neck is usually the seat of more extensive comminution or impaction than the anterior, and as the fracturing force in the majority of cases is applied in the antero-lateral direction, it is only reasonable to expect that outward rotation of the limb is the rule. And this expectation has been verified by clinical observation. Until recently it has been generally supposed that eversion is the result of muscular contraction, and in support of this view it has been suggested that in non-impacted fractures it increases after the muscles have recovered their contractility.

Edmund Owens, on the ground of anatomical demonstrations and carefully made experiments, as well as accurate clinical observation, holds that eversion of the limb takes place independent of muscular contraction, that it is invariably the result of the impacting force or the weight of the limb as the case may be. In intra-capsular fractures it is especially true that eversion is more marked a few days after the injury, but this fact can be interpreted more satisfactorily from a different standpoint. In such cases the fragments are often kept in apposition by an interlocking of the broken surfaces or unlacerated portions of the fibrous investment of the neck; either of these supports may give way to the constant traction from the weight of the limb, or the same result may take place from reflex muscular contractions,

or careless handling of the limb. The great mass of muscles, the external rotators of the hip, after the fracture, are relaxed from the approximation of their points of origin and insertion, and it is difficult to conceive in what way they could effect outward rotation. Dupuytren believed that eversion may also be due to the action of the adductor muscles, and in some instances to the obliquity of the fracture itself. It is also necessary to mention that eversion is not a constant symptom. Cases have been described by reliable observers where the limb remained normal so far as the position of the foot was concerned, and in some even the reverse, inversion occurred. Cases of fracture with inversion have been described by Ambroise Paré, J. L. Petit, Guthrie, Stanley, Dupuytren, Desault, Cruveilhier, Hamilton, R. W. Smith, and others. Desault thought that it occurred in about one case out of every four. Stanley observed one case where the autopsy showed that the fracture was purely intra-capsular, and no satisfactory explanation could be found for the inversion. Wm. Pirrie mentions a case of intra-capsular fracture where the limb was not only inverted but also strongly flexed and adducted, a position he ascribed to the tension of the ilio-femoral ligament. Of the one hundred and thirty cases of intra-capsular fracture of the neck of the femur which came under Pirrie's observation, and where the accuracy of the diagnosis was verified by dissection, this was the only case with flexion, adduction, and rotation inward of the limb. Of the remaining number, in one case only existed inversion, the limb in other respects occupying the usual straight position. Malgaigne[1] reports an exceedingly interesting case. "In 1833, having found the foot inverted in a fracture of the neck of the femur, I ascertained that it was easily everted and again inverted at will, and that it remained as readily in one position as in the other; *whence I concluded that whatever inclination is given to the part upon the supporting plane it keeps by its own weight.*"[2] This observation is exceedingly valuable, and would lead us to the conclusion that whenever the support derived from the cervical portion of the femur is lost, the limb

[1] A Treatise on Fractures. Translated by J. H. Packard, M.D., p. 543.

[2] Italics my own.

will follow the natural law of gravitation, and will turn outward by its own weight, unless opposed by some special conditions at the seat of fracture, or by external influences.

4. *Shortening.*—The significance of shortening as a symptom of fracture of the neck of the femur has received additional interest, since it has been ascertained that in many persons there is naturally a difference in the length of the lower extremities in the same individual. Dr. J. S. Wight, of Brooklyn, has made a valuable contribution to surgery relating to the comparative length of the inferior extremities in the same individual. His first published table comprised the measurements of sixty persons, of varied nationality, pursuits, and ages. In these sixty there were ten persons who presented a parity of length in the two legs, and fifty who showed a difference varying from one-fourth of an inch to one-and-three-eighths inches. The right leg was the longer in eighteen, and the left in thirty-two instances. A second table comprises forty-two measurements, and shows a parity of length in thirteen, and a difference in twenty-nine instances, the difference varying from one-fourth of an inch to one inch. In nine cases the right, and in twenty the left limb was the longer. Hamilton has corroborated these statements by his own researches. Gurson[1] has made some further investigations which tend to establish the correctness of these observations. He examined seventy skeletons of different sexes and ages, and belonging to different races. He found that among this number only in seven were the lower extremities of the same length, and among these the femur, tibia, and fibula were of the same length on both sides in two, while among the remaining five the tibia and fibula and the femur equalized the difference in length. In 54 per cent. of the cases the left extremity was longer than the right, the average difference being 4.8 mm., and the maximum difference 13 mm. The right extremity was longer than the left in 55.8 per cent., with an average difference in length of 3.3 mm., and a maximum of only 8.0 mm.

[1] Inequality in Length of the Lower Limbs. Journ. of Anat. and Phys., vol. xiii. p. 26.

These measurements not only prove that the lower limbs differ in length in a majority of cases examined, they likewise point out the importance of measuring the long bones separately for the sake of comparison when measurements are made for diagnostic purposes.

More or less shortening will take place in every case of fracture of the neck. M. Lisfranc and M. Lallemand[1] each have reported a case where the limb was longer. It is impossible to conceive in what manner the fracture could add to the length of the limb; and still the observations were undoubtedly correct, and an explanation can only be given by assuming that the amount of actual shortening was slight, and the patient's limbs were of unequal length. The amount of shortening depends on the degree of disjunction, the greater the longitudinal displacement, the greater the shortening. The shortening is always the direct result of muscular contraction or longitudinal displacement by impaction. In impacted fractures the maximum is reached at once, and the degree of shortening depends on the depth of penetration or mutual inter-penetration of the fractured ends. In cases of impaction the shortening remains stationary, as the fracture is not disturbed, and can only increase on the advent of inflammatory interstitial absorption. In fractures without the capsule, all resistance to muscular contraction is lost, and the maximum amount of shortening is reached as soon as the muscles have become contracted. If the capsule is intact, and remains attached to the lower fragment, shortening takes place gradually by stretching of the capsular ligament. In case the fragments are held in contact by the denticulated fractured surface shortening can only proceed after this medium of apposition has been removed by displacement of the bones, or after inflammatory osteo-porosis has removed the projecting spiculæ. This condition is often met with in intra-capsular fractures. The degree of shortening immediately after a fracture has been relied upon by some in determining the seat of fracture. Among surgeons there has been, however, such discrepancy of opinion in

[1] Dupuytren, Injuries and Diseases of Bones.

this respect, that no reliable deductions can be drawn from this circumstance in rendering a decision.

Sir Astley Cooper and Amesbury claim the greatest shortening for intra-capsular fractures, while Stanley, Earle, and R. W. Smith entertained an opposite opinion. Impaction and the integrity of the capsular ligament are such important factors in determining the amount of shortening and the time when it takes place, that these conditions must be carefully considered in estimating the value of shortening as a diagnostic aid.

5. *Change of Position of Trochanter Major.*—The trochanter major is displaced upward and backward, in proportion to the amount of shortening and eversion. When shortening has taken place, its upper border has passed beyond Nélaton's line. When the limb is rotated, it describes a smaller arc of a circle. It is less prominent when impaction has taken place, or when the lower fragment is not in apposition with the upper.

6. *Alteration of Motion.*—A false point of motion is always established in non-impacted fractures. Preternatural mobility is most marked if the fracture is not impacted and located outside of the capsule. It is probably in cases of this kind that Gerdy has been able to rotate the limb outward until the toes looked backward, and that Maisonneuve brought into requisition his test of hyper-extension. If the fracture is within the intact capsule, the latter will serve as a retentive measure, and limit the motion between the fractured bones. Dr. Levis has found that in non-impacted fractures the limb can be extended beyond its normal length. In case firm impaction has taken place, the neck has become shorter and thicker, conditions which necessarily impair the natural mobility of the hip-joint.

7. *Fascia Lata.*—Dr. Allis,[1] of Philadelphia, has added another symptom, which indicates fracture through the neck of the femur, namely, the existence of a relaxed condition of the fascia lata between the crest of the ilium and the trochanter major on the injured side, produced by the loss of resistance, which is furnished by the neck when not broken. As the presence of

[1] Mechanism of the Hip-Joint, Med. and Surg. Reporter, vol. xxxvi. p. 303.

this symptom depends on the dislocation of the lower fragment upward and inward, it is only met with when such changes have taken place. The standing position is the only one in which this test can be applied, as in the reclining position the muscles that make tense the fascia are relaxed.

Bezzi[1] has called attention to a sign which he considers as pathognomonic of fracture of the neck of the femur. In examining the space between the trochanter and the crista ilii, it will be found that while on the same side the muscles occupying this region (the tensor vaginæ femoris and the gluteus medius) are tense, and offer to the hand a considerable feeling of resistance, they present on the affected side a deep, well-marked depression, a flaccidity, and diminution of tension, from displacement upwards of their points of insertion. This sign appears under the same circumstances, and possesses the same significance as the one described by Dr. Allis.

I have intentionally omitted to mention crepitus as a symptom, as more harm than benefit has accrued from the efforts of the anxious surgeon to establish a positive diagnosis on the presence or absence of this sign. A careful study of the other symptoms will usually enable us to arrive at a correct conclusion without exposing the patient to the risks incident to the manipulations necessary for the purpose of eliciting this symptom.

XII. *Diagnosis.*

All manipulations, during the examination of a supposed fracture through the cervix femoris, should be performed with the utmost care and gentleness. The so-called "thorough examinations," the search for positive symptoms, has been the source of incalculable mischief. In many instances careless handling of the limb has resulted in disjunction of impacted fractures, or in tearing of periosteal or ligamentous bands, thus precluding most effectually possible union by bone or the forma-

[1] Centralbl. für Chirurgie, July 31, 1880.

tion of a short fibrous union. Years ago, Davis[1] entered his protest against such reckless examinations in the following emphatic manner: "Now, while we willingly concede the importance of a correct diagnosis in its bearings upon the successful treatment of any case, we hold that too much handling and manipulation of the limb in intra-capsular fracture is liable to eventuate in irreparable injury to the patient." Again: "When this connecting link of periosteum and capsular ligament is not severed by officious handling on the part of the surgeon, in his zealous, but often mischievous efforts to ascertain to the fullest extent the details of the injury, then we may hope for better results than have usually followed this accident."

Bryant's[2] caution is equally strong: "In fact the ordinary fracture of the base of the neck of the thigh-bone is primarily an impacted fracture, the impacted bone in some cases being loosened by a second fall, in others by excess of violence received in the original accident, and *in too many by the manipulations of the surgeon in his anxiety to make out the presence of a fracture by the detection of crepitus.* Indeed, this seeking for crepitus in cases of fracture is a practice fraught with danger."

I shall not allude to crepitus as a diagnostic sign; as a satisfactory diagnosis can usually be made without, by a careful consideration of the other symptoms. In every case of suspected fracture we should make careful search for evidences of senile osteo-porosis, and ascertain as nearly as possible the amount of force applied, and the direction in which it was applied. If the general appearances of the patient indicate the existence of senile osteo-porosis far advanced, the amount of force has been slight; and inflicted in the direction of the axis of the thigh-bone, it is more than probable that the fracture has occurred within the capsule. If the fracturing force has been greater, and applied transversely in the axis of the femoral neck, we have reason to expect that the fracture has taken place, at least partly, without the capsule. The sudden and complete loss of function of the limb after an injury to the hip in a person over fifty years of age

[1] Conservative Surgery, 1867, p. 23.

[2] Bryant's Practice of Surgery. Edited by J. B. Roberts, p. 842.

speaks strongly in favor of a fracture through the femoral neck. We can say with Hodgson: "If an elderly person, after a fall upon the hip, is unable to use the injured limb, it is very probable that a fracture of the neck of the femur has been sustained, and this is more likely to be the case, if, during the fall, no such great force has acted upon the greater trochanter as would be necessary to produce a contusion sufficiently severe to render the limb useless."

Aside from a general consideration of the case, the diagnosis will depend on the presence or absence of the two most important symptoms, shortening and eversion. Many of our best surgeons depend almost exclusively on accurate measurements in rendering a diagnosis. The amount of immediate shortening will vary according to the presence or absence of impaction, from a few lines to two inches. In impacted fractures the shortening is immediate, and remains stationary unless displacement takes place, or, during the reparative process, the femoral neck is shortened by interstitial absorption. The progressive shortening, a few days after the accident, is due to a loosening of the fragments which have been in mutual contact by denticulated projections, and to a gradual stretching of untorn portions of the capsular ligament. Mr. Bryant, in speaking of the utility of his "test-line," says: "Indeed, as a proof of its use, I may add that twenty-five consecutive cases of fracture of the neck of the thigh-bone, admitted into my wards to the end of 1877 (the average age of the patients being 74), left the hospital with union of the broken bones and useful limbs."

