

CHAPTER XXXIX
CRANIAL NERVES
GEOFFREY KNIGHT

THE **Olfactory Nerve** is liable to be injured by fractures passing through the cribriform plate, resulting in partial loss of smell (hyposmia), or anosmia of the corresponding side. Olfactory filaments are apt to be damaged as a result of occipital injuries (*contre-coup*, p. 949).

The **Optic Nerve** may be damaged by fractures involving the optic foramen, or by compression by blood or inflammatory exudates in the orbit. Involvement by tumours or aneurisms is not uncommon. Blindness of the corresponding eye results, but contraction of the pupil occurs if the opposite retina is stimulated. The optic nerve is an outgrowth of the brain, and consequently gliomatous tumours occasionally arise in its substance.

The **Third Nerve** is sometimes involved by tumours, trauma, or aneurism, either in the skull, sphenoidal fissure, or the orbit. The following features are noticed.

(a) Ptosis of the upper eyelid, owing to paralysis of the levator palpebræ superioris.

(b) Proptosis, owing to paralysis of the majority of the ocular muscles, which normally exercise traction on the eyeball.

(c) Mydriasis, as the sympathetic fibres are unopposed, and cause unhampered dilatation of the pupil.

(d) Loss of accommodation, owing to paralysis of the ciliary muscle.

(e) Diplopia and external strabismus, with a slight downward inclination of the eyeball due to unopposed action of the external rectus and superior oblique muscles. Owing to their proximity, other nerves passing to the orbit are often affected. Pressure on the nerve above the tentorium occurs in the early stages of midbrain pressure cone formation.

The **Fourth Nerve** supplies the superior oblique muscle, and is rarely involved alone. Diplopia and deficient movement of the eye in a downward and outward direction may be noticed.

The **Fifth Nerve** or its branches are sometimes injured, and sensory disturbances follow (p. 1169).

Trigeminal neuralgia or *tic douloureux* occurs most commonly in females. The cause is unknown but may be related to infection of the nerve by the virus of herpes simplex. Pain usually commences in the third or second division and extends in time to adjacent divisions, the ophthalmic division usually escaping. The pain is characteristically intermittent and extremely severe, but of brief duration, often described as being like red-hot needles searing the flesh. Spasms of pain are precipitated by external stimuli such

as cold draughts, brushing the teeth, washing, speaking, eating, or drinking hot or cold substances. The patient often indicates 'trigger zones,' stimulation of which produces an attack. Pain occurs in bouts of several weeks' duration with long periods of remission. The periods of remission, however, gradually become shorter and shorter and the attacks last longer, until eventually the patient is in almost continuous pain and may become suicidal.

Treatment consists of a thorough search for any source of reflex irritation, either dental, nasal, or ocular, and the use of analgesics. If the condition persists, injection or operation is indicated.

Injection is made into the Gasserian ganglion. The needle is inserted 1 cm. below the zygomatic notch and passed upwards, backwards, and inwards to make contact with the third division at a depth of 5 to 6 cm. The needle is then advanced into the nerve, causing severe pain; a drop of local anæsthetic is immediately injected. Before alcohol is injected, the syringe is aspirated to make sure that no cerebrospinal fluid escapes. If the needle is well into the nerve, considerable resistance is offered to injection of local anæsthetic. The anæsthesia produced by the local anæsthetic indicates the position of the needle point, which is now advanced into the ganglion, and further local anæsthetic is injected until the requisite area of the face is rendered numb. A few millilitres of absolute alcohol are now injected. Relief from pain may last from six months to two years, following which sensation usually returns and pain with it. Repeated injections are then necessary and are made with increasing difficulty owing to fibrosis in, and around, the nerve. If repeated injections are required in a young subject, it is better to proceed to the safe operation of sensory root section in the middle fossa.

Division of the Sensory Root.—Sensory root section is greatly facilitated by operation in the sitting-up position. This reduces pressure in the venous sinuses, minimises bleeding, and facilitates exposure, since any effused blood collects in the floor of the skull and is easily sucked away without obstructing the view.



FIG. 1316.—Fractional section of the lower and outer two-thirds of the sensory root at the apex of the petrous. The motor root is visible behind the cut portion of the sensory root.

The temporal muscle is exposed by a curved-hook incision and divided. An opening is fashioned at the level of the base of the skull in order to minimise the elevation of the dura. The dura mater is separated from the floor of the middle fossa until the middle meningeal artery is seen emerging from the foramen spinosum. A blunt hook is inserted into the foramen, the artery is coagulated with diathermy, and then divided with cutting current. The mandibular nerve is then identified as it passes back from the foramen ovale to the cave of Meckel. The dural sheath is now stripped up by blunt dissection with the point of the sucker, opening Meckel's cave in order to expose first the ganglion and then the sensory root which lies in a sheath of arachnoid farther backward on the apex of the petrous bone. A retractor is inserted into Meckel's cave and the sensory root is exposed and the sheath around it is opened, cerebrospinal fluid escapes in considerable volume and is removed by suction. The sensory root is then distinguished by its loose texture and parallel fibres. The root is now divided with a blunt hook, avoiding the motor root which lies deep to the sensory fibres and crosses behind them at an angle of some 60 degrees. Fractional division of the lower and outer two-thirds of the root preserves sensation in the first division, the fibres of which lie in the upper and inner one-third of the root.

Temporary facial paralysis at one time followed operation as a result of traction on the great superficial petrosal nerve being transmitted to the geniculate ganglion of the

Johann Ludwig Gasser, died 1766. Professor of Anatomy, Vienna. His pupil, Raymund Balthasar, discovered the ganglion and named it after his teacher.
Johann Friedrich Meckel, 1781-1873. Professor of Anatomy, Obstetrics, and Botany, Berlin.

facial. This is now avoided by keeping the third division of the nerve and the ganglion between any dissection and the great superficial petrosal which passes under the ganglion.

Neuropathic keratitis also results from damage to the great superficial petrosal, which is the secreto-motor nerve to the lacrimal gland. In all cases tear secretion is reduced to 50 per cent. of normal for the first six weeks, the eye must therefore be kept covered for this length of time. The operative mortality is less than 0.5 per cent. The operation has been successfully performed in patients of eighty-two and eighty-four years of age.

In Tsjoqvist intramedullary tractotomy the descending root to the fifth nerve conveying pain fibres is divided by an incision 4 mm. wide and 4 mm. deep opposite the lowest vagal fibres in the medulla. This produces analgesia without loss of touch in the face, but is less satisfactory and more dangerous to the patient than sensory root section.

The **Sixth Nerve** is slender and has a long intracranial course. It is sometimes involved in cases of fractured base of the skull or prolonged intracranial pressure, and it may be interfered with in association with other ocular nerves, either in the cavernous sinus, sphenoidal fissure, or orbit. The external rectus muscle is paralysed, and internal strabismus results.

The **Seventh Nerve** is involved by a variety of causes.

1. *Intracranial*.—Lesions within the brain are supranuclear, nuclear, or infranuclear. Supranuclear lesions are characterised by involvement of only the lower half of the face, as the occipito-frontalis and orbicularis palpebrarum muscles enjoy bilateral innervation. In nuclear lesions the whole face and the sixth nerve on the same side are affected and also the opposite arm and leg, as the motor decussation takes place at a lower level. An infranuclear lesion occasionally results from pressure of a tumour, e.g. of the cerebello-pontine angle, in which case involvement of the auditory nerve and cerebellum is also evident.

2. *Cranial*.—The commonest causes of involvement of the interosseous portion of the facial nerve are fractures of the base (fig. 1318), and middle ear disease. In cases of fracture involvement may be immediate, usually due to hæmorrhage within the sheath of the nerve, in which case recovery is probable. Involvement after a few weeks is due to pressure by callus, and the prognosis is problematical. Facial paralysis as a complication of middle ear disease sometimes follows injury if an operation on the mastoid antrum is performed. Compression within the aqueduct of Fallopius occasionally follows chronic inflammation.

3. *Extracranial*.—The facial nerve or its branches are sometimes injured



FIG. 1317.—Tsjoqvist intramedullary tractotomy. The left cerebellar tonsil is lifted up to expose the vagal fibres. The site of incision is shown by the arrow.

outside the skull. The nerve itself is commonly involved by Bell's palsy. This condition is probably due to herpetic neuritis of the nerve, and may



FIG. 1318.—Right-sided facial paralysis following fracture through the middle fossa.

follow exposure to cold or a draught. Swelling within the sheath of the nerve extends into the stylomastoid foramen, and consequently the nerve is compressed within the bony canal. Absorption of exudate usually occurs before the pressure has damaged the nerve permanently, but in about 3 per cent. of cases complete paralysis remains, and in 5 to 10 per cent. some degree of paralysis persists. Tetanus arising from a wound in the distribution of the facial nerve sometimes causes paralysis, the cause being similar to that described above. Malignant tumours of the parotid gland are likely to involve the facial nerve, and this is an important diagnostic sign in distinguishing simple from malignant tumours.

Branches of the facial nerve are injured either accidentally, e.g. by broken wind-screens or by ill-placed operation incisions. Needless to say, operations on the parotid gland for the removal of tumours or drainage of abscesses must be performed through dissection parallel to the main divisions of the nerve.

As a result of facial paralysis, the face is flat and expressionless. The eye cannot be closed, and attempts to do so result in the eyeball being turned upwards and outwards (fig. 1318). Corneal ulceration may follow from exposure. Epiphora occurs owing to drooping of the lower eyelid. Whistling is impossible, as the cheek merely flaps, and food collects between the gums and cheek. Treatment is directed to any cause, and the angle of the mouth should be supported by means of a malleable rod covered with rubber tubing. This is bent like an 'S'; the upper curve hooks around the ear, and the lower passes into the mouth. Small strips of adhesive strapping applied under tension also form a very convenient method of preventing overstretching of the facial muscles (fig. 1319). If considered advisable can the services of a skilled dental surgeon are available, an intraoral splint and be fashioned from plastic material. Electrical treatment and massage are prescribed, and during recovery the patient should practise facial movements with the aid of a mirror. Hypoglossal anastomosis may be considered in otherwise hopeless cases.



FIG. 1319.—The application of strapping to prevent stretching of the facial muscles.

In cases of Bell's palsy early decompression of the nerve by removal of part of the mastoid process reduces the risk of paralysis (Duel).

The **Eighth Nerve** may be involved in fractures of the middle fossa, or compressed by a tumour, e.g. of the auditory nerve sheath, in which case unilateral deafness, such as inability to hear the telephone, is sometimes the first symptom. Vestibular functions are sometimes impaired.

Ménière's disease is a paroxysmal disturbance associated with giddiness, nausea, and vomiting. If medical measures fail, the vestibular portion of the nerve is exposed through the posterior fossa and divided as it enters the internal auditory meatus (fig. 1320).

The **Ninth Nerve** is occasionally injured by a fracture involving the jugular fossa. Some dysphagia may occur from paresis of the constrictor muscles.

Glosso-pharyngeal neuralgia is characterised by severe explosions of pain either in the region of the tonsil or deeply in the ear. The 'trigger' zone is in the tonsillar area, and the diagnosis is clinched by the fact that cocainisation of the zone temporarily relieves the condition. In genuine cases the nerve must be divided. It is approached through the posterior fossa, and severed as it enters the jugular foramen, or across the tonsillar fossa after tonsillectomy.

The **Tenth Nerve** may be damaged in association with a fractured base, or crushed by a ligature which includes it as well as the internal jugular vein or common carotid artery. Œdema of the lung has followed in some cases, but injury to one vagus nerve is unlikely to cause more than a temporary tachycardia. In doubtful cases examination of the laryngeal muscles will reveal vagal injury. Irritation of the nerve by a ligature which is not sufficiently tight to interrupt impulses causes an intractable and distressing cough from laryngeal spasm.

The *recurrent laryngeal nerve* is extremely susceptible, and is often temporarily involved in operations on the thyroid gland or ductus arteriosus, either by traction or pressure by traumatic œdema. Complete involvement sometimes follows division or inclusion by a ligature at operation, infiltration by neoplasm of the thyroid gland and secondary glands from carcinoma of the lung, and on the left side by pressure of an aneurism of the aortic arch. Partial involvement affects the abduction fibres, which are more susceptible than those which supply the adductor muscles, and thus if partial involvement is bilateral, stridor results, and tracheostomy may be required. Complete involvement results in paralysis of both abductors and adductors, and consequent paralysis of the corresponding vocal cord in the half-way or 'cadaveric' position. The opposite vocal cord increases its range of mobility, so that it reaches across the midline and closes the glottis. The voice is adequate but somewhat monotonous.



FIG. 1320.—Unilateral cerebellar exposure. The cerebellum is drawn inwards and exposes the ninth, tenth, and eleventh nerves at the jugular foramen. Above this the eighth nerve has been divided as it lies behind the seventh at the internal auditory meatus.

Hysterical aphonia sometimes follows a sudden shock or violent emotion. It is readily distinguished from true paralysis by the fact that, although the patient can only whisper, yet coughing is readily performed on request.



FIG. 1321.—Drooping of the left shoulder and wasting of the trapezius muscle following division of the spinal accessory nerve. The swellings on forehead and face are soft fibromata—a common condition after middle age.

The **Eleventh Nerve** is rarely damaged by fractures involving the jugular fossa. More commonly it is injured during operations on the neck, particularly in the removal of tuberculous nodes which often entirely surround the nerve. The nerve passes downwards and backwards at right angles to the centre of a line connecting the angle of the jaw and the mastoid process, and emerges from the posterior border of the sternomastoid muscle at the junction of the upper third and lower two-thirds; it then passes across the posterior triangle, and disappears under cover of the trapezius muscle. Division of the nerve in the anterior triangle results in only partial paralysis of the trapezius and sternomastoid muscles, as the trapezius receives an additional supply from the third and fourth cervical nerves, and the sternomastoid from the second and third. If injury occurs in the posterior triangle, the trapezius alone is affected. On inspection, drooping of the shoulder is seen, and wasting of the trapezius is obvious (fig. 1321). The integrity of the sternomastoid muscle is tested by placing a hand under the patient's chin and requesting him to flex his head. Palpation will then detect the rigid band of muscle if contraction is normal. Injury of the nerves to the trapezius results in inability to continue elevation of the arm after it is abducted to a right angle by the deltoid muscle. If the branches to the muscle from the third and fourth cervical nerves are intact, about 20 degrees elevation from the right-angled position is possible.

If division of the spinal accessory nerve is recognised at operation, primary suture should be performed. Secondary suture is unlikely to be successful on account of retraction of the ends and difficulty in identifying them in scar tissue.

The **Twelfth Nerve** escapes in fractures of the base of the skull, as the anterior condyloid foramen is protected by a bony ridge which diverts a fissure towards the foramen magnum. Nevertheless, it is commonly endangered in submental operations, especially those for removal of tuberculous nodes. Hemiatrophy of the tongue occurs, the corresponding side of the tongue being shrivelled and wrinkled. On protrusion the tongue is pushed *towards* the paralysed side (fig. 1322).

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FIG. 1322.—Hemiatrophy of the right side of the tongue following involvement of the hypoglossal nerve by syphilitic basal meningitis.

CHAPTER XL

THE SPINE

GEOFFREY KNIGHT

Sprains in connection with the spinal column are of common occurrence. Spinal ligaments are sometimes injured as a result of a sudden jolt, as in car or railway accidents. Fibres of spinal muscles are occasionally torn by excessive muscular contraction, as attempting to lift heavy weights, or damage may result from a direct injury. In either case severe localised pain follows, accentuated by any movement which stretches the damaged structure. Palpation reveals a tender spot, and if muscular fibres are torn, some bogginess, due to extravasation of blood, is often detected. An exact diagnosis is usually difficult, but an X-ray excludes or reveals injury to bone. Treatment consists in rest and cold applications, followed a few days later by massage and graduated movements. If the site of pain can be localised with accuracy, an injection of 5 ml. of procaine (2 per cent.) may cause immediate improvement. This is particularly true in relation to the interspinous ligaments which are liable to be overstretched in association with compression fractures of the vertebra.

DISLOCATION

A *true* dislocation can occur only in the upper cervical region, because the oblique and vertical directions of the articular processes in the dorsal and lumbar regions respectively do not permit of dislocation without fracture.

Dislocation following hanging occurs between the atlas and the axis. Forward displacement of the atlas follows rupture of the transverse ligament, or less commonly fracture of the odontoid process. Death occurs immediately owing to shock from injury to the brain stem and paralysis of the muscles of respiration. Dislocation at this level has also occurred as a result of lifting a child by means of the hands encircling the neck from behind.

The base of the odontoid process may be cracked through following head injuries, and displacement may then occur spontaneously after an interval of days. X-rays of the odontoid process, taken through the mouth, is essential in all cases where persistent occipital pain complicates head injuries.

Dislocations at a lower level usually occur between the fourth and fifth or fifth and sixth vertebræ at the most mobile sections of the spine. This accident is classically produced by falls on the head when riding or by diving into shallow water, which causes excessive flexion of the upper part of the spinal column. The inferior articular process of the fifth vertebra is forced over the front margin of the superior articular process of the sixth. When bilateral there is usually some associated fracture. The condition is then one of fracture dislocation.

If the dislocation is *unilateral*, the head is turned towards the opposite side, and all movements are restricted. Severe pain may be referred along the corresponding nerve root, which is nipped in the intervertebral foramen.

The dislocation is usually readily reduced under general anæsthesia, by further flexion of the head, followed by lateral flexion towards the opposite side. If reduction fails, the joint should be exposed, and a minimum of bone removed in order to allow unlocking. If the dislocation is unreduced, pain and deformity will persist. Involvement of the spinal cord is uncommon in one-sided dislocations.

In *bilateral* cases associated damage to the cord often occurs, usually of a complete nature. In more fortunate cases, owing to the large size of the cervical canal, the cord escapes serious injury. The head is displaced forwards, and obvious deformity is present. Pain is referred to the neck, or arms, along the compressed nerve roots, which are usually lower cervical.

Emergency reduction should be attempted, under anæsthesia, by means of a chin strap or halter. This is connected to a band which passes around the waist of the manipulator so that traction is applied when he leans backwards, and the hands are free for manipulation. If reduction is accomplished, traction is maintained for a week or so, and a plaster cast is then applied. Should manipulation fail, continuous skeletal traction is applied by means of a skull calliper.

As a last resort, open operation is performed and a minimal amount of bone is removed from the articular processes until unlocking is possible. To prevent recurrence the spinous processes should be wired together. The head and neck are immobilised in plaster for six weeks.

Pathological dislocation of the atlanto-axial joint occasionally complicates a retropharyngeal abscess, or even tonsillitis. Flexion of the head and torticollis are obvious signs. The condition is confirmed by X-rays. Traction is required for a few weeks, followed by plaster fixation, and the pharyngeal abscess receives appropriate treatment (p. 273).

FRACTURES

Incomplete fractures are those which do not interfere with the continuity of the spinal column. They include fractures of the spinous and transverse processes, laminae, and fissured or compression fractures of a vertebral body. Fractures of the processes or laminae are usually due to direct violence. The most common situation for fracture of a spinous process is the dorsal region, where these processes are relatively long and exposed to injury. Shovellers' fracture is a 'stress' fracture of spinous processes which occurs in men who use a shovel excessively, especially if they are undernourished. Localised pain and perhaps crepitus suggest the nature of the injury, which is verified by a radiograph. Fracture of the transverse processes occurs most usually in the lumbar region, where these processes are long and comparatively unprotected. Injury to the corresponding kidney is a frequent accompaniment. Fracture of a lamina may be associated with depression of bone and consequent involvement of the underlying cord.

Compression fractures of a vertebral body may cause immediate damage to the cord. In less severe cases persistence of pain demands an X-ray examination which reveals the nature of the injury. (N.B.—In many cases the compression is visible only in the *lateral* X-ray.) It is probable that most cases of Kümmell's disease are due to compression of the vertebral body at the time of injury, rather than to subsequent osteitis, as was formerly believed. Pain and deformity leads to an X-ray examination, which reveals rarefaction and collapse of the body of a vertebra, usually in the lumbar region (fig. 1323). Support to the spine is necessary for one year,

Hermann Kümmell, 1852-1937. Professor of Surgery, Hamburg.



FIG. 1323.—Kümmell's disease affecting the first lumbar vertebra.

although Albee's bone-graft operation finds favour with some surgeons. Injection of the interspinous ligaments may be beneficial in relieving pain.

Traumatic intraspinal hæmorrhage may occur in association with incomplete fractures of the spinal column, such as fractured lamina and pedicles, or compression fractures.

Hæmorrhage occurs either in the cord itself (hæmatomyelia) or as an extramedullary condition (hæmatorachis); in the latter case the blood escapes either into the cerebro-spinal fluid, or outside the dura mater, as in the case of a torn ligamentum subflavum. Extradural hæmorrhage may fill the spinal canal gradually from below upwards, causing progressive compression of the cord, followed by paraplegia (Thorburn's gravitation paraplegia). Intradural hæmorrhage is shown by blood in the cerebro-spinal fluid following a lumbar puncture.

Hæmatomyelia causes symptoms which follow the injury immediately. Destruction of the anterior horn cells causes a flaccid paralysis of the muscles concerned, while injury of the pyramidal tracts results in some spasticity of the spinal muscles or legs. Pain and irritation are much less in evidence than in cases of extramedullary hæmorrhage.

Hæmatomyelia in the cervical region sometimes results from comparatively minor injuries. In the early stages symptoms and signs are often vague. Subsequently, obvious neurological signs, e.g. muscular wasting, present themselves, and are usually permanent.

Complete fractures are those which interrupt the continuity of the spinal column and consist of *fracture-dislocations of the spine*. These may occur from direct violence at any level, but are usually produced by indirect violence from excessive flexion and then occur at the sites of maximum mobility, cervical C.5 to C.7 and L.3 to L.5, or at the junction of fixed and mobile portions of the spine. Separation commonly occurs through an intervertebral disc which carries with it a portion of the anterosuperior lip of the vertebral body below, forming a fracture dislocation. *In all cases the prognosis is governed by the presence or absence of injury to the spinal cord and nerve roots.*

SPINAL CORD INJURY

may be produced by three factors :

(1) By long axis stretch occurring at the moment of acute flexion, causing concussion or rupture of nerve fibres and vessels within the cord.

(2) By nipping of the cord between the lamina of the vertebra above and

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William Thorburn, 1861-1923. Professor of Surgery, University of Manchester.

the edge of the fractured body below, producing a local crush of the cord substance.

(3) By the protrusion of a disc at the moment of flexion leading to compression of the front face of the cord.

In the adult the spinal cord ends at the level of the lower border of the body of the first lumbar vertebra; hence fracture-dislocations below this level can only be associated with injury to the cauda equina. Important anatomical factors govern the extent of the cord and nerve lesion at various levels.

In the cervical spine the horizontal line of the articular processes and the large intervertebral discs produce a high degree of mobility with little strength, hence dislocation or fracture-dislocation occurs readily as a result of relatively minor forces sustained in injuries at sport, such as falls on the head in riding, diving, cycling, or football. Since there is relatively little 'follow-through' produced by small forces and since the size of the neural canal in the cervical region is large in relation to the cord, cord injury may be partial or absent. When greater forces are in action, as when the neck is struck by a falling bough, considerable displacement occurs. Cord injury is then complete and often fatal.

In the dorsal spine the vertical articular processes and low mobility, combined with great strength, account for the fact that the spine can only be broken by major forces, such as the collapse of a roof in a mine-working; displacement is therefore considerable, little space is available around the cord and cord injury is invariably present and severe.

In the lumbar spine vertical articular processes and great strength are combined with mobility. Fracture-dislocations are produced by major forces, often combined with some degree of rotation which causes interlocking of the displaced articular facets. But since the roots of the cauda equina enjoy ample space in the lumbar theca, nerve injury may be absent or limited to a few roots of the cauda. The treatment of fracture-dislocations (see p. 1006) is of secondary importance to the treatment of the associated cord injury.

Injuries of the spinal cord occurring in association with fracture-dislocation and dislocation consist of (1) spinal concussion or (2) partial or complete spinal contusion.

Spinal concussion (spinal shock) is produced by long axis stretch on the spinal cord accompanying flexion. The grey matter of the cord consists of numerous nerve cells and synapses supported on a delicate tissue framework. The long axis stretch causes displacement of these structures with resulting disturbance of synaptic conduction. There is therefore an immediate loss of all functions below the level of the lesion which depend upon synaptic activity. Each anterior horn cell receives some hundreds of synapses, the stimuli passing through which maintain the central excitatory state in the nerve cell, by which the cell is maintained in a state of readiness to respond and act as the final common path for voluntary movement, muscle tone, and reflex activity.

Cessation of the central excitatory state following synaptic disturbance therefore results in complete loss of voluntary movement, abolition of tone and reflex activity below the level of the lesion, producing a flaccid paralysis and retention of urine.

Pain and temperature sensation which cross a synapse in the inferior sensory decussation are also lost, but joint position sense which ascends the posterior columns is preserved. If the injury is merely spinal concussion, voluntary power and sensation will return within twenty-four to forty-eight hours. If concussion is superimposed upon an underlying partial or complete cord injury, the stage of spinal shock is prolonged. As time passes without improvement, recovery becomes increasingly improbable, and the appearance of a mass reflex at a later stage renders the outlook gloomy.

Partial or complete contusion of the cord is produced by nipping of the cord between the lamina of the displaced vertebra above and the edge of the fracture vertebra below; this causes a transverse zone of contusion and bruising. Above and below this level minute petechial hæmorrhage may be seen, resulting from the rupture of cord vessels by the long-axis stretching force. Œdema developing around these hæmorrhages may lead to a rise in the level of paralysis and sensory loss in the early days after the injury. Massive hæmorrhage "hæmatomyelia" is occasionally seen in the cord substance. Whatever damage is inflicted on the cord is permanent and irreparable.

Clinical Features.—The immediate effect of injury produces an initial picture of spinal shock resulting from the long axis stretch which masks the effects of the underlying organic rupture. There is, therefore, complete flaccid paralysis below the level of the lesion with retention of urine. The diagnosis of cord contusion can only be made with certainty in the early stage:

(1) *If there is complete loss of all forms of sensation below the level of the lesion.* This indicates interruption of the posterior columns (which escape the synaptic disturbance of concussion) by bruising on the back of the cord.

(2) If the level of sensory loss and paralysis rises after injury, indicating ascending œdema.

(3) If the stage of spinal shock persists for more than forty-eight hours. In general terms, the duration of the stage of flaccid paralysis is proportional to the severity of the contusion. This stage of spinal shock may last for weeks in bad cases.

The clinical course of cord contusion falls into three stages:

(1) The stage of spinal shock.

(2) The return of reflex activity.

(3) The stage of septic complications.

In the stage of spinal shock, we take suitable measures to protect the cord from further damage, and await the return of reflex activity in order to judge from the character of the reflex changes observed the nature and extent of the cord lesion, and also endeavour to prevent or combat the onset of septic

complications, such as urinary infection, bedsores, and pneumonia, in order to bring the patient to the final phase of active rehabilitation.

The Management of Cord Injuries.—In the stage of spinal shock every care must be taken to avoid unnecessary movement or examination which might increase the cord damage.

First Aid Treatment.—Cervical injuries may be transported on the back with the head supported between sandbags without flexion. Dorsal and lumbar fractures should be transported with the patient face downward. The patient must be lifted and turned on to a blanket, placed on a stretcher, by three people controlling the head, trunk, and pelvis, without bending or torsion of the unstable spine. Morphia or other available sedation should be

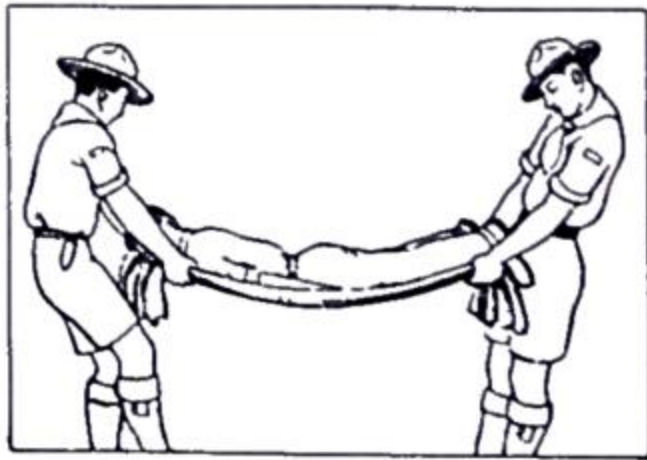


FIG. 1324.—Transporting a patient with a fractured spine.

given to relieve pain and anxiety. On arrival at hospital the patient should be left lying on his stretcher; he should not be moved either for X-ray or clinical examination. Partial cord lesions may be rendered complete by excessive movement during clinical examination or overzealous attempts to obtain a 'good' X-ray picture.

Evidence or history of an accident is usually obtainable. Neurogenic shock frequently accompanies the injury, but the patient may be able to

state that he has severe pain in the back, girdle pains encircling the body, or that he 'feels dead' below a certain level.

