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X-Ray Examination of the Nervous System

Leo M. Davidoff

X-RAY EXAMINATION OF THE NERVOUS SYSTEM*

*By Leo M. Davidoff***

INTRODUCTION

The penetrating quality of the mysterious Roentgen ray through visually opaque bodies has made it one of the most important adjuncts in medical diagnosis. Its diagnostic value depends upon the different degrees of penetrability of various tissues in the body. Thus the osseous system is the most easily demonstrated by roentgenography, because the shadows of bones are most easily seen against the less radio-opaque softer tissues. On the other hand, the contents of the chest cavity are well visualized through the greater penetrability of the air-filled lungs. Again foreign bodies that are metallic, or metal containing, like lead-containing glass, are easily seen on the X-ray film of the portion of the human body that has been penetrated by them, because of their greater density even than bone. This recognition of the value of contrasting shadows has led to the introduction into the body by various routes of various media which by means of their high degree of penetrability to the X-ray, like air or other gases,—or their low penetrability, like bismuth, barium or iodine containing mixtures or chemicals,—produce shadows of tissues and organs that are otherwise not visualized.

That portion of the nervous structure to which we apply the designation "central nervous system" consists of the brain and the spinal cord, as contrasted to the "peripheral nervous system" which is made up of nerve cables running in all parts of the body serving the functions of bringing to the central nervous system individual messages from one's environment, and of relaying orders from the complex central station to those effector servants of the brain, the muscles and glands. The highly complex structure and function of the cells and fibres of the central nervous system—probably the most complex and most perfect mechanism in creation—has robbed them of any intrinsic capacity of self-protection or repair. Nature has, therefore, provided a "self-sealed" fluid-jacket that surrounds them, and in which they are suspended—the cerebro-

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spinal fluid. This is contained in a series of envelopes—the meninges. These are surrounded by a hard durable shell, the skull and the spinal column.

It is most important to realize from the beginning that the help to be obtained from X-rays in the diagnosis of disease or injury to the nervous system, especially when unaided by contrast media, is the evidence which can be demonstrated of indirect or coincidental abnormalities of the bony case in which the nervous system is stored. With the help of contrast media such as air, oxygen or helium in the cranial cavity,—or lipiodol or pantopaque in the spinal canal,—the outlines of the nervous system can be more intimately delineated by visualizing the fluid medium in which it floats, inside of the meningeal-lined, bony container.

All of this is by no means an attempt to minimize the value of X-ray as an aid to the diagnosis of nervous system abnormalities, but to establish its limitations. For it is obvious, at once, that while a demonstrable lesion, such, for example, as a fracture of the skull or spine, may lead one to presuppose a concomitant injury of the brain or spinal cord has occurred, and this is often found to be true, it is not necessarily or universally the case. It is a daily experience of the neurological or neurosurgical clinician to see patients with extensive fractures of the skull, or fractures and dislocations of the spine, with only minimal or even no demonstrable injury to the brain or spinal cord. On the other hand, serious, even fatal, disease or injury of the contained brain or spinal cord may be present without any abnormality of the skull or spine.

The Roentgen Appearance of the Human Skull

For a proper interpretation of diseases of the central nervous system from the roentgenogram, one requires properly taken films and a sound basic knowledge of the normal anatomy of the parts involved, as seen on the X-ray films.

It is well to establish standard positions of the skull in relation to the position of the X-ray tube for routine use, and special positions under special circumstances. The most useful routine films are those taken with the head on the side (lateral view) and with the occiput[1] nearest the film (postero-anterior view.) The lateral views should be taken stereoscopically; that is, without any change in the position of the head, two films are exposed with a calculated shift of the roentgen tube so that these may later be

[1]Occiput: The back part of the head.

viewed through a stereoscopic viewing box that will give a three-dimensional image. The other routine, or any special, views may also be taken stereoscopically if a study of the routine films make this desirable. Especially in the case of fracture, a view of the base of the skull may be desirable.

Because of the numerous structures to be examined on the roentgenograms of the skull, the interpreter should follow a well established routine in order not to overlook some important point. The antero-posterior and postero-anterior views should be the first to be scrutinized. From these it can be established whether the head is of normal size and the bones are of normal thickness, and whether the two sides of the cranial cavity are symmetrical. Thus all paired structures are to be compared, especially the supraorbital, sphenoid, and petrous ridges,—the frontal, temporal, parietal and occipital bones,—the bony orbits, the frontal, ethmoidal and maxillary sinuses, the bones of the face and jaw and the front teeth.

The pineal body, or gland, which is a small structure of a few millimeters in diameter located normally in about the center of the brain, is the seat of a deposit of calcium salts in the majority of people above the age of 10 years, and thus casts a visible shadow on the roentgenogram. In the antero-posterior or postero-anterior view, when seen, it normally occupies a position a few centimeters above the bridge of the nose and equidistant from each side. Its lateral displacement (to one side of the midline) which can be recognized in these views is one of the most important signs of a space-occupying, intracranial lesion like a tumor or massive hematoma (blood clot).

The most revealing roentgenograms of the skull are the lateral views. Routinely these should be examined stereoscopically. After again noting its size and shape and the thickness of the bones, special attention should be given to the floor of the skull. Here the most important structure is the cup or saddle-shaped depression, the sella turcica, which houses that important hanger-on of the brain, the pituitary gland itself. But the sella turcica, by a diminution in the quantity of calcium in the bone which comprises its walls, is a most sensitive indicator of the existence of an abnormal elevation of intracranial pressure, usually produced by the presence of a tumor, or abscess, or a blood clot within the cranial cavity.

Shadows of abnormal calcium deposits in or around the sella turcica are to be noted, as well as the appearance of that portion of skull just in front of the sella turcica—the *tuberculum sellae,* and the impressions in the floor of the frontal bones which form the roof of the nasal cavity, the *cribriform plates.*

A survey of the skull as a whole is now in order calling for special attention to the interdigitating junctions of the flat bones of the skull—the *cranial sutures;* and the grooves or channels in the bone made by the arteries and veins with their characteristic although widely varying patterns.

The shadow of a calcified pineal gland is usually also visible in the lateral skull X-ray. Its position normally varies in accordance with the size and shape of the skull. For this reason Vastine and Kinney[2] have established a chart, later amplified by Dyke,[3] to which certain measurements from any given case may be applied and if these fall outside the limits of these charts, proof exists of the displacement of the pineal gland either upward, downward, forward or backward as the case may be, as a result of the push upon it of an abnormal intracranial mass.

The effect of elevated intracranial pressure upon bone has already been indicated in pointing out the loss of calcium in the sella turcica under these conditions. The reason why the sella shows these effects first is because it projects up into the cranial cavity like a boulder in the midst of a swiftly flowing stream. As pressure continues, the inner table of the skull generally also begins to show thinning in areas which we believe correspond to the convolutions of the brain, giving rise to changes in the skull on the roentgenogram of a "hammered-silver" appearance. This is called convolutional markings or convolutional atrophy. This is much more significant in the case of adults above the age of twenty, since during the growth period the pressure of the enlarging brain produces a similar effect on the normal skull. In the immature skull, moreover, in which the cranial sutures have not yet been bridged with bony material and thus largely eliminated, these sutures may often be spread apart or widened by excessive pressure—a change which is also easily discernible in the X-ray film.

Among the numerous variations in the intracranial cavity that the X-ray can disclose still within the limits of normal are the deposits of calcium salts in certain regions of predilection. Calcification of the pineal gland, which has already been mentioned, is

[2]Vastine, J. H., and Kinney, K. L.: Pineal Shadow as Aid in Localization of Brain Tumors, Am. J. Roentgenol. *17:* 320 (Mar., 1927).

[3]Dyke, C. G.: Indirect Signs of Brain Tumor as Noted in Routine Roentgen Examinations; Displacement of Pineal Shadow; Survey of 3,000 Consecutive Skull Examinations, Am. J. Roentgenol. *23:* 598 (June, 1930).

seldom seen in individuals before 10 years of age, then rapidly increases so that from the age of twenty on, 59 per cent of individuals show a visible shadow of the pineal on roentgenograms of the skull.

In about 8 per cent of adults, deposits of calcium, sufficient to cast a shadow on the X-ray film, occur in the choroid plexuses. These are the structures within the ventricles[4] of the brain which are largely responsible for the production of the cerebrospinal fluid.[5] The calcium is usually laid down symmetrically in the atrial portion[6] of each choroid plexus within the lateral ventricles of the brain. They appear in the antero-posterior or postero-anterior X-rays as symmetrical shadows, more or less round, slightly irregular, of about 0.5 to 1.0 cm. in diameter above the location of the smaller pineal shadow and about 2 to 3 cm. to either side of the mid-line. In the lateral views they are also seen above, and slightly posterior to the location of the pineal shadow. By the beginner, especially

[4]Ventricles of the brain: A ventricle is any small cavity. The ventricles of the brain are small cavities within its substance including the two *lateral*, the *third*, the *fourth*, and the *fifth*.

[5]Cerebrospinal fluid: The fluid contained within the cerebral ventricles, within the space surrounding the brain formed by the pia mater and the arachnoid mater and within the space in the central canal surrounding the spinal cord bounded by the same two membranes. The pia mater invests the brain and spinal cord so closely that it is adherent to both and the arachnoid mater is separated from them by a small intervening space filled with circulating cerebrospinal fluid which thus forms a watery cushion for the brain and spinal cord. Hemorrhage in the brain or spinal cord from vessels which communicate with the space containing the cerebrospinal fluid will cause blood to appear in the spinal fluid; expanding lesions of the brain or cord such as tumors tend to cause the usual pressure of the fluid to be elevated. An important diagnostic measure in studying the nervous system in many cases is to perform a lumbar puncture. The spinal cord ends at about the level of the first lumbar vertebra. After injecting a local anesthetic (procaine hydrochloride—i.e., novocain) into the overlying tissue, a special needle can be inserted into the spinal canal (usually between the third and fourth lumbar vertebrae) without causing any pain. The needle is hollow and permits the examiner, by using a manometer, to measure the pressure of the spinal fluid. Samples of the fluid can also be taken for laboratory analysis and oftentimes the result casts considerable illumination upon the cause of the patient's illness. Lumbar puncture is not to be considered a serious procedure in the ordinary case; it is routinely performed with but little discomfort to the patient.

As to the function of the cerebrospinal fluid, Best and Taylor have this to say: "The fluid within the elastic meningeal sac serves as a protective covering for the nerve cells. By change in its volume, compensation for change in the amount of blood is effected and the contents of the cranium thus tend to remain of constant volume. There is probably considerable exchange of metabolic materials between the nerve cells and the fluid." Best, C. H., and Taylor, N. B.: The Physiological Basis of Medical Practice (2d ed.) Baltimore, The Williams and Wilkens Co., 1940, at p. 1518.