Dr. J. S. Wight, of Brooklyn, has written an exceedingly interesting and practical paper on diagnosis of fractures of the femoral neck, based on the report of twenty-one cases.[1] For the purpose of avoiding errors, which might accrue from asymmetry of the lower extremities, he directs that the following measurements should be taken: "1. Inside measurements from the superior anterior spines of the ilium to the lower ends of the internal

[1] The Diagnosis of Twenty-one Cases of Fracture of the Neck of the Femur. Proceedings of the Med. Soc. of the County of Kings, Oct. 1881.

malleoli. 2. Outside measurements from the superior anterior spines of the ilium to the lower ends of the external malleoli. 3. Measurements from the tops of the great trochanters to the lower ends of the external malleoli. 4. Measurements from the bases of the tibiæ to the lower ends of the internal malleoli. 5. Measurements from the superior anterior spines of the ilium to a line drawn transversely in front between the tops of the great trochanters."

The object of all these comparative measurements is to determine the possibility of original asymmetry of the two limbs, and to find out, as far as possible, if the injury to the hip has caused any shortening of the limb on the injured side, so that we can infer the *probability* of there being a fracture of the femoral neck. He gives the results of examination of twenty-one such fractures, where a diagnosis was made without eliciting crepitus. In eight of these cases there was probably impaction. The average shortening was $\frac{58}{100}$ of an inch, as shown by the inside and outside measurements. In no case of fracture of the femoral neck does he use force to find crepitus. He considers the other evidences of fracture as sufficient to come to a practical conclusion. His concluding statements contain so many practical and useful suggestions that I do not hesitate to quote them in full.

"1. Moving the outer fragment when it is in contact with the inner fragment, will generally carry the inner fragment with it, and there will be no crepitus. And, when there is impaction, ordinary manipulation will not cause crepitus to be felt. Yet crepitus may, at times, be felt when there is impaction of the neck of the femur. 2. Moving the outer fragment when it is not in contact with the inner fragment, of course will not give crepitus. 3. Hence unwarrantable force will be required in order to get crepitus in many cases of fracture of the neck of the femur, and more than this—*an impacted fracture of the neck of the femur may be broken up by severe manipulation, and a patient that would have had a useful limb may be quite completely disabled for life—for an impacted fracture of the neck of the femur is the best setting of the bony fragments that a surgeon can have.*

"In a suspected fracture of the neck of the femur, I examine

all the witnesses of fracture except crepitus, and if these witnesses agree substantially, I pronounce a verdict in favor of fracture of the neck of the femur; and if there is a doubt as to the correctness of such a verdict, I give the patient the benefit of that doubt by treating the case as if there was a fracture of the neck of the femur, and then the surgeon receives a benefit from the doubt. But if there is no fracture, the patient has had some days of needful rest, and has had a contused hip well treated."

The instrument recommended is an accurate steel tape-line, with feet and inches on one side, and meters and centimeters on the other side. This tape-line will not elongate under tension. It is superfluous to mention that the patient should be placed in the recumbent position, on an even surface, when the measurements are taken. It is to be hoped that the text-books of the future will say less of crepitus as a sign of fracture, and will substitute for it accurate methods of measurement.

Eversion of the limb is the next most reliable symptom. In impacted fractures the position of the limb depends on the direction of the fracturing force. If the force acts in the direction of the axis of the cervix, and is severe, causing implantation of the whole base of the neck into the trochanteric portion of the femur, the limb will retain its natural position. If the anterior wall is impacted by force applied against the outer and posterior aspect of the trochanter major, the limb will remain in a position of inward rotation. From the anterior obliquity of the neck, and the usual manner of falling (forwards and on the side), and the thinness of the compacta of the posterior concave surface of the neck, as compared with the anterior, we would naturally infer that posterior impaction takes place in the great majority of cases. This supposition has been abundantly verified by clinical observation. Impaction, then, is usually attended by eversion. If the fracture is located within the capsule, eversion frequently will increase for a few days, or weeks, after the accident, from the same causes which give rise to secondary shortening. In cases of posterior impaction, where the fragments

remain firmly implanted during the process of repair, eversion increases from the weight of the limb and the inflammatory absorption of the impacted fragments, permitting increased rotation outward of the lower fragment. The abnormal position of the trochanter major is also an important diagnostic sign. If we can exclude dislocation of the hip upward and backward, the application of Nélaton's test may decide the diagnosis. In cases of fracture of the neck of the femur, the upper border of the greater trochanter will be found above Nélaton's line, the distance corresponding with the amount of shortening. In non-impacted fractures, the false point of motion diminishes the axis of rotation which the greater trochanter describes in rotating the limb. This symptom is mentioned simply to be condemned, as the manipulations necessary to apply this test, like the search for crepitus, have done a great deal more harm than good. In doubtful cases, more particularly when dislocation is suspected, the patient should be carefully placed in the erect position, when the position of the limb and an examination of the contour of the hip, as well as an inspection of all the landmarks in that locality, will render material assistance in arriving at correct conclusions. In case of doubt, if we err at all, we should err on the safe side, and treat the case as one of fracture. Many cases which were in a condition most favorable for union by bone to take place, have been rendered hopeless by not following this rule. The surgeon should ever bear in mind that the most favorable cases present the least degree of deformity, and that in our anxiety to make a correct diagnosis we sacrifice all the conditions which are essential for obtaining bony union.

In response to my circular as to the possibility of bony union after impacted intra-capsular fracture, Prof. Alfred C. Post, of New York, after replying in the affirmative, kindly wrote: "But the difficulty in proving this proposition depends on two circumstances: I. The want of absolute demonstration that fracture has actually occurred. II. The want of opportunity to demonstrate by autopsy that bony union has actually occurred.

"It is a common thing for a person of advanced age to meet with an accident rendering him or her unable to stand or walk,

or to raise the affected limb from the bed. There is a certain amount of pain and lameness about the hip, with eversion of the toes, and a scarcely perceptible shortening of the limb. On careful examination, without using much force, neither crepitus nor abnormal motion can be detected.

"There is probable evidence, but not certain demonstration of impacted intra-capsular fracture. If the surgeon is contented with this imperfect diagnosis, he treats the case as one of fracture, and recovery takes place with a perfectly sound limb. But the proof of the fracture and reunion is incomplete. If the surgeon in his anxiety to obtain a perfect diagnosis moves the limb freely in all directions, he overcomes the impaction, rupturing the cervical ligament, demonstrates beyond all doubt the existence of the fracture, and effectually destroys all hope of reunion. For my part, I prefer an imperfect diagnosis for the surgeon, and a perfect limb for the patient, rather than a perfect diagnosis for the surgeon and a useless limb for the patient."

These remarks require no explanation. They are concise, plain, practical, and to the point. Unimpacted fractures of the neck of the femur seldom give rise to any difficulty in diagnosis; the symptoms attending them are so well marked that a correct conclusion can be reached without causing needless suffering or sacrificing important tissues in searching for any one particular positive sign. Fractures with impaction present the same symptoms in a minor degree, their presence can usually be recognized by a careful consideration of symptoms, the elucidation of which does not necessitate the disengagement of the fragments; and, finally, if we have reason to believe that a fracture with impaction exists, although the symptoms are not sufficiently well marked to warrant the diagnosis, it is our duty to initiate the treatment in accordance with such a supposition.

XIII. *Production of Callus.*

In assuming an affirmative position concerning the possibility of bony union after intra-capsular fractures, it becomes necessary, from a theoretical standpoint, to allude to the results of recent

researches on the production of callus. A brief historical review of this subject will be of interest to illustrate in how far the opinions of surgeons, regarding the mode of repair after fractures, have been influenced by the views they entertained as to the source from which callus is produced. Galen looked upon callus as a substance thrown out around the seat of fracture for the purpose of cementing the bones together, without, however, becoming changed into bone. Van Swieten claimed that the cement of Galen is transformed into bone. J. L. Petit compared the healing process of bone with the repair of soft tissues. Duhamel de Monceau attributed to the periosteum and endosteum the function of producing callus. Haller, and his prosector Detlef, believed that the periosteum took no part in the regeneration of bone, but that callus is derived from the fractured ends of the bones, more especially the myeloid tissue.

Dupuytren, from a clinical aspect, revived the theory of Duhamel, and at the same time attributed to the soft tissues around the seat of fracture bone-producing functions. He also introduced the terms provisional and definitive callus. He made the assertion that the definitive callus does not make its appearance until four to five months after the injury, and is not complete before eight to twelve months. Cruveilhier did not recognize the different kinds of callus described by his teacher, and ascribed its source to the lacerated soft parts surrounding the fractured bone-ends, the periosteum, connective tissue, muscles, tendon, etc.

Bransby B. Cooper defined callus as a plastic exudation from the inflamed ends of the broken bone. Lambron asserted that a broken bone can unite directly through the medium of an interfragmentary callus without the formation of a provisional callus. P. Flourens believed that the periosteum alone is capable of furnishing material for new bone. Subsequently, however, he modified his view, and made a distinction between the periosteal or permanent callus, and the temporary or muscular callus. August Voetsch speaks of callus as the product of traumatic periostitis. Rokitansky declares that callus is developed directly from bone and its connective tissue, including the periosteum.

Reinh. Hein,[1] who has studied this subject with great care by means of the microscope and experimentally, has come to the following conclusions: The regeneration of broken and resected bones commences, as a rule, from connective tissue. The process of regeneration is, at times, limited solely to the connective tissue of bone and periosteum, but in most cases the connective tissue of adjacent parts, more especially the muscles, contribute to it.

According to Virchow, callus is produced from connective tissue outside of the bone, and as well as from myeloid tissue in the interior of bone.

Preparatory to his studies on the production of callus, Hofmokl[2] has traced the histology of bone during fœtal life. During the development of bone, cartilage-cells are transformed into bone-cells. The primary marrow spaces are formed in the interior of cartilage-cells, which, with their contents, are transformed into marrow spaces. The normal development of callus appears, histologically, as a return of perfect bone into its primary stage, embryonal development. The periosteum, bone, and marrow are active in the production of callus. The neighboring soft tissues assist in the process of repair only in so far that they may become converted into bone. In point of importance, the callus-yielding tissues are arranged in the following order, periosteum, marrow, bone. The bone-cells take an essential part in the production of callus, since they become enlarged, multiply, and thus form marrow spaces with myeloid cells; changes which are observed very distinctly upon the surfaces of the ends of broken bone, on the periosteal, as well as on the medullary side. Ossification invariably begins from the margins of a medullary space.

Gegenbauer[3] takes the ground that bone is produced directly from connective tissue. Sharpey's fibres, if traced carefully,

[1] Ueber die Regen. gebrochener u. resec. Knochen. Virchow's Archiv f. Path. Anat. B. 15, 1858.

[2] Ueber Callusbildung. Virchow u. Hirsch, Jahresbericht, 1874, p. 294.

[3] Ueber die Bildung des Knochengewebes. 2 Mitth. Jenaische Zeitschr. f. Med. B. 3, S. 206.

always spring from a bony point between the Haversian canals, from which point they radiate towards both sides into the lamellar systems. The fibres form networks; and, at points of intersection, bone-cells are produced, and a deposit of lamellæ takes place around connective-tissue fibres. The intercellular substance is regarded by Gegenbauer as a product of secretion of cell elements, and not as a metamorphosis of cells, as was asserted by Waldeyer, who believed that the protoplasm of the cells is transformed in part or entire into basis substance.

Kassowitz,[1] in carefully studying the process of ossification, has come to the conclusion, that the deposit of earthy material in the fibrillary reticulum, as well as in the osteoblasts, is dependent on the condition of the circulation. The fact that the immediate neighborhood of the vessels does not ossify, and that the deposition of earthy material takes place in advance of the vessels, induced him to accept the theory that active circulation prevents the deposition of earthy material, while diminution of blood pressure favors ossification.