On examination, the utmost gentleness must be exercised in order to prevent further injury to a cord which is only partially damaged or to avoid injury to an undamaged cord. Deformity of the vertebral column may be noticed, but if the patient has been turned on to his back 'recoil' usually follows, and the spinal column regains its alignment. If the fracture is due to direct injury, bruising or local trauma is evident. Paraplegia and anæsthesia extending from the level of the lesion are usually present, and are due either to spinal concussion, pressure on, or actual crushing of, the cord. The only examination required is to test the sensory level to pin-prick on the trunk, which will indicate the segmental level of the cord lesion, and to test whether the patient can recognise movement of the foot or knee. If he can appreciate these movements, the case may be one of concussion. If there is complete sensory loss the outlook is grave. Having determined the segmental level of the lesion, as good an X-ray as possible should be taken by the lateral route at the corresponding vertebral level without disturbing the patient. Fracture of the manubrium sterni may be associated with fractures in the dorsal region. If a fracture dislocation is present the fracture is immobilised as soon as the patient's general condition permits, but it may be necessary before this to apply restorative measures to counteract shock.

Cervical fractures are treated by head traction with skull callipers, the patient lying on an inclined plane. After reduction is complete, a Minerva plaster collar is applied from the crown of the head to the chest wall.

Dorsal and lumbar fractures are treated by reduction. The fracture usually follows excessive flexion of the spine, and hyperextension corrects this deformity. In most

cases morphia and scopolamine are adequate, but if advisable pentothal or general anæsthesia is administered. Hyperextension is effected by laying the patient prone between two tables, the one which supports the head and arms being 12 to 18 inches (30 to 45 cm.) higher than the table on which the legs and pelvis rest; a sling, if available, gives comfortable support (fig. 1325).

In special clinics an Abbott's frame and a canvas sling are used; straps are applied to the patient's ankles, which can then be raised to the desired height. The trunk is covered with a stockinette vest, and the plaster is applied from the pelvis below to the axillæ above. A completely crushed vertebra consolidates slowly, so the jacket must be worn for from four to six months.

Acute dilatation of the stomach is a rare but important complication of hyperextension of the spine, as in that position the small intestine gravitates into the pelvis, and consequently the superior mesenteric vessels are rendered taut. In addition, the third part of the duodenum is thrust forward by the lumbar convexity; this further encourages compression.

Removal of the plaster may be necessary. Less severe cases of abdominal distension are usually relieved by cutting a window in the plaster.

Contraindications to Hyperextension.—In the following conditions (about 10 per cent. of cases), hyperextension may cause damage to the cord, therefore it is essential that adequate X-rays are taken to detect the precise nature of the fracture.

(i) Fracture-dislocation with locking of articular processes. The superior processes of the lower vertebra must be excised, as until this is done hyperextension merely stretches the cord.

(ii) Comminuted fractures which involve the neural canal. The spine is immobilised in the normal position with head traction if necessary.

(iii) Fractures due to hyperextension associated with rupture of the anterior common ligament of the vertebræ.

It must be emphasised that these methods of immobilisation only serve to protect the cord from further injury, they do not relieve the existing damage to the cord. The treatment of the case now resolves itself into nursing problems and care of the bladder.

Nursing.—Symptomatic treatment is now instituted. Spinal shock should show some evidence of abatement at the end of 48 hours, if no sign of recovery is evident after the expiration of this period the prognosis is gloomy and anxiety is confirmed by the subsequent development of the mass reflex (p. 1008). The prevention of bedsores should be a constant preoccupation of the nursing staff. Prophylactic measures should never be relaxed (p. 1010). The patient should be turned every four hours throughout the day in a Hey-Groves bed or on banks of pillows. Since plaster immobilisation increases the risk of sore formation plasters should only be kept on in cases of incomplete cord lesion in which there is prospect of neurological recovery. Once there is definite evidence that the cord is hopelessly damaged the plaster case should be removed to diminish risk of sore formation which would seriously

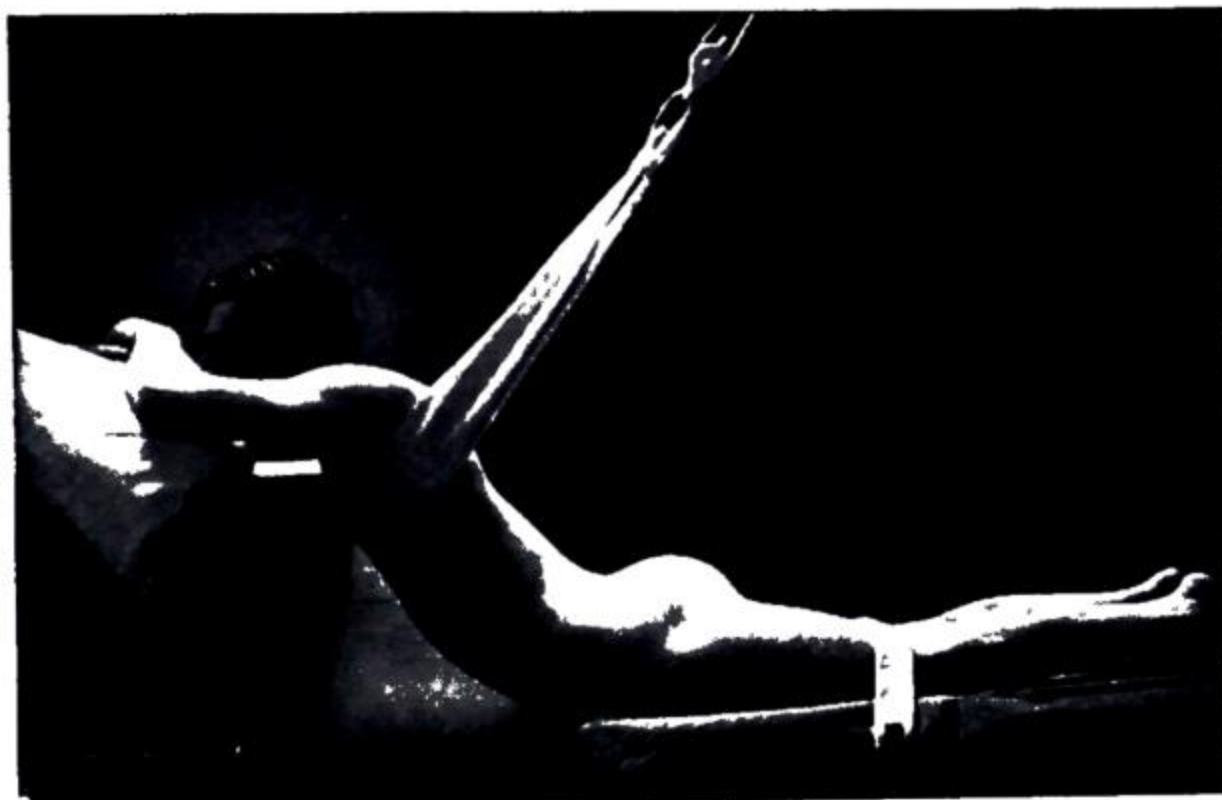


FIG. 1325.—The spine is hyperextended by a band with block and tackle. The patient supports himself on a padded chair. The legs are strapped. The stockinette vest in this case has been omitted.

delay the possibility of commencing active rehabilitation. Attention to the bowels is necessary, and aperients or enemata are administered as required. If meteorism is allowed to occur upward displacement of the diaphragm causes pulmonary embarrassment. Hypostatic pneumonia is a grave danger, particularly if important accessory muscles of respiration, e.g. abdominal muscles, are paralysed, when coughing and expectoration are hampered. Contracture of muscles is prevented by frequent passive movements of the limbs.

Diet.—The patient should be given a high-protein diet to compensate for loss of serum from bedsores.

Care of the Bladder (see also p. 797).—All cord injuries suffer from retention of urine in the initial stages. This may last for a few days to a year in recoverable lesions, or be permanent in complete lesions. Sixty per cent. of the mortality of spinal injury is attributable to ascending urinary infection producing pyelonephritis, and this infection results from instrumentation. Over-distension of the bladder must be avoided. In the early stages scrupulous intermittent catheterisation is the safest temporary measure to employ. The utmost aseptic precautions must be taken, and irrigation of the anterior urethra with a weak antiseptic (e.g. oxycyanide of mercury 1 : 4,000) is some safeguard if combined with antibiotic treatment.

An indwelling catheter should be inserted as soon as it becomes obvious that long-standing retention is inevitable, that is, if there are no signs of recovery in a week or ten days; later cystostomy may be required if heavy infection supervenes. The opening in the bladder should be about 3 inches (7.5 cm.) above the pubic symphysis. This 'high' cystostomy facilitates control of escaping urine, and obviates adherence of the bladder to the pubic bones, which delays subsequent spontaneous healing or renders operative closure more difficult. Sulphonamides or antibiotics will assist in preventing or controlling infection.

The Return of Reflex Activity.—The phase of spinal shock and flaccid paralysis persists for days or weeks according to the severity of the cord lesion. When it passes off it will be seen that lower motor neurone paralysis persists in a few muscle groups corresponding to the level of the lesion, owing to the crushing of the anterior horns at this level.

Partial cord lesions show spastic paralysis in extension with exaggerated reflexes and extensor plantar responses and sometimes with uninhibited flexor spasms. There may, however, be some return of sensation. Retention of urine may persist for periods up to one year.

Complete cord lesions recover to a state of spastic paralysis in flexion with gross flexor spasms and the appearance of mass flexor reflexes of spinal automatism, which indicates complete lack of inhibition of the spinal flexor reflex arcs. In this reflex the slightest touch on the foot will produce flexion of the ankle, knee, and hip on the side of stimulation followed by a similar contraction of the opposite leg, sometimes associated with evacuation of the bladder and rectum. The sight of this reflex may be distressingly encouraging to the patient as it may be misinterpreted as evidence of recovering

function, whereas it indicates that function can never recover. This reflex and the position of flexion may lead to the production of deep sores on the front of the thigh where this is cut into by the plaster shell. Since the cord is irreparably damaged the plaster case should be discarded once the diagnosis is established in order to keep the patient in as good a condition as possible for rehabilitation.

The phenomena which follow cord injuries at different levels are summarised as follows :

Cervical.—If above the fifth segment, all the respiratory muscles are paralysed, including the diaphragm, which receives its motor supply from the phrenic nerve, mainly the C.4 segment. If the fifth segment is injured, the arms, trunk, and legs are all paralysed, and the patient only breathes with his diaphragm. A lesion of the sixth segment results in the arms being abducted and externally rotated, with the forearms flexed and supinated (fig. 1326). This position is due to irritation of the



FIG. 1326.—Irritation of fifth cervical segment. Abdominal distension is developing.



FIG. 1327.—Attitude following irritation of the sixth cervical segment.

fifth segment, and consequent spasticity of the muscles innervated by it, the most important being the biceps, brachialis anterior, supinators, spinati, and deltoid. Similarly, a lesion through the seventh segment causes irritation of the sixth, with spasticity of the serratus anterior, part of the pectorals, and the pronators; consequently, the arms are drawn forwards and adducted, the forearms being flexed by the pronator teres and pronated by both this muscle and the pronator quadratus (fig. 1327).

Dorsal.—Injury at the level of the second dorsal segment is liable to cause contraction of the pupils owing to irritation of the oculopupillary fibres, which leave the spinal cord at the segment above. Hyperæsthesia may extend along the inner side of the arms. At lower levels a band of hyperæsthesia is usually detected encircling the trunk, and is present one segment above the site of the injury. Destruction of the cord at any level above the mid-dorsal region results in paralysis of the abdominal muscles, but below this level the paralysis is partial, depending on the site of injury.

Lumbar.—The lumbar enlargement corresponds to the twelfth dorsal and first lumbar vertebræ, and it contains the centre for nervous control of the urinary bladder. An injury above this level prevents inhibitory impulses from the cortex reaching the centre, and after a period of retention, due to spinal shock, reflex micturition occurs. If the lumbar enlargement, or the nerves passing from it to the bladder (principally the third and fourth sacral), are damaged, then persistent retention follows from paralysis of the sphincter.

The centre for defæcation is also situated in the lumbar enlargement, and damage to this is followed by a patulous anus and incontinence.

Cauda Equina.—Injury to the nerves in the spinal canal below the level of the lumbar enlargement rise to a degree of disability which corresponds with the actual nerves involved the lesion occurs just below the formation of the

cauda equina, the legs and perineal muscles are completely paralysed, and anæsthesia of the legs and a saddle-shaped area in the perineum is present. The patient will suffer from true incontinence of fæces and urine. Injury at a lower level will not affect the nerves which arise from the upper lumbar segments, e.g. the femoral, obturator, genito-femoral, so that corresponding groups of muscles are spared, and anæsthesia of the legs is incomplete. If the femoral nerve is intact, sensation remains on the front of the thigh, and along the distribution of the internal saphenous nerve, i.e. the inner side of the leg and foot as far as the head of the first metatarsal.

Rehabilitation.—If the patient has a partial or recoverable cord lesion, plaster immobilisation of the injured segment must be maintained for an adequate period of time of from two to four months. If, however, the cord is hopelessly destroyed, the plaster on the trunk should be discarded in order to minimise pressure-sore formation. The work of Guttman has revolutionised the prospects of the paraplegic patient, who can now be taught to work and earn a living, even with a complete lesion of the cord. The principles underlying Guttman's methods are :

- (1) To bring the patient into the best possible physical condition by the elimination of sepsis from bedsores and urinary tract.
- (2) To over-develop the muscles above the site of the injury so that these may move the pelvis.
- (3) To move the splinted legs by movement of the pelvis.

Rehabilitation from Bedsores.—The effects of bedsores are general and local. The copious discharge of serum leads to protein deprivation and wasting. A high-protein diet is therefore essential. Toxic absorption can depress recovering activity in the cord. Locally, the bed sore is a large carbuncle in the fatty tissue resulting from the entry of infection through moist skin at points of pressure. Regular turning to relieve pressure and scrupulous drying and powdering of the skin with spirit and powder may prevent their formation. Once bedsores are established, they should be treated by (1) removing the plaster as soon as permissible in order to reduce pressure ; (2) by excising the bed sore (carbuncle) *in toto* before it has become large enough to expose bone, thus producing a raw area which can be allowed to granulate up from the base ; (3) the patient should be turned four-hourly until the healing is complete ; (4) healing may be accelerated by skin grafting to the granulated surface.

Rehabilitation of Bladder Function.—Neglected cases are treated by suprapubic cystotomy, if this has not already been performed. The bladder is allowed to work against pressure on a tidal drainage apparatus in order to prevent constriction of the bladder. Suprapubic drainage is discontinued when sepsis has been overcome.

In complete cord lesions above the tenth dorsal segment, the bladder centres are intact and uninhibited, hence an automatic bladder eventually develops, urine being voided automatically when the intravesical pressure rises, the patient wearing a receptacle.

In lesions involving the bladder centres at the tenth thoracic level and below, permanent retention with overflow incontinence occurs, but since the muscle of the upper abdominal wall can be contracted voluntarily by the seventh to tenth dorsal segments, patients can be taught to evacuate their bladder by straining and by pressing the hand above the pelvis during the day. This is made easier if the resistance of the bladder neck is diminished by a transurethral 'V' resection of the internal sphincter. By these means the patient can be kept dry by day but must wear a receptacle at night.

It is important to avoid long-standing open suprapubic drainage without tidal pressure. This will produce a small contracted bladder which forms a sac of pus tightly encasing infected stones.

Rehabilitation of Muscular Activity and Locomotion.—Contractures are first relieved by physiotherapy, tenotomy, or partial neurectomy. If necessary, the lower portion of the completely divided cord is *destroyed* by intrathecal alcohol injection to abolish mass reflexes and flexor spasms which would prevent walking

and which may be extremely painful if any sensory fibres persist. When the legs are straight, rope climbing and trapeze work is started to encourage enormous development of the muscles of the shoulder girdle. Lying in a sling, the patient then learns to swing the pelvis from the shoulder girdle using the long muscles, latissimus dorsæ, erector spinæ, and abdominal recti and obliques. Then, with his arms supported on parallel bars, he learns to move the pelvis like a hula-hula dancer, and when proficient in this art light aluminium splints with controllable knee-locks are fitted. Using sticks, the patient moves the pelvis from his shoulder and with the pelvis go the splinted legs, thus permitting the patient to walk slowly for short distances to a wheeled chair in which he may move about and engage in sport and training in fine occupations, such as watch-making, lens-making, diamond-cutting, etc.

Complications.—Death may result from the following causes :

- (1) Shock, which may be immediately fatal.
- (2) Cessation of respiration from ascending cord œdema, if the lesion is near the fifth cervical segment.
- (3) Hypostatic pneumonia may develop after a few days, especially if the lesion is sufficiently high to cause paralysis of abdominal and intercostal muscles.
- (4) Cystitis is prone to infect the kidneys, causing death from pyelonephritis (*syn.* surgical kidneys). Necropsy reveals the renal cortex and pelvis studded with abscesses and areas of acute inflammation.
- (5) Allusion has been made to bedsores, which hasten death owing to toxic absorption.

Indications for Laminectomy

In the Acute Stage.—For the removal of traumatic cervical disc protrusion causing cord compression without a fracture (see p. 1024), or for hæmatorachis (see p. 1003). Apart from these rare conditions the indications for laminectomy are *nil*. The cord injury is irreversible and is made worse by meddling with indriven bone.

In the Late Stages.—For the relief of pain if the nerve roots are strangled by arachnoid adhesions, and for the relief of cord compression produced by arachnoiditis impairing the recovery of a partial lesion. In these cases cord recovery occurs up to a point, but then deteriorates and lumbar puncture shows a block on Queckenstedt's test (see p. 1018).

Gunshot Wounds of Spine.—Portions of metal driven against the lamina or vertebral body and bouncing off away from the cord may nevertheless inflict an irreversible injury by exciting massive hæmorrhage in the cord substance. Direct penetration reduces the cord to a custard-like mass of diffuent cord and bone chips.

INFECTIVE CONDITIONS

Meningitis.—Acute infective meningitis is likely to follow a penetrating wound or may be a complication of septicæmia. Severe constitutional disturbances follow with local and referred pain, hyperæsthesia, muscular spasms, and increased reflexes. Extension to the basal meninges is usual, and the only hope lies in an adequate course of penicillin and chemotherapy.

Spinal Epidural Abscess.—Pus may collect in the extradural space of the cervical mid-dorsal or lumbar regions, to which infection has extended through the intervertebral foramina from adjacent sepsis, particularly from a perinephric abscess in the lumbar region. This produces a syndrome of progressive cord compression and meningeal irritation. The pus is evacuated by laminectomy.

SPINA BIFIDA

Embryology.—During the second week of intrauterine life a longitudinal furrow appears on the dorsum of the embryo, this groove being formed by infolding of the

Hans Queckenstedt, Contemporary, Physician at Rostock, Germany, described the test in 1917.

epiblast. The margins of the neural groove unite, so that it becomes converted into a tube from which the nervous system is developed. This epiblastic tube becomes

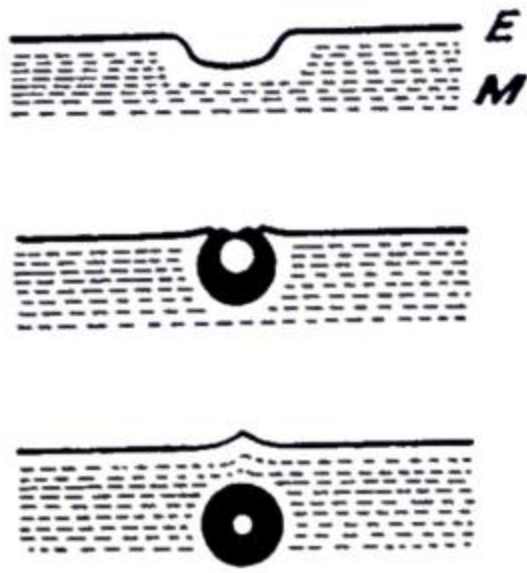


FIG. 1328.—Development of the spinal cord. E = epiblast, M = mesoblast.

separated from the surface by mesoblast, which grows over it from either side, and from which are developed the vertebræ, spinal muscles, membranes, etc. (fig. 1328). In each segment bars of cartilage appear on either side of the neural tube, which during the fourth month fuse with each other to form the vertebral arches. Failure of fusion of these arches gives rise to spina bifida, with which is frequently associated mal-development of the spinal cord and membranes. The incidence of spina bifida, excluding spina bifida occulta, is 0.1 per cent.

The types of spina bifida are as follows :

(1) *Spina bifida occulta* is due to failure of the neural arches to unite, but there is no protrusion of cord or membranes. Frequently only one vertebra is affected, most commonly in the lumbo-sacral region. A local patch of hair, a nævo-lipoma, or a depression in the skin are suggestive of underlying bony deficiency. A fibrous band, the membrana reuniens, connects the skin to the



FIG. 1329.—A typical meningocele which was excised successfully.

spina theca. Growth of the body causes the membrana to pull on the theca and nerve roots. Symptoms of foot-drop, nocturnal enuresis, or backache occur when the child is older or in adult life. Many cases are unsuspected until an X-ray is taken for some other reason.

(2) *Meningocele*.—This is a protrusion of meninges through a defect in the spino-laminar segment (fig. 1329). It contains only cerebrospinal fluid.

(3) *Meningo-myelocele*.—The normally developed spinal cord or cauda equina lies in the sac, and may be adherent to the posterior aspect. The cord or nerves can be seen as dark shadows on transillumination.

(4) *Syringo-myelocele*.—The rarest type of spina bifida, in which the central canal of the cord is dilated, and the cord lies within the sac together with the nerves arising from it.

(5) *Myelocele* results from arrest of development at the time of closure of the neural furrow. An elliptical raw surface is seen, which represents the ununited groove, and at the upper end the central canal opens on the surface and discharges cerebrospinal fluid (fig. 1330).

With the exception of spina bifida occulta, myelocele is the most common type of spina bifida, but many cases are still-born and therefore of no clinical interest. If the child is born alive, death

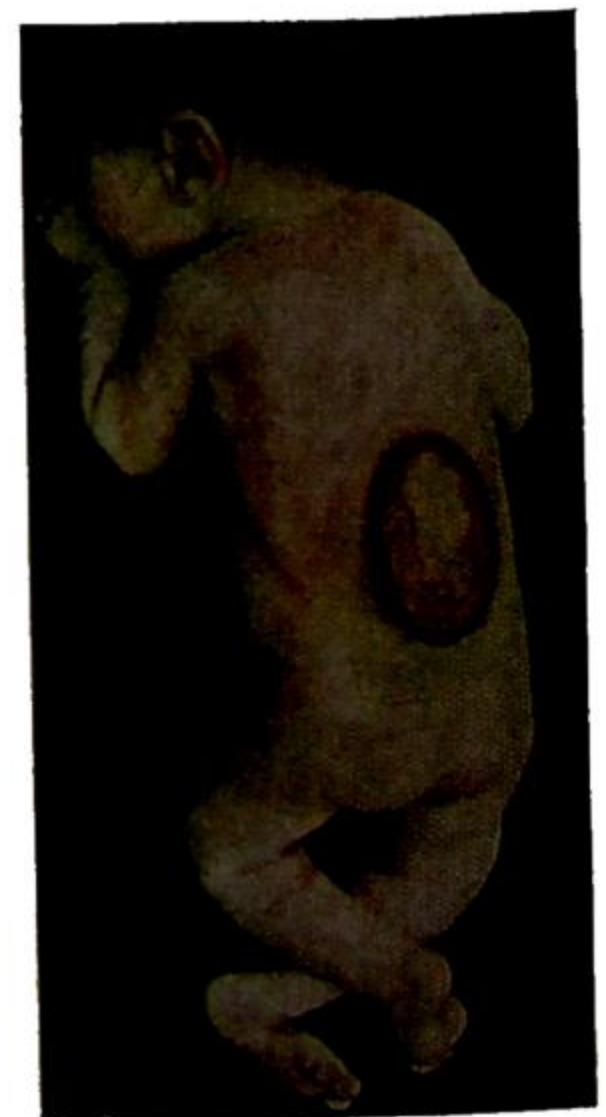


FIG. 1330.—Myelocele, with associated talipes.

ensues within a few days from infection of the cord and meninges. Gross talipes is obvious.

For practical purposes interest centres round meningocele and meningo-myelocele. The two conditions are distinguishable on transillumination, and a depression in the skin due to adherent cord or nerves is sometimes seen in a meningo-myelocele. Interference with the spinal cord or nerves is often associated with either condition. This interference will be more severe in cases of meningo-myelocele, in which condition bilateral talipes with trophic changes is common, and in more advanced cases extensive paralysis of the legs and incontinence are present. In these cases no surgical intervention is indicated.

If associated nervous phenomena are present, the diagnosis of spina bifida is obvious. Cases of meningocele without nerve involvement may present difficulty, especially if occurring in the cervical region. Moreover, a fatty pad occasionally lies over the sac, and thereby masks its physical features.

Treatment.—Operation for meningocele or meningo-myelocele is advisable as soon as the surgeon is of the opinion that the child's strength and condition warrant the procedure (often within a few days of birth), otherwise the sac is liable to grow out of proportion to the growth of the child, and the overlying skin will become atrophic and ulcerate.

Some otherwise successful cases have subsequently developed hydrocephalus. However, most neurologists now consider that hydrocephalus is never caused by repair of a spina bifida, but that it is associated with the Arnold-Chiari phenomenon (p. 991).

Operation is performed under local anæsthesia with the child tied face downwards on a splint. The child is kept with the head low to minimise escape of fluid, and given a feeding-bottle during operation. The sac is opened and redundant membrane excised. If the cord or nerves are adherent, they are either freed by dissection, or separated with a strip of attached membrane and replaced in the vertebral canal. Membranes are sutured over the cord, spinal muscles are approximated, and the wound is reinforced with flaps of sheath from the erector spinæ muscles.

A *complication* of spina bifida occulta consists of nervous phenomena arising during growth, usually between the ninth and twenty-fourth years (fig. 1331). The explanation of this late development of symptoms is that a fibrous band, the *membrana reuniens*, connects the skin with either the spinal cord, nerves, or membranes. In the early months of foetal life the spinal cord ends opposite the coccyx, at birth the cord extends to the third lumbar vertebra, and in adult life to the lower border of the first lumbar vertebra. Thus as the spinal canal grows away from the spinal cord, traction is liable to be exerted by the fibrous band upon the membrane, nerves, or cord itself. The symptoms which follow include weakness or sensory disturbances in the legs, incomplete control of the sphincters, or perforating ulcers of the feet. An X-ray reveals bony deficiency.

The onset of nerve symptoms is a definite indication for operation. On the under-surface of the skin or deep fascia a tough, fibrous band is encountered, which is traced down to the point where it passes through the bony cleft and is attached to the dura mater. The dural sheath is opened and the band excised, together with



FIG. 1331.—Spina bifida occulta with a tuft of hair, and wasting of the right leg due to traction on nerves in the spinal canal. Also right-sided Sprengel's shoulder.

any fibrolipomatous tissue which may be compressing the cord. Excision is followed by improvement in the nervous symptoms, especially if these symptoms have not appeared until adolescence.

INFLAMMATORY DISEASES

Acute osteomyelitis occasionally occurs, either in connection with the epiphysis of the body of the vertebra or, more rarely, with one of the epiphyses from which the neural arch develops. The main features are severe constitutional disturbances, associated with local pain and tenderness. Pain may also be referred along an adjacent spinal nerve. If the disease commences in a neural arch, some local evidence of inflammation is often detected, and invites exploration. Acute osteomyelitis of a vertebral body has been mistaken for spinal meningitis, acute appendicitis, acute pancreatitis, and other abdominal conditions.

As soon as the disease is suspected, penicillin is administered, supplemented by chemotherapy if necessary. X-rays assist in determining the progress of the disease, and evacuation of pus or sequestrectomy is performed if necessary.

TUBERCULOUS DISEASE—See Chapter XLVII

SPONDYLITIS—See Chapter XLIX

TUMOURS OF THE VERTEBRAL COLUMN

Innocent tumours are extremely rare and include chondromata, osteomata, and fibromata. Many cases described as chondromata in the past were in reality protrusions of an intervertebral disc. These tumours produce a syndrome of spinal compression usually affecting the front face of the cord (see p. 1025) associated with characteristic X-ray appearances.

Malignant tumours of the spine are primary or secondary. Primary sarcoma is uncommon and is most frequent in children and young adults. The neural arches are usually affected, and therefore a palpable swelling may be detected in the paravertebral muscles, or invading tumour is discovered at this site during laminectomy performed for spinal-cord compression. Operative removal is always incomplete. Deep X-ray therapy should be given but is seldom effective.

Secondary deposits in the spine are of common occurrence and far outnumber primary spinal or spinal-cord tumours. The majority of cases are produced by metastasis to a vertebral body adjacent to the site of primary growth by spheroidal-cell carcinomas of the breast, thyroid, prostate, and suprarenal. Fifty per cent. of cases are derived from the breast. Paravertebral tumours may invade through the intervertebral foramen and these include carcinomas of the bronchus and the malignant ganglion neuroblastomas of the sympathetic chain.

Clinical Features.—In the majority of cases bone deposits produce severe local pain as the first, and for a variable period the only symptom. Later, as nerves become involved, the pain becomes girdle in type and radiates along one or more nerves. Pain increases in intensity and is aggravated by movement so that the patient may remain crouched in a chair or huddled up in bed for hours at a time. Cord symptoms appear at any time.