[6]Atrial portion: That part of the lateral ventricle of the brain connected with the temporal and occipital cornu ("horn"); cornu means any hornlike excrescence or projection: accordingly, as used here, it means the hornlike forward and backward projections of the lateral ventricles of the brain. (There being a lateral ventricle in each half or hemisphere of the brain.)

when only one choroid plexus is calcified, this shadow may be mistaken for that of an abnormal deposit of lime salts in a tumor, hematoma or other brain lesion.

Another common site for the deposit of calcium in normal adults is in the *falx cerebri.* This is the great sickle-shaped membrane that hangs down from the inner table of the skull in the mid-line, like a stalactite, partly separating the left and right halves of the brain. Similarly, the membranous wall (tentorium) running at right angles to the falx and partly separating the cerebrum[7] in the large anterior portion of the cranial cavity from the cerebellum,[8] or small brain, in the small posterior portion of the cranial cavity, may also be the seat of calcification in the normal adult.

Calcium shadows without particular clinical significance may also be seen in the membrane that separates the pituitary gland from the brain, the *diaphragma sellae,* in the *dura mater*—the tough fibrous membrane that lines the inner table of the skull, in the *superior longitudinal sinus,*—the triangular shaped venous channel[9] between the dura mater and the falx where it occupies the place of a ridge-pole on the inside of the skull.

The Abnormal Human Skull as Seen on the Roentgenogram

The wide variations within normal limits in the configuration of the human skull is the chief concern of the science of anthropology. Certain variations exist that are characteristic of large racial groups, but within a given group tremendously wide variations may occur and still be within normal limits. This is particularly true in a population of such mixed origin as exists in our own country. Thus, there are long heads, short heads, round heads, flat heads, "square" heads, pointed heads, heads with eye sockets wider apart than usual or closer together, etc. Beyond these wide normal variations which must be clearly understood by the competent neuroroentgenologist are the *abnormalities* which, of course, are our chief concern in this paper.

The evidence by which these abnormalities, that is, pathological

[7]Cerebrum: The main portion of the brain, occupying the upper part of the cranium, and consisting of two equal portions, called hemispheres, which are united by a mass of white matter called the corpus callosum.

[8]Cerebellum: That division of the brain behind the cerebrum and above the pons and fourth ventricle. The cerebellum is concerned in the coordination of movements.

[9]Venous channel: The space contained within this sinus performs the function of a vein in transporting blood within the cranial cavity.

changes, can be recognized on the roentgenogram of the skull depends, in general terms, on several categories of deviation from the normal. These are: excessively large head *(megalocephaly)*; excessively small head *(microcephaly)*; thickening of the skull—general or local; thinning of the skull—general or local; congenital malformation of the skull; signs of increased intracranial pressure—convolutional atrophy, separation of the sutures, atrophy and enlargement of the sella turcica; displacement of the pineal shadow; abnormal calcification; spontaneous destructive processes of some part of the skull; evidence of trauma (injury)—as, for instance, imfracture, foreign body, signs of mass hemorrhages.

PNEUMENCEPHALOGRAPHY

Frequently the plain X-rays of the skull are insufficient to supply the evidence we seek in the diagnosis of intracranial disorders. Under these circumstances we resort to the use of contrast media, the commonest of which is air or some other gas, such as oxygen or helium.

In 1913 Luckett[10] published a description of the roentgen appearance of the skull of a patient who had sustained a skull fracture communicating with the nose. This showed the normal fluid-containing cavities of the brain (ventricles) clearly outlined, due to contained air which had apparently been forced into them through an abnormal communication by way of the fracture (traumatic pneumocephaly).

In 1918 Dandy[11] deliberately injected gas into the ventricles, after withdrawing a certain quantity of the contained fluid, by inserting a cannula[12] by way of a surgical opening through scalp, skull and brain. He then closed the small surgical wound and made X-ray exposures of the skull, with results similar to those published by Luckett. This process he named *ventriculography.* The next year he went a step further and succeeded in outlining the ventricles with gas by simply sitting his patients upright, inserting a hollow needle in the lumbar portion of the spinal canal (lumbar puncture) and alternately withdrawing small quantities of cerebrospinal fluid and exchanging them with gas which rose in the form of bubbles into the cranial cavity.

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[10]Luckett, W. H.: Air in Ventricles of Brain Following Fracture of Skull; case, Surg. Gynec. and Obst. *17:* 237 (Aug., 1913).

[11]Dandy, W. E.: Ventriculography Following Injection of Air Into Cerebral Ventricles, Ann. Surg. *68:* 5 (July, 1918).

Dandy, W. E.: Roentgenography of Brain after Injection of Air into Spinal Canal, Ann. Surg. *70:* 397 (Oct., 1919).

[12]Cannula: A tube for insertion into the body.

In 1922 Bingel[13] pointed out that the latter method outlines not only the ventricles but the surface of the brain as well, since the gas enters all the spaces wherever fluid normally exists. He, therefore, suggested the name *encephalography* for this method. Thereafter, more or less by common consent, instead of having to say "ventriculography" and "encephalography" whenever one wishes to speak of the use of gas in the X-ray study of the brain, the term *pneumencephalography* has been used.

Pneumencephalography has become a tremendously important tool in the hands of the neurorontgenologist and has been the subject of numerous reports in medical publications. The appearance of the normal ventricular system, as well as the sulci[14] and cisterns,[15] which also contain cerebrospinal fluid and which can thus also be delineated when the fluid is replaced by gas, should be familiar to every specialist in this field (Davidoff and Dyke).[16] In response to disease these cavities may be changed in size—usually enlargement; in shape—due to local deformity; or position—due to a general displacement, either away from an expanding lesion like a tumor growth, an abscess or a blood clot, or toward an area of loss of substance with scar formation in the brain. These changes will be briefly considered in relation to the individual lesions (types of injury) later on.

The ventricles can also be outlined by introducing opaque chemical substances into them to cast a shadow of greater density than the brain rather than one of lesser density such as gas produces; the important thing is the contrast. For certain purposes opaque contrast media may also be introduced directly into the blood vessels leading into the brain (cerebral arteriography). These methods, however, are more dangerous than gas and have other disadvantages which make their use, up to the present time at least, very much restricted.

Another, relatively new, principle in roentgenography which is being applied with increasing success in the study of disturbances of the central nervous system, is *laminography* or *planography*. The

[13]Bingel, A.: Encephalographie eine Methode zur röntgenographischen Darstellung des Gehirns, Fortschr. a.d. Geb. d. Röntgenstrahlen *28:* 205, 1921-22.

[14]Sulci: Plural of sulcus, a fissure of the brain. The main sulci of the brain are not fewer than 200 in number. They are fissures or furrows in the cortex or external surface of the brain readily visible to the naked eye.

[15]Cisterns: Certain enlarged spaces between the pia mater and arachnoid mater surrounding the brain; they are filled with cerebrospinal fluid.

[16]Davidoff, L. M., and Dyke, C. G.: The Normal Encephalogram, Philadelphia, Lea & Febiger, 1937.

successful application of this principle requires a complicated and expensive apparatus, but the principle itself is quite simple. The ordinary X-ray picture includes the representation of everything interspersed between the source of the X-ray beam and the photographing film. Thus, a lateral view of the head includes the left and right side superimposed on each other as well as on anything in between that may resist the penetration of the ray. This often obscures the appearance of certain structures even when viewed stereoscopically. Laminography, by setting in motion both the X-ray tube and the photographing film at a constant speed but in opposite directions blurs everything in the picture except the plane corresponding to the level at which the fulcrum exists. Thus, by shifting the fulcrum a few centimeters at a time and stopping for a picture at each level, *laminae,* or slices, or cross-sections may be made of the part to be examined as if it had been put through a cheese slicer.

Congenital Anomalies

Racial and individual variations in the appearance of the skull have already been mentioned. Beyond these, certain individuals are born with potential or actual peculiarities which, if they do not affect his well being, are called congenital *anomalies,* or if associated with abnormal functioning of the nervous system, or distinctly abnormal appearance, congenital diseases. Some of these changes are acquired rather than innate, like the oblique skulls of the Javanese resulting from the compression of one side of the occipital region attributable to the custom from earliest periods of infancy of resting the head upon the hard ground while sleeping.

The importance of these changes in the roentgenograms is to recognize them for what they are and thus avoid the mistake of concluding that they have been acquired as a result of a disease or accident.

The different-shaped but normal heads have already been touched upon and need not detain us here. Some heads, however, are misshapen to a degree which makes it a congenital disease rather than an anomaly, and should at least be mentioned. One such condition is known as steeple or tower head *(turricephaly).* It is due to a premature closure of the sutures[17] of the skull in infancy so that the growing brain is crowded toward the anterior fonta-

[17]Sutures: The line of junction of adjacent cranial bones.

nelles[18] and the skull shapes itself accordingly into a cone-shaped deformity. On the X-ray film the turricephalic skull shows, in addition to the odd shape, a marked hammered-silver appearance due to the long-standing excessive pressure of the growing brain against the unyielding skull. The bones are often thin, and the base of the skull is more concave and deeper than normal. The pressure sometimes produces an atrophy of the optic nerves so that many of these patients slowly develop defective vision or may even become blind. A motion picture operator was once referred to the author with a history of failing vision due, he believed, to the exposure of his eyes to the glare of the light used in the projector. He claimed that one month before, a film tore in the midst of a performance and he hurriedly made the repairs without putting on dark goggles. The next day his eyes were inflamed and, when the inflammation subsided, he noticed that his vision was poor. An examination of his optic nerve heads[19] with an ophthalmoscope[20] revealed a degree of long-standing atrophy[21] which could not have occurred in so short an interval, and something about the shape of his head was unusual. X-ray of his skull revealed the presence of turricephaly which undoubtedly accounted for his optic atrophy,

[18]Fontanelle: Any one of the unossified spots in the cranium (skull-bones) of a young infant.

[19]Optic nerve head: The ending of the optic nerve at the back of the eye. These nerve filaments which subserve the function of vision form the so-called "optic cup." A great deal can be learned diagnostically by studying the appearance of the optic nerve head on the two sides, i.e. at the back of each eye.

[20]Ophthalmoscope: An instrument, with special means of illumination, which enables the examiner to view the interior of the eye, especially the optic nerve, the retina, choroid and blood vessels. By this means he can determine whether those structures are normal in appearance or show evidence of disease or of increased intracranial pressure, etc.

[21]Atrophy: Wasting. As Spurling points out, *primary* optic atrophy results from direct pressure upon the optic nerve exerted by solid tumors, cysts, or trauma, or it results from inflammatory, degenerative or toxic lesions, primarily or secondarily involving the optic pathway.