Rigal and Vignal's[2] experimental researches on the formation of callus have an important and direct bearing on the process of repair after fractures. Their practical deductions may be summarized as follows: If periosteum is exposed to a moderate degree of irritation, new bone is produced from the marrow beneath the point of irritation directly, without passing through the stage of cartilage. If irritation is increased by displacing the fragments and rubbing the soft parts, the result is cartilage beneath the periosteum, which is subsequently converted into bone. If the periosteum is completely destroyed by scraping the bone, the defect is repaired by a connective-tissue cicatrix, which somewhat resembles periosteum. If a circular piece of periosteum has been thus removed, and the bone is broken after cicatrization has been completed, perfect union is the result. If the cortical layer of bone is scraped away down to the medullary canal, the defect is replaced by myeloid callus. If the medullary

[1] Die Normale Ossification, etc. Wiener Med. Jahrb., 1879, S. 145.

[2] Virchow u. Hirsch's Jahresbericht, 1883, vol. i. p. 263.

canal is not opened, the process of regeneration is slower, as a considerable period of time will elapse until the resulting rarefying osteitis opens the Haversian canals sufficiently to furnish the required amount of cellular elements from the medullary tissue for the reparative process.

Mr. McNamara, in alluding to this subject, in his excellent work,[1] as applied to the neck of the femur within the capsule, says: "The ossification of the soft structures which grow from the medullary spaces of the broken bone is, in the human subject, a protracted process, and the tissues concerned are so delicate, that unless they are protected from injury by means of artificial splints, they seldom unite at all."

It is now generally conceded that the provisional or temporary callus is the product of the periosteal and para-periosteal tissues, while the definite or permanent callus is produced directly from the osteoid and myeloid tissues. The provisional callus is nature's splint, its only object being to immobilize the parts until the definitive callus firmly and permanently unites the fragments. The temporary callus is accidental, and appears earliest and most copiously where para-periosteal tissues are most abundant, and motion between the fragments greatest; the intermediate or permanent callus is produced later, and is most certain to take place in spongy bones. Fractures of the neck of the femur, partly within and partly without the capsule, unite with as much certainty as fractures in other localities in the usual way, by the formation of external and intermediate callus. In this variety of fractures an abundance of callus, sometimes bordering on deformity, designates the exact location of fracture. In intra-capsular fractures, as in fractures within any other joints, the conditions for the formation of external callus are unfavorable; hence, we find in all cases purporting to be bony union imperfect, if any, attempts in this direction. Anatomy, physiology, and experimental research, all tend to prove that in cases of intra-capsular fracture we have all the conditions present which are necessary for the production of intermediate callus, provided

[1] Diseases of Bones and Joints, 1881.

the fragments are kept in immediate contact for a sufficient length of time. The neck of the femur has been rendered vascular and porous by senile degeneration, and is supplied with an abundance of bone-producing myeloid tissue. The vessels in the red marrow, according to recent observation, are also admirably adapted for the purpose of establishing early and free collateral circulation. In 1869, Hoyer made the discovery that the small veins in the red marrow are without walls, their lumen being bounded by the parenchyma of the marrow. Most of the capillaries are also without walls. The small arteries of the marrow consist of a delicate tube of endothelium, and a single layer of muscular fibres. Rindfleisch corroborated these observations. From this peculiar structure of the vessels in marrow, it is easy to understand how readily the interrupted circulation could be re-established through immediate contact of the severed vessels, or by canalization through the medium of a blood-clot or mass of exudation material. That intermediate callus is thrown out in cases of intra-capsular fractures, where the fragments have not been kept in apposition, and bony union has failed to take place, is evident from examinations made of specimens where the broken surface of the upper fragment, and sometimes the connecting ligamentous band, presented well-marked spurs of hard compact bone; an appearance alluded to by many observers, but more particularly by Sir Astley Cooper and Mr. MacNamara.

XIV. *Can Loose Detached Pieces of Bone Produce Callus, and Aid in effecting Bony Union?*

It has been urged against the possibility of bony union after intra-capsular fractures that the upper fragment is not furnished with a sufficient vascular supply to maintain nutrition, much less to produce callus. Clinical and post-mortem evidence, however, tend to prove that in the great majority of cases the fragment retains its vitality, and in many instances where bony union has failed to take place, the fractured surface shows evidence of callus production. In such cases where the fracture was complete, and

the fibrous investment of the neck was completely torn across, the requisite vascular supply must have been furnished through the round ligament. If the upper fragment was not nourished from some source it would more frequently disappear by absorption, or suffer necrosis, and act as a foreign body, than has been actually observed at the bedside or in the post-mortem room. The establishment of collateral circulation through the ligamentum teres, in maintaining the vitality of the upper fragment after intra-capsular fractures, is, unquestionably, of more frequent occurrence and of greater importance than many are ready to admit.

Taking it, however, for granted that the ligamentum teres furnishes no vessels to the upper fragment, I shall, nevertheless, endeavor to show that in case of impaction it can retain its vitality, assist in the formation of callus, and enter into the production of bony union. It has been known for a long time that, in compound fractures, perfectly detached splinters remain inocuous, and assist in the production of bony callus without giving rise to any particular symptoms of irritation. John Hunter[1] expressed himself as follows on this subject: "Adhesion of the detached splinters also takes place, not only in those which are attached to the soft parts, but even such as are entirely loose. (This was shown in a thigh-bone in which one of the splinters had moved quite around on its axis, and adhered by its outer surface to the bone.) I never examined a compound fracture without finding some of those loose pieces, which shows they must be common. Their union must be similar to that in the transplanted teeth."

Ollier and Philip Walther inform us that they have seen the disk of bone separated by the crown of the trephine, and, entirely removed, reunite with the surrounding bone when replaced.

Prince,[2] in speaking of the drilling operation for ununited fractures, says: "When the operation results in the effusion of plastic lymph without suppuration, there are new centres of

[1] Works of John Hunter. Edited by James T. Palmer, vol. i. p. 502.

[2] Plastics and Orthopedics, 1871.

ossification in the chips of bone cut off by the drill. These are left in the track of the drill; some of them in the soft callus between the ends of the fragments. That these minute fragments of bone become parts of the living tissue is certain; for, if they did not, they would, by the offensive emanations of dead bone, excite suppuration and work their way to the exterior. The importance of these little fragments cut off by the drill, as centres of ossification, may have received too little attention."

Cases, where fragments of bone from the internal table of the skull were completely isolated and yet became attached to the surrounding bone by permanent callus, are reported by Samuel Thomas, Soemmering, Bernhard Beck, von Bergmann, H. Demme, Cluston, Richet, and Ziegler.

Lossen[1] has studied this subject in connection with comminuted fractures of the long bones, and has come to the conclusion that not all loose fragments necrose, but that many are incorporated in the callus and form part of the living ridge between the fractured ends. He is of the opinion that the vessels of the fragment, at some point, unite with other vessels in the lacerated district, thus establishing the circulation. In one of his illustrations may be seen a fragment, five centimeters long and one centimeter broad, completely isolated and denuded of its periosteum, which, with its wedge-shaped end, had been driven into the medullary cavity. The upper end was perfectly united with the bony mass filling the medullary cavity, and its lower end could be seen aside of the necrotic portion of the fractured bone. It can safely be assumed in this instance, that the vessels in the medullary cavity vascularized the fragment and preserved its vitality. Klebs gives a description of a similar specimen, and believes that the vitality of the medullary tissue and periosteum is sufficient to sustain the physiological activity of isolated fragments of bone under favorable circumstances, production of new bone taking place from the transplanted piece of bone.

[1] Kriegs-chirurg. Erfahrungen aus den Barackenlazarethen zu Mannheim, Heidelberg u. Karlsruhe, 1870, 1871. Deutsche Zeitschr. f. Chirurgie. Band II. S. 25.

v. Bergmann describes a specimen of comminuted fracture of the femur, the result of a gunshot wound during the Turko-Russian War, where a fragment, 7.2 ctms. long, 15 mm. broad, and 6 mm. thick, had become completely detached from the soft tissues, and had been forced into the medullary cavity, where it became firmly united with the fractured ends of the bone and the intervening bony callus.

Meek'ren made a series of experiments on animals for the purpose of establishing the fact that isolated fragments of bone devoid of periosteum would, under certain favorable conditions, retain their vitality, and were capable of forming an attachment to bone through the intervention of a bony callus. He removed by the trephine, from the skull of a dog, a disk of bone and replaced it. On the twenty-second day he found this disk firmly united by bony callus to the surrounding bone.

Flourens transplanted a piece of rib from a dog, under the periosteum of the tibia, of the same animal, and in due time found it united by bony callus. The well-known experiments of Ollier are familiar to every surgeon, but as he placed great importance on the preservation of the periosteum as an essential condition for success in bone transplantation, they are not of great importance for our purpose. The experiments of Kosmowski, to ascertain the exact mode of repair in cases of fracture of the skull, indicate that the reparative process in general, and the union of loose splinters of bone in particular, are accomplished by the osteo-genetic functions of the medullary tissue.

Of great practical importance are the experiments of Jakimowitsch.[1] The experiments were made exclusively on the long bones of dogs, and the vascular connections of the transplanted or replanted piece of bone were demonstrated by means of gelatine injections stained with Berlin blue. To insure success, he places great importance on securing accurate apposition and perfect immobilization of the fragment by stitching the periosteum or soft parts over it, and applying elastic pressure and a fixation splint of plaster of Paris. The operation was always

[1] Versuche über d. Wiederanheilen vollkommen getrennter Knochensplitter, Deutsche Zeitschr. f. Chir. B. XV.

done under strict antiseptic precautions. To prove that the detached bone had become a part and parcel of the living bone, some of the animals were fed on madder after the example of J. Wolff. This staining material is deposited during life in the new bone around the fragment in greatest abundance, while it also follows the new vessels into the transplanted piece. In almost all of the cases after death, the vessels of the limb operated upon were injected with gelatine stained with Berlin blue, which afforded an excellent opportunity to follow the course of the vessels into the transplanted or replanted piece of bone. In other instances the examination was made even more complete by decalcifying the bone and submitting it to a microscopical examination. The results of his experiments induced him to conclude that replantation and transplantation of isolated fragments of bone can be successfully performed if the detached piece retains its former relations to its immediate vicinity. Under such circumstances the piece of bone becomes a living part of the bone through the medium of the intermediate callus, and the re-establishment of vascular connections with the surrounding vessels.

Gurlt[1] describes and furnishes illustrations of two specimens of fracture of the femur, where a large fragment of the cortical layer near the centre of the shaft had become completely detached, and in one instance turned completely around, and yet they were found firmly attached by bony union. Both specimens are from the Museum of the Royal College of Surgeons of England, being numbered 108 and 454. He states further, that in comminuted fractures, where many loose fragments must exist, they furnish no obstacle to ready bony union. The fragments either take part in the formation of callus, or are imbedded in the mass, and eventually are removed by a slow process of absorption.

MacEwen[2] resorted to transplantation of small pieces of bone to restore extensive pathological defects, believing that the blood-clot between the fragments served as a medium through

[1] Op. cit.

[2] Virchow u. Hirsch, Jahresbericht, 1881, vol. ii. p. 332.

which the vascular connection between the detached bone and surrounding tissues is established. He operated successfully upon a case of necrosis of the humerus, with extensive loss of bone substance, by transplanting into a groove made in the bone numerous wedge-shaped pieces of bone derived from the tibiæ of six rickety children, the fragments being supplied with periosteum and marrow tissue. The bone grafts retained their vitality, united with, and grew with, the bone.

Prof. von Nussbaum has introduced transplantation of bone as a legitimate operation in surgery, for the purpose of supplying bone defect in cases of ununited fracture, and his success, as well as similar operations by several other German surgeons, certainly prove that the vitality of even compact bone is sustained by a minimum amount of blood-supply through a narrow strip of periosteum.

Spongy bone, containing an abundance of marrow tissue and a rich supply of bloodvessels, is endowed with a higher degree of vitality than compact bone; and is, consequently, better adapted to enter into union with surrounding tissues, in case it has become detached.

It has also been established by way of experiment, that in animals marrow can be transferred to different parts of the body, and if the operation is successful, the transplanted marrow will produce bone.

Baikow, Goujon, and Ollier were successful in their auto-transplantations of marrow, but failed when the tissue was transferred from one animal to another. The most extensive and reliable experiments on marrow transplantation have been made by P. Bruns.[1] He operated upon sixty chickens and six dogs. He failed repeatedly as long as he transplanted the marrow from animal to animal, but as soon as he limited his experiments to auto-transplantation, he succeeded in the great majority of cases. Of nineteen auto-transplantations, twelve proved suc-

[1] Ueber Transplantation von Knochenmark, Archiv. für Klinische Chirurgie. B. XXVI. S. 661.

cessful, three failed on account of suppurative inflammation following the operation, and in four the transplanted tissue was absorbed.