The sudden collapse of a vertebra in which a deposit has developed painlessly may lead to instantaneous development of paralysis and severe back pain as the first symptoms. More commonly, the onset of paraplegia is preceded by a period of local pain and is ushered in with increased reflexes and spasticity, but the cord involvement usually becomes complete in a few weeks and is followed by cystitis, pyelonephritis, bedsores, and death. The diagnosis of secondary tumour is always suspected when symptoms of a

spinal-cord tumour are associated with severe local pain and a high erythrocyte sedimentation rate.

Treatment.—Secondary deposits from the prostate respond remarkably to treatment with stilbœstrol. In other cases, treatment is limited to a support to the spine, analgesics, and deep X-ray therapy. Spinothalamic tractotomy and leucotomy are required to relieve agonising pain and are more satisfactory than destructive intrathecal alcohol injections.

TUMOURS OF THE SPINAL CANAL

Tumours of the spinal cord and membranes are only one-tenth as common as cerebral tumours. On the other hand, at least 70 per cent. can be cured by operation.

Tumours of the spinal canal are extradural or intradural, the latter being either extramedullary or intramedullary.

Extradural tumours are relatively uncommon. Lipomas are described but are very rare. The majority consist of meningiomas or neurofibromas. Meningiomas form a plaque overlying several segments of the cord and compressing multiple nerve roots and the cord in the cervical and dorsal region.

Dumb-bell tumours are neurofibromata. Part of the tumour is extradural, and is connected with a larger paravertebral portion by a narrow isthmus which passes through an intervertebral foramen. Spinal compression eventually develops, necessitating laminectomy and excision. Erosion of an intervertebral foramen is a useful radiological aid to diagnosis.

Extramedullary tumours (75 per cent.) are neurofibromas and meningiomas.

Neurofibromas are commonest in males and usually arise from a posterior nerve root forming a fusiform tumour about 1 to 1½ inches (2.5 to 3.75 cm.) long present on the postero-lateral aspect of the cord. Occasionally there is an extradural dumb-bell extension in an enlarged intervertebral foramen.

Meningiomas occur almost exclusively in women and usually form a small globular tumour the size of a grape attached to the dura and indenting the cord.

Carpet-like tumours corresponding to the meningioma en plaque spread widely over the inner aspect of the dura in the cervical and lumbar regions, where there is considerable available space, and engulf the cervical cord or lumbar nerve roots before producing any symptoms of compression. In the author's experience, one tumour extended from the tenth dorsal vertebra to the bottom of the sacrum and measured 27.5 cm. in length.

Of all extramedullary tumours 12 per cent. grow in the cervical region,
60 per cent. in the dorsal region, and
28 per cent. appear in the lumbar region.

In relation to the cord, three-quarters are on the postero-lateral aspect and only a quarter on the anterior aspect. They are very easily accessible at operation and all except a few diffuse meningiomas or meningiomas invading bone can be removed completely.

Intramedullary Tumours (25 per cent.).—Approximately half these growths are diffuse gliomas which cannot be removed. Others consist of ependymomas, a growth derived from the ependyma lining the central canal, forming either solid tumours like pencils which can be excised, or cysts which can be evacuated. Vascular malformations comprise 4 per cent., and for these little can be done. More than half the intramedullary tumours lie in the cervical cord.

Symptomatology

Spinal-cord tumours produce symptoms :

1. By involvement of posterior nerve roots causing root pain and local sensory loss.
2. By involvement of anterior nerve roots and anterior horns causing lower motor neurone paralysis with wasting and loss of reflexes.
3. By involvement of long sensory tracts causing distant sensory loss below the level of the tumour.

- 4. By involvement of pyramidal tracts, causing upper motor neurone paralysis.
- 5. By involvement of both pyramidal tracts, causing disturbance of bladder function.

Extramedullary tumours are lesions of small size usually situated on the postero-lateral aspect of the cord in relation to posterior nerve roots, hence root pain is the earliest symptom which may precede any evidence of cord compression by a period of years, in the early stage it is often mis-diagnosed; when referred to the shoulders and arms, it may be regarded as arthritis or neuritis. In the thoracic region it is regarded as angina pectoris or pleurodynia. In the abdomen it may be thought to originate from the gall-bladder, appendix, or pelvis.

The spinal origin should be suspected because the pain is *increased by coughing*, which raises the intraspinal pressure and forces the nerve root against the obstruction. Secondly, because pain follows the distribution of a spinal root and is often bilateral. Owing to the overlap of adjacent sensory areas, local sensory loss is absent or slight. Since most muscles receive a double nerve supply, the lower motor neurone paralysis is not recognisable unless extremely important roots are involved, such as the first thoracic.

The distant sensory loss is produced by pressure on the cord, which affects the longest sensory fibres first, hence whatever the level of the tumour the sensory loss starts in the legs and gradually *spreads up* the body as shorter and shorter fibres become affected, it seldom corresponds to the level of the tumour and is usually below the tumour level except in the latest stages. Pyramidal involvement occurs later and the bladder symptoms last of all.

Examination shows bilateral spastic paralysis with a transverse sensory level on the trunk below the level of the tumour. The site of the tumour is only indicated by the level of the root pain.

Intramedullary Tumours.—Fifty per cent. of medullary tumours occur in the cervical region of the cord. These tumours occupy a length of the centre of the cord. Root pain occurs last when the tumour presses against the walls of the spinal canal. Involvement of many posterior and anterior horns causes a wide belt of local sensory loss and lower motor neurone paralysis, e.g. a dorsal tumour may cause extensive paralysis of the abdominal muscles. Distant sensory loss may be disassociated in type, as in syringomyelia, from involvement of spinothalamic tracts. Spastic paralysis and bladder symptoms from involvement of the pyramids occur first of all. Examination reveals a wide belt of local sensory loss and lower motor neurone paralysis associated with spastic paralysis in a patient who has only complained of increasing paralysis and bladder disturbance of a few weeks' duration.

	<i>Extramedullary</i>	<i>Intramedullary</i>
Root Pain	Early	Late
Local Sensory Loss	Nil or slight	Wide
L.M.N. Paralysis	Absent except in C.8, T.1	Wide
Distant Sensory Loss	Ascending	Dissociated
U.M.N. Paralysis	Late	Early
Bladder	Late	Early

Extramedullary Tumours of the Conus Medullaris and Cauda Equina.—All lumbar and sacral nerve roots leave the cord between the tenth thoracic and first lumbar vertebra. Tumours of the conus medullaris lie at the eleventh and twelfth dorsal and the first lumbar vertebra and press upon multiple lumbar nerve roots and the tip of the cord. The symptoms include root pain, sensory loss, and lower motor neurone paralysis in the distribution of the lumbar roots which supply the front of the thigh and legs. There is pain in the thighs, wasting of the quadriceps, and foot-drop and reduction of the knee-jerk. Pressure on the cord produces spastic paralysis in the legs with increased ankle-jerk and extensor plantar response.

Reflexes : K.-J. — —
 A.-J. + + + + + +
 P.-R. ↑ ↑

Tumours of the cauda equina occupy a central position among the sacral nerve roots below the conus, producing root pain, sensory loss, and lower motor neurone paralysis in the distribution of the sacral roots which supply the back of the legs. There is sciatic pain with wasting of the hamstrings and calves, with sensory loss in the saddle area. The knee-jerks are increased owing to weakness of the opposing hamstrings; the ankle-jerks and plantar responses are absent owing to sensory disturbance:

K.-J.	+++	+++
A.-J.	—	—
P.-R.	—	—

The more important localising features are as follows:

Upper Cervical.—Tumours in this region are occasionally fatal from involvement of the phrenic nerve centres, and interference with the medulla oblongata sometimes causes cardiac irregularity and hyperpyrexia. Involvement of the oculo-pupillary fibres which pass down to their nucleus in the first dorsal segment results in myosis, narrowing of the palpebral fissure, and enophthalmos (Horner's syndrome). Neuralgic pains are likely to occur over the mastoid and occipital regions, the neck, supraclavicular or acromial areas, or down the arms.

Lower Cervical and Upper Dorsal.—Irritation or compression of the oculo-pupillary fibres is liable to occur if the tumour is situated at or above the first dorsal segment. Interference with the anterior horn cells from the fifth cervical to the first dorsal segments causes paralysis and wasting of characteristic groups of muscles.

Examination of reflexes may yield valuable information. If the supinator reflex is absent, the tumour is situated at the level of the fifth or sixth cervical segment, while absence of the triceps jerk indicates interference with the seventh segment. A tumour in the lower cervical or first dorsal area is likely to cause pain radiating down the arms. Below this level, intercostal neuralgia or girdle pains will probably be a prominent symptom.

Lower Dorsal.—Interference with the cord between the eighth and twelfth dorsal segments is likely to cause loss of upper or lower abdominal reflexes. Paresis of muscles is sometimes present, and if unilateral, a striking bulge of one-half of the abdominal wall is noticeable when the patient coughs.

Irritation of the seventh to the twelfth posterior roots causes a variety of abdominal symptoms, usually indefinite but persistent, and is a fruitful source of diagnostic errors.

Lumbar Cord.—Disturbances of the rectal and bladder sphincters are common. If the tumour is situated at or below the level of the

second lumbar segment, one or both knee-jerks are diminished or absent. The cremasteric reflex is abolished if the tumour involves the upper part of the lumbar cord. Involvement of centres from which the lumbar plexus is derived causes

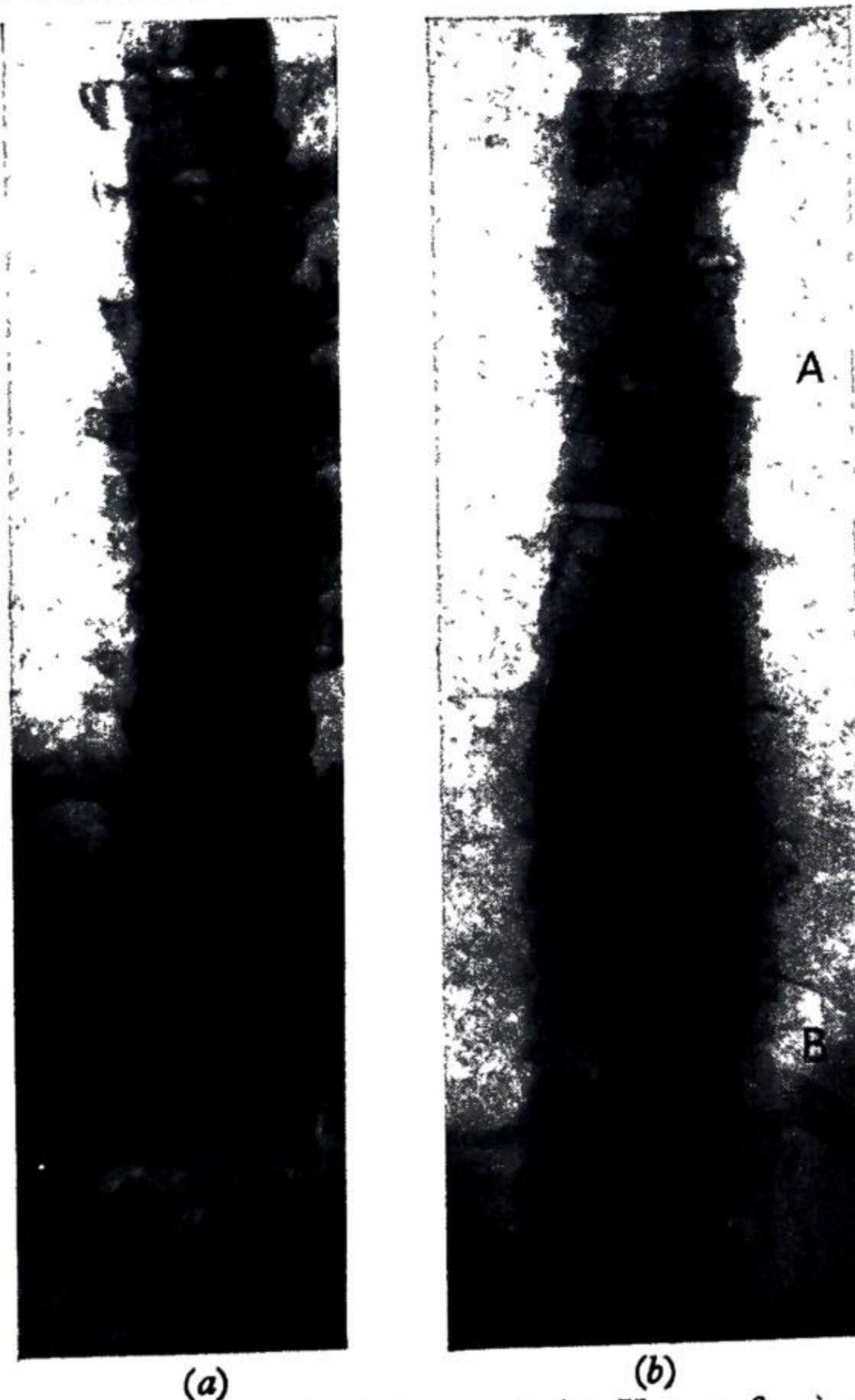


FIG. 1332.—(a) Anteroposterior X-ray of spine showing normal pedicles. (b) Destruction of pedicles between sites A and B by pressure of a long fusiform intramedullary tumour.

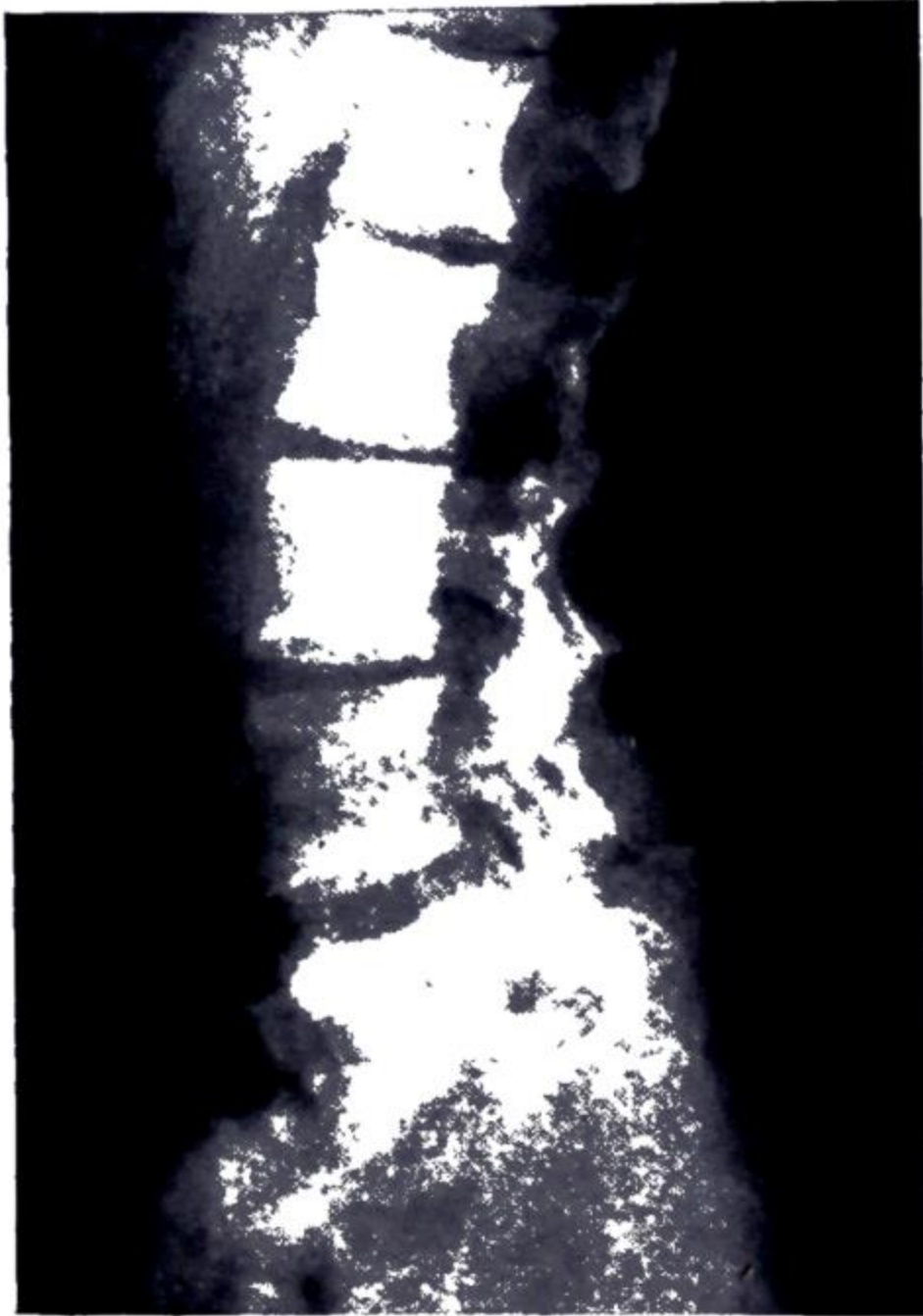


FIG. 1333.—Lateral X-ray showing marked hollowing out by pressure atrophy of the back of the bodies of the lumbar vertebra by a large tumour of the cauda equina extending throughout the lumbar theca. Similar appearances may also occur in the body of the sacrum.



FIG. 1334.—Descending cisternal myelogram showing complete obstruction of the down fall of myodil and the wavy outline produced by the upper border of a meningioma.

paralysis and wasting of corresponding muscles. Owing to the comparatively small size of the lumbar and sacral segments of the cord, sacral nerves are commonly affected in addition to the lower lumbar.

Cauda Equina.—Pain occurs in the back, and extends to the perineum, genitals, and backs of the thighs. Sensory loss usually occurs over the distribution of the sacral nerves (saddle-shaped anæsthesia), and the lower the tumour is situated the smaller is the area of anæsthesia. Bladder and rectal disturbances are usual, and paresis of muscles depends upon the actual nerves involved.

Spinal arachnoiditis may produce simple cysts of the arachnoid, form cystic collections which compress the cord, or multiple diffuse adhesions produce their effect by traction on blood-vessels. The cysts should be localised and removed in the same manner as spinal tumours.

Accessory Methods of Investigation

1. X-ray of the spine may indicate the level of the tumour by showing absorption of the pedicles of the vertebra, enlargement of an intervertebral foramen on the lateral view, or erosion of the posterior aspect of a vertebral body.

2. Lumbar puncture may be required in early cases to differentiate such conditions as disseminated sclerosis. The presence of a tumour is indicated by an obstruction in the cerebrospinal-fluid circulation demonstrated by Queckenstedt tests. Queckenstedt test is performed by charting the rate of rise and fall of the lumbar cerebrospinal-fluid pressure occurring during compression and release of the jugular veins. In normal circumstances compression of the jugular causes a rapid rise in cerebrospinal-fluid pressure and

a somewhat slower passive fall. The first effect of obstruction is to prolong the passive fall, later there is a slight rise and fall, and finally no response at all.

3. Examination of the cerebrospinal fluid—protein figures are also made.

In neurofibromas the cerebrospinal fluid protein is raised from the normal 20 to 40 mg. per cent. to figures of 200 to 400 mg. per cent. without any evidence of block. When block becomes complete, the cerebrospinal fluid in the lower portion of the theca is encysted and transudation occurs between the blood-vessels and the cerebrospinal fluid with exudation of protein and



FIG. 1335.—Descending myelogram showing complete obstruction and the smooth curved margin produced by the curved upper surface of a neurofibroma.



FIG. 1336.—Descending myelogram showing the typical candle-grease appearance produced by myodil trickling down on each side of an expanded cord, an appearance characteristic of intramedullary tumour.

pigments. The fluid becomes yellow and may clot spontaneously (Froin syndrome) and may contain 2 to 5,000 mg. of protein per cent.

Cisternal Myelography.—Cisternal myelography is essential in order to demonstrate the level of the upper border of the tumour before operation. The shape of the shadow produced at X-ray indicates the type of the tumour (see fig. 1334, fig. 1335, and fig. 1336).

Cisternal puncture is performed by inserting a lumbar-puncture needle in the midline at the level of the second cervical spine, the patient's head being flexed. The needle is advanced on a plane passing through the external auditory meatus to the outer margin of the eye. At a depth of 3 cm. the stylet is removed. The needle is again advanced to a depth of 5 cm., when it pierces the occipito-atlantoid ligament, which feels like a sheet of brown paper; the moment this is passed, the operator should wait for fluid to flow out. It may not do so although the needle is in the cisterna magna, therefore the needle should be aspirated before it is advanced farther.

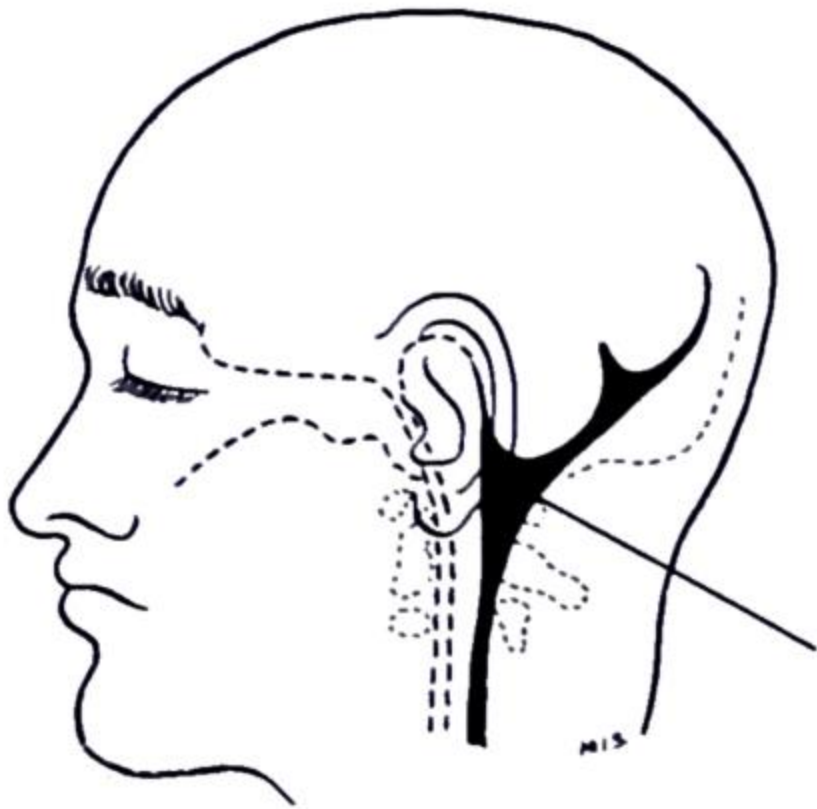


FIG. 1337.—The technique of cisternal puncture.

If no fluid is obtained, it is put in a millimetre or two at a time until fluid escapes. Three ml. of myodil is now injected and gravitates downwards until it is arrested by the tumour, the level of which is localised by examination on a tilting X-ray screen.

Treatment is by laminectomy when the upper level of the tumour has been accurately localised by cisternal myelography.

A meningioma is excised together with a portion of the dura from which it arises.

A neurofibroma is removed with a portion of the nerve sheath to which it is attached.

Intramedullary solid Ependymomas are excised after incision of the cord strictly in the midline between the posterior columns.

Intramedullary cysts are emptied.

LAMINECTOMY

In estimating the level of operation, the discrepancy between the level of the affected segment of the cord and that of the corresponding vertebra must be considered. It must be remembered that owing to the disparity in the length of the spinal cord and vertebral column, a segment in the cervical region lies one vertebra above its corresponding vertebral body. In the upper dorsal region the tumour will be two vertebræ, and in the lower dorsal three vertebræ, above the corresponding vertebral body.

In estimating these levels by palpation of the spinous processes, it must not be forgotten that in the dorsal region the processes overlap the vertebra below. Thus, presuming a tumour is localised to the ninth dorsal segment, it should be opposite the tip of the fifth spinous process, i.e. three vertebræ higher on account of the shortness of the cord as compared with the spinal column, and one vertebra higher because of the obliquity of the spinous process.

The patient is usually placed in the prone position with sandbags under the sternum and pelvis to leave the respiratory excursion of the diaphragm unimpaired in order to minimise back pressure on the epidural veins. The paravertebral muscles are injected with 1 : 100,000 of adrenalin and saline. A midline incision is made, the muscles are separated from the spinous processes by cutting diathermy, and raised from the neural arches with a raspator after tendinous attachments have been cut through with curved scissors. Pressure from hot saline packs produces a dry field after any major vessels have been secured with coagulation. Self-retaining retractors are inserted and spines and interspinous ligaments are incised with bone-cutting forceps. The exposed raw edges of bone at the base of the spines are now drilled through with a Hudson's burr to the level of the dura on each lamina, and finally the laminae are removed with bone-biting forceps, thus exposing the dura and the ligamenta subflava beneath the site of

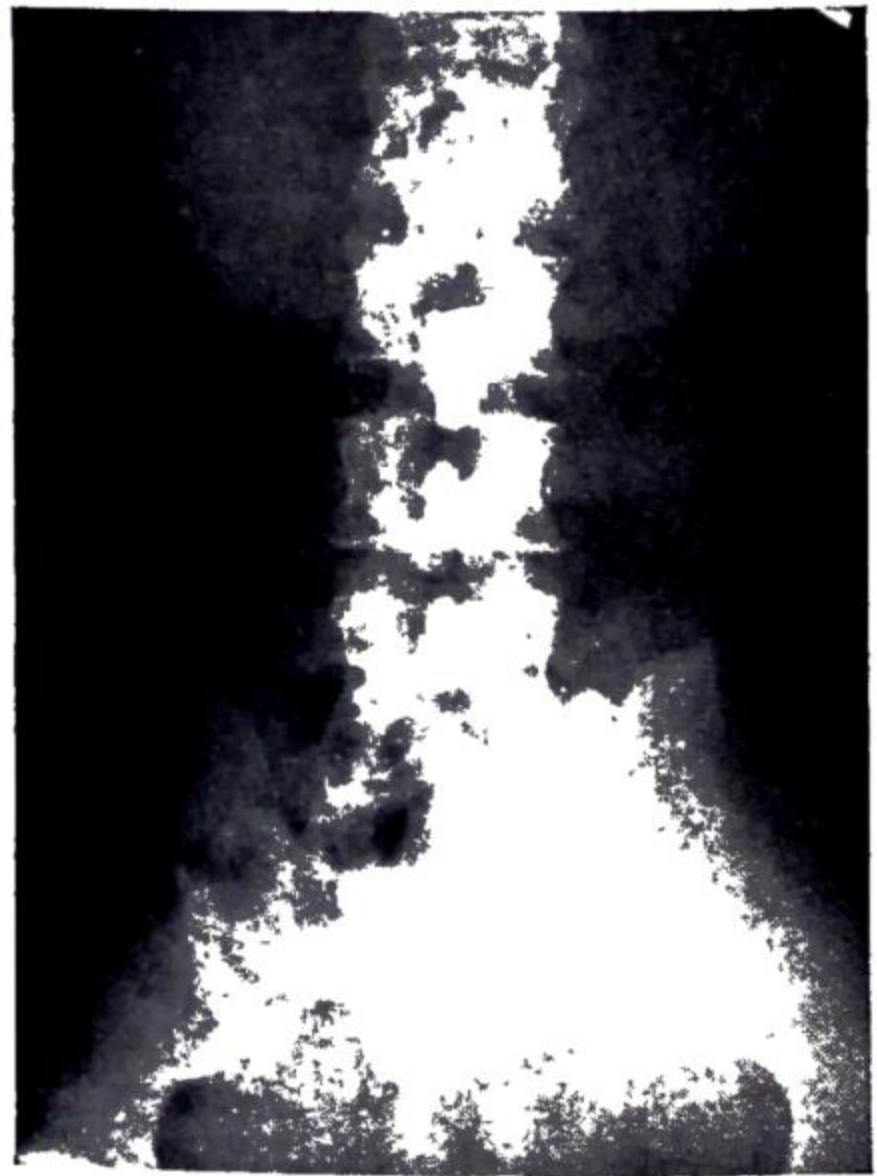


FIG. 1338.—Descending myelogram showing the characteristic curved lower border of the myodil shadow which is produced by the curved sac of arachnoid cyst.

each lamina. The ligamenta subflava and epidural fat are now incised in the midline and the ligaments removed. The dura is then inspected for evidence of the tumour, usually shown by a slight bulge at the tumour site or a zone in which pulsation is absent. If any doubt exists as to the correct level, the dura is picked up on a fine hook and a small midline incision is made, and stay sutures of fine silk are inserted into the dural edge. A No. 3 fine rubber catheter is passed up or down inside the theca to estimate the site of obstruction. If the exposure is correct and no further bone removal is required, the dura is opened fully in the midline by extending the original small incision by slitting the dura up with guarded scissors.

Several fine silk stay sutures are inserted into the dural edge to hold the dura back against the bone and prevent bleeding from the epidural veins. Strips of fine lintine cotton tissue are inserted against the muscle to absorb any minor oozing and to allow for suction on the cotton in order to keep the field dry and free from cerebrospinal fluid. The tumour is now removed in the manner previously described, following which the dura is sutured completely with fine silk, the muscles approximated with strong silk in layers, and the wound closed.

Additional Indications for Laminectomy include :

1. Traumatic. These are considered on p. 1011.
2. Inflammatory paraplegia complicating Pott's disease (p. 1225).
3. Division of suitable posterior roots in order to overcome spasticity in Little's disease (fig. 1340) is now practised by but few surgeons, as division of muscles and peripheral nerves, combined with physiotherapy, usually give better results.



