however, acute suppuration seldom leads to deafness. There is, therefore, a diminution in the number of cases of adult deafness, and this decrease should be progressive, owing to the increased frequency with which tonsils and adenoids are removed in childhood.

RADIOGRAPHY IN MASTOID DISEASE.*

BY

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THIS paper is based on the study of the radiographic pictures of over 500 cases, normal and abnormal.

Before dealing with the radiographic study of the mastoid, it is necessary to consider the normal mastoid development at the various ages and the normal mastoid structure. According to Wittmack's researches, the development of the temporal bone may be divided into three periods: (1) Formation of the tympanum, epitympanic recess, and the mastoid antrum, continuing to the end of the first year. (2) Formation of mastoid cells from these three cavities, which ceases between the fourth and the sixth year. (3) Further formation of cells, which continues throughout life.

Cheatle's researches go to show that the acellular structure of the infantile mastoid is diploëtic tissue, the only cells in addition to the tympanic antrum being a layer on its outer wall. It is stated that this acellular type persists throughout life in 15 per cent. of people. In the second type (cellular or pneumatic) the diploë is replaced by air spaces which have extended from the middle-ear tract. Between the infantile acellular diploëtic mastoid and the cellular or pneumatic mastoid several intermediate varieties of bone are recognized. In the adult bone these represent an arrest of development corresponding with a definite age in the child. This is of special interest in the consideration of asymmetry in the mastoid and its possible etiology.

In the standard x-ray projection we can trace the gradual pneumatization and the approximate normal for the age. The standard projection used gives practically a lateral projection, and the following landmarks should be studied and recognized. We first of all recognize the external and the internal auditory meatus; just a little superior and posterior to this is located the mastoid antrum. Directly posterior to the canal at a variable distance is the groove for the sigmoid sinus. Passing downwards and forward through the mastoid process to the jugular fossa—below and in front of the mastoid tip—the sharp angle or knee of the sinus groove can be recognized, and it is especially important to note the anterior line of this groove. Below this is the tip, and just behind the canal is an opaque area forming the posterior meatal wall with the facial nerve underneath. Above the mastoid antrum and middle ear can be seen the tegmen of middle ear and antrum. The superior line of the squama may be indicated. In front of the meatus we have the temporo-mandibular articulation with the glenoid cavity and the condyle of the lower jaw. Frequently the emissary vein is seen as a worm-like shadow situated anywhere between knee and tip. The area enclosed between the posterior meatal wall in front, the tegmen above, and the anterior wall of the sinus groove forms roughly an inverted triangular area, with the tegmen as base; for descriptive purposes this has been called the triangular area.

Returning to the radiographic studies of the normal mastoid in children, this is found to correspond more or less closely with Wittmack's stages of mastoid pneumatization. (1) From birth to one year the only cell development is seen in the mastoid antrum, which occupies a more superior position to the auditory meatus than in the adult and is of comparatively large size. (2) From the first to the sixth year cell development begins and is confined to the triangular area previously described and forward towards

the zygoma in some cases. (3) From the sixth year to the sixteenth we notice gradual cell development beginning posterior to the anterior sinus groove, starting first at the lower posterior part and tip. (4) The complete pneumatization extends eventually to the upper posterior part and permeates completely the mastoid process.

The pneumatic mastoid in the adult may show cell development corresponding closely to these four stages. Another feature of interest is that cells laid down early in the triangular area are smaller as a rule than those developed at the tip and posterior part of the mastoid later; this is well shown in some of the radiographs.

Symmetry of Mastoids.

By symmetrical mastoids is meant that they are either both pneumatic or both diploëtic in structure. Asymmetrical mastoids would thus mean a diploëtic mastoid on one side and a pneumatic mastoid on the other; a case revealing an extensive pneumatization on one side with a very limited pneumatization on the other is not in the true sense an illustration of asymmetry, but rather symmetrical mastoids with arrested pneumatization on one side.