The operation consisted in removing cylindrical pieces of marrow from the femur or tibia, 2 to 3 ctms. in length, and transplanting them under the skin of the same animal. After the fourteenth day foci of ossification could be distinctly seen, which enlarged and became confluent after the twentieth to the twenty-fourth day. Ossification is preceded by an active proliferation of spindle-shaped cells.

The formation of bone takes place from the pre-existing osteo-blasts in marrow, an opinion which is also supported by Waldeyer. The yellow and red marrow were used in these experiments, and proved alike capable of producing bone.

The success attending bone and marrow transplantation constitutes a potent argument in favor not only of the *possibility* but *probability* of bony union after intra-capsular fractures, in the event that the fractured ends are in accurate and undisturbed apposition for the requisite length of time. The neck of the femur in a state of senile atrophy furnishes a number of favorable conditions for a speedy production of bony callus. It is very vascular, the compact tissue attenuated, the spongiosa exceedingly porous, and its meshes distended with an abundance of bone-producing myeloid tissue. If perfectly detached and denuded pieces of compact bone, and isolated masses of marrow, can be transferred to a distant part of the body, and when properly transplanted, they not only retain their vitality, but become vascular and produce bone, I can see no reason why the upper fragment in intra-capsular fractures, which is still retained in its natural location, should not manifest the same power of self-preservation and repair. In impacted fractures the bone-tissue, marrow, and lacerated vessels are brought in such immediate contact, that the reparative process is taxed only to its minimum extent in restoring the continuity of the bone. In these instances we have an example of bone and marrow transplantation under the most favorable conditions, and the reason it does not succeed

oftener, is simply because these favorable conditions, as a rule, do not exist, or are not allowed to exist, for a sufficient length of time.

XV. *Specimens of Bony Union after Intra-capsular Fracture.*

It is not my purpose to enter into a discussion of the many specimens for which bony union has been claimed by their possessors. Many of them have been the object of the most rigid criticism, at different times and at the hands of different writers. While careful and competent men have brought these specimens before the profession as typical examples of union by bone within the capsule, equally good observers have failed to see the evidence which justified these claims. I have tabulated only the cases reported by competent observers, and where the diagnosis was verified by a post-mortem examination.

No.	Name of Reporter.	Where mentioned or classified.	In whose possession.
1	Adams, R.	Todd's Cyclopedia, vol. ii. p. 813.	Adams.
2	Adler,	Am. Journ. Med. Sci., April, 1873.	Adler.
3	Bardeleben,	Lehrbuch d. Chir. B. ii. p. 477.	Goyrand.
4	Brulatour,	Med. Chir. Transactions, vol. xiii.	Brulatour.
5	Bryant,	Bryant's Surgery, p. 843.	Museum Guy's Hospital.
6	Callender,	St. Barthol. Hosp. Rep., vol. i. p. 154.	
7	Chassaignac,	Thèse inaugurale.	Van Houte.
8	Chelius,	Handb. d. Chir. B. i. p. 319.	Chelius.
9	Chelius,	Handb. d. Chir. B. i. p. 319.	Soemmering's collection.
10	Cushing,	Bigelow, The Hip, p. 133.	
11	Earle,	Practical Obser. in Surgery, 1823, p. 97.	
12	Fawcington,	Am. Journ. Med. Sci., vol. xv. p. 534.	Fawcington.
13	Fischer, H.	Personal communication.	Pathological Museum, Breslau.
14	Fischer, H.	Personal communication.	Ponfick.
15	Field,	Amesbury on Fractures.	Field
16	Geddings,	Am. Journ. Med. Sci., Jan. 1847.	Geddings.
17	Gurlt,	Knochen-brueche, vol. i. p. 308	Giessen Museum.
18	Hamilton,	Hamilton on Fractures, p. 407.	Hamilton.
19	Harris,	Am. Journ. Med. Sci., vol. xviii. p. 246.	Harris.
20	Holthouse,	Holmes's System of Surgery, vol. ii.	St. George's Hosp., Spec. No. 112.
21	Howship	Med. Chir. Transactions, vol. xiv.	Howship.
22	Hutchinson,	Illustr. Clin. Surgery, vol. ii. p. 8.	Leeds Hospital Museum.
23	Hutchinson,	"Museum Notes" of Jan. 23, 1870.	Museum of Trinity Coll. Dublin.
24	Jones,	Med. Chir. Transactions, vol. xxiv.	Jones.
25	Kocher,	Personal communication	Pathological Museum, Berne.
26	Kroenlein,	Personal communication.	Pathological Museum, Zürich.
27	Langstaff,	Med. Chir. Transactions, vol. xiii.	Langstaff.
28	Maas,	Personal communication.	Pathological Museum, Freiburg.
29	Malgaigne,	A Treatise on Fractures, 1859, p. 555.	Musée Dupuytren.
30	March,	Trans. Am Med Association, 1858.	Museum Albany College.
31	March,	Trans. Am. Med Association, 1858.	Museum Albany College.
32	March,	Trans. Am Med. Association, 1858.	Museum Albany College.
33	Mussey,	Am. Journ. Med. Sci., 1857, p. 299.	Mussey.
34	Mussey,	Am. Journ. Med. Sci., 1857, p. 299.	Mussey.
35	Mussey,	Am. Journ. Med. Sci., 1857, p. 290.	Mussey.
36	Pope,	Hamilton on Fractures, p. 407.	
37	Post,	Personal communication.	Destroyed in fire of Univ. Med. Col.
38	Riedinger,	Studien über grund u. einkeilung der Schenkelhalsbrueche, 1874. Pl. xi.	Würtzburg Museum.
39	Roberts,	Personal communication.	Museum Pennsylvania Hospital.
40	Sands,	New York Med. Record, June 1, 1869.	Sands.
41	South,	Chelius Surgery by South, vol. i p. 621.	South.
42	South,	Quoted by Hamilton, Ed. 1871. p. 363.	Museum St. Barthol. Hosp.
43	Smith, H. H.	Princ. and Prac. of Surg., vol. ii. p. 610.	Wister and Horner Museum.
44	Smith, H. H.	Princ. and Prac. of Surg., vol. ii. p. 610.	Smith.
45	Smith, R. W.	Dublin Journ. Med. Sci., Jan. 1873.	Museum Trinity College.
46	Smith, R. W.	Dublin Journ. Med. Sci., Jan. 1873.	Museum Trinity College.
47	Spalding,	Bost. Med. & Surg. Journ., Mar. 4, 1858.	Spalding.
48	Stanley,	Med Chir. Review, vol. xii. p. 170.	Stanley,
49	Swan,	On Diseases of Nerves, p. 304.	Swan.
50	Selden,	Trans. Virginia State Med. Soc., 1877.	Selden.
51	Selden,	Trans. Virginia State Med. Soc., 1877.	Selden.
52	Parker, W.	Johnson, Intracap. Fract., 1857, p. 28.	W. Parker.
53	Zeiss,	Hamilton, Fract. and Disl., 1880, p. 406.	Zeiss.
54	Zeiss,	Hamilton, Fract. and Disl., 1880, p. 406.	Zeiss.

I will only give a description of a few undoubted specimens for the purpose of illustrating the alterations which take place in the femoral neck during the process of repair. R. Adams (Table, No. 1): "The round ligament was sound. The head and neck of the bone had lost their normal obliquity, and were directed nearly horizontally inwards; the cervix presented, both anteriorly and posteriorly, evidence of a transverse intra-capsular

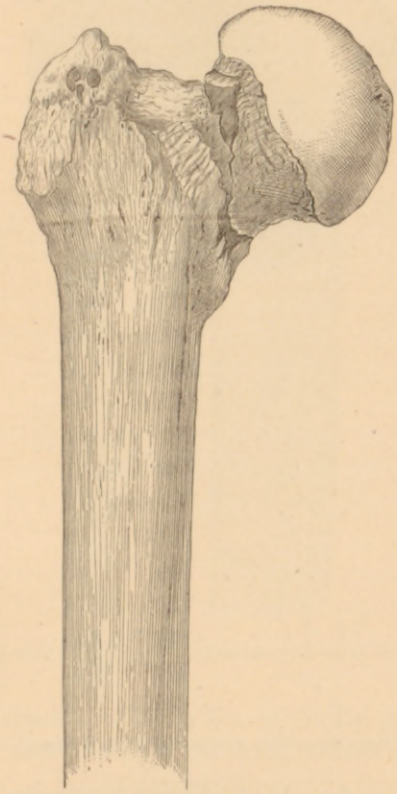
fracture having occurred; the globule-shaped head was closely approximated behind and below to the posterior inter-trochanteric line, and to the lesser trochanter, so that the neck seemed altogether lost, except anteriorly, where a very well-marked ridge of bone showed the seat of the displacement and of the union of the fragments. This ridge is evidently the upper extremity of the lower fragment of the cervix. The fracture of the neck posteriorly was found to have been closer to the corona of the head than anteriorly, and the fibro-synovial fold in the former situation remained unbroken. A section has been made of the bone through the head, neck, and trochanter; one portion has been subjected to maceration and boiling; and the bony union has been unaffected by these tests. Scarcely any portion of the neck can be said to have been left. The section shows the compact line which denotes the union of the fragments; the head and shaft seem to be mutually impacted into each other, and almost the whole of the cervix has been absorbed; the line of union is serrated, solid, and immovable; and the cells of the head and substance of the shaft seem to communicate freely in all places, except where the thin line of compact tissue here and there points out the seat of the welding together of the remaining portions of the head and neck of the femur."

As Mr. R. Adams, in his article, "Abnormal Conditions of the Hip-joint," in *Todd's Cyclopædia*, took the ground that bony union was impossible, and commented unfavorably on the cases which had been reported as cases of bony consolidation, it is evident that this case must have presented convincing proof in order to change his views on this subject. The value of this specimen is increased by a full clinical history of the case.

Chorley's specimen, described by Jonathan Hutchinson (Table, No. 22): "The bone, which supplied the illustration I now publish, is one of the many treasures of the Pathological Museum of the Leeds Hospital. The drawings were (by permission) made for me by Mr. Tuffen West, some years ago, at the time of the visit of the British Medical Association to Leeds. The specimen is the best example of union of an intra-capsular fracture with which I am acquainted, and, as it appears to be beyond all cavil,

I have great pleasure in endeavoring to secure for it a wider recognition. The drawings show so exactly the condition of the bone that it is scarcely necessary to describe them. (Figs. 9, 10, 11.) It will be seen that, whilst the transverse fracture is wholly

Fig. 9.

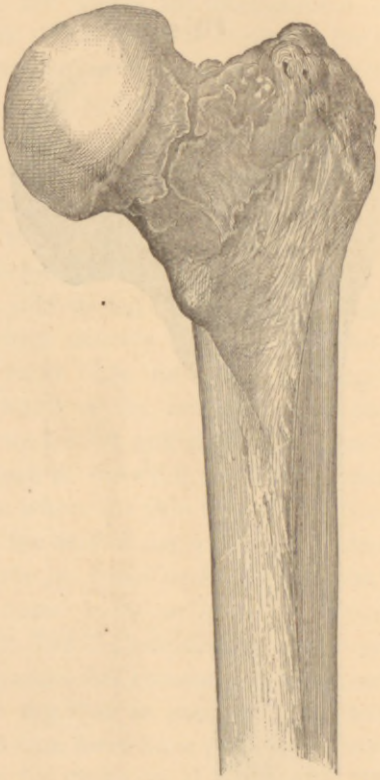


Anterior view of Bony Union after Fracture of Neck of Femur. (Hutchinson.)

within the capsule, and nowhere more than half an inch from the articular head, yet, that on the back of the cervix, some fragments have been detached, which pass much further out. It is worth notice, also, that in the section of the bone, the edge of the lower outer layer is seen to catch in the cancellous tissue of the articular fragment, thus constituting a degree of impaction,

which, no doubt, much favored fixation and union. The specimen was obtained by the late Mr. Chorley, formerly Surgeon

Fig. 10.