In case of the turricephalic skull, however, the atrophy is of the *secondary* variety due to increased intracranial pressure. The optic nerve is immediately surrounded by the pia arachnoid so that the subarachnoid space of the brain with its cerebrospinal fluid is thus continuous with the space around the optic nerve. The effect of increased intracranial pressure is to raise the pressure of the cerebrospinal fluid. This produces venous congestion of the optic disc and retina, due to compression of the central vein of the retina by a distended subarachnoid space around the optic sheath. "Unless the cause is relieved, the condition progresses to secondary optic atrophy. As atrophy ensues, the swelling becomes less; the (optic) disc grows paler and less vascular, the arteries thickened and constricted, and the veins tortuous but no longer engorged. Finally, the disc is snow white with blurred edges." Spurling, R. Glen: Practical Neurological Diagnosis (2d ed.) Springfield, Ill., C. C. Thomas, 1940, p. 29.

although he may quite honestly have been unaware of his poor vision until the accident focused his attention on his eyes.

Innumerable other congenital changes occur which are too rare to discuss here—such as anomalous sutures, anomalous foramina (openings) or anomalous bones of the skull. Some congenital defects also exist in which the changes in the skull, as demonstrable on the X-ray film, are but a part of other more general defects. One such a condition is *dysostosis cleidocranialis* in which the base of the skull is invaginated, the anterior fontanelle generally remains open, the bones of the face are disproportionately small and the lower jaw protrudes (prognathism). In addition, one or both collar bones may be missing, and the teeth, ribs, vertebrae and bones of the hands and feet may be maldeveloped.

One relatively common anomaly which clinically is of no significance but may be a trap to the unwary is a condition known as *bathrocephaly*. This is a situation in which the occipital bone at its junction with the two parietal bones[22] is much thicker than its neighbors. It is often a heredo-familial anomaly and never produces any symptoms. The projection of the one bone beyond its neighbors may be as great as half an inch, and when such a person receives a bump on his head and explores this region with his fingers for the first time, he may be shocked into a state of self-pity and invalidism that may last a long time. This is often aided and abetted by a well-intentioned but uninformed family physician or a "casual" roentgenologist who may interpret the condition as a depressed and malunited fracture. This anomaly frequently stood its fortunate possessor in good stead when he simulated pain and pointed to the deformity in order to be disqualified by the ignorant *felsher* for the hated military service in the armies of the Russian czars.

X-ray Diagnosis of Traumatic Disorders of the Skull and Brain

Direct force applied to the head may result in an injury to the brain, such as concussion, without any injury to the skull, and vice versa. Statistically, however, it is shown that head injuries with skull fractures are usually accompanied by more severe brain injuries than head injuries without skull fractures. Fractures may be 1) linear, 2) comminuted, 3) depressed. Any of these may be simple fractures, that is covered by intact skin, or compound—in

[22]Parietal bones: The quadrilateral bones forming the lateral (side) surfaces of the cranium.

which case the fracture communicates with the outside world through an interruption of the continuity of the soft tissues and skin overlying the bone. The X-ray appearance of fractures differs when seen early, that is within a few weeks after they occur, or late, that is months or years following the injury. It is, furthermore, true that certain existing fractures, especially of the base of the skull, cannot always be demonstrated on the roentgenogram, but can often be diagnosed on the basis of clinical evidence,—such, for example, as the escape of cerebrospinal fluid from the ear or nose, or the spontaneous insufflation[23] of gas in the brain or ventricles as demonstrated on the roentgenograms.

The *simple linear fracture* of the skull is characterized by a sharply outlined linear shadow of diminished density on the roentgenogram, varying in width from a hair's breadth up to several millimeters. It may run in any direction, is usually wedge-shaped, in that it is narrow at one end and wider at the other and is often untraceable when it reaches the base of the skull. Difficulties often arise in differentiating a fracture line from the pre-existing grooves produced by blood vessels. Those formed by veins are easy to recognize because of their uneven calibre and the characteristic branching. The arterial grooves,[24] however, can only be differentiated by a knowledge of their exact anatomical location and by the fact, determined on stereoscopic examination, that they groove only the inner table of the skull rather than involve its entire thickness—as a fracture usually does. Even with these criteria to guide interpretation, an artery may be mistaken for a fracture line or vice versa or some doubt may arise in forming an opinion. There is, for example, an anomalous groove from a branch of the middle meningeal artery which because it crosses, transversely and obliquely upwards, the squamous portion of the temporal bone[25] in certain cases, can easily be mistaken for a linear fracture. On the other hand, a fracture in this region may be mistaken for this anomalous arterial channel.[26] Sometimes this doubt can be resolved only by patiently waiting and repeatedly retaking X-rays at intervals when it will be seen that a fracture line will gradually, in the course of many months, fade out and disappear through the

[23]Insufflation: The blowing of gas or air into a cavity.

[24]Arterial grooves: Grooves in the inner surface of the cranium made by closely adherent arteries.

[25]Temporal bone: The irregular bone at the side and base of the skull, containing the organs of hearing.

[26]Anomalous arterial channel: A deviation from the usual course of the arterial groove made by the middle meningeal artery.

process of healing, while a blood vessel groove will remain unchanged. The healing of linear fractures takes place at a rate which varies inversely with the age of the patient. In young children the fracture line may disappear entirely from the roentgenogram in 4 to 6 months. In adolescents it may be discernible for a year, whereas in adults it may be recognizable up to two years after the injury.

When a linear fracture traverses the groove of a blood vessel, especially that of the middle meningeal artery—the largest one to groove the inner table of the skull—it is especially noteworthy, since such a fracture may result in a rupture of the artery with hemorrhage between the skull and dura mater *(epidural or extradural hematoma)*. Unless this is recognized and promptly treated by surgical operation, it may cause the death of the patient.[27]

Pneumencephalographic studies made on patients with linear fractures of the skull, as might be expected, do not frequently show deviations from the normal. There are two reasons for this: first, many cases of skull fracture are not accompanied by brain injury; second, many cases of brain injury are either confined to physiological changes without any demonstrable anatomical counterparts, or when anatomical changes are demonstrable, they are only microscopic. It is important to realize, therefore, that *a negative pneumencephalogram does not rule out brain injury.*

Comminuted fractures are those in which the bone is shattered into fragments. These are usually the result of more severe injury

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[27]For cases of sub-dural hematoma see:

Yellow Cab and Baggage Co. of San Antonio v. Brennan (Tex. Civ. App. 1943) 171 S. W. (2d) 891 (writ of error refused).

The required surgery is, or course, an item of recoverable damage and if a decompression operation be done, the plaintiff, in presenting his case to the jury, is likely to capitalize upon the dramatic nature of the procedure and any bony defects left by the surgery, as a means of inducing a much larger award of damages. See, for instance:

Freschi v. Mason, (1930) 108 N. J. L. 272, 156 Atl. 757 (1930) (Plaintiff, a comparatively young man, sustained an injury necessitating removal of a section of the skull and penetration through the dura mater to the brain to relieve oedema and congestion; held: a verdict for $20,000 was not excessive.) Ramey v. Missouri Pacific R. R. Co., (1929) 323 Mo. 662, 21 S. W. (2d) 873 (Plaintiff, a 31 year old farmer, accustomed to earning $3,000 a year, sustained a head injury which caused a hematoma and required a trephining operation and suffered a spinal cord injury which produced progressive paralysis of his left side and rendered him sexually impotent; held: a verdict for $25,000 was not excessive.)

Hoffman v. Southern Pacific Co., (1932) 215 Cal. 454, 11 P. (2d) 387, superseded (Cal. App. 1931) 5P. (2d) 44 (Plaintiff, a man, sustained a fracture of the skull which penetrated to the brain, exposing the cerebrum and necessitating trephining of the skull; subsequently he developed traumatic epilepsy; held: a verdict for $50,000, reduced to $25,000, was not excessive; judgment affirmed.)

than that required to produce linear fractures and are usually accompanied by more severe brain injuries. There is seldom any difficulty encountered in recognizing comminuted fractures on the X-ray film. They usually show one or more centrally placed free fragments from which fracture lines radiate in several directions.

Depressed fractures are usually comminuted although single fragments may be depressed. The ordinary depressed fracture is produced by the local blow of a blunt instrument to the head, like a hammer blow. In a child the depression may be only a dent like one in a deflated rubber ball, due to the malleability of the skull, so that no definite edges can be seen on the roentgenogram. In an adult, however, the depression is easily recognized as a cone-shaped indentation of the skull with sharply defined edges of the depressed fragment or fragments. The depressed portion may project into the cranial cavity as much as 2 to 3 cm.,[28] although this varies considerably. It is important to determine the amount of depression accurately by stereoscopic and tangential views, since a depression of even 0.5 cm. is sufficient to produce damage to the underlying brain unless the patient is operated upon to effect elevation of the depression.

Compound fractures cannot be distinguished from simple ones from the X-ray picture alone without examining the patient, except when a foreign body can be shown on the skull or within the cranial cavity, or in those rare instances when spontaneous air shadows are seen in the cranial cavity.

Old fractures. When fractures of the skull are X-rayed for the first time months or years after the accident, and have not yet healed, they characteristically show indistinct margins. Occasionally, instead of disappearing, fracture lines seem to spread; the edges become thin, irregular and scalloped, and lacunae[29] appear in the bone neighboring upon the fracture line. This follows upon an associated injury of the neighboring brain with adhesions which may permit the entrance of cerebrospinal fluid to this area but prevents its free circulation. The result is a cystlike accumulation of fluid under pressure which causes an absorption of lime salts.

Rupture of blood vessels may be caused by injury to the head with hemorrhage into the tissues and resulting accumulation of blood clot in various places such as under the scalp *(subperiosteal*

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[28]Centimeter: A unit of measurement in the metric system commonly employed in scientific discussions; one centimeter is equivalent to 2/5 of an inch.

[29]Lacunae: Small pits, hollows or depressions.

hematoma); under the skull—that is between it and the dura mater *(epi- or extra- dural hematoma)*; under the dura mater, that is between it and the brain *(subdural hematoma)*; or in the brain substance itself *(intracerebral hematoma)*.

The *subperiosteal hematoma* usually can be diagnosed without the aid of X-ray, and ordinarily it is absorbed without any sequelae. Occasionally in infants, however, it may attract the deposition of lime salts which eventually becomes fused with the bone of the skull, producing a localized thickening in this area which, according to Dyke, may persist throughout life.

Epidural hematoma cannot be diagnosed directly from the roentgenogram. However, in cases suggesting the presence of such a lesion from the history and clinical course, the X-ray evidence of a linear fracture which crosses over the groove in the skull made by a blood vessel, especially that of the middle meningeal artery, can be of considerable supportive value in this diagnosis.[30]

Subdural hematoma. Of all the lesions resulting from blood vessel injury, the subdural hematoma is the most frequent, and, therefore, the most important. It is relatively common in infants as a sequel of trauma at birth. Here it usually produces an enlargement of the head, as well as enlargement of the ventricles of the brain as seen by pneumencephalography due to interference with the circulation and probably also with the absorption of cerebrospinal fluid.[31] Its diagnosis depends largely on clinical grounds with some support from the above X-ray evidence. If recognized it is best treated by a carefully planned surgical regimen. Occasionally it may be spontaneously absorbed without any sequelae. Usually a certain amount of damage of the brain accompanies it or results from it, causing various symptoms from behaviour disorders to paralysis, mental deficiency and epilepsy. Sometimes a child presenting these symptoms from birth is X-rayed

[30]Editor: Final proof in suspected cases, is, of course, dependent upon prompt exploratory surgery and this is by no means so serious a procedure as to warrant assessment of a very large amount of additional compensatory damages.