FIG. 1340.—Spastic paraplegia, showing typical attitude and adduction of the legs.

4. Chordotomy. Division of the spinothalamic tracts was devised for the relief of pain due to such conditions as an irremovable new-growth or arthritis. The cord is exposed above the site of the lesion, and the spinothalamic tracts are divided to a depth of 4 mm. as they lie between the denticulate ligament and the anterior root. If the pain is unilateral and not of visceral origin, the tract on the opposite side only need be divided. The patient must be warned against unconscious injury or burns of anaesthetised areas.

5. The tremor of Parkinson's disease is relieved by division of the whole of the lateral tract at the second cervical segment on the side affected (Leslie Oliver). The operation is only suitable for patients under fifty with unilateral tremor, and who are mentally stable. The immediate effects of the operation are total absence of tremor, hemiplegia on the same side, and loss of sensation to pain and temperature on the opposite side.

Later a little tremor is to be found at times of mental stress, and the hemiplegia usually recovers almost completely, but the hemianalgesia and hemithermo anaesthesia are permanent.

SPINOTHALAMIC TRACTOTOMY

Intraspinal division of the spinothalamic tracts will produce loss of pain sensation with preservation of touch on the opposite side of the body. This operation can be employed unilaterally or bilaterally for the relief of chronic long-lasting pain resulting from arthritis, spondylitis, or intermittent claudication, and also be employed to relieve severe pain from incurable



FIG. 1339.—Removal of a meningioma indenting the dorsal cord.

William John Little, 1810-1894. Physician to the London Hospital.
 James Parkinson, 1755-1824. English general practitioner who practised in Shoreditch, London.
 Leslie Oliver, Contemporary. Neurosurgeon, Royal Northern Hospital, London.

new-growths, but only if the general condition of the patient is good and survival is likely to be prolonged. In the terminal stages of cancer, however, cordotomy carries a higher risk of mortality from bronchopneumonia, and pre-frontal leucotomy is, in general, a preferable method.

If pain is unilateral and not of visceral origin, the tract on the opposite side of the body only needs to be divided. For visceral pain bilateral divisions are required. If bilateral sections are to be made, they must be placed at levels two segments apart in the cord in order to avoid the risk of transverse softening and paraplegia.

In choosing the site of operation, allowance is made for the oblique crossing of the spinothalamic tracts. In the dorsal region the incision must be three segments above the level of the pain; in the cervical region, two segments. In the dorsal region the tract lies between the dentate ligaments and anterior roots, but fibres from the lower limbs may be displaced in front of the anterior root. Pelvic fibres will lie deep near the anterior horn. In the cervical region, recently entered arm fibres lie 2 mm. behind the dentate ligament.

The cord is exposed at the required level, the dentate ligament is identified, and divided and grasped with mosquito forceps, which are used to rotate the cord and thus expose the anterolateral aspect to view. An incision 4 mm. deep is now made from the line of the dentate ligament to the anterior root and carried into the anterior horn and beyond, if pelvic fibres are to be divided.

PROLAPSE OF INTERVERTEBRAL DISC

Intervertebral discs are interposed between the vertebral bodies and serve not only as shock absorbers for the column but also provide the normal mobility between the adjacent vertebra. Each disc consists of a soft central portion of spongy material, the nucleus pulposus, containing a remnant of the notochord, which is surrounded by a tough fibrous ring, the annulus fibrosus, which is attached to the adjacent vertebral bodies, the whole being enclosed between fibrocartilaginous plates above and below.

During normal flexion of the spine the disc is deformed and the annulus fibrosus and nucleus bulges backwards slightly into the neural canal.

Intervertebral disc protrusion is produced by the effect of flexion forces acting upon the most mobile portions of the spine. A sudden strain with the spine in an unguarded position will rupture the tough annulus, allowing portions of the torn annulus and soft nucleus to escape into the spinal canal and form either a central protrusion in the midline under the posterior common ligament of the vertebra, or a lateral protrusion at the side of the posterior common ligament adjacent to the intervertebral foramen.

In 80 per cent. of cases the protrusion is traumatic in origin and there is either a history of sudden severe strain or the patient's occupation is one in which flexion strain must be resisted, such as a packer, fireman, porter, etc. The condition is therefore more common in males.

In 20 per cent. of cases the condition is degenerative in origin. There is no history of injury. A small portion of the nucleus pulposus herniates through a weak aperture in the annulus without tearing that structure.

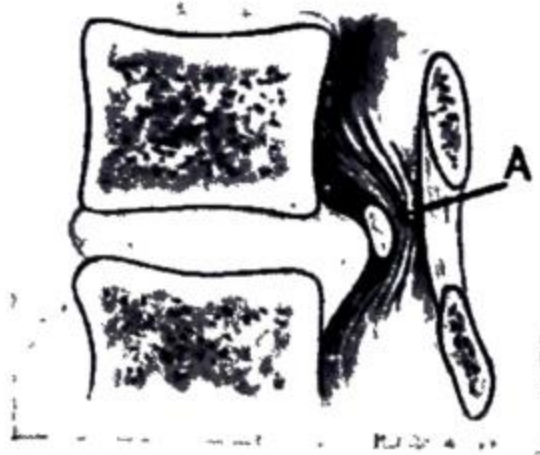


FIG. 1341.—Intervertebral disc protrusion passing towards the intervertebral foramen, the posterior margin of which at A is constituted by the anterior edge of the subflavian ligament.

Since the mechanism demands the combination of stress and mobility, protrusions are most common in the most mobile portions of the spine which are subject to the greatest stress, hence approximately :

19 per cent. occur in the cervical region at the mobile C.5/6 and C.6/7 levels.

1 to 2 per cent. occur in the immobile dorsal spine.

80 per cent. occur in the lumbar regions, particularly at the mobile L.4/5 and L.5/S.1 levels.

Escape of disc material leads to :

1. The narrowing of the intervertebral joint space visible in X-ray in 50 per cent. of cases.

2. Slackening of the anterior common ligament of the vertebra producing abnormal mobility between the vertebra with local joint pain, and ultimately the development of intervertebral arthritis. Traction osteophytes form on the anterior aspect of the vertebra and are visible in X-ray. Compensatory thickening of the ligamenta flava occurs in an attempt to check the abnormal mobility.

Massive protrusions may occur as a result of major cervical injuries (see p. 1025). Alternatively, when the spinal ligaments are softened at the end of pregnancy the strain of labour may force out a massive protrusion in the lumbar region, giving rise to one form of obstetric paralysis.

Lumbar Disc Protrusion.—In the lumbar region the roots of the cauda equina run obliquely over a number of intervertebral joint spaces, hence a lateral protrusion

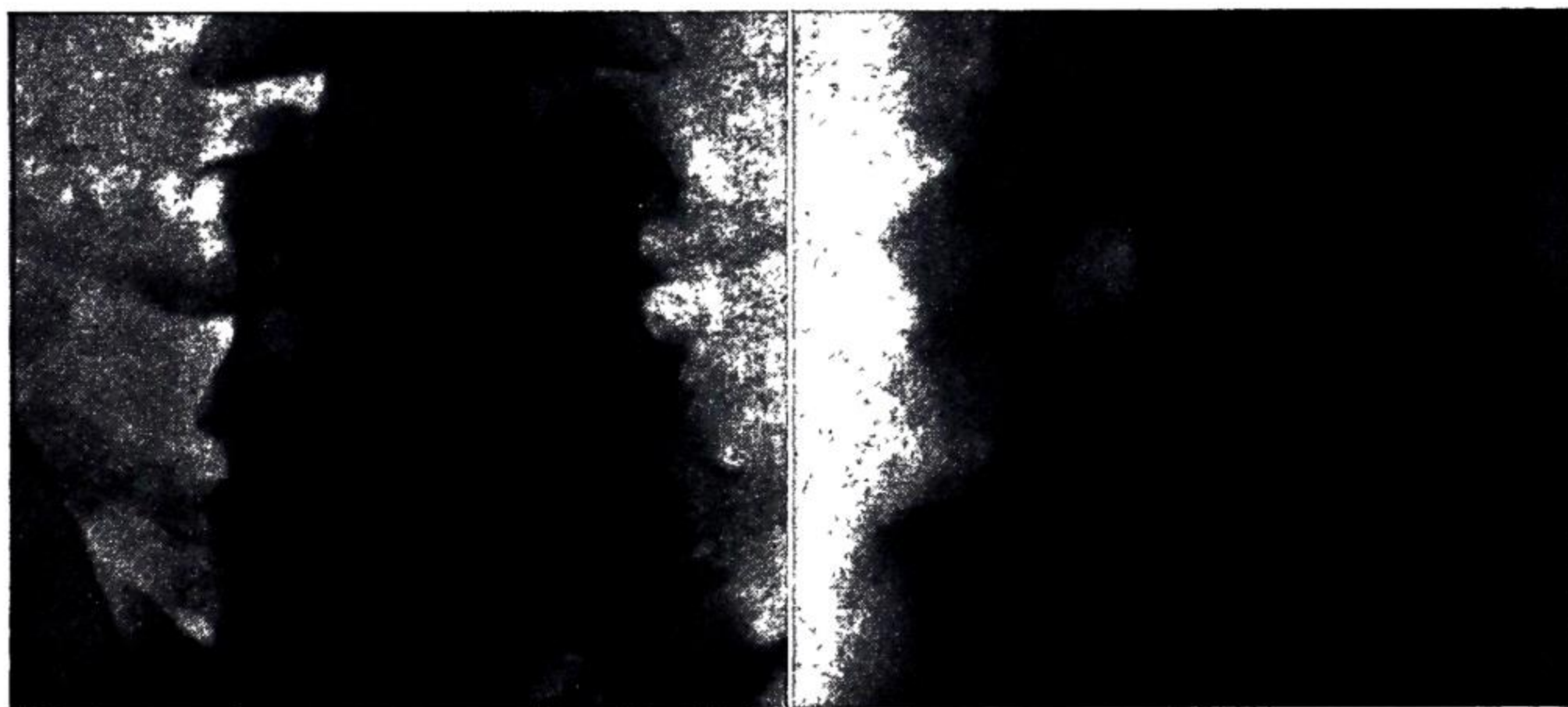


FIG. 1342.—Anteroposterior myelogram showing characteristic lateral filling defect produced by lumbar-disc protrusion.

FIG. 1343.—Lumbar myelogram, lateral view, showing characteristic anterior pyramidal defect crossing to the joint space produced by disc protrusion. Myelography is not completely reliable as it fails to detect the small lesion.

may press on two roots. The nerve root that issues from the corresponding intervertebral foramen may be compressed against the lateral margin of the disc, whilst the nerve root going to the intervertebral foramen next below is caught against its inner margin.

Clinical Features.—In all cases there is an initial period of low back pain resulting from the injury to a disc. Later the pain will radiate to the leg when nerve roots become compressed. There is then root pain accentuated by coughing in the distribution of the affected nerve, paræsthesia and pins and needles in the peripheral portion of that area, cramps, and tenderness in muscles supplied by the nerve, and a variable degree of sensory loss and motor weakness. Since the commonest roots to be involved are the first sacral and fifth lumbar, pain is usually in the back and side of the leg radiating to the sole of the foot and the big toe and is called sciatica. Sensory loss is found on the sole and side of the foot and the ankle-jerk is lost. But in higher disc lesions the pain may be referred to the front of the thigh or leg.

In an endeavour to reduce pressure on the nerve root, the patient adopts a position of scoliosis and walks with a limping gait. Attempts at touching toes or straight-

leg raising or neck flexion with the legs raised increases pain by pulling the nerve root against the protrusion.

Physical Signs.—Pain is produced by friction of the nerve against the protrusion. Small protrusions only compress the nerve root slightly and the nerve is free to rub against the protrusion. *Small protrusions* thus cause very severe pain because there is maximum friction without much loss of conduction in the nerve. Since there is little impairment of conduction, physical signs are slight and limited to a small patch of sensory loss in the periphery of the skin area involved where long sensory fibres have been affected. *Larger protrusions* cause less pain because they lock the root more firmly and there is less friction and the conduction of the nerve is diminished. Since conduction is diminished the physical signs are more marked and sensory loss is extensive owing to involvement of short sensory fibres. *Massive protrusions* completely fix the root and cause no pain whatsoever but produce the maximum sensory loss and motor paralysis (obstetric paralysis).

Root Involved	Pain and Sensory Loss	Motor Weakness	Reflex Change
1st sacral root	Back of leg. Sole and side of foot.	Gastrocnemius weak plantar flexion.	Absent A.-J.
5th lumbar	Back of thigh. Most of lateral aspect of leg. Dorsum of foot to big toe.	Anterior tibials. Weak dorsi flexion.	Nil.
4th "	Side of thigh. Front of inner aspect of leg.	Quadriceps and anterior tibial, weak dorsiflexion and extension of knee.	Diminished K.-J.
3rd "	Front of lower thigh.	Quadriceps.	Diminished K.-J.
2nd "	Front of mid-thigh.	Quadriceps.	Diminished K.-J.
1st "	Groin.	Nil.	Nil.

} Often combined in L.4/5 disc.
} Often combined in L.5/S.1 disc.

Treatment consists of confinement to bed until symptoms abate, which is usually a matter of two to four weeks. A plaster jacket is applied for two to three months, after which a spinal brace is worn for a further period. The majority of cases are cured by this routine. Operation is indicated if symptoms persist or if severe pain recurs, or if motor weakness is developing.

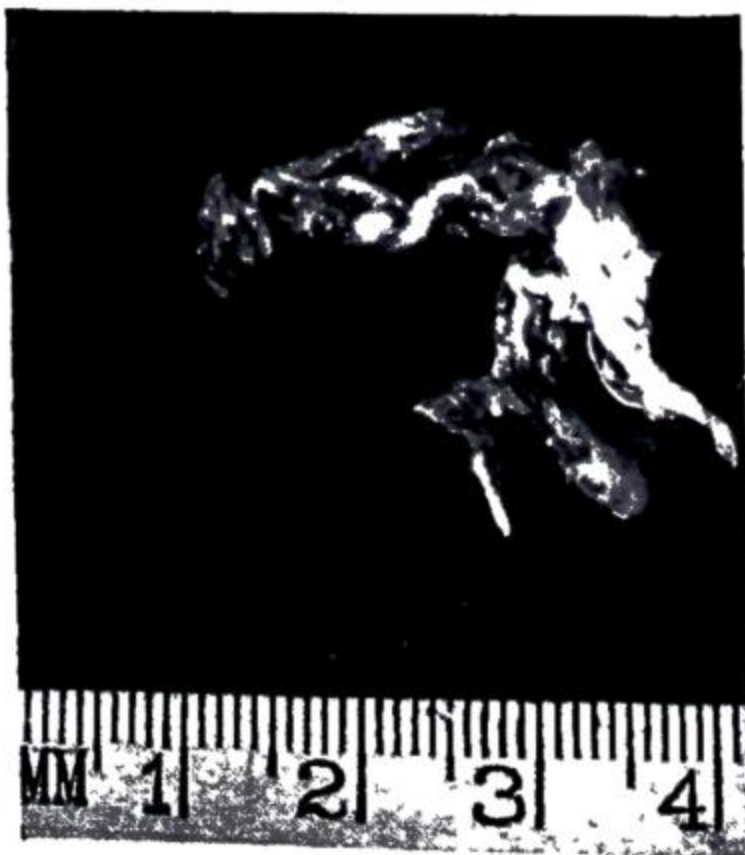


FIG. 1344.—A typical portion of protruded disc removed at operation.

producing sensory loss or motor weakness, or osteoarthritis may have involved the intervertebral joint.

The disc is removed by hemilaminectomy, removing the adjacent margins of two laminae and the subflavian ligament which obscures the view of the nerve root and disc protrusion until it has been excised (see fig. 1344). After removal of the subflavian ligament, the swollen root is seen overlying the protrusion from which it is displaced inwards. Loose disc material is then grasped with forceps and extracted.

A full laminectomy is contraindicated as it encourages further weakness of the spine. Even after satisfactory removal of a prolapsed disc, symptoms or physical signs are not always alleviated. Two conditions may persist. Prolonged compression of the nerve may have resulted in interstitial neuritis

Intervertebral arthritis is to be suspected when pain is not relieved by rest but persists at night and wakes the patient when he turns over in bed. If this condition is present, spinal fusion should be performed when the disc is removed so as to offer complete rest to the affected segment of the spine. Introduction of whole rib grafts, obtained by arrangement with a friendly thoracic unit, produces very satisfactory and economical fusion.

Cervical disc protrusions are relatively uncommon. In the cervical region the nerve roots run transversely and come into relation with one intervertebral disc only. Each nerve issues above the level of the corresponding vertebra. Lateral protrusions press on the corresponding nerve and half the spinal cord, producing cervical rhizalgia with half-cord compression, a Brown-Séquard syndrome. They are never situated sufficiently far laterally to press upon the nerve root alone. Symptoms of brachial rhizalgia without cord compression are produced by intraforaminal osteophytes occurring in association with cervical spondilosis, which may, unlike a disc, affect multiple nerve roots. Each spinal root goes out above the corresponding vertebra, hence C.5/6 protrusion compresses the C.6 nerve root and half the cord (see Table below).

Midline protrusions compress the front face of the cord and affect the anterior spinal artery and the anterior spinal veins. Compression of the anterior spinal artery may affect the pyramidal and spinothalamic tracts and anterior horns. Compression of the veins which ascend on the front face of the cord produce stasis in the anterior horns below the level of the lesion.

Clinical Pictures.—*The symptomatology varies on repeated examination as pressure on the vessels varies and may simulate syringomyelia or disseminated sclerosis or primary lateral sclerosis. In time secondary atrophic changes produce an atrophy of the cord substance with permanent spastic paresis.*

Root	Pain, Sensory Loss	Sensory Loss	Muscle Weakness and Reflex Change
C.6	Trapezius. Shoulder tip, outer border of upper arm. Dorsum of forearm.	Lateral border of upper arm. Dorsum of forearm and thumb.	Weakness of biceps, diminished biceps, and supinator jerk.
C.7	Trapezius. Shoulder tip, back of upper arm, and dorsum of forearm.	Dorsum of forearm and all fingers except thumb.	Weakness of trapezius and extensors of the fingers. Diminished triceps jerk.

Acute protrusions occurring in cervical injuries may produce symptoms of partial or complete cord lesion without bone displacement.

Treatment.—Lateral protrusions are exposed by hemilaminectomy and removed by an extradural approach. Midline protrusions are treated by a full laminectomy of sufficient length to permit one to open the dura and divide the dentate ligaments for several segments above and below the protrusion to allow the cord to fall back away from the protrusion and thus relieve pressure on the arteries and veins. Attempts to remove a mid line protrusion may damage the anterior spinal artery and cause permanent paralysis.

Cervical Spondilosis is a degenerative condition characterised by (1) degeneration of the intervertebral discs with the formation of bony ridges running across the front face of the neural canal and (2) the formation of osteophytes from the neurocentral joints of Luschka which project backwards into the intervertebral foramen. The condition may be entirely symptomless or may give rise to the following neurological symptoms (a)

Charles Edouard Brown-Séquard, 1818-1894. Successively Professor of Medicine in the Harvard and Paris Medical Faculties.

referred pain in the occipital or post-auricular regions and in the upper portion of the trapezius, and between the shoulder blades necessitating the wearing of a cervical support. Persistent occipital and posterior auricular pain can be relieved by excision of the corresponding nerves. (b) Bony ridges on the front face of the cord may compress arteries and veins with

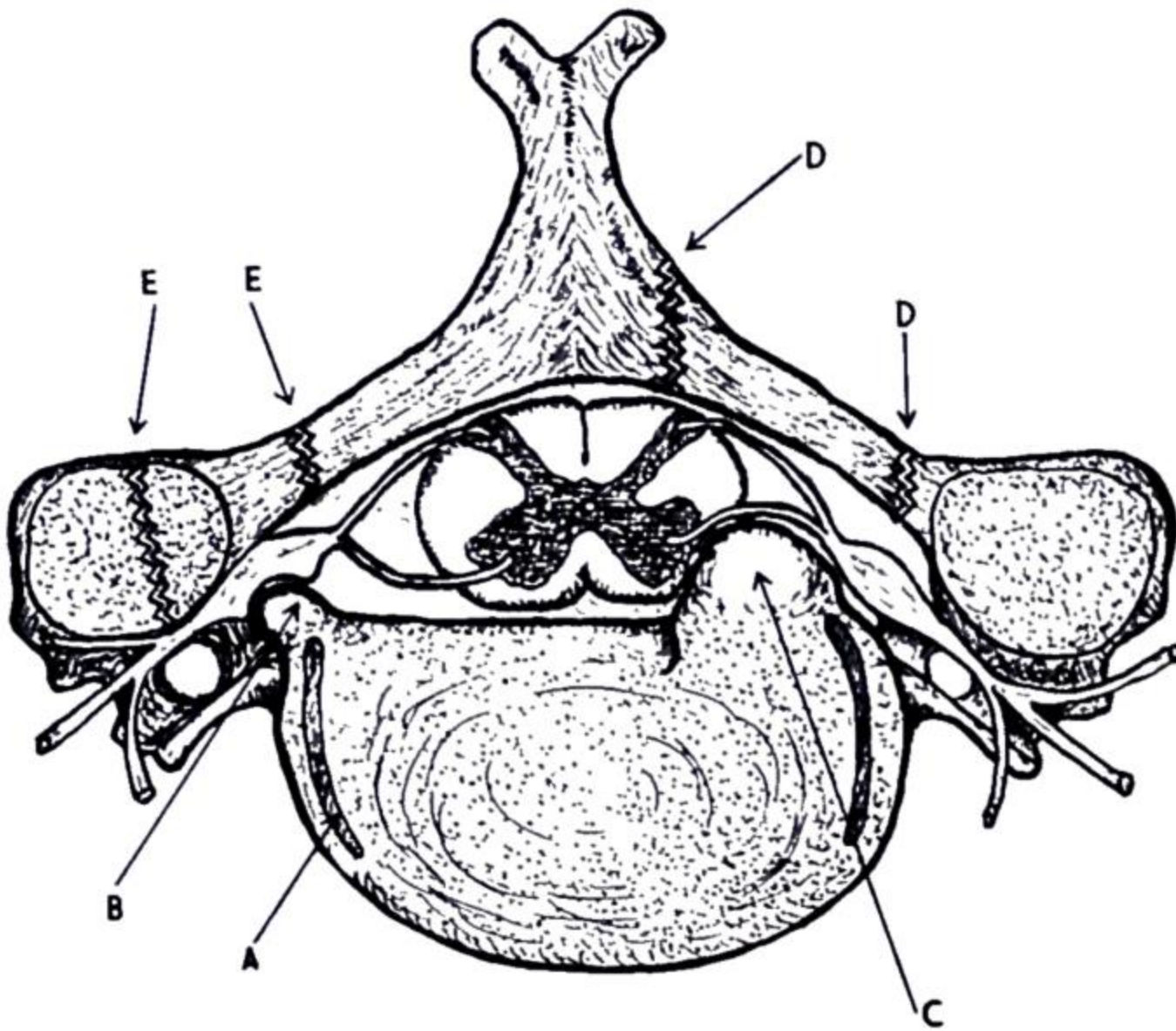


FIG. 1345.—Diagrammatic cross-section of the cervical spine and cord showing the position of (A) the neurocentral joint of Luscha, (B) an intraforaminal osteophyte developing from that joint compressing the nerve root within the foramen, (C) a lateral disc protrusion compressing the cord and nerve root. Projection into the intervertebral foramen is prevented by the position of the joint of Luscha. (D-D) the section of bone removed in hemi-laminectomy giving access to a lateral disc protrusion. (E-E) The section of bone removed in hemifacetectomy giving access to an intraforaminal osteophyte. (G. B. Northcroft.)

consequent neurological symptoms and spasticity and ultimate cord atrophy simulating a mid line disc lesion. This should be treated by division of the dentate ligaments. (c) Intraforaminal compression by osteophytes may effect multiple nerve roots. The nerve roots may be decompressed by excision of the back of the intervertebral foramina by the operation of hemifacetectomy.

LUMBAR PUNCTURE

This procedure is adopted for the following reasons :

1. **Diagnostic**, e.g. meningitis, Wassermann reaction or gold test for syphilis; and to disclose intradural hæmorrhage. Also for the injection of pantopaque, or to assess the protein content, if a tumour is suspected. Manometric readings are essential to assess the intradural pressure.
2. **Therapeutic**, in order to introduce some drug, e.g. penicillin for meningitis, or the relief of pain.

Relief of Pain.—Differential anæsthesia is produced by the injection of 0.75 ml. of absolute alcohol. The pain-conducting fibres passing from the posterior root ganglia to enter the spinal cord possess a much thinner myelin sheath than fibres conducting other forms of sensation. Consequently the pain fibres are more readily affected by alcohol. The patient lies with the affected side uppermost, and a pillow is inserted so that the nerves to be destroyed are at the summit of the curve. Lumbar puncture is performed, usually between L.4 and L.5, and the alcohol injected drop by drop during an interval of about two minutes. The patient should lie on the side for about two hours, and then walk. It is lighter than cerebrospinal fluid, and is rapidly fixed by the nerve fibres and therefore does not injure the cord. Parasympathetic fibres are liable to be involved, so retention of urine occasionally occurs. Some numbness of the leg is experienced, but is transitory. This method is valuable

for relieving intense pain due to malignant neoplasms, e.g. carcinoma of the cervix. If pain is bilateral, the procedure is repeated on the opposite side one week later.

3. **Anæsthesia.**—Stovaine, Novocaine, Spinocaine, and Percaine ; each has its individual supporters.

Spinocaine is composed of Novocaine (100 mg. in each ml.) and strychnine. The dose varies from 1 ml. for children under six years of age to 3 ml. for adults. A pressor substance, such as ephedrine gr. $\frac{1}{2}$ to $\frac{3}{4}$ (30 to 45 mg.) is usually given intramuscularly in order to maintain the blood pressure.

Percaine is used in a 1 : 1,500 solution in 0.5 per cent. saline. The specific gravity of this solution is 1.003, which is lighter than cerebrospinal fluid (sp. gr. 1.006). The average dose is 14 ml., which gives complete abdominal anæsthesia, but 10 ml. is usually sufficient for operations below the umbilicus. After injection the patient lies on his face for five minutes so that the posterior roots are chiefly affected. He is then turned on his back, and slight tilting downwards of the head of the table will help to fix the Percaine caudalwards and counteract any fall of blood pressure.

Catastrophes, such as incontinence of urine or damage to spinal nerves, occasionally occur. These calamities are possibly due to an invisible crack in a phial, which, if submerged in spirit or other antiseptic, may allow some of the fluid to percolate into the interior. *Phials should always be submerged in coloured fluid, and any phial which contains coloured contents is rejected.*

Some premedication, such as omnopon and scopolamine, is safe and humane, but if the intercostal muscles are paralysed, depression of the respiratory centre is dangerous.

It will be remembered that at birth the cord extends to the third lumbar vertebra. In the adult it terminates opposite the lower border of the body of the first lumbar vertebra, and therefore the dural sac can be safely punctured at any site between the second lumbar interspace and the fifth lumbar vertebra. The nerves of the cauda equina are so arranged that a space of 2 mm. to 5 mm. in width exists between the roots on either side, and the needle usually passes between the nerves. Sudden pain in the leg indicates that the needle is in contact with a nerve, but this symptom is of no moment.

A line connecting the highest parts of the iliac crests passes over the fourth lumbar spine, so that a needle entered just above or below should pass through the third or fourth lumbar interspaces respectively (fig. 1346). The depth to which the needle passes varies from 1 cm. in a small child to 10 cm. in a fat



FIG. 1346.—Lumbar puncture. (The site of puncture is usually between the third and fourth lumbar spines.)

adult. If the patient is self-controlled, a small amount of local anæsthetic is desirable, although not imperative, but in the case of children or patients afflicted with tetanus a general anæsthetic is necessary. Flexion of the spine widens the spaces between the neural arches. The needle used should be of medium bore (about 18 to 20 gauge), as the aperture resulting from puncture with a wide needle will allow continuing escape of cerebrospinal fluid from the dura, with consequent persistent headaches, produced by intracranial hypotension. Also the bevel of the needle must be short, so that there is no danger of part of the opening remaining outside the dura mater, and resistance to penetration is more readily perceived with an abruptly bevelled needle. As the needle and stylet are entered, the resistance of the tough ligamentum subflavum is encountered. A little extra pressure perforates this structure, and on withdrawal of the stylet the cerebrospinal fluid should flow from the needle. If only a few drops of blood escape, in all probability the point of the needle is lying in the spinal canal outside the dural sheath, and the blood is escaping from the spinal veins.

The position of the needle should be checked, making sure that it has been introduced vertical to the skin at the point of penetration and is not sloping to one side. This is best judged by looking along the skin of the patient's back. When the canal is entered, a manometer is attached to the needle in order to estimate the cerebrospinal-fluid pressure, the normal being 120 ml. of water in the recumbent position.

In cases of raised pressure only a small quantity of fluid must be removed for investigation, and the pressure should not be reduced, even so low as the normal 120 ml., owing to the risk of causing mid-brain pressure cone or medullary cone in which the medulla is liable to become wedged in the foramen magnum, with fatal consequences.