In their investigations Beck, Law, Reverchon, and others report consistent symmetry. Turner and Porter, in their examination of 1,000 crania, report 12 per cent. asymmetrical. Plum suggests that some of these might possibly indicate arrested development. With regard to the present series, in the normal cases I have examined I have found the mastoid processes consistently symmetrical. Where there was no ear complaint and the x rays revealed apparently asymmetrical mastoids, investigation has shown without exception the presence of either a mastoiditis or a healed condition, often previously unknown to the patient. This apparent or false asymmetry due to some previous pathological condition is a very common occurrence.

We now come to the question of the influence of an inflammatory process on mastoid development and thus indirectly on the question of asymmetry.

Macewen in 1893 stated that: "In chronic cases of inflammation of the mastoid an osteoplastic formation may be set up in the neighbouring bone which results in an eburnating sclerosis and an actual obliteration of many of the mastoid cells." This well expresses the old view regarding the sclerosed mastoid frequently found at operation.

Cheatle has more recently stated that in infancy, with the exception of the mastoid antrum and a few cells on its outer wall, the mastoid consists of diploëtic structure; further, that this so-called infantile type persists in 15 per cent. of people. Cheatle's researches tend to show that the sclerosis produced at first round the antrum is not the effect but the cause of the chronic suppuration, the acellular condition being thus primary. Wittmack, on the other hand, believes that hyperplasia of the mucosa with incomplete or arrested pneumatization is caused by the entrance into the tympanum of amniotic fluid, meconium, etc., during foetal life or at birth, or the entrance of vomitus during the first year of life. Wittmack's theory is supported by Pierce and others.

As I have already stated true asymmetry has not been found in the present series of cases—that is, apart from a previous pathological condition of the mastoid. In addition, I have not been able to find a case presenting normal ears with a sclerosed or ivory mastoid. Assuming Wittmack's theory to be correct regarding the production of the acellular type of mastoid, I have found the acellular mastoid to give the x-ray appearance suggesting a diploëtic mastoid rather than a sclerosed mastoid. Law in 1920 stated that it was impossible to distinguish between a sclerosed mastoid and a diploëtic one.

In the present series of films I have found that the appearance of a sclerosed mastoid is different from that of a diploëtic one. Further, cases of chronic mastoiditis on x-ray examination reveal all degrees of thickness of cell trabeculae, in some cases so thick that the mastoid cells are almost obliterated. This thickening is shown also in the cases of healed mastoiditis, whereas in the normal pneumatic mastoid the trabeculae are of a very uniform degree of fineness and the cells distinct and well marked.

* A paper communicated to the Section of Laryngology and Otology at the Annual Meeting of the British Medical Association, Edinburgh, July, 1927.

Taking the cases where a healed mastoid was found it can be demonstrated that the inflammatory process has undoubtedly produced an arrest of pneumatization on the affected side as compared with the healthy, the subsequent growth of bone in these healed cases being apparently diploëtic in structure as distinct from the ivory sclerosis found in some cases of chronic mastoiditis. This arrest of pneumatization in the adult I have been able to demonstrate as corresponding to the various stages previously mentioned in the normal pneumatization process in the child.

Taking the present series as a whole, normal and abnormal, I have found true diploëtic acellular mastoids to be comparatively rare, whilst those showing arrested development are of frequent occurrence. I have come, then, to the following conclusions from the cases studied:

- (1) That normal mastoids are symmetrical.
- (2) That they are of two types: (a) pneumatic or (b) diploëtic. Apart from chronic mastoiditis, never of the ivory sclerotic type.
- (3) That arrest of pneumatization occurs following otitis media with mastoid involvement; many cases of apparent asymmetry are due to this cause.
- (4) That the normal pneumatic cases far outnumber the normal diploëtic.

The Value of X Rays in Mastoiditis.

Kuttner as recently as 1912 stated that radiology did not furnish any assistance in otology. Winckles and Voss, on the other hand, in 1907 reported x-ray findings verified by operation. Plagmann, by means of a negative, was able to distinguish whether the disease was confined to mucosa in an acute case or whether there was some bone caries. Law in 1920 produced a descriptive atlas, including operation findings and technique. Plum in 1924 gave a record of x-ray procedure with confirmed operation findings.