[31]See f.n. 27, *supra:* A child with hydrocephalus is almost invariably mentally deficient as a result of the condition and is unable to take care of himself. In Thrash v. Vicksburg S. & P. R. Co., (1916) 139 La. 1, 71 So. 197, a three and one-half year old child afflicted with hydrocephalus was standing upon a railroad crossing near his farm home when he was run down and killed by a passenger train. The engineer did not see him until the train was 1400 feet from the crossing; he thereupon blew the whistle and did all within his power to stop the train but the child did not move and was struck and killed. Held: the negligent failure of the parents (Plaintiffs in the present action) to look out for their afflicted child was the proximate cause of the accident; judgment for plaintiffs reversed.

for the first time in later childhood or adolescence. The skull may then show a deformity due to local thinning of bone and local enlargement due to the accommodation of the hematoma at some site. Occasionally the hematoma itself is visualized because of a deposit of calcium (lime) in it, producing a large, irregular scalloped shadow of increased density that is quite easily recognized. Pneumencephalograms in these cases, in spite of the presence of the mass produced by the hematoma which should show a displacement of the ventricles to the opposite side, usually show a displacement of the brain toward the side of the hematoma. This is because the pressure of the mass over a period of years has resulted in so much shrinkage (atrophy) of the neighboring brain, that brain and hematoma together actually occupy less space than normal brain alone would have done.

In some instances in which subdural hematoma has resulted from injury at birth or in early infancy, when relatively little injury has been done to the brain, the patient may recover and remain well even while harboring the lesion in his skull. If such a person during adolescence should have the misfortune to suffer a second injury to the skull, further bleeding may occur within the old hematoma *(juvenile relapsing chronic subdural hematoma)* and symptoms recur. X-ray examination of the skull at this time would reveal the thinning of the bone and local enlargement of the skull already described. Encephalograms, however, would show a displacement of the ventricles away from the site of the enlarged hemotoma due to its push upon a relatively normal brain.

Chronic subdural hematoma. The cases of subdural hematoma in which legal problems arise are usually the ones in which previously healthy adults have been subjected to a trauma to the head from which they appear to recover more or less, then weeks or months later develop symptoms that lead to a diagnosis of subdural hematoma. The severity of the injury may vary greatly. Sometimes it is so slight that it is temporarily forgotten. It may, indeed, never be noted and, therefore, never be recalled. This is especially true if, at the time of the injury, the patient is under the influence of alcohol. In about 25 per cent of cases these hematomas occur on both sides of the head simultaneously—a point of importance for the surgeon to keep in mind.

The X-ray evidence in these cases is for the most part similar to that obtained in cases of other space-occupying lesions. In the plain skull roentgenograms it may produce signs of increased intracranial pressure such as atrophy of the bony walls of the sella turcica. If a visible pineal shadow is discernible, it may show displacement—usually out of proportion to the degree of pressure signs[32] which ordinarily are mild.

In the pneumencephalogram the ventricles usually show a marked displacement away from the side of the lesion. This, too, is out of proportion to the minimal signs of increased intracranial pressure in the plain skull X-rays.

Intracerebral hematoma following head injury is much rarer than subdural hematoma. From an X-ray point of view, it cannot be distinguished from subdural hematoma. In fact, clinically also, this distinction is often difficult to make, so that frequently the diagnosis is not made until the surgeon makes his exploration.

Injury to brain substance. Acute cerebral contusion[33] or laceration[34] of the brain itself without any accompanying hematoma is not demonstrable on the roentgenogram or even the pneumencephalogram. The effects of brain injury resulting in a loss of brain substance either locally or diffusely may be recognized in the pneumencephalogram as early as three weeks following injury.

When a severe injury has occurred to half the brain during birth or in early childhood, that half of the brain lags behind its fellow in growth and development.[35] If, in such a case, an X-ray picture is taken years later, it will be seen that on the side where atrophy of the brain has occurred the skull has become thickened and the air sinuses[36] have become enlarged compared to the normal side. This appears to be an effort on the part of nature to keep the external appearance of the head and face symmetrical. En-

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[32]Pressure signs: The fact of increased intracranial pressure may be detected or confirmed in various ways, namely:

(1) It may cause a so-called "choking" of the optic discs visible when one looks into the interior of the eye with an ophthalmoscope; (2) A lumbar puncture is likely to show the pressure of the cerebrospinal fluid to be elevated; (3) Evidence of the condition may sometimes be gained by testing various reflexes and by performing other steps of the customary neurological examination; and (4) Properly made X-ray pictures of the cranium may reveal characteristic signs of increased intracranial pressure, mentioned *infra,* these being: (a) atrophy of the sella turcica, (b) separation of the sutures, (c) increased convolutional impressions (d) diffuse atrophy of the skull.

[33]Cerebral contusion: Bruising of the brain.

[34]Laceration: A wound produced by tearing or cutting.

[35]The reader's attention is drawn to the fact that the brain is divided into two halves, the right and left hemispheres, joined by a connecting bridge of tissue called the corpus callosum.

[36]Air Sinuses: Air cavities in one of the cranial bones; especially ones communicating with the nose. Such are the ethnoid, frontal, maxillary, and sphenoid sinuses.

cephalography in these cases shows an enlargement of the ventricle on the side of the lesion and a displacement of the ventricular system as a whole *toward* this side.

Less severe, more localized brain injuries do not as a rule affect the skull as such so that plain X-rays even long after the injury show no changes as a result of them.

In the pneumencephalogram, however, a quite characteristic picture is disclosed. Following the localized injury to the brain, a loss of substance occurs which leaves a cavity behind called a *porus,* hence the term *porencephaly* which connotes a cavity in the brain. This usually connects with the neighboring ventricle or with the fluid-containing spaces on the surface of the brain (the subarachnoid space). In either case, when fluid is withdrawn and replaced with gas, the cavity becomes visualized on the encephalogram, sometimes as an outpocketing or even only as a localized dilatation of a ventricle, at other times as a large, irregular space occupying a large part of a cerebral hemisphere.

Injury that diffusely affects the brain as a whole may be insufficient anatomically to produce any demonstrable effect in the encephalogram. It should be emphasized again, therefore, that a negative encephalogram does not exclude the diagnosis of a brain injury. If the injury is sufficiently severe, however, a generalized loss of cerebral substance occurs *(generalized cerebral atrophy)*[37] which is reflected in the size of the ventricles and subarachnoid spaces which naturally enlarge to fill the empty space. The diagnosis of cerebral atrophy from the pneumencephalogram is not easy, since normal variations exist, the upper limits of which may be mistaken for a mild degree of atrophy. Moreover, given a case with definite cerebral atrophy as demonstrated in the encephalogram, the cause and effect relationship with a given trauma is not always clear, since preexisting atrophy from an earlier trauma —even at birth, previous infection such as encephalitis, or preexisting degenerative disease of the brain producing atrophy—may have been responsible for the picture.[38]

[37]Cerebral atrophy: See Georgia R. R. and Banking Co. v. Lokey, (1943) 69 Ga. App. 403, 25 S. E. (2d) 921 (Evidence was conflicting as to whether the cerebral atrophy was traumatic in origin or was due to consumption of alcohol.)

[38]See f.n. 37, *Supra.* In a Workmen's compensation case arising in Scotland, proof showed that the deceased workman had a brain, liver and stomach impaired by chronic alcoholism but that he could have continued at work but for the accident; an award of compensation was upheld on the theory that an accidental injury sustained in course of employment accelerated his death. Connell & Co. v. Barr, (1904) 116 L. T. 127. American courts and compensation commissions follow this rule that pre-existing disease will not bar com-

When cerebral atrophy is diagnosed from the encephalogram, it is safest to base this diagnosis on the demonstration of definitely enlarged ventricles.[39] The dilatation of the subarachnoid spaces with normal sized ventricles is rare. Moreover these spaces vary considerably in size, so that Dyke,[40] for example, was unwilling to consider the "cortical markings" (the gas shadows representing the subarachnoid spaces over the surface of the brain) as seen in the encephalogram, abnormally large unless they had attained a width of at least 0.4 cm. at the site in question.

Much controversy has existed over the problem of the visualization of the cortical markings in encephalograms made in post-traumatic cases.[41] In the earlier days of encephalography the failure of these spaces to be visualized was considered to be evidence of adhesions of the thin arachnoid membrane to the brain, thus obliterating the fluid spaces *(arachnoiditis or arachnoidal adhesions)*. In post-traumatic cases this was considered to be evidence of brain injury. It has since been demonstrated that these spaces sometimes fail to be filled with gas for no known pathological reason since in the same cases in which repeated encephalograms are made, they are sometimes visualized and at other times are not. It is therefore believed at the present time that the diagnosis of arachnoiditis can be made from the encephalogram only when the cortical markings[42] are absent persistently in one given area.

Another point which caused confusion in the earlier days of encephalography was the fact that occasionally for mechanical reasons gas can get into the subdural space, that is the ordinarily potential space between the dura mater that lines the skull and the arachnoid that forms the outer wall of the fluid jacket that surrounds the brain. This forms a wide shadow of diminished density that can now be easily recognized and has no pathological significance,[43] but was formerly misinterpreted as indicative of cerebral atrophy.

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pensation, provided the proof shows that the accidental injury sustained in the course and scope of employment so aggravated the condition that the workman was disabled or died sooner than he would have from his disease alone (acceleration of death.)

[39] Cerebral atrophy: Wasting and shrinking of the brain.

[40] Dyke, C. G.: The Roentgen-ray diagnosis of diseases of the Skull and Intracranial Contents, Diagnostic Roentgenology, Chap. 1, Vol. 1, New York, Thomas Nelson & Sons. 1941.

[41] Post-Traumatic cases: Patients who have previously suffered injury,—here, a head injury.

[42] Cortical markings: The markings on the inner surface of the skull made by the cortex or outer surface of the brain.

[43] Pathological significance: Evidence of an abnormal condition due to disease or injury.

Tumors of the Brain

The word tumor in its strictest sense means swelling, so that a hematoma or an abscess is thus also a tumor. By common usage, however, it has come to signify those masses that are spontaneously newly grown (in the nature of cancer) and these are more accurately and appropriately called *neoplasms*. Neoplasms may originate from any of the tissues of the head—thus the scalp, the interior portions of the nose and throat, the bones of the skull, the meninges, the blood vessels of the brain, the nerve cells of the brain, the tissue supporting the brain cells (the glial tissues), embryonic cells remaining in the brain, the pituitary or pineal glands, or from tumor cells brought into the head by way of the blood stream (metastatic tumors).