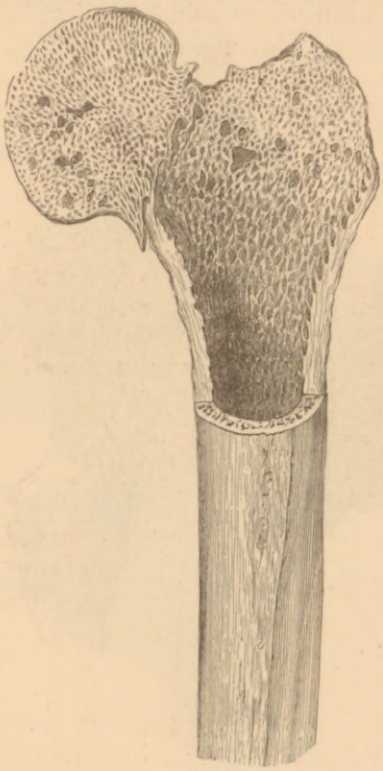


Posterior view of Bony Union after Fracture of Neck of Femur. (Hutchinson.)

to Leeds Infirmary, from the body of a gentleman, aged seventy, whom he had attended several years before his death, with the diagnosis of fracture of the neck of the thigh-bone. The treatment had been by very careful immobilization and long-continued confinement to bed. The recovery had been such that the patient had been able to walk well with a stick."

The well-known ability of Mr. Hutchinson is a sufficient guarantee for the genuineness of this specimen.

Fig. 11.

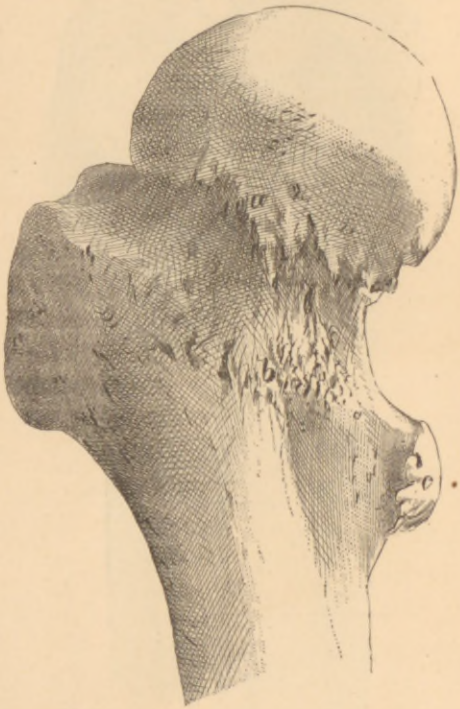


Vertical section showing Bony Union after Fracture of Neck of Femur. (Hutchinson.)

Riedinger's specimen (Table, No. 38): "The neck of the femur is considerably shortened, and the head inclines so far backward, that, superiorly, it comes almost completely in contact with the posterior inter-trochanteric line. From behind, only the cartilaginous surface of the head can be seen; downward, the neck is visible to the extent of 1 ctm. Above, the length of the neck is $1\frac{1}{2}$ ctm. On the anterior surface, the well-marked denticulated line of fracture can be seen close to the head. Its length is 3 ctm. A longitudinal section of the upper portion of the femur, into an anterior and posterior half, discloses the line of fracture

in the loosely cancellated tissue of the spongiosa, and more clearly shows the impaction of the lower fragment into the head,

Fig. 12.



Anterior view of Bony Union after Intra-capsular Fracture. (Riedinger.)

which is especially well marked in the lower cortical portion of the neck (Adams's arch). The length of the implanted portion amounts to 2 ctm." (Figs. 12, 13, 14.)

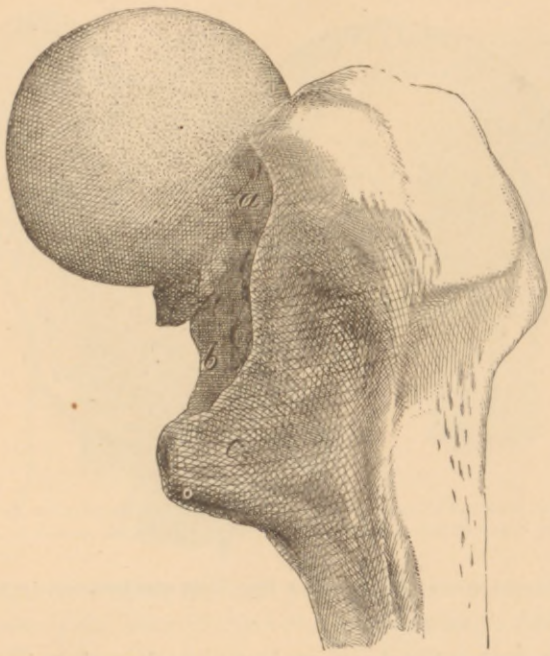
As Riedinger has made fractures of the neck of the femur a special study for many years, no one would for a moment doubt the correctness of his description, or the authenticity of this specimen.

Gurlt's specimen (Table, No. 17): "The fracture runs obliquely through the neck of the femur; in front it is three-fourths of an inch from the base of the neck, posteriorly a little less. The head of the bone is displaced somewhat backward and down-

ward, and is united by bone, although the line of fracture is still visible in places." (Figs. 15, 16.)

Gurlt's name occupies a position foremost among writers on fractures, present and past, and his decision admits of no appeal.

Fig. 13.



Posterior view of Bony Union after Intra-capsular Fracture. (Riedinger.)

To prove the validity of any specimen, it is necessary to examine for evidences which will warrant an affirmative answer to the following questions: 1st. Has the bone been fractured? 2d. Was the fracture within the capsular ligament? 3d. Has the racture consolidated by bone?

The first question can only arise in specimens without a clinical history. Post-mortem specimens have been brought forward as instances of bony union, when the changes in the bone were due to other causes, as rickets or senile coxitis. In all cases of

interstitial absorption without fracture, the wasting of the neck takes place in a more symmetrical manner; the neck may become greatly shortened, and yielding to the vertical pressure, the head may descend to a level with the upper border of the

Fig. 14.

Vertical section showing Impaction with Bony Union after Intra-capsular Fracture. (Riedinger.)

trochanter major, but does not incline backward, as is generally the case when fracture has taken place. In senile coxitis the head is enlarged, and presents the characteristic deep depression for the round ligament, at the same time its upper and anterior surface is deprived of cartilage, and presents an eburnated appearance. (Fig. 17.) If rickets, or senile osteo-malacia, has been the cause of the deformity, the disease affects both joints simultaneously. An intra-capsular fracture always unites with some degree of deformity. Longitudinal sections of the specimens usually disclose the direction and extent of displacement of the fragments. From causes which have been previously enumerated, absorption of the neck is more extensive in the posterior portion of the

neck than in the anterior, permitting the head to approach the posterior inter-trochanteric ridge. If the fracture has been entirely within the capsule, little or no provisional callus is found over the seat of fracture, while in senile coxitis irregular bony

Fig. 15.

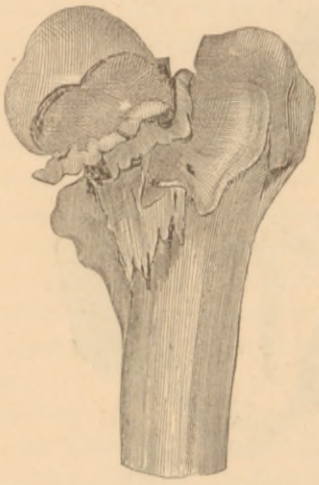


Fig. 16.

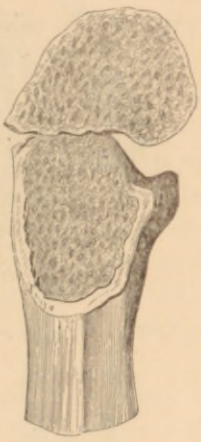


Fig. 15. Anterior view of Bony Union after Intra-capsular Fracture. (Gurlt.)
Fig. 16. Section through Neck showing Bony Union within Capsule. (Gurlt.)

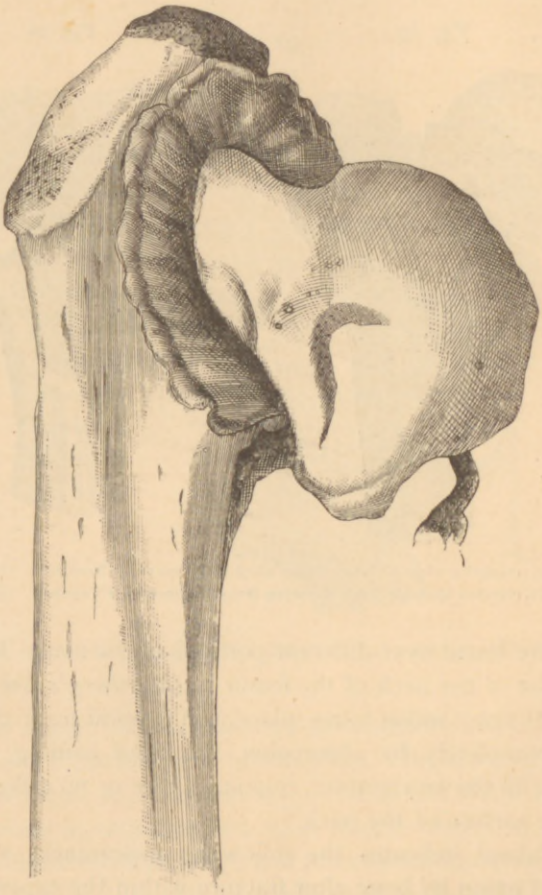
masses are found over different portions of the neck. The writer on fracture of the neck of the femur in *Eulenburg's Encyclopædia* says: "If bony union takes place, the femoral neck disappears almost completely by absorption, the head coming nearly in contact with the trochanteric region. Little or no callus is found upon the surface of the neck."

Bardeleben[1] indicates the following appearances as characteristic of union by bone after fracture within the capsule: "If it can be ascertained with certainty that a fracture had occurred during life, and on post-mortem examination we find a bone cicatrix, that is a disk of dense bone through the intra-capsular portion of the neck, and there are no other evidences of syno-

[1] Lehrbuch d. Chirurgie, 1871, B. II. S. 473.

vitis or osteitis, then we are justified in claiming for such a case that a fracture within the capsule has united by bone."

Fig. 17.



Appearances of Head and Neck of Femur in Senile Coxitis. (Richardson.)

Erichsen[1] remarks: "When bony union has taken place, the head will usually be found somewhat twisted round, in such a

[1] The Science and Art of Surgery, 1869.

way that it looks toward the lesser trochanter, owing to the eversion that has taken place in the lower fragment."

Gurlt[1] states: Absorption of the fragments takes place exclusively in fractures involving joints, and proceeds hand in hand with the process of repair. In some joints, as in the hip-joint, it may be so extensive that almost the entire neck is absorbed. This is more likely to be the case if the fracture is within the capsule. In such cases the head of the bone may be very near the great trochanter at the base of the cervix femoris. The cause of this absorption is not known.

The characteristic deformity presented by specimens of bony union of fracture through the neck of the femur corresponds to the direction of the displacing forces—shortening and eversion. The cause of the primary displacement is the fracturing force itself. The secondary displacement takes place upon the accession of inflammatory osteo-porosis, and is the result of softening and absorption of the bone, muscular contraction, and gravitation.

Exacting critics have questioned the validity of many specimens of bony union on the ground that the fracture was not purely intra-capsular. Indeed, this argument has been the main support of all modern believers in non-union. In all specimens of bony union, the point of attachment of the posterior portion of the capsular ligament is changed; instead of being inserted near the middle of the femoral neck, it is found attached at or near the posterior inter-trochanteric line, and on this account it has been asserted that the fracture extended beyond the capsular ligament. I believe, however, that this alteration in the attachment of the capsule admits of a more satisfactory explanation. All fractures are followed by inflammatory osteo-porosis in the ends of the broken bones, and this is especially well marked in the articular extremities of the long bones. During an inflammation of this kind, the periosteal covering of the bone is loosened, and readily changes its relative position to the bone during the process of interstitial absorption, and carries with it the capsular

[1] Handbuch d. Lehre v. d. Knochenbruechen, 1862, vol. i.

ligament with which it is intimately connected. Interstitial absorption precedes and attends the production of callus, and is most active in that portion of the bone supplied with the greatest number of bloodvessels. The upper fragment being scantily supplied with bloodvessels, absorption, if it takes place at all, occurs at a later date, and progresses very slowly; while the reverse is the case in the lower fragment. The point of attachment of the capsular ligament is no indication as to the seat of fracture, as almost the entire femoral neck may disappear by absorption, and the capsule approaches the trochanteric region in proportion to the amount of bone absorbed. A more important sign is the presence or absence of new bone upon the outside of the capsule. In intra-capsular fractures little or no external callus is produced within or without the capsule; while extra-capsular fractures, from obvious anatomical reasons, yield an abundance of exuberant callus, part of which at least remains permanently. The last test is to ascertain the nature of the connecting medium. This can be done by submitting the specimen to a microscopical examination, or to the boiling process. In the first test the tissues at the seat of fracture will show the histological elements of true bone in all genuine specimens. The boiling process will destroy the ligamentous union between the fragments in all doubtful cases; and is, therefore, the simplest and most certain method to demonstrate the restoration of the continuity of the broken bone.