It would be well to emphasize at once that, as in other branches of medicine and surgery, the diagnosis should not be attempted on x-ray findings alone, but, if properly studied and applied, we have a very valuable addition to our other clinical means of investigation.

At the throat and ear clinic of the Royal Infirmary, Glasgow, we have employed this method to all possible cases of mastoiditis, acute and chronic, coming to operation; it has thus been possible to compare the x-ray and operation findings. The initial difficulties were many.

If radiography is to be of any use as a routine method several things are, in my opinion, essential. The first essential is to decide on a *standard position*. Next it is necessary to become familiar with the normal appearances at different ages, and the various results of pathological processes. Good plates, indeed very good plates, are essential. The following have been selected: (1) A large series of normal mastoids, child and adult. (2) A series of pathological conditions in children. (3) The conditions seen in a series of 50 operations with the x-ray findings noted. (4) A series of cases illustrating other conditions—for example, simple acute otitis media, furuncle of meatus, etc.

Plum (1924) has suggested that an x-ray photograph does not reveal whether disease is active or healed, and that only repeated negatives during the process of disease give indication of active lesion. It is undoubtedly the case that, taking negatives alone, this may be true, and also that repeated negatives may be considered in acute cases, but, if the other clinical observations are combined with a single x-ray plate, a fairly accurate opinion may be given regarding conditions in the mastoid. It has also been stated by various authors that x-ray findings in cases of chronic suppurative otitis media are of less value than in acute cases. It has been possible, however, to demonstrate from the present series many interesting and suggestive changes in chronic cases verified by operation.

X-Ray Appearances in Normal Mastoids.

The characteristics depend on the type being examined. A radiogram of both sides should be obtained on one plate for comparison; this is especially valuable in unilateral cases. If bilateral, the surgeon must compare with what he would assume to be the normal condition at the age of the case under review.

Dealing first with the mastoid with arrested cell development at some period under 6 years of age, we can distinguish the following features: (1) the auditory canal; (2) the posterior wall of the bony meatus; (3) the sinus groove, especially the anterior wall; (4) the line of the tegmen of the antrum; (5) the tip of the mastoid process. The only cell development noticed here is in the triangular area. The sinus groove is usually well seen, but the antrum is indistinct; the remainder of the mastoid is usually diploëtic in structure.

The Diploëtic Mastoid.—This shows all the features of the above except cell development in the triangular area, the mastoid throughout being of uniform fine meshwork, much finer than in the smallest pneumatic mastoid. Only a very good film will show the true nature of the diploëtic structure.

The Pneumatic Type.—Primarily, although the size of the cell may vary in individuals, the smallest cells are found in the triangular area, whilst the largest are in the tip and posterior to the sinus groove. These latter cells are developed later. The cells frequently run well forward into the zygoma. Another important point in the normal pneumatic mastoid is the character of the lines indicating the anterior sinus groove. This line sometimes shows clearly, at other times only faintly. This depends on the thickness of the sinus plate compared with superimposed cells. It has already been stated that normally the mastoids of any particular case are symmetrical. This not only applies to the type of mastoid but to the size of the cells; where there is a large cell or collection of cells in one situation, a similar collection is usually seen in the same situation on the other side. This makes it possible to distinguish sometimes between an area of cell development and an area of caries with bone absorption. The size and position of the emissary vein should be noted as a matter of interest.

The Sclerotic Type.—This I have only found associated with a chronic process in the mastoid; often no cell outline can be distinguished, but, as sclerosis is not always uniform, areas of caries with absorption can be noticed. The anterior sinus groove is often well marked.

From the series of x-ray findings followed up to operation I have been able to verify the following conditions:

1. Hyperaemia of mastoid cells in acute otitis media without obvious mastoid disease.
2. Acute mastoid inflammation.
3. Purulent mastoiditis.
4. Caries indicated by breaking down of cell trabeculae in pneumatic mastoids, or areas of bone absorption in previously diploëtic or sclerotic mastoids.
5. Exposure of sinus; extradural perisinus abscess.
6. Exposure of middle fossa dura with low middle fossa.
7. Cholesteatoma.
8. Sclerosis with often a sinus groove unusually far forward. This condition gives more or less definite x-ray appearances.