In a certain percentage of persons with tumor of the brain, it is possible to tell from the roentgenogram that a tumor is present, its exact location, and its probable origin as well as its probable microscopic appearance. In other cases only the evidence that a tumor exists and the side of the brain it involves can be read from the roentgenogram. In still other cases even the side cannot be determined. Finally, in a considerable percentage of cases, in spite of the clinical evidence of a brain tumor, the X-rays are entirely negative. Additional evidence in all these classes is obtainable by the use of pneumencephalography.

In the plain roentgenograms of the skull, evidence of tumor may be in the nature of 1) signs of *generalized* increased intracranial pressure, and 2) *local* or direct signs of tumor.

The signs of generalized increase in intracranial pressure have already been mentioned. These are: 1) atrophy of the sella turcica, 2) separation of the sutures, 3) increased convolutional impressions and 4) diffuse atrophy of the skull. Naturally any space-occupying lesion like abscess or hematoma as well as tumor, and also any process obstructing the normal circulation of cerebrospinal fluid can produce signs of increased intracranial pressure. However, the commonest cause is brain tumor. Experience has taught that it takes a period of at least 3 to 4 months to produce this evidence on the X-ray picture. This undoubtedly accounts for the absence of such signs in cases of certain rapidly growing brain tumors.

Atrophy of the sella turcica is the earliest and most important sign of increased intracranial pressure. It is recognizable by the disappearance of the sharp white line that marks the inner edge of the sella. As pressure continues, the loss of calcium from these parts reaches such a point that they seem to disappear altogether. This does not represent destruction—only decalcification, since it has been shown that after the tumor is removed by a surgical operation, the shadow of the sella turcica reappears in the course of six to twelve months (Davidoff[44]).

The changes in the sella turcica apparent on the X-ray film which result from increased intracranial pressure must be differentiated from those produced by tumors arising from the pituitary gland itself. The latter also produce atrophy of the sella turcica but this is accompanied by an early enlargement of the sella as a whole and an absence of other signs of increased intracranial presssure.

Separation of the cranial sutures is extremely valuable as a sign of increased intracranial pressure, but is seldom seen after the age of 12 years, since the sutures become obliterated after this age.

Increased convolutional markings, on the other hand, are of greater significance in adults than in children, since the latter show varying degrees of convolutional markings as a result of pressure upon the skull of the normally growing brain.

In adults, too, one occasionally sees as a result of increased intracranial pressure a generalized diminution of lime in the bones of the vault of the skull, giving them a grayish blurred appearance rather than the sharply outlined white that is seen in the X-ray negative of a normal skull.

Localized evidence of tumor of the brain may take the form of 1) local proliferation of bone on the skull; 2) local thinning and absorption of the skull; 3) localized increase in the blood vessel markings of the skull; 4) abnormal deposition of calcium within the cranial cavity which is usually within the tumor itself; 5) displacement of the pineal shadow or the calcium shadows which may occur normally in the choroid plexuses of the falx.

Tumors originating from different tissues tend to show characteristic changes of the above varieties detectable on the roentgenogram. The study of the individual tumor types and their numerous subdivisions roentgenologically requires a background in neurophysiology and neuropathology which cannot be supplied

[44]Davidoff, L. M.: Variations in Intracranial Pressure Revealed by the Roentgenographic Appearance of the Skull, Emanuel Libman Anniversary Volumes, *1:* 357 (Oct., 1932).

in the present study. It is thought important, however, to discuss the individual types of local signs enumerated above, at least briefly, in order to familiarize the reader with typical and well defined changes produced by brain tumors.

Local proliferation of bone. This is produced by tumors which originate in the bony tissue of the skull itself *(osteoma),* or as a proliferative reaction to tumors in or adjacent to the skull but originating from the neighboring membranes *(meningioma),* or the blood vessels in the skull *(hemangioma).* It is recognized in the roentgenogram as a projection of additional bone shadow connected with the inner or outer table of the skull or both. It is sometimes quite small, about 1 cm. in diameter, but may rarely cover the whole vault in area and almost equal the whole head in thickness. It may throw a dense solid shadow, or consist of porous bone or radial spicules that produce corresponding shadow patterns on the X-ray picture. These different patterns are characteristic of certain types of tumors which can thus be recognized in the film. Furthermore, some tumors have sites of predilection so that they can be detected not only from the characteristic pattern of the bony proliferation but from its location—for example, beside the mid-line of the vault (parasagittally), on the wing of the sphenoid bone, on the tuberculum sellae or in the olfactory groove.

Bone absorption or destruction. Occasionally tumor of the brain may produce pressure upon the neighboring area of the skull which may result in local thinning, and diminished density of the bone due to absorption of lime which can be easily detected on the roentgenogram. Some tumors not made up of bony tissue but infiltrating the bone, either by local extension to it, or by implantation through the blood stream from a distant source (these characteristic transplantations of cancer or malignant tumor cells to new sites are called metastases) cause a destruction of bone giving an irregular moth-eaten appearance of the skull in the X-ray film. In the case of metastatic tumors, these areas are often multiple. Of course, metastases may occur to the brain without involving the bone, in which case no local bone destruction occurs. The only evidence, then, of tumor may be signs of increased intracranial pressure if these have gone on long enough to be apparent in the roentgenograms.

Some tumors neighboring upon the skull infiltrate the bone of the skull causing an absorption and irregular destruction of its normal bony tissue and at the same time produce a proliferative reaction of bone so that both processes may take place in the same locality.

Local increase in blood vessel markings in the skull often takes place in relation to tumors adjacent to it, like meningiomas, or tumors of the skull itself, originating from its own blood vessels. This may be detected in the roentgenogram if one has a thorough acquaintance with the normal blood vessel patterns. These vary so markedly within normal limits in the case of the veins that local unusual variations are not of much significance. The arterial pattern, however, is much more stereotyped and a local enlargement above the normal calibre or an increased number of arterial channels is usually a sign of tumor when seen in the skull X-ray.

Abnormal deposition of calcium. Calcium shadows within the skull cast by normal structures like the pineal gland, etc. have already been discussed. When a calcium shadow is seen in the roentgenogram of the skull outside of the areas known to show normal calcium deposits, it almost invariably indicates lime in a tumor. Sometimes the shadow is large and dense, almost like bone, and is present in every part of the tumor. At other times it consists of tiny flecks which are difficult to see, and can be demonstrated only by an experienced examiner and upon careful study of the stereoscopic roentgenograms. Theoretically, lime deposits can occur in almost any tumor, but it is more characteristic of some types of tumors than others. On the whole, it occurs more frequently in the more slowly growing, and thus more benign tumors, than in the more rapidly growing ones. The situation becomes complicated, however, by the fact that certain tumors which on the whole are rapidly growing, and thus are more malignant, have areas within them which are older, slower in growth and which may harbor enough calcium to be visualized on the X-ray film, while other, on the whole benign tumors, with large calcium shadows may contain areas of rapid growth in which there is no calcium.

The *displacement of the pineal* shadow can be determined by the application of measurements as mentioned previously. Demonstration of such a shift indicates the presence of a mass located in an area of the cranial cavity opposite to that toward which the pineal has been displaced. The calcified choroid plexuses, the normal position of which is well known, if seen to be displaced, may also sometimes help in localizing a tumor. This is particularly true when the shadow of the pineal is not visible and the choroid plexus is seen. The falx which, if calcified, appears like a narrow wedge hanging down from the center of the inner table as seen in the anteroposterior or posteroanterior view, may show a displacement of its free edge toward the side opposite a tumor in a manner similar to the displacement of a pendulum in its course.

Pneumencephalography has its widest application in the diagnosis of brain tumors. In the presence of increased intracranial pressure, however, it is sometimes a little hazardous to apply. This is especially true if one uses encephalography, by which the interchange of fluid and gas is made with a needle in the spinal canal, as against ventriculography in which this is done by the direct insertion of a cannula into the ventricles of the brain through a surgical opening. Even when it is not dangerous, it is usually uncomfortable, causing, as a rule, severe headache, occasionally vomiting and sometimes shock.

In a medical-legal problem, therefore, even when the evidence to be obtained from this method of examination is very important, it may not be available owing to the right of the patient to refuse to submit to the procedure.

Interpretation of the pneumencephalogram in the diagnosis of a brain tumor depends upon a knowledge of the normal size, contour and position of the ventricular system and other fluid-containing spaces of the intracranial cavity. Thus any deviation of these spaces from normal, as seen in the pictures obtained after the gas is insufflated, in their size, position or shape can be recognized as due to a lesion that is responsible for the change. Gross changes such as a marked shift of the ventricular system to one side by the presence of a large tumor on the other side are obvious to any one. Less obvious deviations due to small tumors and tumors in unusual locations require the experience of a specialist in this field for their proper interpretation.

The question of the relationship of brain tumor formation to preceding trauma is still a moot one. Although trauma may play some part in the formation of a small percentage of certain brain tumors, like meningiomas, its part is not an important one. The question is nevertheless frequently raised in cases of brain tumor in which a preceding trauma can be proven. It is further complicated by the fact that the initial symptom of brain tumor may be a loss of consciousness which may result in a head trauma.

If roentgenograms taken immediately or within a few weeks after a head trauma are available in a patient who later develops evidence of a tumor of the brain, the demonstration of abnormal calcification or atrophy of the sella turcica in them would prove the preexistence of the tumor since we know that these signs require a matter of 3 to 4 months to develop.[45]

[45]There has been considerable litigation in American courts based upon the alleged causation or aggravation of neoplasms (various forms of cancer or tumors) by different sorts of external stimulation or injury. It is interesting, however, that neither brain tumors nor spinal cord tumors have figured prominently in such litigation.

In Bobo v. Blinn Lumber Co., (1914) 1 Cal. Ind. Acc. Comm. Dec. (No. 19) 45, in an application for Workmen's Compensation benefits, evidence was presented in behalf of claimant that while he was working in an independent lumber yard, he moved quickly to avoid being struck and in so doing moved his head backward suddenly; that this caused him considerable pain; that next day he was sick and had symptoms indicative of paralysis of the left side which had increased until at the time of hearing he was bedridden and in a stupor. Compensation was denied on the strength of medical testimony that plaintiff's condition might possibly be due to a rupture of a diseased cerebral blood vessel, brought about by the described movement of his head, but that it was probably due to natural causes. Shortly afterward the claimant died and an autopsy was performed which revealed that death was due to a glioma (a malignant brain tumor) which obviously had been present for some time before the date of the alleged accident.