In recapitulation, it may be stated, that the validity of a specimen is established whenever the clinical history has revealed the existence of fracture during life, and the post-mortem examination has demonstrated that the fracture has been within the capsule, and that the union is by bone.

XVI. *Non-union after Intra-capsular Fractures.*

Sir Astley Cooper enumerates the causes of non-union under the following heads: 1. Want of proper apposition of the bones. 2. Want of pressure of one extremity of the broken neck upon the other, even though the limb preserved its length, and the

fractured parts are consequently not much displaced. 3. Absence of nutrition in the head of the thigh-bone. 4. Atrophy of bone.

The first cause can only apply to non-impacted fractures, where treatment has failed to keep the fractured ends in immediate and uninterrupted contact for a sufficient length of time for union by bone to take place, and as such constitutes the principal, if not the only, cause of non-union. There is no other fracture where immobilization is so difficult to accomplish. Every movement of the body disturbs the fractured ends. No apparatus yet devised has answered the first and principal indication in the treatment of all fractures, namely, to secure immobility and permanent coaptation.

Colles,[1] who fully endorses the views of Sir Astley Cooper on the subject of fractures within the capsule, in speaking of the causes of non-union, remarks: "However this may be, I think the difficulty of keeping the parts motionless on each other would be sufficient of itself to account for it." Gurlt,[2] who has studied the process of repair in fractures with the most assiduous care, says: "There is no specific tendency to non-union in any form of fracture. If the ends of the broken bones can be kept in accurate apposition, union by bone will take place." As illustrations of this statement, he mentions the following fractures: Neck of femur, patella, coronoid process of inferior maxilla, coracoid process of scapula, olecranon, coronoid process of ulna, trochanter major, tuberosity of calcaneus, spinous processes of vertebræ, and some of the sharp prominences of the pelvic bones.

The second cause of non-union. Want of pressure of one fragment upon the other implies a want of apposition, expressed in other words. Dupuytren and Brainard were of the opinion that oblique resulted more frequently in non-union than transverse fractures, and the former applied this rule to fractures of the neck of the femur. Experience has shown that of all frac-

[1] Lectures on Surgery, 1845.

[2] Handbuch der Lehre von der Knochenbruechen, 1862, vol. i.

tures within the capsule, none are so prone to result in non-union as transverse fractures through the narrowest portion of the neck. Lateral pressure applied over the trochanter major is an important measure for obtaining union by bone, but this desirable result does not follow from the fact that pressure is made, but simply because by the pressure coaptation and immobilization are effected.

Deficient vascular supply of the upper fragment is prominently mentioned by almost every author against the probability of union by bone. On the other hand, it is generally submitted that fractures of the anatomical neck of the humerus unite by bone, and that completely isolated pieces of bone, when properly replanted or transplanted, retain their vitality and physiological properties. It is also well known that traumatic or pathological epiphyseolysis may be repaired by bony callus. Why should the upper fragment in intra-capsular fractures, with at least a doubtful supply of blood through the round ligament, make an exception to this general rule? Simply because, in this instance, coaptation, without impaction, is next to impossible, with the present method of treatment. On this point MacNamara[1] makes this statement: "I hardly think the non-union between the ends of the bone in instances of intra-capsular fracture of the neck of the femur is most frequently due to the insufficient blood-supply of the head of the bone; otherwise we should more commonly meet with examples, after fractures of this kind, in which the head of the bone had become absorbed; but, as you will see in the specimen I now show you, the cancellated tissue of the head of the bone is supplied with blood through vessels passing along the round ligament and through the fibrous structure uniting it with the trochanter major."

The fractured head of the humerus, deprived of all vascular supply, unites by bone like any other fracture, because the anatomical relations about the seat of fracture are such that coaptation is maintained without difficulty, and fractures within the capsule of the hip-joint will follow the same rule as soon as

[1] Diseases of Bones and Joints, 1881.

the surgeon can successfully combat the obstacles which cause displacement. The last cause, atrophy of bone, is the weakest argument in favor of non-union. Clinical experience furnishes abundant proof that in persons suffering from fragilitas ossium fractures not only unite, but unite very promptly. Mr. Holmes, in his System of Surgery, quotes from Gibson the case of a youth of nineteen, who had twenty-four fractures, and from Esquirol another with as many as two hundred fractures. Earle records a case of eight fractures in a child of ten years, and Flemming observed a case where a person suffered fifty-three fractures between the ages of one-and-a-half and twenty-five years. In all of these cases union took place rapidly. Gurlt reports a large number of similar cases. He states very distinctly that *old age does not retard the process of union, as has been erroneously supposed; the reparative process is the same as during adult life.*[1]

I believe non-union is more frequently, observed in young, robust persons than in old people. I have seen a fracture of the femur, at the junction of the middle with the upper third, in an old decrepit man, suffering at the same time from locomotor ataxia, unite firmly by bone in less than six weeks. Fracture of the lower end of the radius is common after middle life, invariably unites, and in a remarkably short time. Senile osteo-porosis is a condition of bone favorable to the production of intermediate callus. Atrophy of bone facilitates inflammatory osteo-porosis, an event which always precedes the formation of callus. Some authors mention still other causes for non-union, as the presence of synovia and the absence of a nidus for the formative material. Both of these conditions simply remind us that the bones are not in apposition, otherwise they have no significance in preventing union by bone. From this short review we are not only justified, but warranted, in asserting that the only cause for the non-union in cases of intra-capsular fracture is to be found in our inability to maintain perfect coaptation

[1] Italics my own.

and immobilization of the fragments during the time required for bony union to take place.

XVII. *Bony Union after Intra-capsular Fractures.*

In a circular letter, I addressed to prominent surgeons in this country, England, France, Germany, and Switzerland, for the purpose of ascertaining the prevailing opinion on the subject of bony union after intra-capsular fractures, I asked this question: "In your opinion does bony union ever occur after impacted intra-capsular fracture of the neck of the femur, and under what circumstances?

To this question I received fifty direct replies. The opinions were divided as follows: Yes, 27; no, 18; doubtful, 5. It is a significant fact that the replies from professors of surgery in German universities, 5 in number, were without exception, in the affirmative, while the greatest diversity of opinion appeared to exist in our own country; at least fifty per cent. of the correspondents replied with an emphatic "No." I believe the answers received reflect correctly the sentiments of the entire profession on this point. If we add the five doubtful correspondents to the eighteen negative, we have nearly 50 per cent. who do not believe it possible for bony union to take place within the capsule even under the most favorable circumstances.

I consulted the text-books and monographs on this subject with about the same result. It would then appear that nearly one-half of the profession still doubt the possibility of union by bone in cases of intra-capsular fractures.

Having shown that there are no anatomical and physiological impossibilities present to prevent osseous union after intra-capsular fractures, and having referred to a number of reliable and well-authenticated cases of this kind, I will quote the opinion on this subject of a few recognized authorities.

Sir Astley Cooper, the originator of the controversy on this subject, and who is always quoted as authority on the negative side of this question, never denied the possibility of union by

bone, as is evident from what he says on page 137 of his work:[1] "I have only met with one in which a bony union had taken place, or which did not admit of a motion of one bone upon the other. To deny the possibility of this union (bony union), and to maintain that no exception to the general rule can take place, would be presumptuous, especially when we consider the varieties of direction in which a fracture may occur, and the degree of violence by which it may have been produced." He enumerates a number of conditions which would maintain permanent apposition, and then proceeds: "Such a favorable combination of circumstances is of very rare occurrence." At the time this was written the process of repair in bone was but imperfectly understood, and the occurrence of impaction within the capsule was either unknown, or its importance as an essential element for bony union was not appreciated.

Heister,[2] nearly a century and a half ago, after explaining that the frequency of non-union in cases of fractures of the femoral neck was owing to the difficulty of keeping the broken ends of the bone in apposition, makes the following statement: "If an instrument could be invented which would keep such a limb so extended that during the cure, or at least during the first two or three weeks, it could be kept as long as the healthy one, there would be hope that the fracture could be cured more satisfactorily than has been the case heretofore." Since we have learned that the production of the intermediate callus requires months instead of weeks, Heister would have to modify his statement by greatly extending the period of time required for maintaining apposition.

Desault,[3] in combating the popular idea of insufficient blood supply as a cause of non-union, states: "The head of the bone separated from the soft parts, and attached to the acetabulum by the round ligament, receives a sufficiency of nutriment to enable it to live in that cavity; for there is no instance of its having suffered mortification in consequence of a fracture. Why, then, should it not partake of the properties of life, and particularly of

[1] Fractures and Dislocations.

[2] Chirurgie, 1747, p. 193.

[3] A Treatise on Fractures, etc. Edited by X. Bichat; translated by Chas. Caldwell, 1817.

the faculty of reunion when placed in regular apposition with the body of the bone?"

The following quotation is from Syme:[1] "But none of the arguments, which have been adduced to prove the *impossibility* of osseous junction, seems to be conclusive, and though the small extent and mobility of the broken surfaces, the absence of vascular tissues surrounding the fracture, and, perhaps, also the presence of synovial fluid, may render the cure very difficult, it ought still to be regarded as a possible occurrence."

Richter[2] claimed that bony union could take place in impacted fractures, or where, by careful treatment, apposition and retention were fully accomplished. He evidently was impressed with the importance of the bone-producing function of the periosteum, as he advanced the theory, that, in fractures of the neck with complete rupture of the periosteum under favorable conditions, bridges could be thrown across the line of fracture from one membrane to the other, from which bone could be produced.

Dupuytren,[3] in criticizing the treatment followed by the English surgeons, and alluding to the secondary displacements following the too early removal of retaining apparatus, gives the following advice: "But, if these surgeons had adopted the practice of the *Hôtel-Dieu*, in keeping their patients in bed for eighty or even a hundred days, they would have been convinced of the practicability of reunion and complete cure without deformity." And again: "I can only say, for my part, that, if the specimens at the *Hôtel-Dieu* are insufficient to satisfy any one who may take the trouble to examine them, I am at a loss to know what amount of evidence such sceptics would require. For my part, I regard the osseous union of intra-capsular fracture as demonstrated and placed beyond doubt."

Malgaigne[4] is a firm exponent of Sir Astley Cooper's teach-

[1] The Principles of Surgery, 1832, p. 261.

[2] Lehrbuch von den Bruechen und Verrenkungen der Knochen, 1833.

[3] On the Injuries and Diseases of Bones. Edited and translated by F. Le Gros Clark, 1847.

[4] A Treatise on Fractures. Translated from the French by John H. Packard, 1859.

ings, and yet, after the most critical examination of specimens for which bony union was claimed, he is forced to acknowledge that three of them were genuine. He says: "When a fracture unites, the fragments do not undergo such enormous losses of substance as we should be forced to admit in the neck of the femur; and in Swain's case, which Sir Astley Cooper himself acknowledged as an instance of bony union, the neck of bone had not changed its form. It was so also in Stanley's case; and, lastly, one femur (No. 188), in the Musée Dupuytren, has lost nothing, either in form or volume, except as the result of very trifling displacement. I admit that these three examples demonstrate quite positively the existence of consolidation; but I cannot say the same of the rest." Loss of substance and change of direction of the neck can no longer be regarded as evidence against the existence of bony union, as they only indicate the presence of impaction followed by interstitial absorption, the consequence of inflammatory osteo-porosis.

Nathan R. Smith,[1] in recommending his anterior splint in the treatment of fractures of the neck of the femur, expresses his convictions as follows: "This apparatus, with slight modifications, is applicable to all fractures of the femur. To none is it more appropriate, and in none has it accomplished more satisfactory results, than in fractures of the cervix, the events of which are so justly regarded as an opprobrium of surgery. So uniformly has non-union and deformity resulted, that eminent surgeons have denied that bony continuity is ever restored within the capsule. We hope to show that these results are rather the consequence of insufficient treatment, than defect in the reparative power of nature."