FIG. 1347.—Indicating direction of needle.

SACRAL PUNCTURE

The sacral epidural space may be entered through the large triangular opening on the dorsum of the bone, and sacral anæsthesia obtained by the injection into the space of 20 ml. of 1 per cent. novocaine. Operations on the lower bowel and anal margin can then be performed painlessly, and some obstetricians practise this method in order to relieve the pains of child-birth, an additional advantage being that the infant is unaffected.

To perform sacral puncture the median crest of the sacrum is palpated until the depression caused by the sacral opening is recognised. A lumbar-puncture needle is introduced directly forwards until the ligaments covering the opening are pierced, after which the direction of the needle is changed so that it passes vertically upwards within the sacral canal (fig. 1347). In order to ensure that the point of the needle is within the epidural space, it is wise to inject a few millilitres of normal saline; if the needle has not penetrated the canal, infiltration of the subcutaneous tissues will be evident, in which case it is withdrawn and a fresh attempt is made.

CHAPTER XLI

NERVES

GEOFFREY KNIGHT

INJURIES of nerves are classified according to the extent of the damage to the nerve fibres and sheath, as neurapraxia, axonotmesis, and neurotmesis.

Neurapraxia is the equivalent of concussion.

In axonotmesis there is an intrathecal rupture of nerve fibres, the sheath remaining intact.

In neurotmesis there is partial or complete division of nerve fibres and sheath.

NEURAPRAXIA

is the equivalent of concussion. There is physiological paralysis of conduction in the intact nerve fibres as the result of stretch or distortion without any organic rupture. Fibres remain intact within the intact sheath. There is no degeneration of the axons. When the power of conduction returns, all functions, motor and sensory, return together, sensation recovering in the whole limb within a period of hours. Recovery is complete.

Neurapraxia is produced by minor stretch injuries or by the concussion and vibratory effect of a high-velocity missile passing near a nerve without dividing it. It produces sensory loss, paræsthesiæ, and weakness of muscle groups lasting for days. During this time there is no reaction of degeneration in the muscles.

Treatment consists of splinting the limb in a position of relaxation of the paralysed muscle groups until spontaneous recovery occurs—usually in a matter of days.

AXONOTMESIS

consists of the intrathecal rupture of nerve fibres within an intact sheath. According to the cause, the nerve fibres are damaged to a variable degree (see below). Distal Wallerian degeneration occurs in the distal portion of the broken axons, leaving an empty tubule. Intraneural fibrosis occurs at the sites of axonal rupture and minute intraneural hæmorrhages. Recovery takes place slowly by the proliferation and down-growth of axons into the distal tubules, the combined bulk of the proliferating axons and intraneural fibrosis producing a fusiform neuroma on the course of the nerve. There is some loss of nerve fibres owing to the blockage of the down-growing axons in the intraneural fibrosis, but since the relative position of axon and distal tubule is preserved by the intact sheath there is little maldistribution, hence the quality of regeneration is often good except in the case of progressive

Augustus Volney Waller, 1816-1870. English Physiologist.

fibrosis. Recovery is delayed until the down-growing fibres reach their appropriate endings, and occurs first in the muscle groups nearest to the site of division and lastly in the peripheral skin areas, where the anæsthetic area begins to decrease steadily from the margin inwards. The length of time required for the recovery depends upon the level of the lesion. After an initial delay of approximately ten days, down-growing axons proceed distally at a rate of approximately 1 mm. a day, and on arrival at their endings there is a further delay of three weeks before the end organs become activated. Partial or complete intrathecal rupture of fibres may complicate a single stress occurring in association with fractures or dislocations, or excessive vigour during attempted reduction of such injuries; it also accompanies traction injuries at birth and may be produced by clutching for support when falling, as in brachial plexus lesions. It may follow contusion of a nerve with extensive hæmorrhage into its sheath or be the result of severe and acute compression by tourniquets, splints, or incorrect posture on the operating table.

Gradually increasing lesions are produced by progressive compression from crutches, splints, callus, and scar tissue or by repeated minor stretch of a nerve which becomes fixed near a mobile joint. The latter is seen when a nerve such as the external popliteal becomes fixed at the head of the fibula or the ulnar nerve becomes fixed behind an arthritic elbow or stretched in cubitus valgus; in such cases movement of the joint pulling on the fixed nerve produce repeated minor ruptures at different levels, each of which is succeeded by a small degree of fibrosis, which gradually induces a progressive fibrosis and progressive loss of function within the nerve.

Clinical Features of Axonotmesis.—Following a severe stretch, there is an initial picture of neurapraxia with widespread loss of sensation, tone, power, and reflex activity in the limb; this is followed by an incomplete recovery. The resolution of concussion will restore sensation and movement to certain areas of the limb to which the nerve fibres remain intact. The numbness and paralysis will persist in those areas where the fibres have actually ruptured. Usually the total area affected is less than the known anatomical distribution of the nerve as a proportion of fibres have escaped.

Treatment of closed injuries of nerves consists in maintaining the nutrition of the limb and combating the secondary physiological changes which would otherwise follow nerve injury, by suitable means, in order to maintain the muscles and joints in good working order pending the arrival of down-growing axons.

Secondary pathological changes accompanying nerve injury affect the skin, muscles, and joints. Impaired circulation consequent on disuse renders the part blue and cold. The skin becomes thin, the nails brittle, and so-called trophic changes occur as a consequence of minor unrecognised trauma. Those muscles which are paralysed and flaccid will be over-stretched by unopposed action of antagonist groups. Within three weeks the reaction of degeneration appears. The muscle fibres no longer respond to the rapid make-and-break of faradic stimulation owing to an increase in

the duration of chronaxie accompanying paralysis, but they will still respond to the slow make-and-break of galvanism. The polarity also changes so that A.C.C. becomes greater than K.C.C. If the muscle nutrition is not maintained by galvanic stimulation, muscle fibres degenerate and progressive fibrosis replaces withered fibres. Recovery is then impossible. Periarthritic adhesions eventually form around the immobile joints and fix them in a contracted position. To combat these effects the part must be protected by warm padding to prevent injury, and splinted in a position of relaxation of the paralysed groups. The electrical reactions of the muscles are taken and muscle movement is maintained by regular galvanic stimulation of all paralysed groups. All joints are put through full passive movements daily to prevent contraction. In the case of the hands, joint movements and exercise of the paralysed muscles are best maintained by the use of elastic splints in which strands of catapult elastic are attached to leather thimbles, which are inserted over the finger-tips and mounted on wire frames in positions corresponding to the paralysed tendons, so as to provide an elastic counter-pull to replace the normal contraction of the paralysed muscles against which the opponents can act. This not only ensures full normal movement of all joints, but will also permit partial use of the hand during recovery.

Considerable encouragement must be given to the patient during the long period of time required for restoration of function. Progress is carefully checked by taking regular records of the electrical reactions and skin sensitivity. Electrical reactions change back to normal in the proximal groups as the downgrowth of fibres proceeds. These changes must be recorded, together with diagrams of the skin sensation, in order to determine whether normal recovery is taking place. Failure to recover, or regression after the initial recovery, is an indication for the local exploration of the injured site. It is occasionally necessary to deal with a perineural scar or remove an intraneural fibroma.

Movements produced by unaffected muscles must not mislead the observer. Thus, in a case of radial paralysis, the fingers can be extended by the interosseus and lumbrical muscles, provided that the hand is supported. Also vicarious movements may be performed by adjacent muscles, e.g. in the case of division of the median nerve, the adductors of the thumb, acting in conjunction with the extensor ossis metacarpi pollicis, can produce opposition of the thumb.

H. J. Seddon *et al.* have endeavoured to calculate the rates of nerve regeneration, basing their results on the following clinical data:

(1) Tinel's sign—the course of the nerve is lightly percussed with a patella hammer, from below upwards. A tingling sensation is experienced when the level of regeneration is reached.

(2) Measurement of the rate at which pain and touch sensibility return.

(3) Observation of the times at which the function of muscles returns at different levels from the injury.

It appears that regeneration occurs initially at about 2 mm. a day, but the rate diminishes as time passes, so that after about three months it has slowed down to about 1 mm. a day. (Other factors which influence the results of suture are discussed on p. 1034.)

Compression.—The first symptoms usually consist of paræsthesiæ, numbness, and tingling along the distribution of the nerve associated with

Luigi Galvani, 1737–1798. Italian Physicist.

H. J. Seddon, P. B. Medawar, H. Smith, Contemporaries Peripheral Nerve Injury Centre, Oxford.

Jules Tinel, Contemporary. Physician, Hôpital Beaujon, Paris.

neuralgic pain. Complete paralysis and wasting of muscles are uncommon unless the initial compression has been prolonged and severe, but when the compressing cause is progressive, paralysis can occur later and may then necessitate operative measures.

Treatment is by removal of the cause, usually a tight splint or plaster, but may necessitate exploration of the nerve and the excision of perineural scar tissue, or mobilisation of the nerve from callus, following which a new bed is prepared for the nerve in adjacent muscles, the nerve itself being wrapped in a layer of tantalum foil.

Sensory symptoms are satisfactorily relieved by these steps, but if intervention is delayed too long intraneural fibrosis may lead to persistent motor disability.

Progressive fibrosis produced by fixation of the nerve has to be treated by nerve transplantation (see p. 1042); recovery may be complete or incomplete, according to the degree of fibrosis.

NEUROTOMESIS

is usually produced by penetrating wounds and results in partial or complete division of the nerve sheath and fibres. Very rarely, complete rupture of nerves may occur in major plexus injuries. In war injuries extensive soft tissue damage to muscle and skin and associated fractures greatly complicate the problems of repair.

Partial lesions produce a lateral neuroma of the nerve. Complete division produces a terminal neuroma on the end of the proximal segment. In the proximal portion of the divided axons, retrograde degeneration occurs as high as the first node of Ranvier. After an interval of ten days the axons begin to subdivide to produce an excess of end bulbs, which then commence to grow downwards. By this time, however, the gap between the divided nerve ends, which was at first filled with blood, has now been replaced by organising clot and scar tissue, which presents an almost impenetrable barrier to the out-growing axons. In the distal segment of the divided nerve, Wallerian degeneration of the axons occurs, but the cells of the sheaths of Schwann proliferate, forming a slight bulb at the commencement of the distal end from which sprouts of Schwann cells grow proximally into the plane of division, being drawn by chemotaxis towards the down-growing axons. A few axons may by this means succeed in entering the distal segment, producing there a deceptively encouraging Tinel's sign, but any spontaneous healing is minimal.

Even after accurate nerve suture the quality of regeneration is less perfect than in cases of axonotmesis owing to the wastage of axons in the scar tissue at the suture line and mal-distribution of those fibres which reach the distal segment. The density of scar tissue at the suture line is increased by local sepsis and inflammation and by tension at the suture site.

Mal-distribution of fibres is greatest in the case of mixed motor and sensory nerves, for motor fibres may then grow to sensory endings. It is also greatest in those motor nerves which supply a large number of small muscles; hence

the quality of recovery is best in the case of a pure motor nerve, such as the musculospiral, which supplies a few groups of large muscles concerned in coarse movement, and is worst in mixed sensory and motor nerves supplying a large number of small muscles concerned in fine movement, such as the ulnar or median nerves at the wrist.

Treatment is by suture under suitable conditions, in the absence of sepsis and in the absence of tension, when the nerve can be placed in a suitable bed. In war injuries where there has been considerable loss of surface tissue, preliminary plastic operations such as pedicle grafting must precede attempted repair of the nerve in order to provide a suitable covering and bed at the suture site.

Open Wounds.—Until recently it was considered that unless infection was anticipated immediate primary suture was the ideal treatment for a divided nerve. Surgeons with special experience of these injuries now recommend that the wound should be treated on accepted lines, i.e. excision and closure if possible, but that the nerve suture should be postponed until three or four weeks after the injury. If a divided nerve is encountered during excision of the wound, the ends are approximated by one stitch of fine silk, which prevents retraction during the period of delay. On no account should an attempt be made to identify or scrutinise a nerve in the vicinity. If only one end of a nerve is seen, then a suture should be inserted so as to fix it to adjacent muscle or fascia.

The advantages of early secondary suture over immediate primary suture are as follows :

(i) Primary suture usually requires enlargement of the wound by further incisions, so as to mobilise the nerve in order to allow approximation of the ends without tension. As the wound is potentially infected, exposure of previously uncontaminated tissues should be avoided.

(ii) The normal nerve sheath is a delicate structure, which is easily torn by the slightest tension, and accurate suturing is essential for the success of the operation. In addition, the sheath is often further weakened by longitudinal slits or tears. After about three weeks of the injury, epineural fibrosis occurs and the sheath becomes thicker and tougher, consequently the insertion of sutures and accurate coaption of the nerve ends are greatly facilitated.

NERVE SUTURE

The two ends of the nerve are identified, the incision being prolonged sufficiently to expose the nerve well above and below the seat of injury, in such a position that its normal anatomical relations are not obscured by scar tissue. The two ends of the nerve are freed and 'freshened' by means of a scalpel or a Bard-Parker knife. Scissors should not be used, as the nerve is crushed thereby. Slices are removed from the ends of the nerve until the projecting fibres are seen, and blood freely oozes from the cut surface. Apposition of the two ends is accomplished by the following manœuvres :

(a) *Mobilisation.*—The two ends are dissected from surrounding structures, care being taken to preserve important motor branches. Branches can often be stripped from the parent nerve in order to facilitate mobilisation.

(b) *Posture.*—The limb being held in a suitable position.

(c) *Transposition*.—The radial nerve is brought in front of the humerus, or the ulnar nerve in front of the internal condyle (p. 1042).

(d) *Nerve Anchoring*.—If it is obvious that the two ends of a divided nerve cannot be brought together, on account of excessive loss of tissue or retraction, then the two untrimmed ends are approximated as closely as possible by tension stitches, the position of the limb being such that approximation is facilitated. Subsequently the nerve is stretched by gradually straightening the limb, and at a second operation the two ends are brought together. In some cases adequate suture can be performed while the limb is flexed, and extension is gradually regained.

(e) *Resection of Bone*.—This extensive procedure may be justifiable if nerve injury is associated with an ununited fracture, which also needs operative measures, e.g. in the case of the radial nerve and a fractured humerus.

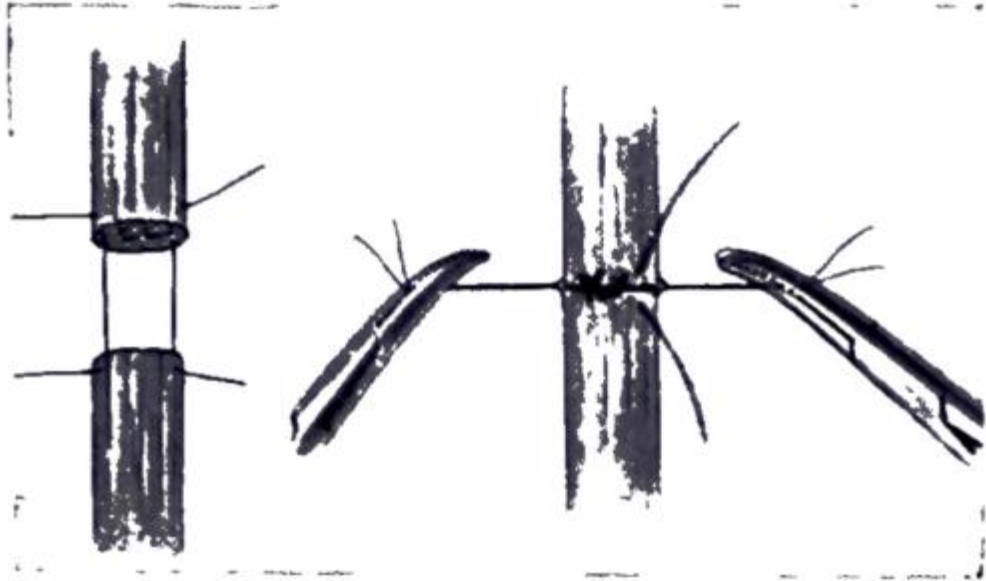


FIG. 1348.—Primary nerve suture. Two sutures are passed through the sheath of the nerve in order to approximate the cut ends. The sheath is then sutured.

Approximation having been obtained by one of the above procedures, sutures are introduced through the nerve sheath (fig. 1348). Non-irritating material is used, such as fine black silk or tantalum wire. Catgut encourages fibrosis of the nerve. The suture line can be further supported by painting with fibrin glue. Torsion of the nerve ends must be avoided, so that, as far as possible, proximal nerve fibres will join with their corresponding distal fibres. 'Shunting' is thus avoided, and delay due to re-education of groups of muscles is obviated. If adjacent tissues are fibrosed,

a new path can be constructed for the sutured nerve by opening a muscle sheath, and embedding the nerve among the muscle fibres. Finally, a layer of tantalum foil is always wrapped round the nerve to prevent epineural fibrosis and the out-sprouting of axons from the suture line, which may produce a painful local lesion. The limb is placed in a suitable position to prevent any strain on the sutured nerve, and a plaster cast may be advisable for a few weeks to immobilise the limb.

RESULTS OF NERVE SUTURE

This depends on many factors :

1. **Pre-operative**.—(a) *The Nerve Affected*.—Suture of nerves which supply muscles whose actions are intricate usually give disappointing results ; thus, recovery of palmar muscles, after suture of an ulnar nerve, may be negligible. On the other hand, muscles which perform coarse movements, e.g. those supplied by the radial nerve, often, to all appearances, recover completely. In addition, the radial nerve is mainly composed of motor fibres, hence there is little likelihood of motor fibres being 'shunted' into sensory ones, with consequent wastage.

(b) *Infection* not only causes delay before subsiding, but some degree of interstitial neuritis will result, and further damage to the nerve may be caused by contraction of surrounding scar tissue.

(c) *Time*.—Early secondary suture (p. 1033) yields the best results, and further delay is detrimental, but delay of up to six months is harmless if special measures are necessary to deal with sepsis or to prepare a suitable nerve bed.

(d) *Pre-operative Treatment*.—If muscles and tendons have been allowed to stretch or if the tone of the muscles has been neglected, then the chances of recovery are correspondingly diminished.

2. **Operative**.—This consists of attention to the details already mentioned, e.g. hæmostasis, prevention of torsion and tension, preparation of suitable bed, and the use of non-irritating suture material.

3. **Post-operative**.—(a) *Absence of Infection*.—If the wound is already infected, or if infection supervenes, or being already present lights up again, then little improvement is likely.

(b) *After-treatment* consists in continuance of the relaxation of paralysed muscles,

massage, electrical treatment, and muscular effort gradually increased as muscles recover their power.

(c) *Co-operation of the Patient*.—This important factor must receive due consideration and the patient given every encouragement during his long and tedious rehabilitation.

(d) *Vicarious Movements*.—Although the physiological results of nerve suture may be poor, yet adjacent muscles often take upon themselves some of the functions of those which are paralysed, e.g. if the hamstrings are paralysed and flexion of the knee thereby affected, the sartorius and gracilis muscles hypertrophy, and partially compensate for this deficiency. Thus the functional result of a nerve injury is often more satisfactory than the physiological recovery would suggest.

Irremediable Injury.—If suture is impossible on account of loss of tissue or wide separation of the ends of a divided nerve, the following procedures may be considered :

(a) *Nerve anastomosis*, e.g. part of the hypoglossal nerve is united to the distal end of the facial nerve. This method often results in improvement, but 'successful' cases are sometimes associated with uncontrolled grimaces on movement of the tongue.

(b) *Nerve grafting* has produced encouraging results in selected cases, e.g. a gap in the facial nerve within its bony channel may be bridged by insertion of an autograft from the external cutaneous nerve of the thigh. Grafting of peripheral nerves is disappointing.

(c) *Tendon transplantation*, e.g. in the case of radial paralysis, tendons and muscles of the forearm may be transplanted into the extensor group. However, if proper relaxation of the extensor muscles has been consistently maintained, drop wrist should not occur, as the extensor tendons will not be over-stretched.

(d) *Arthrodesis*, e.g. in the case of injury to the sciatic nerve, arthrodesis of the flail ankle joint will render it stable and rigid.

(e) *Amputation*, for persistent sores and ulcers on the foot, particularly if growth is impaired. Sympathetic ganglionectomy might first be tried (p. 1047).

Incomplete division of a nerve gives rise to a central or lateral neuroma. Effects vary according to the extent of the injury. Fibres supplying certain muscles are often constant in position, and hence are more liable to injury if their position exposes them to trauma. Thus partial division of the great sciatic nerve affects the external popliteal portion nine times more commonly than the internal popliteal, which passes down on the inner and deeper aspect of the great sciatic nerve.

Partial lesion of the median or internal popliteal nerves, or injury to their branches, may give rise to the distressing condition of *causalgia* (p. 1049).

Injection lesions are due to accidental injection of therapeutic agents. They are more common in tropical countries where amœbiasis, schistosomiasis, and malaria are treated by intramuscular injections. The sciatic and radial nerves are usually involved. Injections in the buttock should always be given into the upper and outer quadrant, and in the case of the arm into the upper half of the deltoid muscle.

SPINAL NERVES

Injuries of the **Cervical Plexus** are uncommon, although muscular branches, e.g. to the trapezius and sternomastoid muscles, are occasionally damaged (p. 1000).

The **Phrenic Nerve**, which arises from the third, fourth, and fifth cervical nerves, is commonly crushed in order to cause a temporary diaphragmatic paralysis and so reduce the size of the pleural cavity in such conditions as

bronchiectasis, tuberculosis, and also to diminish movement after repair of the diaphragm for a hernia.

Division of the nerve, as first practiced, frequently gave disappointing results, for an accessory phrenic nerve arising either from the fifth cervical nerve, or the nerve to the subclavius, is present in 20 to 30 per cent. of cases and joins the main nerve between the first rib and the root of the lung. Thus avulsion replaced division, the nerve being exposed and divided and the distal end withdrawn from the thorax. In modern practice the only operation ever performed by thoracic surgeons is the phrenic crush, which produces a temporary paralysis. Should the temporary paralysis produced by crushing prove to be insufficient, it is not difficult to recrunch the nerve.

Paralysis of the diaphragm secondary to malignant disease in the thorax is equally frequent on the right and left sides and is often due to direct invasion of the phrenic nerve by adjacent growth (fig. 1349). When phrenic



FIG. 1349.—Elevation of the diaphragm following involvement of the right phrenic nerve by extension of a malignant tumour.

paralysis is due to glandular metastases, it is almost always due to involvement of a node which lies alongside the phrenic nerve at the level of the pulmonary artery at the upper level of the hilum.

Brachial plexus lesions are either complete or partial (fig. 1350).

Complete lesions are rare, as an injury of sufficient severity to damage all the roots of the plexus will probably inflict fatal injuries on adjacent important structures.

In the event of a complete lesion, anæsthesia of the upper limb occurs except over areas supplied by the supra-acromial branches of the cervical plexus and the intercostohumeral nerve. Complete paralysis of arm usually distal to the site at which the nerve of Bell and the nerve to the rhomboids arise, and consequently the serratus magnus and rhomboid muscles escape.

Incomplete lesions, if due to stabs or cuts, are liable to affect any of the roots, the clinical features depending on the nerves divided. The commonest type of injury is due to traction or pressure, and affects either the upper or lower portions of the plexus.

Although the segmental innervation of the arm muscles is somewhat inconsistent, the following table summarises a distribution which is commonly accepted :

<i>Nerve</i>	<i>Muscles</i>
C.v . . .	Rhomboids, spinati, deltoid, teres minor, biceps, brachialis, brachioradialis, supinator brevis.
C.vi . . .	Pectoralis major (clavicular head) and minor, subscapularis, coracobrachialis, latissimus dorsi, teres major, serratus anterior, triceps, pronator teres, pronator quadratus.
C.vii . . .	The extensors of the fingers, extensor carpi ulnaris, and sternal part of the pectoralis major.
C.viii . . .	The flexors of the wrist and fingers.
D.i . . .	The small muscles of the hand.

Upper Lesion (Erb-Duchenne, fig. 1350 (1)).—This injury is due to excessive displacement of the head, depression of the shoulder, or a combination of these two conditions.

Thus, it not uncommonly occurs during a difficult confinement, and in adults may be due to weights falling on the shoulder, or more commonly to a motor-bicycle accident. The fifth and sometimes the sixth cervical roots are involved. In the former case the muscles affected are the biceps, brachialis, brachio-radialis, supinator brevis, spinati and deltoid, and thus the limb, internally rotated by the unopposed subscapularis, hangs by the side with the forearm pronated, in the well-known 'tip' position (fig. 1351). Sensory changes are absent if the fifth nerve only is involved, but if the sixth nerve also suffers, an area of anæsthesia is present over the outer side of the arm.

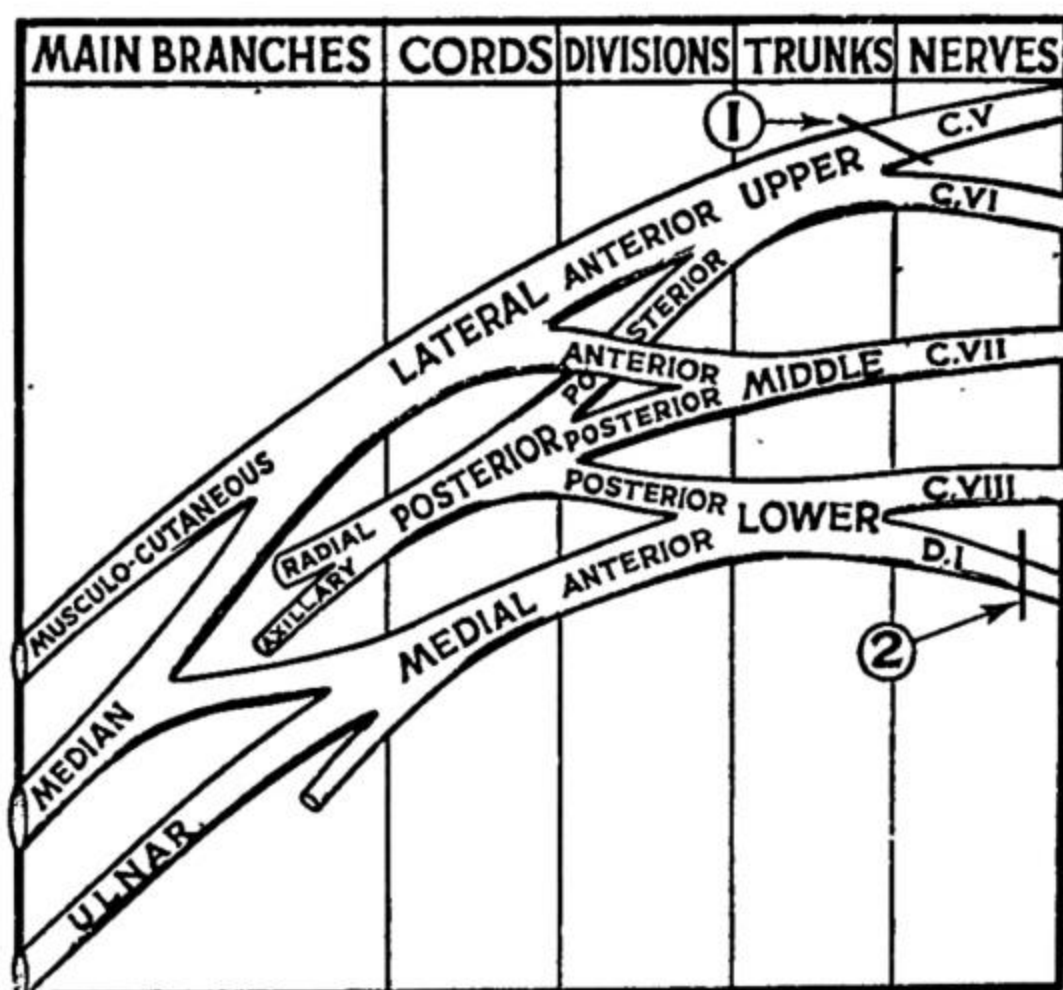


FIG. 1350.—The brachial plexus, showing two classical sites for injury—see text.

Lower Lesion (Klumpké, fig. 1350 (2)).—The lower nerve trunk or the inner cord are injured either above the clavicle, or classically by inclusion with the subclavian artery in a ligature, or in the axilla, as by an unreduced dislocation of the humerus. In either case, the inner portion of the plexus is involved, and wasting of all the small muscles of the hand occurs, together with sensory changes along the inner side of the forearm and the inner three and a half fingers, owing to involvement of the ulnar and inner head of the median nerves.



FIG. 1351.—Erb's paralysis.

Nerve roots may be avulsed from the spinal cord, as in the case of a falling person clutching at an object and hyper-abducting his arm, e.g. failing to obtain a foothold on a passing bus. The first dorsal root is usually affected. Paralysis of the intrinsic muscles of the hand results, with anæsthesia of the inner three and a half fingers in front, and inner one and a half behind. In addition, the oculopupillary fibres, which pass along the dorsal nerves to the rami communicantes, and so to the cervical sympathetic, are also affected, and Horner's syndrome follows (p. 1052). Hæmorrhage sometimes occurs in the spinal cord following avulsion of the nerve root, and results in damage to the pyramidal tract and consequent spasticity of the leg on the same side.