In Morrissey v. Union Pacific R. Co., (1926) 68 Utah 323, 249 Pac. 1064, defendant's train while moving rapidly downgrade through mountainous country, over a track with numerous curves, lurched somewhat and plaintiff's decedent, X, a mail clerk, was thrown to the floor. Plaintiff contended that this fall was the cause of X's death three months later. Medical testimony, based upon an autopsy, showed that X's death was due to a tumor of the brain. There was no evidence which would warrant a finding that the tumor was caused by external violence nor was there any real evidence that the slight lurching of the train was unusual or in any way negligent. The trial court entered a judgment of non-suit and on appeal this was affirmed.

In Heise v. Bainbridge Players, Inc., (1934) 191 Minn. 417, 254 N. W. 462, a proceeding for Workmen's Compensation benefits, evidence showed that claimant, an actor, in course of a play in which he appeared, was supposed to fall or jump from a girder or beam to the stage floor, landing upon a mattress. On prior occasions he had done this safely, but at the performance in question he missed the mattress, striking the back of his head on the stage floor. He was unable to arise for several minutes. Symptoms of injury began to appear shortly after the fall, although claimant was able to continue work for about three months. He was then operated and a tumor in the posterior portion of the brain was removed. The operating surgeon revealed that some of the claimant's brain tissue was jammed down into the opening at the base of the skull (the foramen magnum). Within eleven months after the surgical operation, claimant was able to resume work. Held: the evidence was sufficient to sustain an award of compensation made by the commission on the theory that the claimant's accidental fall caused an aggravation of his existing brain tumor.

Dr. Davidoff's suggestion that X-rays be taken immediately or soon after a head injury to rule out pre-existing brain tumor is an excellent one; such a course would settle such disputes as arose in the case of Biddle v. Jones, (1914) 116 Ark. 82, 172 S. W. 258. According to the evidence adduced in that case, X received a blow to his head in a train collision; a week later he began to develop signs and symptoms of increased intracranial pressure and grew worse, finally dying. Physicians who had attended X attributed his condition and death to a blood clot pressing on the brain and growing in size (expanding hematoma); doctors testifying for the defendant attributed them to a brain tumor. No autopsy was performed. The appeal

INFECTIOUS DISEASES

Osteomyelitis. Bacterial infection of the bones of the skull, usually with the staphylococcus germ, results most commonly from extension of infection from a neighboring sinus,[46] most frequently the frontal or ethmoidal sinus, or the mastoid cells.[47] It may also result from the introduction of infection through an open wound, as, for instance a compound fracture of the skull, either linear, comminuted or depressed; or the infection may be carried in with a bullet or other foreign body. It may occur even where there has been no fracture of the skull as in case of simple lacerations of the scalp which become infected and secondarily infect the skull.[48]

In the X-ray film osteomyelitis appears as an area of diminished density with an irregular margin which may vary from only a centimeter in diameter to the size of a half dollar, or it may increase to involve the whole frontal, temporal or parietal bone. The neighboring blood vessel grooves usually become widened and their margins blurred because the infection usually travels along these grooves. When this condition becomes chronic, there is often a proliferation of bone resulting in increased density as well as thickness, in the midst of which small areas of bone destruction may still be visible.

Osteomyelitis infections of syphilitic or tuberculous origin are now fortunately rare diseases. They usually reach the bones of

court, in affirming judgment for the plaintiff, said: . . . "Indeed, there is no cause assigned for deceased's condition, except that he did sustain an injury in this collision, and it is only surmise and conjecture that there might have been some other cause. Under this state of the proof we do not feel disposed to overturn the verdict of the jury. The failure to have an autopsy performed was a circumstance to be considered by the jury, but we cannot say, as a matter of law, that that failure must defeat a recovery."

In the following cases, awards of Workmen's Compensation benefits were made in cases of brain tumors (gliomas—very malignant brain tumors) on the theory that head injuries accelerated their growth or aggravated them: Pfeiffer v. N. D. Workmen's Compensation Bureau, (1928) 57 N. D. 326, 221 N. W. 894 (glioma caused blindness); Gotchy v. N. D. Workmen's Compensation Bureau, (1923) 49 N. D. 915, 194 N. W. 663 (X had pre-existing glioma; he received a severe blow to his head by bumping it against an iron pulley; immediate operation revealed cerebral hemorrhage and this hemorrhage was the cause of X's death; held: under the medical testimony presented it was probable that external violence superinduced the hemorrhage which caused X's death. And see De Groot v. Henry Becker & Sons, (1940) 17 N. J. Misc. 387, 9 A. (2d) 695 (Head injury allegedly aggravated a pre-existing but unknown brain tumor.)

[46]These are air pockets in the cranial bone.

[47]Mastoid cells: Cells in the mastoid bone or process immediately behind the ear; the mastoid is really a part of the temporal bone.

[48]For collection of Workmen's compensation cases dealing with sufficiency of evidence to establish causal connection between osteomyelitis and employment, see 20 A. L. R. 62; 73 A. L. R. 534.

the skull by way of the blood stream and practically never are they introduced directly through an open wound.

Brain abscess. Brain abscess results most commonly from an extension of an infection originating in the mastoids or sinuses. It may also, however, result from infection introduced through the wound of a compound fracture following an osteomyelitis of the skull, or without the skull itself being affected. Finally the infection may reach the brain by the blood stream from a distant source like the lungs.[49]

A brain abscess is not demonstrable in the roentgenogram of the skull. However, if long standing, it can produce signs of increased intracranial pressure, it may cause a displacement of the pineal shadow, or if very old, and especially if the infection burns itself out, it may be the seat of calcification which is visible in the X-ray. In the pneumencephalogram it may de demonstrated as a space-occupying lesion which distorts and displaces the ventricular system.

Rarely, in our country, parasitic cysts of the brain can be demonstrated on the X-ray negative by a shell of calcium deposited in its wall.

Other infections of the central nervous system, like meningitis[50] or encephalitis[51] can seldom be diagnosed from the X-ray.

NUTRITIONAL DISEASES

A considerable group of diseases based on metabolic changes due either to unknown causes, changes in the functional activity

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[49]For a case of fatal brain abscess allegedly due to a depressed fracture of the skull resulting from an accidental injury sustained in the course and scope of employment, see Baker v. Pitt Construction Co., (1936) 124 Pa. Super. 176, 188 Atl. 421 (Verified by post-mortem examination; award of compensation affirmed.) For abscesses between cranium and periosteum allegedly due to accidental injury, see Oliveira v. Warren, (1938) 24 Cal. App., 712, 76 P. (2d) 113.

[50]Meningitis: Inflammation of the meninges or membranes which cover the brain. When it affects the dura mater (the outermost membrane investing the brain) the disease is termed *pachymeningitis;* when the arachnoid and pia mater are involved, it is called leptomeningitis, or meningitis proper.

For alleged traumatic hemorrhagic pachymeningitis, see Eller v. A. C. Lawrence Leather Co., (1942) 222 N. C. 23, 21 S. E. (2d) 809.

For cases of alleged traumatic meningitis see: Alcoff v. Phila. & Reading Coal & Iron Co., (1921) 6 Pa. W. C. Dec. 172; Williams v. Brownfield-Canty Carpet Co., (1933) 95 Mont. 364, 26 P. (2d) 980; Matarazzo v. Alderney Dairy Co., (1937) 15 N. J. Misc. 448, 192 Atl. 83. (Meningococcus meningitis was not caused by accident.)

[51]Encephalitis: Inflammation of the brain. See Shaw's Case, (1928) 126 Maine 572, 140 Atl. 370 (Encephalitis lethargica allegedly caused by injury to eye; court refused to recognize causal connection and sustained employer's appeal; compensation discontinued.)

of some of the glands of internal secretion, inadequate intake of vitamins, or the introduction into the body of certain poisons, cause changes in the skeleton and may be recognized in X-rays of the skull. From the point of view of the present paper, the importance of this group of conditions is that some one of them may preexist with or without the knowledge of the patient before the occurrence of some industrial disease or accident, and unless correctly interpreted may lead to false cause and effect deductions.

One of these conditions is a disturbance in the metabolism of fats called *xanthomatosis* or *Schüller-Christian's disease,* which results in the deposit of fat-laden cells in the bones of the skull and other parts of the skeleton, occurring as a rule during childhood. Where these cell masses collect, the normal bony structure is replaced and one sees in the roentgenograms of the skull and other bones, areas (usually multiple) of diminished density, with indistinct margins which are quite characteristic of this disease, especially when considered together with the clinical picture.

Rickets, which is a disease occurring in childhood due to deficient vitamin D intake, produces softening of the bones which in X-rays of the skull is manifested by a widened, rather flattened head with thin bones generally, but oftentimes one sees localized thickening of the frontal or parietal areas. The fontanelles are likely to stay open later than usual.[52]

Another disease of bone affecting adults usually past the age of 30 years is called *osteitis deformans* or *Paget's disease.* The cause of this condition is unknown. It produces, by a peculiar combination of bone destruction and proliferation, a marked enlargement of the head and a shortening of the entire skeleton which is quite characteristic in its advanced stages. The roentgenograms of the skull in this disease show a thickening and at the same time a diminished density of the bones suggesting a "cotton wool" appearance.[53]

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[52]The possibility of preexisting rickets should be borne in mind in evaluating X-ray examinations made of children following receipt of head injury.

[53]The disease named for Sir James Paget, the Scot who gained fame in London as a surgeon (1814-1899). Paget gave his masterly description of the disease in 1876. For a case involving alleged aggravation of existing Paget's disease by a compression fracture of vertebrae, see Flynn v. First Nat'l. Bank & Trust Co. of New Haven, (1944) 131 Conn. 430, 40 A. (2d) 770 (Fall by a woman to sidewalk; verdict of $6,000 held not excessive). For other cases allegedly involving causation or aggravation of Paget's disease by injury, see: St. Goddard v. Potter & Johnson Machine Co., (1943) 69 R. I. 90, 31 A. (2d) 20. Watkins v. Town of Cicero, (1941) 312 Ill. App. 380, 37 N. E. (2d) 785; Nelson v. Tillou, (1938) 16 N. J. Misc. 409 (Plaintiff had osteoarthritis and beginning Paget's disease; fall caused fracture of

Numerous other conditions with characteristic X-ray changes of the skull such as *osteoporosis circumscripta, osteitis fibrosa localisata, leontiasis ossea, osteomalacia, hyperactivity of the parathyroid glands, marble bones,* etc. are too rare to receive more than mention here.

Two conditions, however, that deserve consideration from a medical-legal standpoint, are the effect on the skeleton and particularly the skull, of radium poisoning, that is the ingestion of any radioactive substance, and poisoning with phosphorus. Both these conditions may be the result of industrial hazards, and the problems of compensability and responsibility for total disability and even death often lead to involved legal and medical controversies.[54] Radium poisoning, according to Dyke, produces irregular small areas of bone destruction in the skull affecting chiefly the outer table and distributed mainly along the coronal and lambdoid sutures. Other bones, especially the lower jaw, are usually affected and the roentgen picture, taken in conjunction with the history of the case, is usually characteristic. In phosphorus poisoning also, multiple destructive lesions of the osseous system occur, but here the lower jaw, characteristically, is primarily involved.[55]

Diseases of the Spinal Column and the Spinal Cord

The Normal Spinal Column

The spinal column which serves as the bony container of the large conglomeration of nerve bundles known as the spinal cord,

cervical spine weakened by disease); Gorman v. Miner-Edgar Chemical Corp., (1938) 16 N. J. Misc. 170, 198 Atl. 404 (Hip injured; accident allegedly activated Paget's disease.)