H. H. Smith[2] advocates the possibility of bony union in the following language: "That osseous union has been seen, cannot reasonably be doubted, and from a careful analysis of the seat of fracture in these cases, I think it is evident that there are a com-

[1] Treatment of Fractures of the Lower Extremity, by the use of the Anterior Suspensory Apparatus, 1867.

[2] The Principles and Practice of Surgery, 1863.

paratively limited number of cases in which osseous union does occur; and I suggest that, as a general rule, based on observation, it will be found that the nearer a fracture is situated to the head of the bone, or, in other words, the shorter the upper fragment, the greater will be the possibility of osseous union; because the shorter the upper fragment, the greater the chance that the vessels which supply it with blood through the round ligament will be able to furnish it with an amount of material sufficient to enable osseous union to take place by a deposit of bone from the Haversian canals."

Samuel Solly[1] writes: "If you can diagnose that the fracture is an impacted fracture of the cervix, then you may with tolerable confidence predict complete union and a sound limb. I have shown by reference to the preparations in the College of Surgeons' Museum, and also in our own, that fractures of the cervix within the capsule will unite, though not so frequently as those without."

Chelius[2] claims that bony union may have been observed less frequently in England than on the Continent, on account of neglected treatment in cases diagnosticated as intra-capsular fractures.

Erichsen,[3] in discussing this subject, remarks: "In some cases, however, bony union takes place. This may happen when the cervical ligament remains intact, or when the fracture is impacted."

Holthouse[4] says: "Bony union in this fracture (intra-capsular) is rare, and by some has been considered impossible; but a sufficient number of undoubted cases have now been brought to light, both in Europe and America, to place the fact beyond a doubt."

Agnew,[5] in speaking of Astley Cooper's method of treatment of intra-capsular fractures, remarks: "There have been recorded

[1] On Fractures of the Neck of the Thigh-bone, London Lancet, 1867.
[2] Handbuch der Chirurgie, B. I. S. 119.
[3] The Science and Art of Surgery, 1869.
[4] Holmes's System of Surgery, 1875, vol. ii. p. 846.
[5] Principles and Practice of Surgery, 1878, vol. i. p. 938.

a sufficient number of cases of bony union, after what was believed to be intra-capsular fracture, to justify a hope that some of the cases encountered by the surgeon may have a similar termination."

Gant[1] expresses a similar opinion: "Bony union at one time, and for many years, thought never to take place, does assuredly in some rare cases; but only, it would seem, when the capsular ligament remains entire, or the fragments are impacted, whereby a due supply of blood can be speedily established."

Bryant[2] makes use of the following language: "In the impacted fractures union ought to be looked for if the broken fragments are left alone, and not loosened by a careless and too curious manipulation. In the purely intra-capsular fractures, union may take place, osseous in many cases, fibrous in more."

MacNamara[3] affirms: "I believe, if you can keep the parts at rest, in many cases of intra-capsular fractures, union of the ends of the bones will occur."

Koenig[4] realizes the importance of impaction in the reparative process, as may be seen from his statement that intra-capsular fractures heal less frequently by osseous union than extra-capsular fractures, because they are less frequently impacted.

Hueter,[5] who classifies fractures of the neck of the femur into those with and without impaction, regardless of the attachment of the capsular ligament, lays it down as a rule that impacted fractures usually unite by bony union.

Stimson,[6] in discussing this subject, advances the following as one of his arguments in favor of the possibility of bony union: "Even if we disregard all existing specimens of alleged bony union, the possibility of such union must, I think, be admitted, because of the demonstrated fact that the head preserves its vitality, and has shown its ability to produce granulations and

[1] The Science and Art of Surgery, 1878, p. 646.
[2] Principles of Surgery, edited by J. B. Roberts, 1881.
[3] Diseases of Bones and Joints, 1881.
[4] Lehrbuch der Speciellen Chirurgie, 1879, B. II. S. 857.
[5] Grundriss der Chirurgie, 1882, B. II. S. 884.
[6] A Treatise on Fractures, 1883, p. 503.

bone; the former proved by the examples of fibrous union, the latter by eburnation or condensation of its spongy tissue."

I will close the list of witnesses who testify to the possibility of bony union after intra-capsular fractures, by quoting the last sentences of Jonathan Hutchinson's description of the specimen in the Pathological Museum of Leeds Hospital. "This specimen is alluded to by Malgaigne and Hamilton, as if it were of doubtful validity; but neither of them had probably seen it. I cannot but hope that the publication of these life-size drawings of the bone will set at rest all scepticism as to the possible union of intra-capsular fractures. I trust, also, that it may lead to greater hopefulness in the treatment of these accidents, and thus to more systematic care in securing coaptation."

With such an array of unprejudiced, honest, and conscientious witnesses before us, who unanimously and most positively testify that union by bone can, and not infrequently does, take place, we are no longer warranted in denying its possibility. The number of well-authenticated specimens has been gradually increasing, and the knowledge derived from clinical observation and experimental investigations on this subject during the last few years, can leave no further doubt pertaining to the production of bony callus in intra-capsular fractures. In the interest of science, and for the benefit of the patients, this controversy ought and must be decided in favor of the affirmative, and then the profession will be prepared to seek for measures which will secure better results.

XVIII. *Treatment.*

In no other fracture are the indications for successful treatment so difficult to meet as in fracture of the neck of the femur. Every unprejudiced surgeon is forced to admit, that the usual bad result in these cases is owing more to the insufficiency of the treatment employed than to the anatomico-pathological conditions of the broken bone. The causes of non-union are not to be found in the broken bone, but in the difficulties encountered in the treatment. All the various methods of treatment, sug-

gested and practised, have failed in securing perfect coaptation and uninterrupted immobilization. In all intra-capsular fractures union is effected by the production of an intermediate callus, from the broken surfaces; nature's splint, the external callus, for well-known anatomical reasons, is always wanting, hence, the surgeon's splint has a more important and prolonged application than in fractures in other localities. The time required for bony union to take place in fractures of the femoral neck is an unusually long one. Gurlt[1] fixes the time at from 56 to 207 days, and the average duration at 84 days.

Dupuytren estimates the time at from 100 to 120 days, and states, that it has been customary at the *Hôtel-Dieu* to keep these patients in bed at the hospital for 80 to 100 days. There can be no doubt that many cases, which promised well from the beginning, terminated unfavorably by abandoning the treatment too early. To prevent secondary displacements, the retentive measures should not be removed for at least 80 to 100 days. In deciding upon a course of treatment to be pursued it is important to make a distinction between impacted and non-impacted fractures. In impacted fractures the fragments have been placed in the best possible condition for bony union to take place, and the object of treatment consists simply in maintaining the mutual penetration until the reparative process is completed, and the continuity of the bone restored. The surgeon must be satisfied with securing consolidation of the broken bone in the position in which it has been placed by the accident. Any attempt to correct the deformity is unjustifiable, and would necessarily result in loosening of the impaction, an event which would almost to a certainty be followed by non-union. Permanent fixation of an impacted fracture is necessary for the following reasons:—

1. It maintains the impaction. 2. It prevents secondary shortening and eversion during the stage of inflammatory osteoporosis. 3. By keeping the injured parts at rest, it serves as a preventive measure against the accession of arthritis and paraarthritis. 4. It enables the patient to leave the bed before com-

[1] Knochenbrueche, vol. i. p. 331.

plete consolidation of the fracture has taken place. Extension is always contra-indicated in these cases, as it certainly can do no good, and may result in irreparable damage by loosening the impaction. The best dressing to accomplish permanent fixation is a plaster-of-Paris bandage. To insure complete immobility of the hip-joint, the bandage must include the injured limb from the toes upwards, the entire pelvis, and the sound limb from the pelvis to at least as far as the knee. For the purpose of greater durability and security of the dressing, a tin or wood splint can be incorporated in the plaster bandage. In the application of this bandage it is necessary to protect all prominent bony projections, more especially the trochanter major over the affected side, with salicylated cotton, to guard against excoriations; a flannel bandage should be applied next the skin. During the application of the bandages, and until the plaster sets, it is necessary to place the patient on a pelvic rest, such as is described by Bardeleben. During the setting of the plaster, it is important to make lateral pressure over both the greater trochanters, in order to secure firm support to the broken bone.

With such a dressing, the patient can be moved without fear of disturbing the fracture, and in a few days he can leave the bed, and in a few weeks can walk on crutches, if deemed necessary for the purpose of preventing complications. Unless indications arise, it is advisable not to disturb the dressing until osseous union has become sufficiently firm to support the fragments. It is particularly dangerous to change the dressing from the third to the fifth week, as during this time the inflammatory osteoporosis has a tendency to loosen the fragments. I am satisfied that a dressing of this kind is vastly superior to any splint in affording comfort to the patient and securing the best attainable result.

In the treatment of non-impacted fractures the same principles should govern us as in the impacted variety. In this class of fracture, however, another important indication arises, namely, to effect coaptation of the fractured ends; at the same time retention is more difficult to accomplish. The nearer we can imitate impaction, the better the prospects for a favorable result.

If we could keep the broken surfaces in perfect coaptation, and maintain retention and immobility, these fractures would heal in the same way as impacted fractures. That these indications have not been fulfilled by the usual treatment with different splints, extension by weight and pulley, and pelvic belt, nobody can deny. Even extra-capsular fractures have healed, as a rule, with so much shortening as to cripple the patients for life, while the results after intra-capsular fractures have almost universally been so bad, that many of the most distinguished surgeons have abandoned all active measures, limiting their treatment exclusively to palliation. Prominent among the advocates of the expectant treatment in intra-capsular fractures, I will mention Sir Astley Cooper, Velpeau, Langlet, and Lavacherie. That the views of many surgeons on this point have undergone no material change since Sir Astley Cooper's time is apparent from more than one recent work on surgery. I quote verbally from Gant's surgery, page 647: "No bony union taking place, as a rule, in intra-capsular fractures of the neck of the femur, it will generally be useless to adjust the fracture and apply any retentive apparatus with a view to such union; and the more so, in proportion to the years of the patient."

If the results attending the different methods of treatment have been so bad as to induce men of the highest professional attainments to abandon all active treatment as useless, the question naturally arises, are there any other means which are better adopted to accomplish the desired result? The question as to possible bony union after intra-capsular fracture, in the light of recent researches, has been decided in the affirmative, and a more practical question arises, how can it be obtained? By what means can we keep the fragments in mutual coaptation during the process of repair? I would suggest the following points in the treatment: 1. Immediate reduction and coaptation of the fracture under the influence of an anæsthetic. 2. Fixation with a plaster-of-Paris splint. 3. Lateral pressure. 4. Direct fixation of fragments by bone-pegs.

I. Extension by means of the weight and pulley overcomes the shortening only gradually, and seldom completely, at the

same time it necessitates the recumbent position for a long time, and thus exposes the patient to all the risks and inconveniences incident to such position. If the patient is placed thoroughly under the influence of an anæsthetic, muscular action is temporarily annihilated, and the limb can be extended at once to its natural length, while coaptation can be effected at the same time. The advantages arising from immediate reduction and coaptation are the following: 1. The untorn portions of the joint structures are replaced at once into their normal relations; a procedure which cannot fail to influence favorably the circulation in vessels which may have escaped injury. 2. The sharp and irregular margins of the broken surfaces act as irritants to the surrounding soft tissues; immediate reduction, by placing the bones at once in mutual coaptation, acts as a preventative against the supervention of undue inflammation in and around the hip-joint. 3. With coaptation the process of repair is initiated at once, the blood and exudation material between the fragments act as a temporary cement substance, and at the same time serve a useful purpose in re-establishing the interrupted circulation. 5. Perfect reduction and coaptation prevent muscular spasms and diminish pain.

II. Having reduced the fracture, retention should be maintained in a similar manner, as in impacted fractures; with the exception, however, that eversion should be carefully corrected. The plaster-of-Paris splint is applied as for impacted fracture, only that over the trochanter major of the injured side a fenestrum, about two inches wide and four inches long, is left open for the purpose of applying lateral pressure.