Treatment.—Subcutaneous injuries are at first treated on expectant lines, paralysed muscles being relaxed. Thus, in the case of an Erb's paralysis, the arm should be fixed in a position of right-angled abduction and eversion,

William Erb, 1840-1921. Professor of Medicine at Heidelberg.
Guillaume Duchenne, 1806-1875. Practised Medicine in Boulogne and Paris.
Madame A. Déjérine-Klumpké, 1859-1927. A Neurologist of Paris.
Friedrich Horner, 1831-1886, Professor of Ophthalmology, Zürich, described his syndrome in 1864.

to relax the deltoid and spinati, the forearm being flexed and supinated in order to relax the biceps, brachialis, and supinators. In serious brachial plexus lesions, physiotherapy must be continued for two years before recovery is assessed.

Some minor improvement usually occurs during this time, especially if the initial loss of function has been due to neurapraxia and stretching rather than rupture of nerve fibres. When fibres have been ruptured, a great deal of mal-distribution of down-growing fibres among the complex plexus branches is bound to result in considerable reduction of functional efficiency. Where the nerve tracts are torn across (neurotmesis) little recovery is to be expected, and such cases are not improved by exploration of the brachial plexus, an account of which is appended.

The brachial plexus is exposed by an incision along the posterior border of the sternomastoid. If necessary the incision may be carried backwards along the middle third of the clavicle or, if complete exposure of the plexus is desirable, the original incision is prolonged over the clavicle, which is drilled for subsequent wiring, and divided. The weight of the arm separates the ends of the divided clavicle, and the plexus is freely exposed. Three difficulties now confront the surgeon—identification, approximation, and accurate suturing.

Identification is hampered by fibrosis and matting together of structures by organisation of extravasated blood. When torn nerves are recognised and dissected from their fibrous bed, approximation is difficult on account of retraction, and posture can give but limited assistance. Finally, rupture commonly occurs where nerves fuse or divide, so that accurate suture is a difficult problem in that it may be necessary to suture two roots to one trunk.

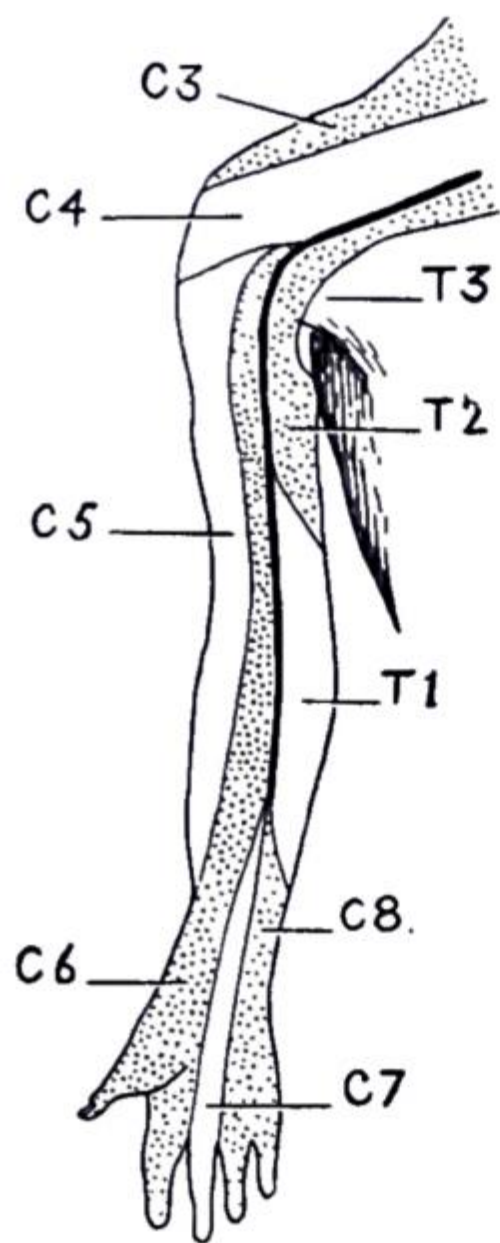


FIG. 1352.—The dermatomes of the upper limb.

BRACHIAL NEURALGIA

This condition (*syn.* brachial neuritis) is comparable to sciatica in the leg. The cutaneous distribution of the cervical nerves is illustrated in fig. 1352, and the muscular innervation is summarised on p. 1036. Some of the more important causes of brachial neuralgia are as follows :

Spinal tumour (p. 1014).—Evidence of pressure on the cord is usually present, and Queckenstedt's test is commonly positive.

Prolapsed intervertebral disc (p. 1022) is often difficult to distinguish from osteoarthritis, but localised pain in the neck, which often appears suddenly and which is aggravated by coughing, suggests a disc lesion.

Osteoarthritis of the cervical spine causes neuralgia either as a result of pressure on a spinal nerve by an osteophyte or from absorption of the disc and consequent compression of the spinal roots. The onset is gradual and symptoms intermittent, and radiography usually establishes the diagnosis.

Costo-clavicular syndromes are due to many conditions (p. 193). Sagging of the shoulder girdle, especially in middle-aged females, is a common

cause, quite apart from cervical rib. Exercises and physiotherapy directed to improving the tone of muscles which elevate the shoulder may relieve the symptoms in such cases.

PERIPHERAL NERVES

The **Circumflex Nerve** passes through the quadrilateral space, and winds around the shaft of the humerus about one finger's-breadth below the centre of the deltoid muscle. It is sometimes injured by a direct blow, or involved by a fracture or dislocation of the humerus.

The deltoid muscle is paralysed and wastes rapidly (fig. 1353), and a patch of anæsthesia over the outer side of the arm distinguishes this condition from a partial lesion of the fifth cervical nerve. Paralysis of the *teres minor* is unrecognisable clinically.

Recovery commences in a few weeks if the cause of the compression is removed, provided that the arm has been supported in right-angled abduction.

The **Nerve of Bell**, or external respiratory nerve, arises from the fifth, sixth, and seventh cervical nerve roots. It may be injured by blows or carrying a heavy object on the shoulder, or during operations on the breast or chest wall, as it lies on the inner wall of the axilla.

Paralysis of the *serratus anterior* allows 'winging' of the scapula, i.e. the vertebral border and inferior angle are unduly prominent (fig. 1354). The 'lunge' stroke of fencing is dependent on the *serratus anterior*, and this and similar movements, such as pushing forward with the arm, are deficient. Owing to inability to rotate the scapula on the chest wall, difficulty is experienced in raising the arm above a right angle from a position in front of the body.



FIG. 1354.—Winging of the scapula; the patient is pushing against a wall.

Suture of the nerve is sometimes possible. Otherwise, if disability warrants such a procedure, the scapula is steadied by a slip of *pectoralis major* muscle, which is detached from the humerus and fixed to the inferior angle of the scapula.

The **Radial** or musculospiral nerve is commonly injured. The classical sites are the axilla and the radial groove.

I. Injury in the **axilla** follows:

(i) Crutch palsy: all crutches should have hand-grips, and their length should be carefully adjusted, especially if use is likely to be prolonged. Paresis has occurred after only four hours' use with crutches unsupplied with hand-grips.

(ii) Fractures and dislocations of the upper end of the humerus, or by attempts at their reduction.

(iii) Rarely by pressure of an aneurysm or new-growth.



FIG. 1353.—Wasting of the left deltoid muscle due to bruising of the circumflex nerve.

Clinical Features.—(a) *Motor.*—The triceps and extensors of the wrist and fingers are paralysed, and consequently inability to extend the elbow, wrist, and fingers results, and drop wrist is present. If the hand is supported, as by resting it upon the table, extension of the fingers can be produced by the action of the lumbricals and interossei, which are inserted into the extensor expansions. The supinator and brachio-radialis are also paralysed, but supination is ably performed by the biceps. The brachio-radialis muscle is tested readily by endeavouring to flex the semi-prone forearm against resistance. If the muscle is active, the contraction is visible, and the rigid muscle is easily palpable.

(b) *Sensory.*—Anæsthesia is commonly present over the back of the hand, thumb, and outer two and a half fingers, with the exception of the nail-beds, which are supplied by the median nerve, but this area of anæsthesia is sometimes reduced to a patch over the ball of the thumb, owing to overlap by the musculocutaneous nerve.

(c) *Trophic.*—These are usually trivial.

2. Injury in the **radial** groove is due to :

(i) Pressure, e.g. of the arm on the edge of the operating table, especially in Trendelenburg's position, or as in 'Saturday night' paralysis, due to the enjoyment of a heavy sleep with the arm over the sharp back of a kitchen chair. Prolonged application of a tourniquet is especially liable to compress the radial nerve, as it lies close to the bone, and possibly the median and ulnar nerves as well. For this reason a sphygmomanometer should always be used on the arm.

(ii) Fracture of the shaft of the humerus, immediate involvement of the nerve occurring in about 8 per cent. of cases. It is often overlooked owing to the more obvious fracture overshadowing the nerve injury, in which case involvement in callus is usually blamed, rather than oversight on the part of the surgeon.

(iii) The nerve is liable to be overstretched during operations on the humerus, e.g. in dealing with an ununited fracture.

(iv) 'Intramuscular' injections of drugs have been given into the radial nerve.

Clinical Features.—(a) *Motor.*—These are similar to those following injury in the axilla, except that the triceps and anconeus muscles escape.

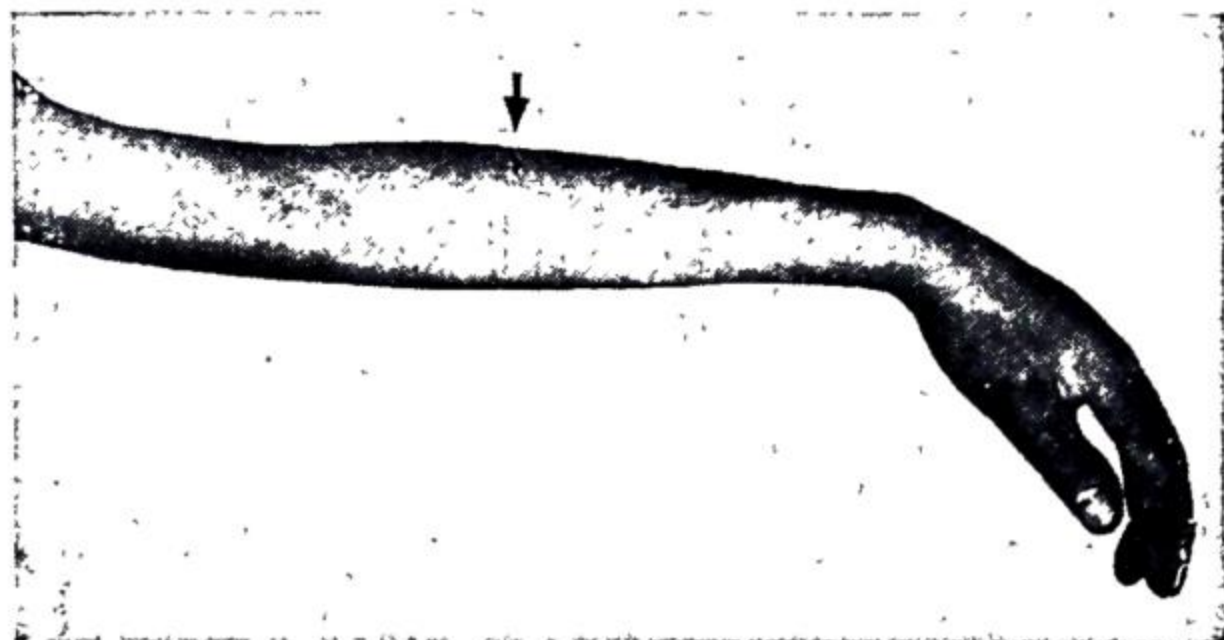
(b) *Sensory.*—If the external cutaneous branch escapes, anæsthesia will be limited to a patch over the ball of the thumb. Division of the radial nerve in the upper third of the forearm is symptomless. Below this position the musculocutaneous nerve joins the radial, and division then causes anæsthesia over the ball of the thumb.

(c) *Trophic.*—These are slight.

The *posterior interosseous nerve* may be injured as a result of fracture or dislocation of the upper end of the radius, or in operations performed to deal with these conditions. Paralysis of the extensors of the wrist and fingers results (fig. 1355). The upper end of the nerve has been sutured with excellent results. If nerve repair is impracticable, good results are obtained by tendon and muscle transplant, e.g. the radial carpal flexor is transplanted to

the extensor tendons of the thumb and fingers, and the pronator teres into the extensors carpi radialis longus and brevis.

FIG. 1355.—Wrist-drop following an incised wound which divided the posterior interosseous nerve. The wound is indicated by the arrow.



The **Median Nerve** is classically injured at the wrist or elbow.

1. Injuries at the **elbow** are due to fractures of the lower end of the humerus or dislocations of the elbow joint. A tourniquet endangers the nerve at any level in the arm, in which case other nerves, particularly the radial, will also be involved.

Clinical Features.—(a) *Motor.*—The pronators of the forearm and flexors of the wrist and fingers, with the exception of the flexor carpi ulnaris and the inner part of the flexor profundus digitorum, will be paralysed. As a result of paralysis of the flexor carpi radialis, the hand deviates to the ulnar side when flexed against resistance. The index finger cannot be flexed at the phalangeal joints—the ‘pointing index’—but flexion of the other fingers is performed by that portion of the flexor profundus digitorum which is supplied by the ulnar nerve. Flexion of the terminal phalanx of the thumb is impossible, owing to paralysis of the flexor longus pollicis. The muscles of the thenar eminence are wasted and paralysed, and on inspection the eminence is flattened, so that the metacarpal bone of the thumb is apparently on the same plane as the other metacarpal bones—the so-called ‘simian’ or ‘ape-like’ hand. Paralysis of the two outer lumbricals is unrecognisable.

(b) *Sensory.*—Appreciation of touch is lost over the thumb and outer two and a half fingers in front, and posteriorly as far proximally as the middle of the proximal phalanges. Loss of response to pin-prick affects the terminal phalanges of the index and middle fingers, but sometimes a larger area is involved. Deep sensibility is lost over the terminal phalanges of the index and middle fingers.

(c) *Trophic.*—Obvious trophic changes are usually seen in the hand and affected fingers. Severe causalgia may complicate partial injuries (see p. 1049).

2. Injuries at the **wrist** are comparatively common, and are due to cuts from a variety of causes. Fractures of the lower end of the radius or dislocation of the semilunar bone sometimes cause injury to the median nerve.

Clinical Features.—(a) *Motor.*—The muscles of the thenar eminence are paralysed and wasted. The hand is ‘simian,’ and abduction and opposition of the thumb are lost. Attempts to oppose the tip of the thumb

to the tip of the little finger result in flexion and adduction of the thumb, as the patient is unable to swing it across the palm.

(b) *Sensory*.—Sensory losses resemble those following an injury at the elbow. Muscular sense is not impaired if tendons are not severed. Thus, as no striking muscular deficiency occurs, and as no part of the hand is completely anæsthetic, a divided median nerve at the wrist is readily overlooked, particularly in those who use refinements of sensation but little, e.g. a horny-handed labourer.

(c) *Trophic*.—These occur, as with an injury at the elbow.

The poor prognosis of a divided median nerve is rendered even more gloomy if tendons are also severed.

Median compression occasionally occurs as the nerve passes through the carpal tunnel. Paræsthesia, followed by wasting of the thenar muscles, suggests the diagnosis. Relief is obtained by division of the anterior annular ligament.

The **Ulnar Nerve** is also classically injured at the elbow and wrist.

I. Injuries at the **elbow** are due to the following causes :

- (i) Fractures in the region of the internal condyle.
- (ii) Excision of the elbow joint.
- (iii) Cubitus valgus, due to old injury of the humerus and increase of the 'carrying angle.' Hence the nerve is unduly exposed, and friction occurs as the groove on the internal condyle becomes a pulley, and this continuous friction results in interstitial neuritis. This condition may occur many years after the original injury, and transposition of the nerve is required.

Anterior transposition of the ulnar nerve is sometimes required for friction (axonotmesis), following fracture of the internal condyle, pressure by an osteophyte, or recurrent dislocation of the nerve, and injury which results in loss of substance, so that approximation is thus rendered possible. The nerve is exposed by a curved incision with the concavity forwards, and the humeral head of the flexor carpi ulnaris is divided. Careful dissection is necessary so as to avoid injury to motor branches, and the internal intermuscular septum should be divided or excised, otherwise the nerve may be kinked by this structure when it is displaced forwards. A bed is then prepared in the flexor group of muscles and the nerve buried therein (fig. 1356).

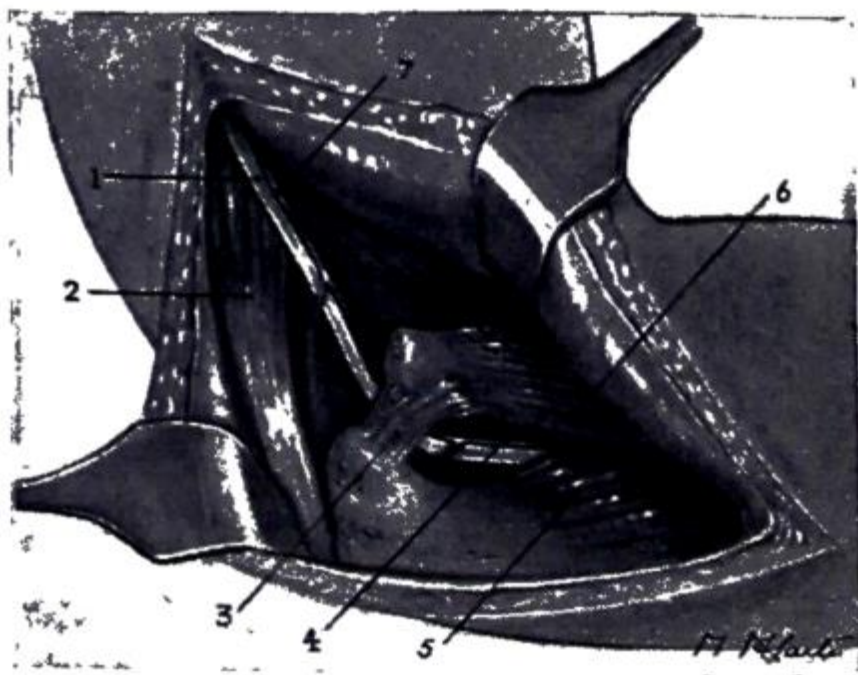


FIG. 1356.—Anterior transposition of the left ulnar nerve.

1. Ulnar nerve.
 2. Triceps.
 3. Olecranon head of flexor carpi ulnaris.
 4. Posterior ulnar recurrent artery.
 5. Flexor profundus digitorum.
 6. Superficial flexor muscles.
 7. Inferior profunda artery.
- (The dotted line represents the new course of the nerve.)

Clinical Features.—(a) *Motor*.—The flexor carpi ulnaris and inner portion of the flexor profundus digitorum are paralysed. Normally, on flexion of the wrist, the tendon of the flexor carpi ulnaris is readily palpable just above its insertion into the pisiform bone, but when the muscle is paralysed the tendon is impalpable, and wasting causes flattening of the

inner border of the forearm. Weakness of the flexor profundus digitorum results in hyperextension of the little, ring, and slightly of the middle fingers at the metacarpophalangeal joints.

Paralysis of the small muscles of the hand also results, with the exception of the thenar muscles and outer two lumbricals. Inability to abduct and adduct the fingers results, and the patient cannot grip a piece of paper placed between the fingers (fig. 1357). If the patient pinches a piece of paper between his thumb and fingers the terminal phalanx of the thumb assumes a flexed position, as weakness of the adductor pollicis permits over-action of the long flexor of the thumb (Froment's sign). Considerable wasting occurs, which

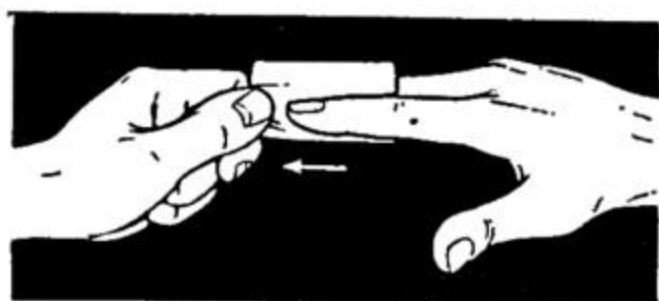


FIG. 1357.—Test for weakness of the interosseous muscles.

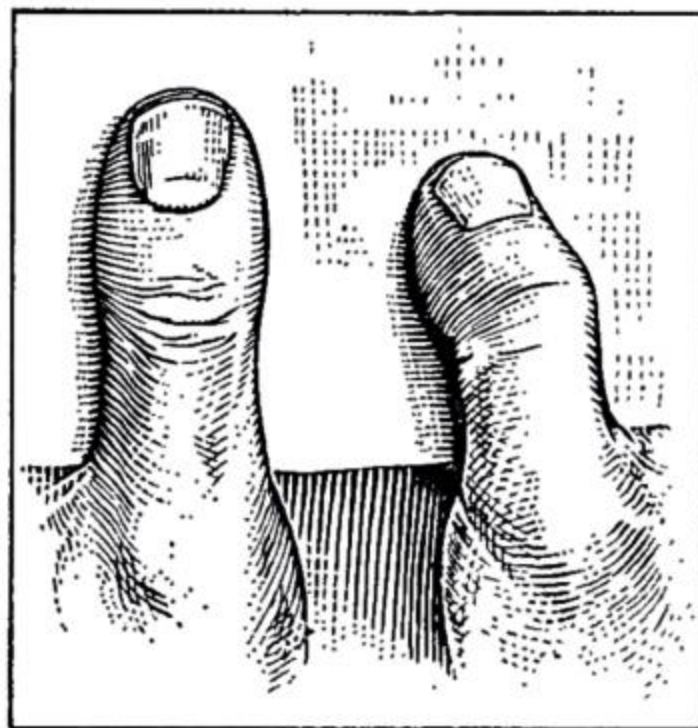


FIG. 1358.—Froment's sign for right ulnar paresis.

is obvious in the interosseous spaces and along the inner border of the hand, the normal curve being lost (fig. 1359).

(b) *Sensory*.—The appreciation of light touch is lost over the inner one and a half fingers in front and behind. Response to pin-prick is lost over the little finger and ulnar border of the palm.

(c) *Trophic*.—These changes are usually well marked.

2. Injury at the **wrist** is due to the same causes as those enumerated in connection with the median nerve. The ulnar nerve passes in front of the anterior annular ligament, and is damaged by more superficial injuries.

Clinical Features.—(a) *Motor*.—Paralysis and wasting of small muscles of the hand, as described above.

(b) *Sensory*.—The dorsal cutaneous branch of the ulnar nerve leaves the main trunk about $2\frac{1}{2}$ inches (6.25 cm.) above the styloid process of the ulna. Sensation is therefore lost only on the anterior aspect of the inner one and a half fingers.

(c) *Trophic*.—Correspond to the area of sensory loss.

The **Twelfth Dorsal Nerve**, as in the case of the intercostal nerves, is sometimes implicated by severe neuralgia, which may be associated with herpes zoster. More commonly the nerve is implicated by a suture during a kidney operation, or by subsequent scar tissue. Resulting pain is occasionally sufficiently severe to necessitate exposure and excision of part of the nerve.



FIG. 1359. — Wasting of the hypothenar eminence following injury to the left ulnar nerve.

The **Ilio-inguinal Nerve** may be damaged on the right side in a gridiron incision for appendicectomy, although with care the nerve should be avoided. If drainage tubes are inserted through this incision, the resulting scar tissue may implicate the nerve. On the left side, injury to the nerve may follow iliac colostomy. Weakness of the conjoined tendon results, with consequent predisposition to the formation of an inguinal hernia (fig. 1360).



FIG. 1360.—An inguinal hernia which followed appendicectomy with drainage through a gridiron incision one year previously.

The **External Cutaneous Nerve** is occasionally compressed as it passes through the deep fascia of the thigh, especially in muscular subjects, e.g. rowers. The condition is termed meralgia paræsthetica, and resection of part of the nerve is sometimes necessary to rid the patient of pain or paræsthesia.

The **Sciatic Nerve** is occasionally injured by wounds, fractures, or 'intramuscular' injection of drugs. The component nerves in the pelvis may be involved by fracture, tumour, or aneurysm. Injury in the upper part of the thigh sometimes complicates deep wounds or posterior dislocation of the hip joint. If the lesion is above the origin of branches to the hamstrings, the following features will be present:

(a) *Motor*.—The flexors of the knee are paralysed, but some degree of flexion is possible owing to the action of the sartorius and gracilis muscles. Complete paralysis exists below the knee, and drop foot results from gravity.

(b) *Sensory*.—Complete loss below the knee, with the exception of the skin supplied by the long saphenous nerve, i.e. a strip along the inner side of the leg extending along the inner border of the foot to the ball of the big toe.

(c) *Trophic*.—Especially on the sole of the foot and toes.

(d) Causalgia may complicate partial lesions.

Partial involvement of the sciatic nerve affects the external popliteal portion nine times as commonly as the internal popliteal (p. 1035).

A fibrous band, which arises from the sacro-sciatic notch and reinforces the origin of the gluteus minimus muscle, occasionally causes pressure on the sciatic nerve, and consequent sciatica. The condition is analogous to a cervical rib exerting pressure on the brachial plexus, and when other causes of sciatica, notably a prolapsed disc, have been excluded, a search for the band beneath the pyriformis is justifiable.

The **External Popliteal Nerve** is injured as follows :

- (i) Subcutaneous tenotomy of the biceps tendon.
- (ii) Fracture or excision of the upper end of the fibula.
- (iii) Pressure from plasters or splints.

Clinical Features.—(a) *Motor*.—Complete paralysis of the extensor and peroneal groups of muscles, with resulting talipes equino-varus.

(b) *Sensory*.—Anæsthesia on the outer side of the leg in its lower two-thirds, and of the dorsal aspects of all the toes, with the exception of the outer side of the little toe, which is supplied by the external saphenous (sural) nerve, as one contributory branch—the sural communicating from the internal popliteal nerve—escapes.

(c) *Trophic*.—Corresponding to the sensory loss.

The **Internal Popliteal Nerve** is but rarely injured on account of its protected position. The calf muscles and muscles of the sole are paralysed, and talipes calcaneo-valgus may result. The sole is anæsthetic, and trophic changes are usually severe. Causalgia occasionally follows a partial injury of the nerve or injury to one of its branches.

THE SYMPATHETIC NERVOUS SYSTEM

Anatomy.—The sympathetic nervous system is composed of preganglionic fibres, ganglionated trunks, and postganglionic fibres.

Preganglionic fibres are axons of the 'connector' cells situated in the lateral horns, which are present in the grey matter of the dorsal and upper two or three lumbar segments of the spinal cord. These fibres are medullated and pass from the anterior roots of the dorsal and upper lumbar spinal nerves (white rami communicantes) and join the ganglionated trunk. Here some form synapses, while others pass through the ganglia to reach visceral ganglia and plexuses. Certain preganglionic fibres pass to the medulla of the suprarenal gland (which is developed from nerve tissue, the medulla itself representing the synapse and postganglionic fibres).

The **ganglionated trunks** of the sympathetic lie upon the sides of the bodies of the vertebræ, and extend from the skull to the coccyx. There are three cervical ganglia—Superior, Middle, and Inferior. Twelve dorsal ganglia, of which the upper is fused with the inferior cervical ganglion to form the stellate. Four lumbar ganglia and several small ganglia arranged in the pelvis as far down as the fifth piece of the sacrum where the ganglionated trunks fuse and terminate. In addition to the ganglionated trunks visceral ganglia also exist and are innervated by respective splanchnic branches—cervical, thoracic, and lumbar—which contain preganglionic fibres which have traversed the ganglia of the sympathetic cord.

The **postganglionic** or second relay of fibres are nonmedullated, and originate in the trunk and visceral ganglia from cells (termed excitor cells) which form synapses with the preganglionic fibres. These postganglionic fibres innervate the sweat glands, pilomotor muscles, vessels, viscera, and other structures influenced by the sympathetic system and are chiefly distributed through the medium of the grey rami communicantes which return from the ganglia of the sympathetic trunk to the corresponding spinal nerves. Other postganglionic fibres pass inwards to the aorta to constitute the periaortic plexus and others run up or down within the sympathetic chain to join the branches of the great plexuses through which they are distributed to the upper and lower extremities. The level of the sixth dorsal spinal segment represents the plane of separation between the fibres distributed to the head and upper extremities and those passing to the lower portion of the trunk and lower extremities. Fibres from the first thoracic rami pass up through the cervical sympathetic chain to the superior cervical ganglion to innervate the structures of the head, eye, and cranial vessels. Lesions of the first thoracic root thus cause a Horner's Syndrome with contracted pupil and enophthalmus. Fibres from the first to the sixth ganglion pass upwards through the stellate and middle cervical ganglion to be distributed to the branches of the brachial plexus in which they are carried into the limbs to be eventually distributed to the arterioles and peripheral structures constituting the main sympathetic supply to the limb. The proximal portion of the limb vessels are innervated only by fibres carried peripherally from the periaortic plexus in the tunica adventitia; this plexus is later reinforced from peripheral nerves. The fibres on the roots of the great vessels play very little part in limb innervation, hence the fact that periarterial sympathectomy on the main vessel has far less influence on the local circulation than ganglionectomy or sympathetic trunk section which will interrupt the main sympathetic distribution passing to join the peripheral nerves through the limb plexus. A similar distribution occurs below the level of the sixth thoracic segment fibres passing downwards through the lumbar and sacral chains to be distributed to the lumbar and sacral plexus, the peripheral branches of which reinforce the fibres carried into the tunica adventitia of the femoral artery from the lower portion of the periaortic plexus.