[54]For medicolegal cases involving exposure to radioactive substances, see the following: La Porte v. U. S. Radium Corp., (D. Ct. N. J. 1935) 13 F. Supp. 263 (Occupational exposure); Crawford v. Duncan, (1923) 61 Cal. App. 647, 215 P. 573 (Medical treatment: Scars); Scott v. Sciaroni, (1924) 66 Cal. App. 577, 226 P. 827 (Medical treatment - overexposure); Vallat v. Radium Dial Co., (1935) 360 Ill. 407, 196 N. E. 485, 99 A. L. R. 607; Furgason v. Bellaire, (1924) 197 Iowa 277, 197 N. W. 13 (Medical treatment: cancer); Graham v. Updegraph, (1936) 144 Kan. 45, 58 P. (2d) 475 (Medical treatment); U. S. Radium Corp. v. Globe Indemnity Co., (1935) 13 N. J. Misc. 316, 178 A. 271, affirmed in (1935) 116 N. J. 90, 182 A. 626 (Occupational exposure); Pine v. Waterbury Clock Co., Inc., (1936) 245 App. Div 605, 283 N. Y. S. 763 (Industrial); Jacobs v. Grigsby, (1925) 187 Wis. 660, 205 N. W. 394 (Medical treatment).

See also, in this Symposium series, the following paper: Dunlap, Charles E.: Medicolegal Aspects of Injuries from Exposure to X-Rays and Radioactive Substances, to be published in Occupational Medicine (Spring, 1946) and to be submitted for legal publication.

[55]For medicolegal cases involving poisoning by phosphorous, see the following: Victory Sparkler and Specialty Co. v. Francks, (1925) 147 Md. 368, 128 Atl. 635, 44 A. L. R. 363; Turner v. Virginia Fireworks Co., (1928) 149 Va. 371, 141 S. E. 142; Malzac v. Salmio, (1940) 206 Minn. 430, 288 N. W. 837.

has in addition other functions, which consist of adaptations serving to support the body in all the variety of positions of which the remarkably agile human frame is capable. For this reason it consists of a number of segments or vertebrae cunningly articulated with each other to allow for a maximum of flexibility. Each vertebra consists of a "body" anteriorly (forward) with an arch of bone posteriorly and the floor of the latter is formed by the posterior aspect of the "body." In this way a ring is produced so that the "body" and arch together in cross section give roughly the impression of a padlock. These units are stacked up in a pile, "body" on "body," to form the column, and arch upon arch to form the canal through which the spinal cord passes. The vertebrae are modified to fill the special needs in the various parts of the body. Thus, the neck or cervical vertebrae are small with small "bodies" and large arches: the chest or thoracic vertebrae have extra articulations on each side to accommodate the ribs. The loin or lumbar vertebrae are especially heavily constructed since they bear the greatest weight, and the sacral vertebrae are all fused in one mass since stability here is more important than flexibility. The "bodies" of the vertebrae are separated from each other by extremely remarkable biological shock absorbers, the *intervertebral discs.* These have a hard cartilagenous and fibrous peripheral ring attached to and flush with the rims of the vertebral bodies above and below them; but the center of each disc is almost semi-liquid and exists under pressure, thus serving as a real cushion. The center of the intervertebral disc is called the *nucleus pulposus.* The arches which were roughly described as consisting of bony rings are each actually formed like cross sections of a Greek temple. The columns connecting the floor (posterior aspect of the body) with the roof are the *pedicles,* and the distance between the right and left pedicle represents the width of the spinal canal at that level. The slightly pitched roof is made up of flat bony "shingles" called *laminae,* the projections at the eaves are called the *lateral processes* and a rather prominent projection posterior from the ridge pole, so to speak, is called the spinous process. As these arches are stacked up on each other, there are spaces (intervertebral foramina) between the pedicles of the vertebra above and those of the one below through which the spinal nerve roots leave and enter the spinal cord to make connections with the muscles, bone, skin and organs. The articulations of the vertebrae with each other exist near the base of the pedicles at their junctions with laminae. Great ligaments running up and down the spinal column help to bind it together into a functioning unit.

The X-ray appearance of a normal spinal column is like that of a dried disarticulated specimen since only the bone is seen and none of the ligaments, discs, muscles, etc. are visualized with any degree of distinctness. One notes not only the individual vertebrae and their separate parts, but also the relation of one to the other as well as the contours of the natural curves of the column as a whole. For tumor work it is also important to determine the width of the spinal canal at various levels by actually measuring the width between the pedicles.

Abnormalities of the Spine and Spinal Cord

As is true of the brain, so also is it true of the spinal cord that 1) the cord may be seriously impaired in the absence of any changes demonstrable on the roentgenogram, and 2) marked abnormalities of the spine may exist evident both on inspection of the patient and on viewing the roentgenograms, and yet no evidence may exist of any disturbance of the spinal cord.

Congenital anomalies and diseases. The spinal column is subject to a great variety of congenital variations from the normal, only a few of which can be mentioned here. One, for example, striking, though relatively rare congenital anomaly is the *Klippel-Feil* syndrome. This is a condition in which the patient appears to have a very short neck, or may even seem to have his head resting directly on his shoulders. It is due to a fusion of the cervical vertebra and often the absence of several of them. It may be associated with congenital deformities of the sternum, ribs and scapulae and is quite easily recognizable on the X-ray film. It conceivably could be mistaken for a healed fracture or for tuberculosis of the spine and influence damages awarded in a personal injury case unless the roentgenologist is familiar with it and makes a proper identification of the anomaly.

Another congenital deformity that can easily be misinterpreted as a dislocation is a condition known as *spondylolisthesis*.[56] This is

[56]Undoubtedly, many claimants are securing awards of damages or of compensation on the assumption that their spondylolisthesis was caused or aggravated by injury when in fact they have had this congenital deformity since birth. For cases involving alleged causation or aggravation of spondylolisthesis by trauma (injury) see the following: Doane v. Board of Com'rs of Port of New Orleans, (La. App. 1935) 163 So. 717; Smith v. Hyman, (La. App. 1942) 10 So. (2d) 647; Di Fazio v. J. G. Brill Co., (1939) 133 Pa. Super. 576, 3A (2d) 216. (Evidence failed to show that spondylolisthesis was caused by accident.)

a forward displacement of the lumbar vertebrae on the sacrum and is often accompanied by a contraction of the pelvis. It is easily seen on the roentgenogram but may only be disclosed after the onset of pain in adult life which in turn may or may not be associated with a back injury. It may be further complicated by the coexistence of a herniated nucleus pulposus in the same patient.[57]

Another anomaly usually located in the same area is *spina bifida*. This is a failure of the posterior arch of the spine to close and may involve also the muscles and skin above it, so that only a thin-walled sack consisting of the meninges filled with fluid may represent that part of the back *(meningocoele)*. Less frequently this may occur in the cervical (neck) region. Sometimes the nervous structures may also be included in the sack, thus giving rise to paralyses of the legs, bladder and rectum. On the X-ray film this condition is characterized by a widening of the spinal canal and an absence of the posterior arch. More frequently only a small portion of the arch of one or two vertebrae fails to be completed and the overlying tissues are intact *(spina bifida occulta)* so that the X-ray evidence is the first indication that the condition exists and, as above, these X-rays may be taken for the first time only after an injury to this region or the occurrence of spontaneous pain.[58]

Traumatic conditions of the spine. Fractures of the spine usually occur as a result of a sharp forward flexion of the body. They may be accompanied by lesions ranging from a slight injury up to complete severance of the spinal cord or by no injury to the cord at all.[59] They occur most commonly in the lower cervical

[57]Herniated nucleus pulposus: This is usually referred to as ruptured intervertebral disk—see discussion, *infra.*

[58]It is obvious that mistake or imposition in determining the nature and extent of an alleged injury in the low back region may result where the plaintiff previously had the condition of *spina bifida.*

[59]For a case involving complete severance of the spinal cord, among other injuries, see Zamecnik v. Royal Transit, (1941) 239 Wis. 175, 300 N. W. 227. For case involving virtual severance of spinal cord, see Sterns v. Hellerich, (1936) 130 Neb. 251, 264 N. W. 677. (Paralyzed from waist down.) Serious injuries of the spinal cord resulting in permanent paralysis of any sort may require steady employment of an attendant for the patient and the proper measure of damages is therefore very high.

[60]For cases involving serious or fatal injury to the vertebral column or spinal cord from diving accidents, as from diving into shallow pools, see the following: Turlington v. Tampa Electric Co., (1911) 62 Fla. 398, 56 So. 696; Norberg v. City of Watertown, (1928) 53 S. D. 600, 221 N. W. 700; Hoffman v. City of Bristol, (1931) 113 Conn. 386, 155 Atl. 499, 75 A. L. R. 1191 (holding that where a city was guilty of creating and maintaining a nuisance, in the form of a shallow and dirty lagoon, it could be held liable on this theory for serious injuries sustained by plaintiff as a result of diving

(neck) or upper lumbar (low back) regions, that is, just above or just below the splinted chest segment of the spinal column. They happen most commonly in the cervical region as a result of diving accidents,[60] and in the lumbar region are frequently due to falls or to automobile accidents. They usually result in a compression of the body of the vertebra involved, changing it into a wedge-shaped structure with the base of the wedge posteriorly. It may be further wedged by an unequal compression of the body laterally. These deformities are easily demonstrable on the roentgenograms. Fracture of the posterior arches of the vertebrae seldom occurs except as a result of a bullet or some other penetrating wound. In certain individuals who have some underlying disease like osteomalacia,[61] metastatic tumor to the spine,[62] parathyroid disturbances,[63] etc.,

into the shallow water, even though the municipality enjoyed an immunity from liability based upon negligence; *held*: such immunity would not relieve it from liability for special injuries resulting from its creation or maintenance of a nuisance); Jones v. City of Atlanta, (1926) 35 Ga. App. 376, 133 S. E. 521; Carta v. City of Norwalk, (1929) 108 Conn. 697, 145 Atl. 158; Waddell's Adm'r v. Brashear, (1934) 257 Ky. 390, 78 S. W. (2d) 31, 98 A. L. R. 553; Chardon v. Alameda Park Co., (1934) 1 Cal. App. (2d) 18, 36 P. (2d) 136. (Plaintiff, an adult, descended slide at amusement park and in landing on the ground below sustained a fractured spine and serious internal injuries allegedly due to failure of defendant to replenish sand at the bottom of the slide.) Louisville Water Co. v. Bowers, (1933) 251 Ky. 71, 64 S. W. (2d) 444; Blanchette v. Union St. R. Co., (1925) 248 Mass. 407, 143 N. E. 310. (Plaintiff went down diving chute at bathing beach and struck his head on the bottom, the water being shallow, and as a result sustained serious injuries. *Held*: fact that defendant had erected a sign painted in large letters notifying bathers that they used the float and appliances at their own risk would not make plaintiff guilty of contributory negligence as a matter of law as there was evidence that he was unaware of the sign. The question was for the jury to decide upon all the evidence.) Jones v. City of Atlanta, (1926) 35 Ga. App. 376, 133 S. E. 521.