Mild Acute Mastoiditis.—The diseased side in pneumatic mastoids shows a faint haze covering the mastoid, as compared with the clear outline of the healthy side. The cell trabeculae are still distinctly seen. I have found that this haziness is especially marked in the region of the mastoid antrum. A case presenting these features with free drainage should be left alone providing other signs do not indicate operation. Where, because of cessation of discharge, increase of pain in the ear, with elevation of temperature, etc., operation has been undertaken, the mucous lining of the cell is found to be oedematous, a collection of haemorrhagic serous fluid is found in the mastoid antrum, but there is an absence of caries or pus. Sydney Lange records this degree of mastoid involvement in 50 per cent. of cases of apparently simple acute inflammatory otitis media.

Acute Purulent Mastoiditis.—In these cases the cells are filled with purulent discharge; there is a greater degree of cloudiness of the cells, especially in the triangular area, obscuring the antrum; the sinus groove is well marked. Such an appearance may be associated with symptoms or signs indicating operation; I have found beads of pus throughout the mastoid, the mucous membrane oedematous, and, on opening the antrum, a collection of pus; there is no breaking down of the cell trabeculae.

Severe Purulent Mastoiditis, Acute or Chronic.—The pneumatic mastoid here appears entirely blurred. Areas of apparent rarefaction consequent on the breaking down of cell trabeculae or caries indicate the necessity for operative measures, and at operation extensive caries may be found with collection of pus especially surrounding the antrum or towards the tip; these areas, however, may be found at any point in the mastoid. Up to the stage of caries the line of the anterior sinus groove is intact and more visible than in the normal side; but where the sinus plate is affected the intact line becomes broken, and at operation the sinus is seen to be exposed and sometimes covered with recent granulations—granulations and pus being found throughout the mastoid. An x-ray plate with the above findings indicates immediate necessity for operation apart from the presence or absence of such signs as temperature, mastoid oedema, tenderness, etc. In several operation cases I have been able to demonstrate abscess formation in acute and chronic suppurative mastoiditis in the x-ray films. In these cases the cell trabeculae break down and numerous cells appear to have coalesced, the outline of the abscess being sometimes clearly marked. Frequently in these cases the lines of the tegmen and of the anterior sinus groove become broken or blurred, and operation has revealed extradural, middle fossa, and perisinus abscess. A common situation for abscess formation is in the large tip cells.

The edges of an area of bone formation corresponding to an abscess are often blurred and hazy, but readily distinguishable. It has been noted in some cases that the area of maximum tenderness corresponds accurately to the area showing bone absorption. Cholesteatoma formation occurring in chronic cases sometimes presents a diagnostic picture of an indefinite haziness; this is usually surrounded by an area of increased density, the surrounding bone having undergone osteoplastic change resulting in ivory-like sclerosis. The condition is most commonly noted in the triangular area surrounding the antrum. The density of the shadow found in cases where operation has revealed ivory sclerosis has, in my experience, never been seen in the mastoid process of the normal ear; in the presence of a chronic discharge, indeed, this type of change is a distinct indication for a radical mastoid operation, as there is little chance of a permanent cure.

There are several other conditions where x-ray evidence is of great assistance in diagnosis:

(1) **Marked Dermatitis or Eczema.**—Frequently cases occur of eczema or dermatitis of the external auditory canal with stenosis; in these, because of their chronicity, a middle-ear origin is suspected. The x-ray picture in some of these cases pointed directly to the mastoid as the source of infection, whilst in others a beautiful healthy pneumatic mastoid has been found, absolutely excluding mastoid disease.