Splanchnic branches are distributed as preganglionic white rami which have passed through the ganglia of the cervical dorsal and lumbar chains. Fibres derived from the second, third, and fourth thoracic segments pass up to the superior middle and inferior cervical ganglia to be distributed as the cervical splanchnics to the heart and lungs. Fibres from the fifth to the ninth thoracic segments enter the great splanchnic, from the tenth and eleventh thoracic segments, the lesser splanchnics, and twelfth, the least splanchnic, which innervate the cœlic and superior mesenteric ganglia. The branches from the upper two lumbar ganglia constitute the lumbar splanchnic nerves which pass to the inferior mesenteric ganglion. The downward prolongation of the periaortic plexus constitutes the presacral nerve. A central sympathetic controlling centre exists in the posterior two-thirds of the hypothalamus and is influenced by stimuli from the frontal areas and elsewhere. Clinical evidence shows that a tumour which interferes with the anterior and superior portions of the thalami causes sympathetic derangement (Penfield).

The function of the sympathetic nervous system is to deal with emotional and psychological emergencies. It is designed to prepare the animal for defence. Thus the blood pressure is raised and pulse-rate increased so as to maintain the circulation at a high pitch of efficiency, and contraction of the spleen forces additional red cells into the circulation so as to assist in oxygenation, which is supplemented by dilatation of the bronchioles. The pilomotor muscles contract and cause the hair 'to stand on end,' which is a useful phenomenon in the case of an animal, as its apparent size and ferocity are increased. In order to maintain muscular efficiency, glucose is set free from the liver, and exophthalmos and dilatation of the pupil widen the visual fields. The unstriped muscle of the intestine is inhibited in order to prevent waste of energy by peristalsis, and sphincters are contracted. Sweating assists in preventing a wasteful rise of temperature. The supply of adrenalin is increased so that the reaction already commenced by stimulation of the sympathetic is augmented and maintained.

The **parasympathetic system**, controlled from a centre in the anterior third of the hypothalamus, has its outflow in branches of the cranial nerves, the posterior nerve root, vasodilators, and sacral branches of distribution. Mass parasympathetic action induces the phenomena observed in sleep.

Cranial parasympathetic fibres pass to the pupil, salivary glands, the heart, and alimentary canal, including its developmental outgrowths, i.e. lungs, liver, and pancreas. Parasympathetic impulses stimulate the secretion of saliva and cause contraction of the pupil. It is secretory and motor to the alimentary canal, and inhibitory to the heart.

The sacral portion of the parasympathetic system is concerned with the "emptying processes." Thus it supplies motor impulses to the rectum and bladder, and is concerned with penile erection.

The above summary explains two important clinical observations. Firstly, in cases of ileus a spinal anæsthetic frequently results in a copious motion, and in doubtful cases the effect of a spinal anæsthetic is a useful method of discriminating between mechanical and paralytic obstruction. The beneficial effects of spinal anæsthesia are due to paralysis of the inhibitory sympathetic fibres, with the result that the motor parasympathetic impulses are unopposed.

Secondly, the fall of blood pressure which occurs during spinal anæsthesia is due to paralysis of the vasoconstrictor nerves. This can be to some extent counteracted by an intramuscular injection of ephedrine gr. $\frac{1}{2}$ to $\frac{3}{4}$ (30 to 45 mg.).

INDICATIONS FOR OPERATION

I. To Improve Circulation

Sympathectomy by removing the influence of vasoconstrictor fibres will allow dilatation of the arterioles with consequent increase in the speed of blood flow through the capillaries. Since this leads to washing out of metabolites, the capillaries become constricted and hence the limb is warm and dry and pale. Pathological changes in the walls of the arterioles may seriously impair their capacity for dilatation and therefore pre-operative tests

are necessary in order to estimate the degree of improvement likely to be obtained by operation.

Tests for Vasodilatation

(i) *Spinal Anæsthesia*.—A spinal anæsthetic which reaches the level of the sixth dorsal segment will inhibit vasoconstrictor impulses to the legs. A precise temperature record is obtained by means of thermocouples or special skin thermometers which are attached to the toes and dorsum of the foot. After the limbs have been cooled to an even temperature in a cool room for ten to fifteen minutes to produce a basic level, a novocaine injection is administered and the resulting change in temperature is recorded at two-minute intervals and charted.

(ii) *Paravertebral Block*.—Sympathetic fibres to the upper limb can be anæsthetised by injection from behind of 5 ml. of 1 per cent. novocaine below the neck of the first and second ribs; the stellate and upper dorsal ganglia are then blocked, vasoconstrictor to the arm are interrupted. This effect may, however, be more easily obtained by heating the body.

(iii) *Heating the Body*.—The patient sits in a chamber constructed of non-conducting material so that his head and wrists or ankles protrude, the basis of the investigation being the estimation of the reflex dilatation produced by heating the body. The hands are cooled by immersion in water at 15° C. (59° F.), the temperature of the room being maintained at that level, and the patient is sealed in the chamber. The temperature of the chamber is raised to 50° C. (122° F.), and by means of an electric thermometer the effect upon the peripheral circulation is accurately estimated.

Thrombo-angitis Obliterans.—Juvenile obliterative arteritis (*syn.* Buerger's disease) is a progressive vasospastic condition (erroneously stated to be more common in Russian Jews) occurring in patients before the age of thirty. It affects mainly the lower limbs, usually terminates in gangrene, and is associated with severe pain and sometimes with intermittent claudication. Two factors are present—vasospasm, and thickening and inflammatory changes in the arterial wall and veins which may progress to obliteration. There appears to be a direct relationship to tobacco consumption. It is possible that spasm, by interfering with circulation through the vasa vasorum, may increase the changes in the arterial walls owing to defective nutrition.

A similar obliterative condition involving the arteries without involving veins in patients over the age of thirty is attributable to presenile arteriosclerosis.

Examination will reveal reduction of peripheral pulses. The leg blanches and the veins empty on elevation of the limb owing to the deficiency of arterial blood flow. Differential diagnosis is important in distinguishing more favourable conditions, for example, the popliteal thrombosis attributable to presenile arteriosclerosis which will also provoke intermittent claudication of the calf, but in which the proximal pulses of the femoral or popliteal artery are affected whereas the peripheral pulses of the dorsalis pedis and posterior tibial arteries are maintained by collateral circulation and limb nutrition is good. Femoral arteriography serves to distinguish the two conditions.

Treatment.—In early cases measures are taken to preserve the nutrition of the limb and to keep the patient ambulatory. Warm stockings, avoidance of trauma to the feet, and gentle exercise within the limit of tolerance are important. If vasodilatation tests are satisfactory, lumbar ganglionectomy should be performed early in cases of thrombo-angitis in order to relieve

Leo Buerger, 1879-1943, American Urologist of Austrian birth, Mount Sinai Hospital, New York, described his eponymous disease in 1908.

pain and spasm and promote the healing of ulcers. Prognosis is to be guarded. Many cases after remarkable initial improvement in skin nutrition are apt to relapse although pain is usually relieved at first. In young subjects ulceration and gangrene eventually necessitate amputation. The prognosis in the young patient is always worse than in the older subject in whom arteriosclerosis runs a less progressive course. Total abstinence from smoking is imperative.

Early cases of arterial spasm are sometimes improved by Padutin (Bayer Products, Ltd.). This is an active dilator substance, and is administered orally or intravenously. Another popular preparation is Priscol. Arteriosclerotic claudication is often ameliorated by lumbar ganglionectomy if the skin temperature rises with reflex heating. Thrombosis of the popliteal artery does not respond to treatment by lumbar ganglionectomy but the pain of claudication may be relieved by spinothalamic tractotomy. Suitable cases may be cured by a by-pass arterial graft.

Raynaud's Disease is a spasmodic condition occurring in women, which affects the upper extremities more than the lower and in which the peripheral pulses are normal. The condition may also affect the feet, and infrequently, the ears and nose. The condition is attributable to abnormal sensitivity in the direct response of the arterioles to cold. When cooled these vessels go into spasm. As a result the part becomes blanched and incapable of finer movement. The decreased blood flow leads to an accumulation of metabolites in the capillary circulation. The capillaries dilate and become filled with slowly flowing disoxygenated blood, the part therefore becomes swollen and dusky. As the attack passes off the arterioles relax, oxygenated blood returns into the dilated capillaries, the hands become red and a burning sensation or pain is produced by increase in tissue tension, thus accounting for the characteristic sequence of blanching, dusky anoxia, and red engorgement. Eventually obliterative changes occur in the peripheral vessels, superficial necrosis occurs, the tips of the fingers undergo dry gangrene, and the distal parts of the terminal phalanges are absorbed. In some cases scleroderma affects the hands and face. Early cases of Raynaud's disease must be distinguished from chilblains and vascular disturbances which are sometimes associated with the costoclavicular syndrome.

The immediate results of ganglionectomy in Raynaud's disease are good, but after a few months the susceptibility to cold returns, although cyanosis is not so severe as before the operation, and subjective symptoms are less marked. This partial relapse is an indication that the underlying cause of Raynaud's disease is not in the sympathetic system, but is due to some abnormality in the smaller arteries and arterioles; sympathectomy apparently raises the threshold at which spasm occurs. From the practical point of view preganglionic section of the thoracic sympathetic chain can be recommended as a palliative procedure in Raynaud's disease, especially if performed before the onset of scleroderma, ulceration, and absorption of the terminal phalanges. The sympathetic trunk is divided below the third thoracic ganglion and the rami communicants of the second and third ganglia are severed.

Infantile paralysis.—The improvement in the circulation which follows ganglionectomy is said to encourage growth in the limb of a growing child. This is

doubtful, but trophic sores and ulcers are encouraged to heal and also the areas of fat necrosis over the calf. In *erythrocyanosis frigida*, a condition in which young girls develop painful nodules like chilblains over the calf, similar benefit is obtained. This condition, at one time designated Bazins disease, was erroneously thought to be due to tuberculous infection owing to the presence of giant cells of foreign body type laden with saponified fat found on section of the subcutaneous nodules.

Selected cases of scleroderma, in which the hands and face are principally affected, are improved by cervico-thoracic ganglionectomy. The pain and stiffness of polyarticular osteoarthritis are alleviated by a suitable ganglionectomy. Callous ulcers, such as those associated with trophic lesions or leprosy, sometimes respond to periarterial neurectomy, and indolent ulcers of the face often improve after excision of the superior cervical ganglion.

Perniosis may cause such disablement that sympathectomy is indicated, especially when the chilblains affect the toes.

II. Painful Conditions

In hollow viscera, pain is probably caused by stretching of the muscular coat resulting from intravisceral tension, and similarly increased tension in solid viscera stretches the fibrous capsule.

Visceral Pain.—Bladder.—The constant wearying pain of chronic cystitis is relieved by resection of the presacral nerve, which may be combined with division of the sympathetic cords. Carcinoma of the bladder (or uterus) is apt, sooner or later, to escape from the confines of the viscus and cause pain from invasion of the lumbo-sacral plexus and other structures, which is beyond the aid of sympathectomy.

Uterus.—Certain cases of spasmodic dysmenorrhœa which resist less drastic measures are cured or relieved by presacral neurectomy. No untoward effects on uterine (including parturition) or bladder function have been recorded.

Renal Pain.—The diagnosis of sympathetico-tonus is confirmed if the pain is relieved by eserine. In these cases pyelography shows clubbing of the calyces. Stripping of the renal pedicle results in sympathetic denervation and restoration of neuromuscular balance.

Angina pectoris is relieved by removal of the upper five thoracic ganglia. In cases of difficulty the lower two, if out of reach, can be injected with alcohol. It was formerly alleged that to abolish pain was to remove a danger signal, but further experience disproves this. Equally good results appear to follow thyroidectomy.

Causalgia is a condition in which paroxysmal attacks of pain follow an incomplete nerve injury, especially of the brachial plexus, sciatic or median nerves. In more than half the cases symptoms supervene immediately after the injury, in the remainder symptoms are deferred for any length of time up to two or three months. The incomplete lesion on the nerve, usually a lateral neuroma, gives rise to antidromic impulses which pass peripherally to the sensory nerve endings where stimuli give rise to the production of histamine-like substance (H substance) similar to that liberated by the posterior nerve root vasodilators. The accumulation of H substance causes vasodilation and renders the part red and engorged, the affected area also sweats profusely and is exquisitely painful and hyperæsthetic owing to the increased pressure. It is noticeable that the patient tends to keep the limb elevated and usually prefers to have the affected area out of bed at night in order to diminish vascular engorgement. The skin is often thin as the result of trophic changes. The pain is alleviated by cold (e.g. a wet sock or glove). Sooner or later the patient loses his morale and becomes introspective and unco-operative. Some cases of causalgia tend to recover gradually, but the condition is so distressing that surgical alleviation is highly desirable as soon as the condition is confirmed. Paravertebral block (either D.2 and 3, or L.1, 2 and 3) relieves the pain for a short time, and confirms the necessity for operation.

Treatment.—Periarterial sympathectomy gives variable relief, but is worthy of

trial in a patient who is unfit for more drastic procedures. Thoracic sympathetic trunk section or lumbar ganglionectomy is the treatment of choice. The increase in the rate of capillary blood flow resulting from the dilatation of arterioles washes away the H substance and this diminishes tissue tension which is the principle cause of pain. Sometimes the relief is incomplete although the area of pain involvement is reduced in superficial extent.

III. Secretory Disturbances

Excessive sweating (hyperidrosis) is sometimes so distressing to the patient that he is willing to undergo surgical measures in order to obtain relief. Excessive sweating of the face, which is sometimes associated with emotional stress, is abolished by removal of the superior cervical ganglion. Sudden, offensive feet, the skin of which is cracked and painful, may be a genuine disability for which lumbar ganglionectomy is justified.

A parotid fistula, which fails to respond to cautery or radium, is encouraged to heal by avulsion of the auriculo-temporal nerve, which is exposed in front of the ear in relation to the superficial temporal artery. The parasympathetic secretory fibres are ablated, and the fistula closes.

IV. To Relieve Spasm

Retention of Urine (see p. 794).

Essential hypertension in patients who are below the age of fifty, and who have no impairment of the renal or cardiovascular systems, is often improved by bilateral resection of the splanchnic nerves together with the sympathetic trunks from the ninth thoracic to the first lumbar ganglia. Benefit results either from depression of the activity of the adrenal glands, or by dilatation of the splanchnic vessels and those of the lower limb, which thus provides a reservoir for blood. In our experience the fall of blood pressure may be slight, but headache, palpitations, and dizziness are often relieved for many months to a few years.

OPERATIONS

Periarterial Neurectomy.—Leriche, who popularised this operation, performed it in the belief that all the sympathetic fibres pass to a limb in the adventitia of the main artery. It is now known that the arteries to a limb receive sympathetic fibres not only from the aortic plexus, which accompanies the main vessel, but also from mixed nerves which join the vessels at varying levels. Thus periarterial neurectomy does not remove all the vasomotor fibres passing to the limb.

Nevertheless, periarterial neurectomy occasionally yields satisfactory results, though these are less consistent than with ganglionectomy. Therefore the operation is more or less palliative, but it is sometimes of value in patients whose general condition is unsuited for the more extensive operation of ganglionectomy.

The operation is readily performed under local anaesthesia. The vessel is exposed for a distance of 2 or 3 inches (5 or 7.5 cm.), and the sheath and adventitious coats are divided and stripped off the vessel, which is conveniently rotated with an aneurysm needle. Flooding the wound with saline reveals the sympathetic threads which are adherent to the muscular coat, and the last remnants of nerve fibres are destroyed by mopping the artery with 90 per cent. alcohol. Temporary contraction of the vessel follows an adequate neurectomy.

Presacral Neurectomy.—The patient is placed in the Trendelenburg position and the abdomen is opened by a subumbilical paramedian incision. The bifurcation of the aorta is exposed by a vertical incision through the overlying peritoneum, which is easily lifted from the vessel. The presacral nerves are usually represented by a plexus, and in order to ensure complete removal, all the nervous, fatty, and areolar

tissues lying over the lower inch of the aorta and the sacral promontory are excised (fig. 1361).

Preganglionic cervicodorsal sympathectomy is most easily performed by the anterior approach developed by Gask and Ross. An incision is made $\frac{1}{2}$ inch



FIG. 1361.—Displaying the presacral nerve. The presacral and inferior mesenteric sympathetic nerves (following the inferior mesenteric artery) are divided. (After Sir James Learmonth.)

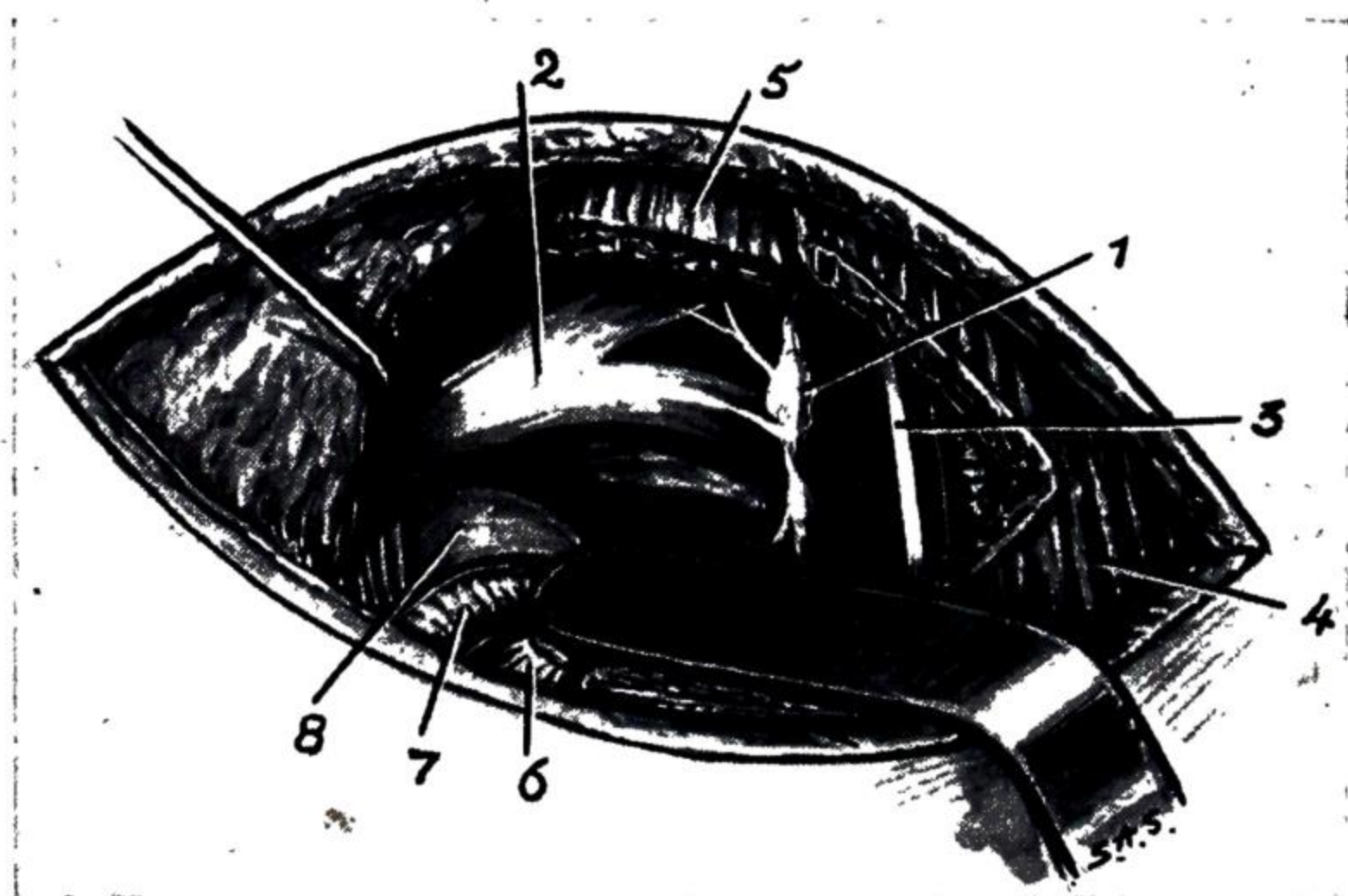


FIG. 1362.—Exposure of the right cervicodorsal sympathetic from the front.

- | | |
|--|--|
| 1. Stellate ganglion. | 5. Divided scalenus anticus muscle. |
| 2. Lower trunk of brachial plexus. | 6. Divided posterior belly of the omo-hyoid. |
| 3. Phrenic nerve displaced inwards. | 7. Subclavian artery displaced downwards. |
| 4. Partially divided sternomastoid muscle. | 8. Dome of the pleura. |

(1.25 cm.) above the inner half of the clavicle, and the clavicular part of the sternomastoid, the posterior belly of the omo-hyoid, and the scalenus anterior muscles are divided, the phrenic nerve being displaced inwards. The subclavian artery is thus exposed, and the thyro-cervical trunk is divided between ligatures. Occasionally the posterior scapular artery arises directly from the subclavian, in which case it also

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Sir James Paterson Ross, Contemporary. Professor of Surgery, St. Bartholomew's Hospital.
Sir James Learmonth, Contemporary. Professor of Surgery, Edinburgh.*

is ligated. The subclavian artery is depressed and Sibson's fascia is divided, so that the dome of the pleura can be displaced downwards and outwards. The stellate ganglion is then identified as it lies on the neck of the first rib (fig. 1362), the superior intercostal artery being on the outer side. The sympathetic trunk is traced downwards and divided below the third thoracic ganglion. All rami communicantes associated with the second and third ganglia and the nerve of Kuntz are meticulously divided. Deep bleeding-points are best controlled by silver clips. A small drain is inserted for twenty-four hours. Not infrequently the ganglion on the opposite side is also removed at the same operation.

Cervicodorsal ganglionectomy was formerly practised, and although somewhat easier to perform, a successful ablation was followed by Horner's syndrome, i.e. myosis, enophthalmos, ptosis, and hypoidrosis (diminished sweating) of the face and neck.

Lumbar Ganglionectomy.—*Unilateral ganglionectomy* is sometimes performed in cases where one limb has already been amputated for gangrene. The approach is extraperitoneal, and is similar to the exposure required for nephro-ureterectomy. The muscles are divided, and the colon and peritoneum, to which the ureter clings, are stripped inwards so as to expose the inner border of the psoas muscle (fig. 1363).

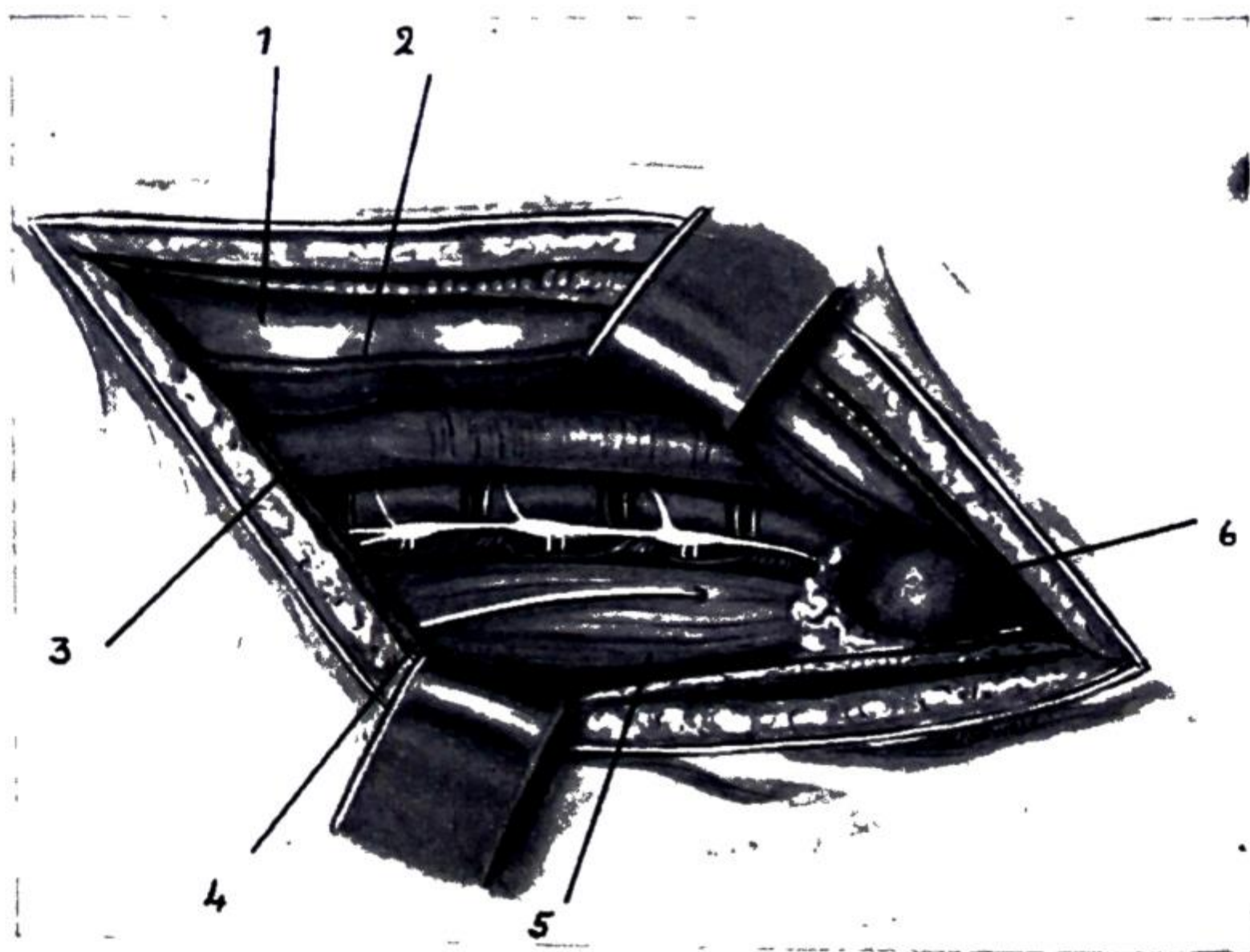


FIG. 1363.—Left lumbar ganglionectomy.

- | | |
|--|--------------------------|
| 1. Peritoneum stripped forwards, with ureter (2) adherent to it. | 4. Genito-crural nerve. |
| 3. Aorta. | 5. Psoas. |
| | 6. Lower pole of kidney. |

The sympathetic trunk lies on the side of the bodies of the lumbar vertebræ, and on the right side is overlapped by the vena cava. Lumbar veins are apt to cross the trunk superficially, and must be meticulously ligated as they pass directly into the adjacent inferior vena cava. (We have seen a case of fatal hæmorrhage from a lumbar vein.) The sympathetic trunk is divided on the side of the body of the fourth lumbar vertebra, and the trunk is traced upwards to below the duodenum on either side, where it is divided and resected.

Bilateral ganglionectomy is commonly performed transperitoneally. A left paramedian incision is made from above the umbilicus to an inch or two above the pubis. Intestines are packed off, and on the right side the posterior layer of peritoneum is incised vertically over the outer side of the vena cava. The mesenteric attachment is displaced upwards, together with the ileo-colic and right colic arteries. The sympathetic trunk lies under the outer border of the vena cava, and is divided above after displacement upwards of the duodenum. It is traced downwards until it disappears behind the right common iliac vein, when it is divided and resected.

On the left side exposure is gained by incising the peritoneum on the outer side of the pelvic colon. The bowel is stripped inwards, together with the left colic vessels and ureter. The genito-crural nerve is seen emerging from the psoas, and eventually

the inner border of the muscle is exposed. The sympathetic trunk is then identified as it lies on the vertebral bodies. It is divided above after displacement upwards of the duodenum, and is dissected downwards until it disappears underneath the left common iliac artery, where it is divided and removed.

Many surgeons now perform bilateral ganglionectomy through two separate incisions in the loins (as described for the unilateral operation), as the incidence of post-operative complications is diminished, and the duodenum can be more easily displaced forwards from the loin. Also, although two incisions are required, shock is diminished if the peritoneal cavity is unopened.

Thoraco-lumbar splanchnicectomy (Smithwick) has been considerably modified since its introduction for hypertension. The essential feature is removal of the sympathetic chain from about the eighth thoracic to below the third lumbar ganglion, with division of the splanchnic nerves.

The modified technique is briefly as follows. The patient is placed in the kidney position, and an incision is made from the lateral border of the erector spinæ muscle along the eleventh rib, and continued to the linea semilunaris. The eleventh rib is excised, the flank muscles are divided, and the sympathetic chain is exposed by stripping up the peritoneum. It is divided below the third ganglion and freed in an upward direction to the internal arcuate ligament. This ligament and the crus of the diaphragm are incised upwards, and the greater splanchnic nerve is observed piercing the crus. The sympathetic chain is cleared to as high a level as possible above the diaphragm. The thoracic attack begins by opening the pleura at the posterior end of the wound. The lung is retracted upwards and the sympathetic chain is readily seen lying on the necks of the ribs, with the greater splanchnic nerve on the inner side. The pleura covering the chain is divided in the neighbourhood of the eighth ganglion, and the chain is dissected downwards with the greater splanchnic nerve until the upper part of the abdominal dissection is reached, and the lumbar and thoracic parts of the chain appear in continuity, and it is then resected with the splanchnic nerves.