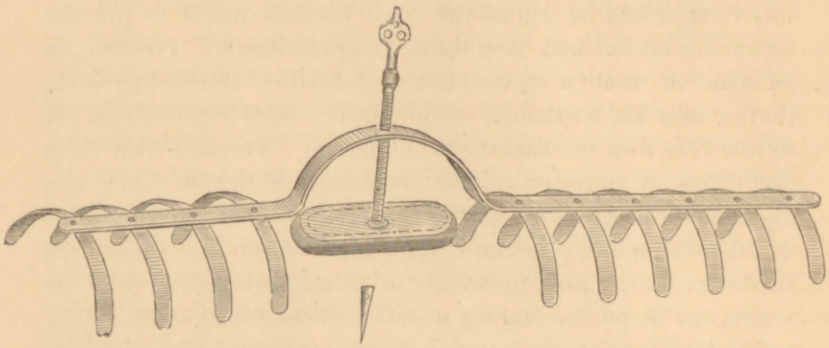
III. Many fractures of the femoral neck are kept from becoming displaced for a variable period of time by interlocking of the denticulated broken surfaces, a condition which has been called by Bigelow "rabbeting." Believing that the surgeon should imitate the reparative resources of nature wherever it is possible to do so, it appears to me that artificial rabbeting could often be produced by lateral pressure. The fractured surfaces being placed as accurately as possible opposite each other, lateral pressure would cause perfect coaptation and a mutual

interlocking of the fragments. Lateral pressure, applied with this view, would be one of the most reliable means to prevent secondary lateral and longitudinal displacements. Pressure, to be effective, must be applied in the direction of the broken neck, that is, over the trochanter major, and in such a manner as not to interfere with the superficial circulation. Pressure with belts and strips of adhesive plaster encircling the whole pelvis, can exert but little influence on the fractured bone, at the same time it impedes the superficial circulation. With the fenestrated plaster-of-Paris splint, pressure can be applied directly over the trochanter major, by placing a well-cushioned pad, with a stiff, unyielding back, corresponding in size to the fenestrum, in the opening of the splint, and applying the necessary amount of pressure by means of a Petit's tourniquet, or some other similar contrivance. A small amount of pressure, if well directed, would be sufficient to retain the fragments in apposition. By removing the pad from time to time, and washing the parts with dilute alcohol, there would be no danger of producing excoriation. The pad could also be made smaller, and the pressure surface changed as often as necessary, as an additional precaution against superficial excoriations. Lateral pressure and fixation, however, could be applied more directly and advantageously by means of a long, sharp, steel pin, regulated by a set-screw passing through the centre of a curved steel bar, incorporated in the plaster-of-Paris bandage over the fenestrum, in such a way that the sharp point of the pin would perforate the soft parts over the centre of the bone of the femoral neck, and by penetrating a small distance into the bone, would secure perfect immobility of both fragments. By removing the steel pin and adjusting the pad, this instrument can be used for applying ordinary lateral pressure. I present for your inspection an instrument of this kind. (Figs. 18, 19.)

Heine[1] has used a somewhat similar instrument in the treatment of ununited fractures of the femur and tibia. The super-

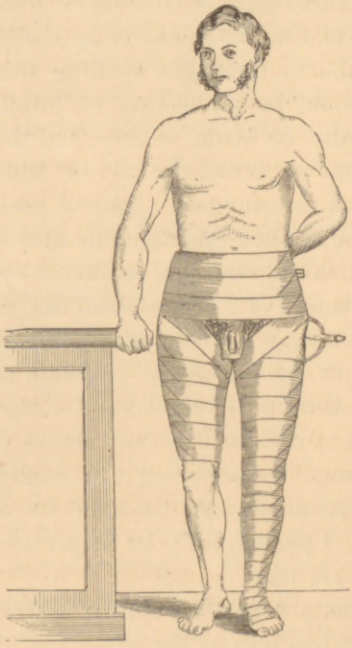
[1] Ueber operative Behandlung der Pseud-arthrosen, Verh. d. Deutsch. Gesellsch. für Chirurgie, 1877, p. 220.

Fig. 18.



Apparatus for treating Fracture of Neck of Femur.

Fig. 19.



Apparatus applied; steel point of instrument fixed in Trochanter Major.

ficial site of the greater trochanter would render this dressing of easy application, and from the absence of very sensitive struc-

tures, the pain inflicted would not be as severe as in using Malgaigne's hooks for fracture of the patella. Undue inflammation of the soft parts could readily be avoided by the use of antiseptic precautions. It would probably not be necessary to continue this treatment for more than two to four weeks, when the ordinary pad for lateral pressure could be substituted for the steel pin.

IV. Apposition of the fractured ends could be secured and maintained with the greatest degree of accuracy by measures, which are calculated to operate directly upon the fragments. Such measures have been successful on other joint fractures, where the usual prescribed methods of treatment had failed in effecting union by bone. In the case of fracture of the femoral neck, however, the injured parts are so inaccessible as to exclude the propriety of any cutting operation for the purpose of exposing the fragments to view and securing apposition through the wound. At the same time, this injury is limited almost exclusively to a class of patients whose general condition would forbid an operation of such magnitude for such a purpose. If, however, an operation could be devised which would be devoid of immediate or remote danger to life, and that would not incur any loss of blood, nor add to the suffering of the patient, and at the same time would render substantial aid in maintaining permanent apposition of the fragments, then our prospects for securing better results would indeed become more encouraging. I believe we have such an operation in subcutaneous drilling of the neck of the femur, and nailing the fragments together by means of a bone-peg.

The observations of Volkmann and Heine have shown that driving ivory-pegs into osteo-porotic bones will produce an osteo-plastic inflammation and osteo-sclerosis. The operations of drilling and insertion of bone-pegs have been resorted to for a long time, for the purpose of promoting the formation of callus in cases of ununited fractures, and it is only reasonable to assume that the same operations would have a similar effect in recent fractures. The operation offers no great technical difficulties in its execution, and if done under strict antiseptic precautions,

does not expose the patient to any additional risks. The idea of immobilizing fractures by nailing the ends of the broken bone together is not a new one. It is alluded to by David Prince,[1] in treating of the subject of ununited fractures, when he says: "Perhaps a bone might be drilled through both fragments, and held in apposition by a rivet of one of these metals. The presence of the rivet after the completion of the healing process would do no harm, and if a permanent discharge should be the result, the metal could be readily removed."

As yet a discrepancy of opinion prevails as to the future fate of bone- and ivory-pegs when imbedded in living bone. Trendelenburg[2] operated for a very oblique ununited fracture of the femur at the junction of the lower with the middle third, by fixing the fragments with an ivory-peg. He had an opportunity to examine the specimen two-and-a-half years after the operation. The fracture was firmly united, and the ivory-peg was found intact in the bone-tissue, having undergone no change whatever, except that a portion which had projected into the knee-joint had become detached, and was found imbedded in a cyst in the interior of the joint, surrounded by giant cells.

Riedinger[3] made similar observations. Introducing ivory- or bone-pegs into the bones of animals, he found them after a variable period of time either entirely unchanged, or only slightly diminished in size. The diminution in size appeared to be in proportion to the vascularity of the living bone. The growth of the bones thus treated was stimulated, as was shown from an increase in their length as compared with the opposite bones.

Bidder[4] found that by boring a hole into the spongiosa of the epiphysis of the long bones in old rabbits, into the lower end of the femur, for example, that no regeneration of bone took place, the loss of substance being replaced by fibrous and myeloid tissue. In young adult rabbits a slight attempt at regeneration

[1] Plastics and Orthopedics, 1871, p. 220. [2] Ibidem.

[3] Virchow u. Hirsch's Jahresbericht, 1881, vol. ii. p. 333.

[4] Exper. Beiträge u. Anat. Untersuchungen d. Knochengewebe, etc., Archiv f. Klin. Chir. B. XXII. p. 155.

was manifested. The process of regeneration, however, was increased by driving ivory-pegs into the perforations, or by injecting iodine or lactic acid.

Brainard[1] taught that simple perforation of bone increased the formation of callus, while insertion of ivory, wooden, or metallic pegs not only disminished it, but with few exceptions produced absorption of bone.

Volkmann[2] treated a pseud-arthrosis of the femur by excision of the fractured ends, and immobilized the fracture by driving a peg made of a piece of fresh bone, taken from another patient, into the medullary cavity of both ends. The fracture united and the transplanted piece was not seen again.

Riedenger's[3] experiments on animals have shown that ivory- and bone-pegs implanted into bone increase the nutrition of the bone, and remain without giving rise to any undue irritation, and are finally partially or completely absorbed. Metallic substances remain firmly imbedded. Wood and rubber invariably gave rise to suppurative inflammation. Clinical experience and experimental investigations have sufficiently demonstrated that bone- and ivory-pegs, if implanted under antiseptic precautions, do not act as foreign bodies, and never give rise to suppuration; and can, therefore, be safely employed in securing accurate coaptation of recent fractures, if this is deemed desirable and necessary, and not attainable by simpler measures. It has also been shown that these pegs produce osteo-plastic inflammation, and thus materially hasten the process of repair. The operation of direct immobilization of the fragments by means of bone- or ivory-pegs is, therefore, particularly adapted to the treatment of intra-capsular fractures, whenever it is decided to make every legitimate attempt to secure union by bone. A somewhat similar operation has been performed several times for the purpose of relieving the pain incident to pseud-arthrosis, following fractures of the femoral neck. Before the introduction of antiseptic

[1] Treatment of Ununited Fractures, Trans. Am. Med. Ass. 1858.

[2] Ueber Pseud-arthrosen der Vorderarm Knochen. Verh. d. Deutsch. Gesell. f. Chir., 1881, ii. p. 167.

[3] Verhandl. d. Deutschen Gesellsch. f. Chir., 1877, p. 134.

surgery, von Langenbeck[1] operated by exposing the greater trochanter, and passing a silvered drill through it into the upper fragment so as to secure apposition. The fracture was oblique and extra-capsular in an aged female. The operation was followed by destructive inflammation, hospital gangrene, and death. Lister operated in a similar manner, but under the protection of antiseptic surgery, and secured a good result by a short fibrous union.[2] In this case, however, it appears that the upper fragment was not transfixed by the screw. Koenig[3] repeated Langenbeck's operation under antiseptic precautions, and secured a favorable result. My experiments on animals have satisfied me that it is not always an easy task to find the upper fragment with the drill, and perforate it at the proper point. To overcome this difficulty, it has been suggested by Trendelenburg,[4] to expose the seat of fracture by a small incision from behind, and after forcibly abducting the limb, perforate the lower fragment from within outward, and by reinserting the drill from without inward, guided by a finger in the wound, and, after straightening the limb, transfix the upper fragment. A silver screw is inserted in the hole made by the drill, and the two fragments are screwed together. The screw is to be removed after two weeks. For the purposes for which we have urged the operation, Trendelenburg's advice is too severe and dangerous. By using bone- or ivory-pegs no disastrous result would follow in the event the peg should miss the upper fragment and be driven into the joint.

Trendelenburg's case and my experiments on animals furnish positive proof that bone- and ivory-pegs driven into the interior of joints do not give rise to any serious results. The operation of drilling the femoral neck and the subsequent insertion of the ivory-peg is facilitated by placing the limb in its natural position and securing it by the plaster-of-Paris dressing. The drilling is done through the fenestrum over the greater trochanter in the plaster splint, by sliding the skin and making a passage for the

[1] Verhandlungen d. Deutschen Gesellsch. f. Chirurgie, 1878, p. 92.

[2] MacCormac, Antiseptic Surgery, 1880, p. 200.

[3] Verhandlungen d. Deutschen Gesellsch. f. Chirurgie, 1878, p. 93.

[4] Idem.

drill through the soft tissues down to the bone with a tenotome at a point corresponding to the centre of the base of the femoral neck, and drilling in the direction of its axis toward and into the femoral head. The length of the bone- or ivory-peg should correspond to the distance between the outer surface of the greater trochanter and the centre of the femoral head. The advantages arising from the treatment as suggested above would be:—

1. The most perfect degree of coaptation and immobilization of the fragments.

2. The patient could be placed in any position in bed, or even be taken out-doors as soon as the dressing is applied, thus effectually preventing excoriations and the diseases incident to prolonged confinement to bed in the recumbent position.

I do not advise, of course, that all the means suggested should be called into use in every case. When the general condition of the patient is such as to preclude any possibility of obtaining a good result, the severer measures, which aim at accurate adjustment and immobilization, are not to be used. In such cases, it is only necessary to adjust the parts as accurately as possible, and apply the plaster-of-Paris dressing, which, by keeping the parts at rest, secures for the patient the greatest degree of comfort, and, moreover, does not exclude the possibility of recovery by the formation of a short ligamentous union. If the patient's health is fair, and the symptoms are such that point to the existence of the fracture within the capsule, then we are justified in resorting to the means which will insure the greatest accuracy in the approximation of the parts, and thus furnish nature with the only known means by which she can restore the continuity of the bone.