(2) **Furunculosis.**—With post-aural infection and oedema the x rays have again given valuable diagnostic assistance and sometimes prevented a mastoid operation. In these cases a haze is apparent over the mastoid, but there is no indication of caries. The employment of routine x-ray examination of mastoids of all cases of otitis media enables us to decide whether conservative measures—for example, removal of polypi, ionization, douching, drops—are likely to prove satisfactory. I have found in this way cases with chronic aural discharge, but no other symptoms where radiography has revealed cholesteatoma or dural exposure.

Conclusions.

1. Mastoids are normally symmetrical.
2. Mastoids are usually pneumatic, occasionally diploëtic.
3. Nothing has been found to disprove Wittmack's views of the origin of the diploëtic mastoid.
4. Pneumatization proceeds in a more or less definite manner in children normally; mastoiditis, mild or severe, tends to arrest cell development, resulting in the persistence in adult life of a partially pneumatized mastoid process.
5. If reinfected this arrested or infantile type of mastoid may develop a sclerotic character, and is probably more liable to chronicity.

6. A dense sclerosed mastoid has not been demonstrated without at least evidence of a pre-existing otitis media.

This investigation has been carried out in the throat and ear clinic of the Royal Infirmary, Glasgow, under the charge of Mr. James Harper. The operations were performed by Mr. Harper, Dr. Leitch, and myself. I am indebted to Mr. Harper and Dr. Leitch for the operation findings in their cases and for permission to include them in the present series. I desire also to express my indebtedness to Dr. Bruce MacLean, our radiologist, and his staff, for the very considerable trouble taken with the radiograms. I am also indebted to Dr. Logan Turner and Dr. J. S. Fraser of Edinburgh for very valuable references.

Memoranda :

MEDICAL, SURGICAL, OBSTETRICAL.

PULMONARY EMBOLISM WITH KNOT FORMATION IN THE CLOT.

THE accompanying photograph shows the appearance of an embolic clot found at the bifurcation of the pulmonary artery in a patient who died suddenly with the usual symptoms of pulmonary embolism. The clot, when found, was not spread out as in the photograph, but lay curled up at the bifurcation of the pulmonary artery; it extended a little into the right pulmonary artery, and a very little into the left pulmonary artery. The only true knot, however, was the one illustrated. The total length of the clot is almost 17 in.

A possible clue to the knotting is provided by the unusual site of origin of the clot. This was in the left axillary vein. A more angled path to the pulmonary artery had thus to be followed than is the case with the more common clots coming by way of the inferior vena cava from the pelvic or leg veins. The clot may thus have been retarded for some time when only part had passed the tricuspid valve, and the portion in the ventricle may have been knotted by the repeated contraction of that chamber, particularly if the part still lodged in the tricuspid orifice was causing some incompetence at the same time, and so modifying the blood currents in the ventricle.

The history tends to support this view, for the patient lived for nearly an hour after the pain in the chest and respiratory distress commenced, and then died suddenly. He was a man aged 56, and was suffering from an abscess of the left axilla, resulting from neglect of a slight wound of the hand. The wall of the axillary vein was inflamed and surrounded by pus. The femoral and pelvic veins were healthy.

I have to thank Mr. J. Marnoch, professor of surgery, Aberdeen University, for the notes of the case, and Professor Shennan, of the Pathological Department, for permission to publish this report.

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ACUTE VERONAL POISONING, WITH LOBAR PNEUMONIA AND BEDSORES.

THE following case of veronal poisoning which occurred in my practice in Valparaiso, Chile, this year, four months before I left for England, seems worthy of record in view of the large dose taken and the subsequent complications which delayed recovery.

I was summoned urgently one night at about half-past ten to see a woman who had taken an overdose of veronal, and about fifteen minutes later I found her deeply unconscious. She had been given some hot water and had vomited a little brownish fluid. The pulse was regular and the colour good; the pupils reacted normally. I washed the stomach out with warm water containing sodium bicarbonate until the solution became clear, the first returns being brownish and containing mucus. Two tablespoonfuls of sodium sulphate in half a pint of water were left in the stomach. Hypodermic injections of strychnine, digitaline, caffeine, and camphorated oil were given at regular intervals.