[61]Osteomalacia: A calcium-phosphorus deficiency disease characterized by distinct metabolic and histological changes which are readily restored to normal if adequate therapy is administered. The deficiency here is the same as causes rickets in children, namely a deficient calcification of all osteoid tissue. The disease is endemic in many parts of northern India, northern China and Japan but is rarely seen in the United States.

[62]Metastatic tumor to the spine: A tumor (or cancerous growth) which arose originally at some other site and spread secondarily to the spine by way of the blood stream or the lymph vessels. Carcinoma (a type of cancer) of various organs, such as the prostate, frequently lead to metastaces to the vertebrae and these may greatly weaken the bone structure predisposing to spontaneous fracture. In Thomson v. Garten, (1945) 115 Ind. App. 330, 58 N. E. (2d) 942, claimant had suffered a jarred or strained back. It was contended that this was causally connected with metastatic carcinoma of his spine; *held*: medical testimony that the jar or strain could not cause metastatic carcinoma nor accelerate the employee's death, sustained an award denying compensation.

[63]Parathyroid disturbances: The parathyroid glands are imbedded in the thyroid gland inside of the neck. They were first recognized as separate structures and described by Sandstrom in 1880. Among the chief functions of the parathyroid gland is that of regulating calcium in the body. The condition

a spontaneous fracture like the above may occur, or it may happen as a result of a minor injury, and the question then arises as to whether, granting the predisposition, the injury, though slight, was an adequate cause of the fracture or whether it had no causal relation to its production.

Occasionally, a situation is further complicated by facts such as the following: a person has sustained an injury to the back, and X-rays are taken within a few days or weeks following the injury but no fracture or other abnormality is seen on the film. The patient, however, continues to complain of pain, or after an interval of several months the complaints recur and reexamination of the spine by X-ray shows a collapse of a vertebral "body" with the resulting deformity. This is a recognized condition known as *Kümmel's disease*[64] and occurs as a result, it is believed, of an interference with the blood supply to the vertebral body in question following the accident, this secondarily producing the collapse of the vertebral "body."

A somewhat similar condition seen in minors may occasionally involve medical-legal connotations. This is a disease called *kyphosis dorsalis juvenalis* or *Scheverman's disease.* It occurs in adoles-

of hyperparathyroidism (osteitis fibrosa cystica), described some years ago by von Recklinghausen and sometimes spoken of as von Recklinghausen's disease, involves decalcification of the bones with formation of cyst-like cavities and resorption of the bony tissue of the trabeculae and shaft of bones which become largely replaced by fibrous tissue. This weakening of bone may lead to spontaneous fracture. Mandl, in 1926, demonstrated that the disease is due to a tumor (adenoma) or hyperplasia (overgrowth and over-function) of the parathyroid gland; the indicated treatment is surgical removal of the enlarged parathyroid tissue and if this is done early in the course of the disease, chances for marked recovery are excellent. In that case the bone cysts fill in slowly, the bones become heavier and the bone pains and general lassitude promptly disappear with marked reduction and gradual disappearance of other symptoms. The disease will progress if the tumor is not removed, causing the bones to become so thin that spontaneous fractures occur and collapse of vertebrae, the patient becomes bedridden and as a rule dies of renal (kidney) insufficiency.

[64]Kümmel's disease: Also referred to as traumatic or posttraumatic spondylitis. Spondylitis means inflammation of a vertebra. The disability is similar to that following ordinary compression fracture except that in absence of proper and adequate support and treatment, severe permanent disability usually results. For a case of alleged Kümmel's disease attributed to wrenching of back when ice man lost control of 400 pound block of ice, see Easthope v. Industrial Commission of Utah, (1932) 80 Utah 312, 15 P. (2d) 301. (Some of the medical experts testified that X-ray pictures of plaintiff's vertebrae did not show evidence of any recent injury but rather a disease which had probably existed for ten or twelve years; compensation commission entered an award denying compensation and this was affirmed on appeal.) And see: Dermo v. Pine Hill Coal Co. (Pa. Com. Pl. 1941) 7 Sch. Reg. 178; Walkowiak v. Pullman Co., (1937) 249 App. Div. 912, 292 N. Y. S. 525.

cents and consists of a partial wedging of several thoracic vertebrae[65] and is believed to be due also to an interference with the blood supply to these parts. It seems to occur in children who are forced to perform physical labor out of proportion to their age and strength.

In addition to fractures, *dislocations* of the spine may occur with or without fractures. These take place most commonly at the same sites as fractures. They are recognized on the X-ray as a disturbance in the alignment of the vertebral bodies. Dislocations usually occur in a forward direction, less frequently in a lateral direction (to the side) and occasionally both forward and to one side. Most dislocations occur at the joints on both sides of a given pair of vertebrae. A unilateral dislocation (i.e., of a single vertebra) may occur, but because of the normal wide range of movements of the spine may be extremely difficult to recognize or to rule out from X-ray examination. Dislocations, even more than fractures, may be accompanied by extremely severe injuries to the spinal cord, and again the nervous structures may escape all injuries. One important thing to remember, however, is that a dislocation may occur especially in the cervical (neck) region, and even cut the spinal cord in two, and the vertebrae may then snap back into place as a result of muscle spasm or inadvertent manipulation before X-ray films are made, so that the injury may prove to be fatal and yet no demonstrable abnormality may be visible on the roentgenogram.

Herniated nucleus pulposus from an intervertebral disk. An ever increasing number of cases of "slipped disk" or more accurately *herniated nucleus pulposus* is coming to the attention of the orthopedic and neurosurgical specialist. It occurs most commonly in the lower lumbar region although it may occur anywhere along the spine. It is the opinion of this writer that the actual number of cases is not increasing except proportionately to the increased tempo of war production, but, that in the past, many cases were dismissed, unrecognized under the designation of sciatica, sacro-iliac strain, lumbago, fasciitis, etc. Because of the frequent history of heavy lifting and straining preceding the onset of symptoms of this condition, it is the subject of much medical-

[65]Thoracic vertebrae: The spinal column consists of thirty-three bones or vertebrae as follows: seven cervical (in the neck region), next, going downward, twelve thoracic or dorsal, five lumbar, five sacral and four coccygeal.

legal discussion, especially in workmen's compensation courts.[66]

From a roentgenographic standpoint much valuable information is available in the diagnosis of this disease; it nevertheless is never one hundred percent accurate, and may be entirely negative in spite of the presence of such a lesion. X-ray evidence favoring the diagnosis of a herniated nucleus pulposus is the presence of scoliosis,[67] obliteration of the normal lumbar lordosis,[68] a narrowing of the intervertebral space at the site of the lesion. However, all of these changes may exist without the presence of a herniation and the clinical as well as operative evidence is often necessary to prove its presence.

In addition to the plain X-rays of the spine, further information may be obtained by the replacement of some of the cerebrospinal fluid with gas or with an opaque medium consisting of oil combined with iodine *(lipiodol,* or a better, later product called *pantopàque).* This process is called *myelography.* In the presence of a herniated disk a defect is seen in the column of contrast material opposite the level of the disk involved and usually on the side corresponding to the pain. However, the size of the defect usually depends on the degree of herniation, and a small herniation may produce severe symptoms and yet show no deformity.

Tumors. The greatest field for activity of the neurosurgeon in relation to the spine is in connection with tumors of the spinal cord. Their diagnosis may often be facilitated by roentgenography as a result of the changes they frequently produce in the neighboring bone or even the soft tissues contiguous to the spine. These effects, briefly, take the form of proliferation or destruction of contiguous bone, deformity of the shadow of the paraspinal soft

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[66]For cases of ruptured intervertebral disk allegedly caused by a compensable injury, see Gavula v. Sims Co., (1944) 155 Pa. Super. 206, 38 A. (2d) 482; Caddy v. R. Maturi Co., (1944) 217 Minn. 207, 14 N. W. (2d) 393; Mo. Pac. Ry. v. Sorrels, (1941) 201 Ark. 748, 146 S. W. (2d) 704.

See, in this Symposium series, the following study: Barr, Joseph S. and Craig, Winchell M.: Ruptured Intervertebral Disk, to be published in the Spring number of the Journal of Nervous and Mental Disease and in Insurance Law Journal (May or June, 1946.)

[67]Scoliosis: Abnormal curvature of the vertebral column, especially a lateral curvature, (i.e. to one side). For cases of alleged traumatic scoliosis, see the following: Okla. Natural Gas Co. v. Kelly, (1944) 199 Okl. 646, 153 P. (2d) 1010; Noyes v. Des Moines Club, (1919) 186 Iowa 378, 170 N. W. 461, 3 A. L. R. 605; Raymore v. K. C. Public Service Co., (Mo. Appl. 1940) 141 S. W. (2d) 103. And see: White v. Hasburgh, (1939) (Mo. App.) 124 S. W. (2d) 560; King v. City of De Soto (1936) (Mo. App.) 89 S. W. (2d) 579; Timmons v. Kurn, (1937) 231 Mo. App. 421, 100 S. W. (2d) 952.

[68]Lordosis: Curvature of the spinal column with a forward convexity.

tissue,[69] and sometimes actual calcification in the tumor substance. A very important point to which Dyke and Elsberg drew attention is the widening of the space between the pedicles[70] demonstrable by actual measurements as compared to a chart of normal average measurements for corresponding vertebrae. Finally, myelography in these cases is extremely valuable in that the tumor usually blocks the canal and the opaque substance can be demonstrated to be stopped at the site of the block.[71]

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[69]Paraspinal soft tissue: The soft tissue along the spinal column.

[70]Pedicles: Pedicle is the process which connects the lamania of a vertebra with the centrum or body.

[71]Though there has been a great deal of litigation in this country involving the alleged causation or aggravation of neoplasms (various forms of cancer or tumors) by injurious stimuli, tumors of the spinal cord or of the vertebrae have figured scarcely at all in a direct manner in these claims. However, we know medically that carcinoma of other parts of the body tends to send metasteses (i.e. spread secondarily by the blood or lymph channels) to the vertebral column. In like manner, primary tumors of the spinal cord may account for symptoms which the claimant attributes to recent injury. For that reason, it is very important, in dealing with alleged injury to the spine or spinal cord, to make proper neurological and x-ray studies designed to rule out presence of pre-existing disease including neoplasms.

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