Transpleural approach is preferable to stripping the pleura from the thoracic wall as less shock follows, and if hæmostasis is not absolute, a collection of blood in the pleural cavity is preferable to an extrapleural effusion, as it can easily be aspirated (A. M. Boyd).

Bilateral lumbar ganglionectomy may result in temporary postural hypotension, and bilateral removal of the first and second lumbar ganglia leads to sterility, but not to impotence (Learmonth). Sweating of the feet and legs is abolished after lumbar ganglionectomy.

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CHAPTER XLII
THE BREAST

Surgical and Comparative Anatomy.—Mammals are distinguished and so-called because they are provided with mammary glands. The cow, sheep, goat, mare and the elephant have an udder surmounted by teats, while other animals are furnished with breasts, the number of pairs of which vary with the species, and is related to the average number of offspring in each litter. Thus the sow has four to nine pairs, rodents six or seven pairs, while, like man, the anthropoid apes, the lioness, the sea-cow and, as John Hunter first noted, the whale, have but a single pair.

In anatomical works the protuberant part of the human breast is generally described as overlying the second to the sixth ribs, and extending from the lateral border of the sternum to the anterior axillary line. Actually a thin layer of mammary tissue extends considerably farther on all sides, viz : to the clavicle above, to the seventh or eighth ribs below, to the mid-line medially, and to the edge of the latissimus dorsi posteriorly. This fact is of importance to a surgeon when he seeks to remove the whole breast. The full extent of the breast becomes apparent in cases of milk engorgement.

As age advances the parenchyma of the breast undergoes considerable atrophy and becomes loose in texture, making the detection of lumps within it more facile.

The axillary tail of the breast is of considerable surgical importance. In some normal cases it is palpable, and in a few it can be seen in the pre-menstrual phase and during lactation. A well-developed axillary tail is sometimes mistaken for a mass of enlarged lymph nodes or a lipoma.

The lobule is the basic structural unit of the mammary gland (fig. 1364). In the human breast the number and size of the lobules vary exceedingly : they are largest and most numerous during early womanhood. From ten to more than a hundred lobules empty by means of ductules into a lactiferous duct, of which there are from fifteen to twenty. Each lactiferous duct is provided with an ampulla—a little reservoir for milk or abnormal discharges.



FIG. 1364.—Showing the lobules and the lactiferous ducts, with their ampullæ.

The ligaments of Cooper are hollow conical projections of fibrous tissue filled with breast tissue, the apices of the cones being attached firmly to the deeper layers of the skin overlying the breast. These ligaments account for the dimpling of the skin overlying a scirrhous carcinoma, or other lesions of the breast accompanied by fibrosis.

The Areola.—The subcutaneous tissue contains involuntary muscle arranged in concentric rings as well as radially. The areolar epithelium contains numerous glands of three kinds—sweat glands, sebaceous glands, and accessory mammary glands. The sebaceous glands (known as the glands of

Montgomery) enlarge strikingly during pregnancy and serve to lubricate the nipple during lactation. The accessory mammary glands are minute, inconstant, and possess ducts that open on the areola.

The Nipple is covered by a thick and rather crinkled skin. Near its apex, and very difficult to see because of the cutaneous corrugations, lie the orifices of the lactiferous ducts. The nipple and the areola of a virgin are pink ; with succeeding pregnancies these structures become increasingly pigmented by deposits of melanin. The bulk of the nipple is made up of smooth muscle fibres arranged concentrically and longitudinally ; thus the nipple is an erectile structure.

Lymphatics.—The lymphatic vessels of the breast drain into (1) Rotter's nodes, that lie between the greater and lesser pectoral muscles ; (2) the thoracic chain of lymph nodes along the lateral thoracic artery ; (3) the subscapular chain that extends from the lateral thoracic wall to the axillary vein, and thence along the axillary vein,

John Hunter, 1728-1793. Surgeon, St. George's Hospital, London.
Sir Astley Cooper, 1768-1841. Surgeon, Guy's Hospital, London.
William Montgomery, 1797-1859. Professor of Midwifery, Dublin.
Josef Rotter, 1857-1924. Chief Surgeon, St. Hedwig-Krankenhaus, Berlin.

most of the nodes being on the caudal aspect of that vessel; (4) the central group, which is the largest, lying at the apex of the axilla. The highest of these nodes is sheltered beneath the clavicle and is known as Halsted's node.

It is highly important to know that: (a) there is free communication between the subclavicular and the supraclavicular lymph nodes which are involved in 33 per cent.

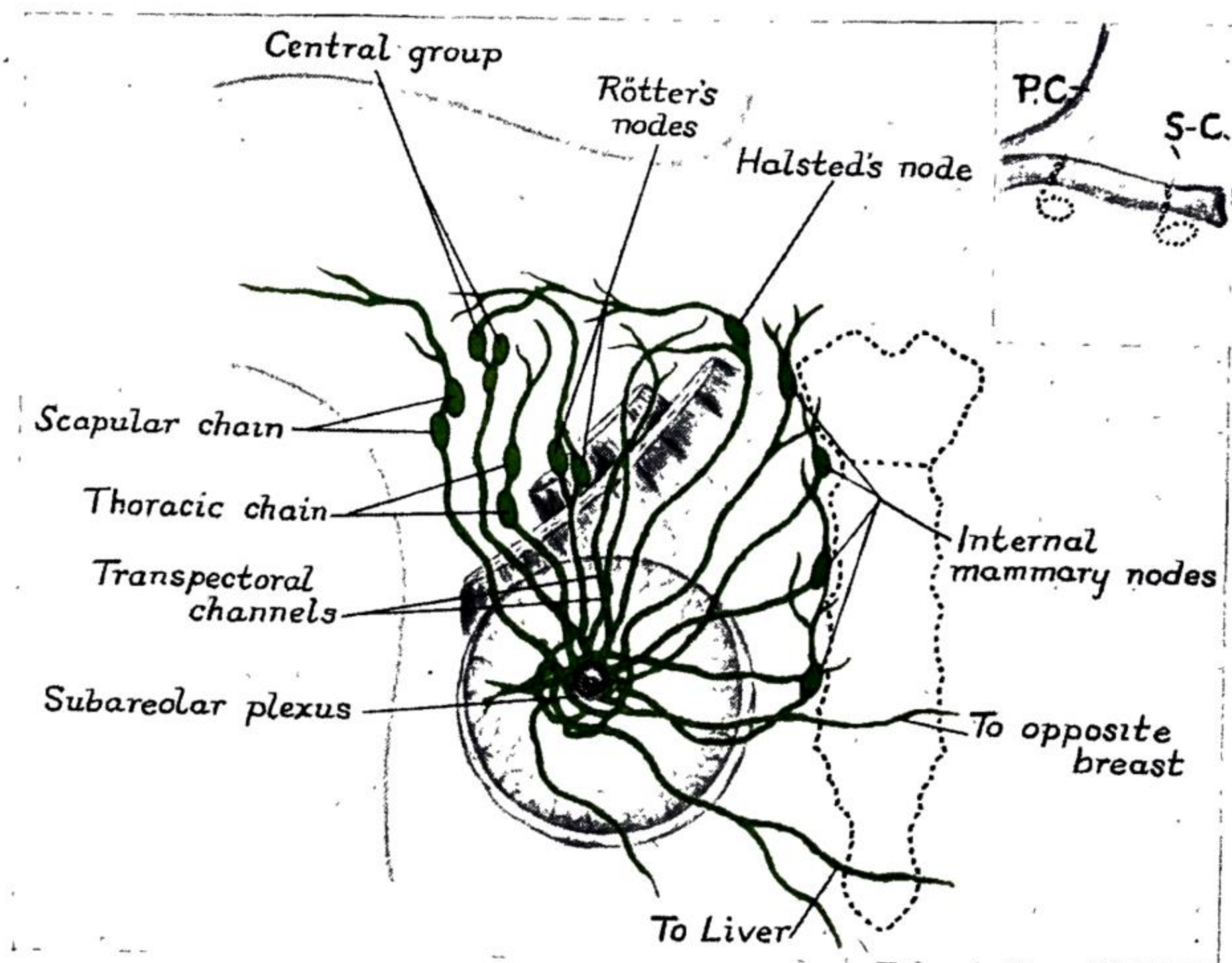


FIG. 1365.—The lymphatics of the breast. Inset.—P.C. = post-cervical chain. S.C. = supraclavicular nodes. (After P. Poirier.)

of cases in which the axillary lymph nodes are the seat of secondary deposits of carcinoma (M. Andreassen); (b) that the postero-cervical chain of lymphatic nodes are linked with those of the axilla, and that (c) the nodes along the internal mammary artery are involved in 48 per cent. of cases in which the axillary nodes are implicated (R. S. Handley).

THE NIPPLE

Absence of the nipple is very rare, and usually it is associated with amazia.

Supernumerary nipples are fairly common, particularly in the male. Usually they occur along a line extending from the anterior fold of the axilla to the fold of the groin. This constitutes the milk line of lower mammalia. Unless the clinician is familiar with the anomaly, supernumerary nipples are liable to be mistaken for moles or warts.

Retraction of the nipple is of two exceedingly important varieties: (a) that occurring at puberty (remote), and (b) that occurring during womanhood (recent).

(a) **Retraction occurring at puberty** is due in most instances to a developmental abnormality; the nipple, for some unknown reason, does not develop *pari passu* with the breast. It is possible that in a few instances the retraction is an aftermath of mastitis of infancy. In about one-quarter of the cases the condition is bilateral.



William S. Halsted, 1852-1922. Surgeon, Johns Hopkins Hospital, Baltimore, U.S.A.
Mogens Kristian Andreassen, Contemporary. Surgeon, Rigshospitalet, Copenhagen.
Richard Sampson Handley, Contemporary. Surgeon, Middlesex Hospital, London.

Non-protuberance of the nipple hinders an infant suckling at the breast. Clinical experience shows that a breast with long-standing retraction of its nipple (fig. 1367) is prone to fibroadenosis and, especially during lactation, to infection and abscess formation.

Treatment.—During and soon after puberty: if the patient draws out the nipple between finger and thumb daily for about three weeks the condi-

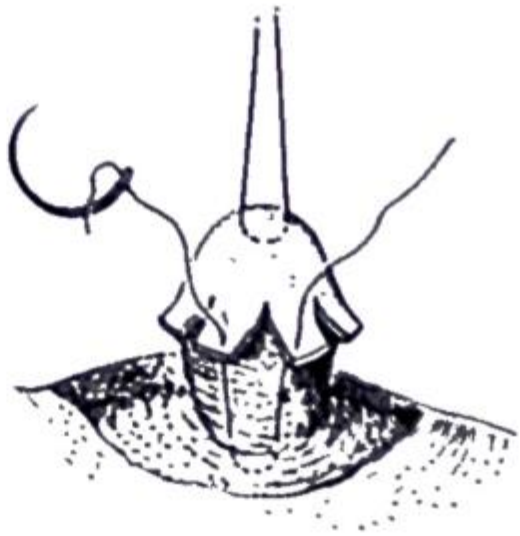


FIG. 1366.—Sellheim's operation for retracted nipple. The edges of the V-shaped excised portion are drawn together, and dead space obliterated by placing and tying sutures, as shown. The base of the nipple is then stitched to the free edge of the skin.

tion is usually remedied. In somewhat older patients, the regular application of a large warmed test-tube over the nipple may create sufficient suction to rectify the deformity. By the time the patient is in her late twenties, operative correction is necessary (fig. 1366.)

(b) **Recent Retraction.**—The importance of long-standing retraction of the nipple is dwarfed by the ominous diagnostic significance of recent retraction (fig. 1367), which is a frequent accompaniment of scirrhus carcinoma (see p. 1073).

Therefore the all-important question to put to the patient is: "How long has this nipple been retracted?"

Cracked Nipple.—Want of care in the preparation for lactation and neglect of the hygiene of the nipple during lactation are the chief causes of this not uncommon condition. Its main importance lies in the fact that the crack is the forerunner of acute infective mastitis.

Prophylaxis.—During the last two months of pregnancy the nipples and their areolæ should be especially washed, dried, and anointed with a little glycerol each day. The same routine may be continued, with advantage, after suckling¹.

Treatment.—The mother should discontinue suckling at that breast until the fissure has healed. The nipple is washed with a weak solution of flavine, and covered with dry aseptic gauze. The affected breast must be emptied with a breast-pump, as necessary. Healing often occurs within two or three days. After the crack has healed, for the first few days the baby should be put to that breast for only a



FIG. 1367.—Recent retraction of the nipple.



FIG. 1368.—Rubber nipple shield.

¹ In some maternity hospitals the nipple is cleansed before and after suckling by wiping it with a sponge removed from 70 per cent. alcohol solution kept in a jar labelled with the patient's name.

few minutes at a time. Especially if the nipple is partially retracted, the use of a nipple shield (fig. 1368) will prevent recurrence.

Papilloma of the nipple presents the features of a cutaneous papilloma. Sometimes it grows to a large size, but the pedicle is always narrow. The treatment is excision together with a tiny disc of the skin from which it grows.

Retention Cyst of a Gland of Montgomery.—These glands, situated in the areola, secrete sebum and, as a result of an orifice of one of the glands becoming blocked, a sebaceous cyst forms.

Chancre of the Nipple.—The majority of chancres of the nipple occur by infection from a syphilitic buccal mucous patch in the mouth of a member of the opposite sex. Although wet-nurses are now seldom, if ever, employed in this country, when this form of infant feeding is used sometimes the nipple is infected from the mouth of a syphilitic baby. The mother of such an infant is immune to re-infection from her own child.

Eczema of the nipple is often bilateral, and presents features common to eczema elsewhere.

Paget's disease of the nipple must be distinguished from the foregoing. Paget's disease will be considered under the heading of 'Carcinoma of the Breast' (see p. 1075).

ABNORMAL DISCHARGES FROM THE NIPPLE

The discharge occurs from one (rarely more) of the lactiferous ducts.

A clear serous discharge is associated usually with a retention cyst, consequent upon fibroadenosis.

A blood-stained discharge is pathognomonic of duct papilloma or duct carcinoma. The former condition is more common than the latter.

A black or green discharge may be due to altered blood from the foregoing, but is much more frequently an accompaniment of retention cysts of fibroadenosis. In cases of a dirty green discharge, when the breast is removed usually it is found to be riddled with cysts containing the same material.

A milky discharge can sometimes be expressed long after lactation has ceased. It can be associated with a galactocele (see p. 1067), but this condition is rare.

A purulent discharge sometimes occurs in connection with a breast abscess.



FIG. 1370.—An accessory and functioning breast on the left thigh. (After G. J. A. Wiskowski.)



FIG. 1369.—Congenital absence of the right breast.

THE BREAST

CONGENITAL ABNORMALITIES

Amazia.—Congenital absence of the breast may occur on one (fig. 1369) or both sides. It is sometimes associated with an absence of the sternal portion of the pectoralis major. Amazia, which is rare, is more common in males.

Polymazia.—Accessory breasts have been recorded in the axilla, groin, buttock, and thigh, the most frequent site being the axilla. They have been known to function during lactation (fig. 1370).

DIFFUSE HYPERTROPHY

Diffuse hypertrophy of the breasts occurs sporadically in otherwise healthy girls at puberty and, much less often, during the first pregnancy. The breasts attain enormous dimensions, and may reach below the knees when the patient is sitting. This tremendous overgrowth of the mammary glands is due, apparently, to their extreme sensitivity to oestrogenic hormone. Sometimes the hypertrophy is unilateral¹. Except in those cases occurring during pregnancy, when it is possible that the enlargement will subside at the conclusion of lactation, a plastic operation should be performed, because the deformity and weight of the breasts are real handicaps to the patient (fig. 1371).

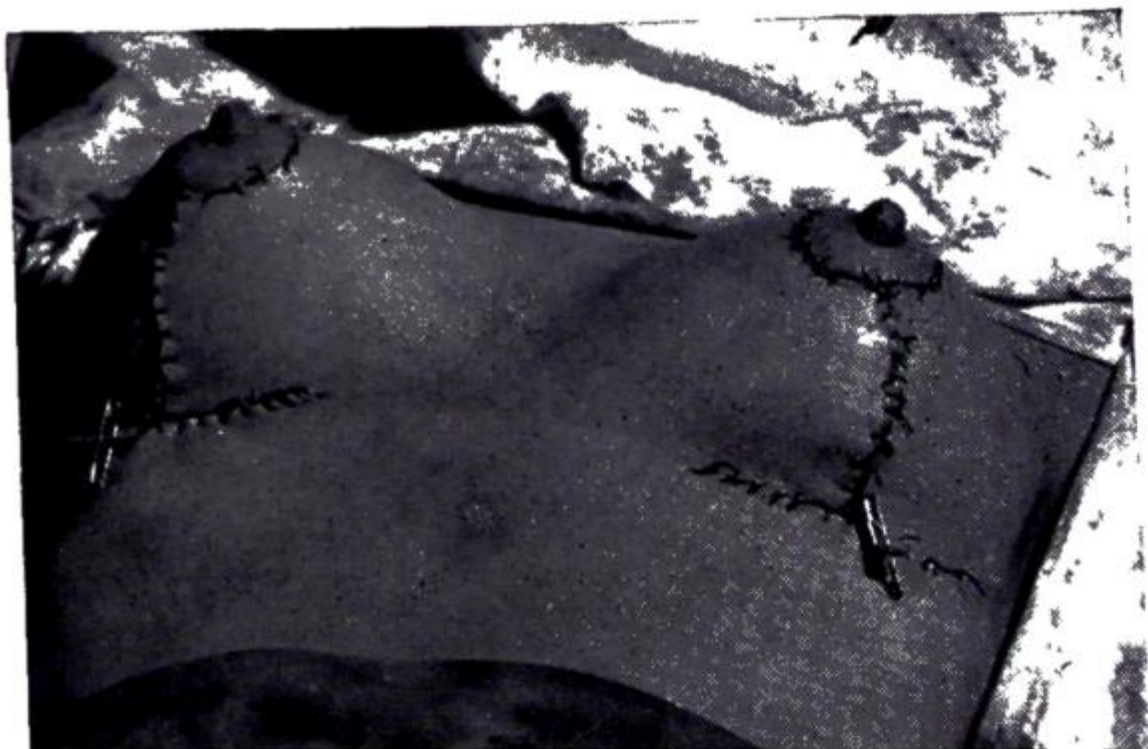


FIG. 1371. — Diffuse hypertrophy (virginal).

PENDULOUS BREASTS

Flabby breasts that hang loosely and are frequently, but not necessarily, over-size is a common cosmetic mammary complaint. The cause of the condition is regression from a former fullness, due to (a) over-development at adolescence, (b) a terminated pregnancy, (c) lactation, or (d) obesity. To a limited extent the condition can be improved by endocrine therapy similar to that advised for under-development of the breasts. For the more extravagant cases, plastic reconstruction

FIG. 1372.—A circular incision is made in the skin around the areola. Through a T-shaped incision skin and subcutaneous tissue have been dissected from the lower two-thirds of the patient's breast, but the nipple and areola have not been disturbed from their attachment. By extending the vertical incision upward, the nipple is placed at a higher level, and accommodation made for it in the skin. Excess of mammary tissue and skin are removed from the most dependent portion of the breast before closing the skin. (Mr. Matthew Banks, London. By courtesy of Smith and Nephew Ltd.)



of the breasts (one breast at a time) can be undertaken. One of the many methods is illustrated in fig. 1372.

UNDER-DEVELOPMENT OF THE BREASTS

In patients between the ages of twenty and thirty some increase in size can be expected following a two months' course of an oestrogen preparation.

¹ In tropical countries this must be distinguished from filarial elephantiasis of the breast.

INJURIES OF THE BREAST

Injuries of the breast are rare and comparatively unimportant.

Hæmatoma, particularly a resolving hæmatoma, gives rise to a lump which, in the absence of overlying bruising, is difficult, if not impossible, to diagnose correctly until an exploratory incision has been made.

Traumatic fat necrosis may be acute or chronic, and usually occurs in stout, middle-aged women. Following a blow, or even indirect violence (e.g. contraction of the pectoralis major), or the administration of subcutaneous infusion into the breast, a lump, often painless, appears. In the absence of a definite lead the swelling, which is often attached to the skin, is usually diagnosed as a carcinoma. A definite history of injury, especially that inflicted by subcutaneous infusion, should bring the condition to the clinician's mind. On incising the lump the macroscopic picture is fairly characteristic. The chalky white area of necrotic fat is akin to the areas of fat necrosis seen in cases of subsiding acute pancreatitis.

Milk fistula can follow an incised wound of a lactating breast or an operative incision, usually of an abscess beneath the areola. As a rule the fistula heals spontaneously. Should the fistula continue to discharge after an intramuscular injection of 12.5 mg. of hexœstrol dipropionate (see p. 1061) and, if infected, appropriate antibiotic treatment, the condition should be diagnosed as a chronic abscess with a bottle-necked opening and treated accordingly.

ACUTE AND SUBACUTE INFLAMMATIONS OF THE BREAST

Mastitis of infants is at least as common in the male as in the female. Its ætiology is closely related to the lactation of infants. On the third or fourth day of life, if a mamma of an infant is pressed lightly, a drop of colourless fluid can be expressed; a few days later there is often a slight milky secretion, which finally disappears during the third week. This is popularly known as 'witch's milk.' The explanation of this phenomenon is that the hormone which stimulates the mother's breast reacts also upon the mammary tissue of the fœtus.

Mastitis of infants is essentially a physiological activity. It may lead to a true mastitis by retrograde infection. This true mastitis usually resolves; occasionally it suppurates.

Mastitis of puberty is encountered rather frequently, usually in males. The patient, aged about fourteen, complains of pain and swelling in the breast. In 80 per cent. the condition is mainly or entirely unilateral. On examination the breast is enlarged, tender, and slightly indurated.

Treatment is expectant. Suppuration never occurs. The symptoms usually disappear in fourteen days or so, but induration often persists for several weeks.

Mastitis of mumps is usually unilateral, and occurs more commonly in females.

Mastitis from local irritation, which is commonly subacute and seldom suppurates, may be produced from a too tight elastic brassière. The condition is by no means rare in men (see p. 1085).

Mastitis from milk engorgement is liable to occur about weaning time; and sometimes in the early days of lactation when one of the lactiferous ducts becomes blocked with epithelial débris. In the latter instance a sector only of the breast becomes indurated and tender.

Treatment.—Unless the engorgement can be relieved with a breast

pump (fig. 1373), or, in the second instance, by sucking of the infant (stagnant milk being such a good medium for bacterial growth), bacterial infection is liable to supervene. Antibiotic treatment as detailed below, if commenced early, can be expected to abort the infection in a number of instances. The advisability of weaning the infant and inhibiting secretion of milk (see later) should receive weighty consideration.



FIG. 1373.—A simple form of breast pump.

Bacterial mastitis, which is by far the most common variety of mastitis, nearly always commences acutely. Although often referred to as mastitis of lactation, it is incorrect to assume that acute mastitis in women is necessarily lactational. Of a hundred consecutive cases of breast abscess, thirty-two occurred in women who were not lactating (L. de Jode); possibly some were from infection of a hæmatoma. In almost every case the infecting organism is a staphylococcus, and in a high percentage it is penicillin-resistant. In cases where the infection is acquired in hospital no less than 90 per cent. of the infecting staphylococci are insensitive to penicillin. There are two varieties of this condition:

Intramammary mastitis (80 per cent.) frequently goes on to suppuration. In lactational cases the sufferer is often in the *first* month of her *first* lactation, or, less frequently, is suckling an infant six or more months old, when its incisor teeth are commencing to appear.

Ætiology.—In maternity wards, staphylococcal infections of the breast sometimes assume almost epidemic proportions, due, no doubt, to a staphylococcal carrier among the nursing staff. Usually the intermediary is the infant; after the second day of life 50 per cent. of infants harbour staphylococci in the nasopharynx.

‘Cleansing the baby’s mouth’ with a swab is also an ætiological factor. The delicate buccal mucosa is excoriated by the process; it becomes infected, and organisms in the infant’s saliva are inoculated on to the mother’s nipple.

There seems little doubt that in the great majority of cases the precursor of intramammary mastitis is failure of secretion to escape because one (rarely more) of the lactiferous ducts become blocked with epithelial débris—a hypothesis that is strengthened by the fact that, whether they are lactating or not, intramammary mastitis and abscess of the breast is relatively frequent in women with an inverted nipple. So sudden and so severe is the onset of intramammary mastitis in a lactating woman that Mavis Gunther believes that sometimes rupture of the overdistended alveolus of the duct occurs, and that the early, very high temperature is due, not to bacterial activity, but to absorption of pyrogens from extravasated milk. While stasis in some part of the lactiferous tree is a major factor in the production of this condition, undoubtedly the older hypothesis—ascending infection from a sore or an infected cracked nipple—must not be spurned. Once within the ampulla of the duct, staphylococci cause clotting of milk. Within the clot organisms multiply rapidly.

Clinical Features.—The affected breast, or more usually mainly one

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quadrant of it, presents the classical signs of acute inflammation, and what is aptly called 'the cellulitic stage' of a breast abscess has been reached.

Treatment during the Cellulitic Stage.—The patient must be confined to bed. Antibiotic treatment, if not being given already for milk engorgement, should be started forthwith, the antibiotics of choice being terramycin, aureomycin, chloromycetin or streptomycin, in that order. The chosen drug should be administered in quantities of 250 to 500 mg. four times a day for seven days. Aureomycin causes pruritus and vaginitis in some instances. Occasionally, as a result of the rest to the inflamed breast and antibiotic therapy, resolution occurs. Support to the breast with a firm many-tailed bandage over wool will help to relieve the pain, and permit facile examination of the inflamed breast daily, which is essential. Fomentations and other counter-irritants are not recommended.

Masking of signs of inflammation by antibiotics not infrequently leads to undue delay in opening a breast abscess, with a resulting excessive destruction of mammary tissue sometimes amounting to a functional mastectomy. Now and then the excessive fibrosis thus induced, and the absence of tenderness, has caused the diagnosis to be revised in favour of carcinoma. Another disadvantage of undue delay is the deposition of a wealth of exuberant granulation tissue on the walls of the abscess: this has brought about profuse hæmorrhage when the abscess is incised. To obviate these untoward possibilities, when in doubt as to the presence of pus, the indurated mass should be explored with a hollow needle connected to a syringe, under general anæsthesia. If pus is found, the abscess is incised.

To wean or not to wean is a question of great importance. Except when the patient has been suckling the child for over nine months, undoubtedly it is better not to wean. Feeding is continued from the uninfected breast, and the infected breast is emptied after each feed by manual expression, carried out by the patient herself; this is more effective than a breast pump, which does not always clear obstructed ducts. The milk expressed from the inflamed breast is boiled for five minutes before being given to the child in a feeding bottle. In patients with bilateral acute mastitis the baby can be fed entirely on the milk obtained by expression and boiled; this is not detrimental to the baby.

In cases where already the child has been breast-fed too long, or the mother finds manual expression too painful, weaning is advisable. A single dose of hexœstrol dipropionate, 12.5 mg. given intramuscularly after the breasts have been emptied, usually inhibits lactation completely; occasionally a second dose is required.

Indications for Operation.—The breast should be incised when, after emptying, an area of tense induration is felt and/or when œdema of the overlying skin is found. Usually the area of induration is sector-shaped, and in early cases about one-



FIG. 1374.—Intramammary breast abscess.

quarter of the breast is involved (fig. 1374); in many later cases the area is more extensive (fig. 1375).

Drainage of an Intramammary Abscess.—An incision following the cutaneo-alveolar margin (fig. 1376) has a high cosmetic value and permits access to the whole



FIG. 1375.—Intramammary breast abscess. The abscess should always be drained before it becomes subcutaneous. (Mr. T. A. Bouchier-Hayes, Dublin.)



FIG. 1376.—Incision exactly at the areolar margin.

of the interior of the affected segment. The incision passes through the skin and the superficial fascia. A long hæmostat is then driven into the abscess cavity. Every part of the abscess is palpated against the point of the hæmostat, and its jaws are opened. All loculi and 'lactoceles' that can be felt are entered. Finally, the hæmostat having been withdrawn, a finger is introduced and any remaining septa are disrupted. In cases where the abscess cavity is situated in the lower half of the breast a counter-incision is made at the most dependent part, and through this the drainage tube is inserted; in this instance the primary incision can be sutured.

Dressings are carried out aseptically on the second day, when the tube is removed, and subsequently every other day. Antibiotic therapy is continued for at least one week.

Subareolar mastitis (20 per cent.) results from an infected (sebaceous) gland of Montgomery, or from a furuncle on or near the areola. The inflammation develops insidiously, usually without constitutional symptoms. When the patient presents early, often there is an area of induration no larger than a pea. No matter how small, if a lump can be felt, pus is present (fig. 1377), and the abscess should be drained without delay. Spontaneous rupture, if it is allowed to occur, does not cure the condition; it merely results in recrudescence or chronicity.

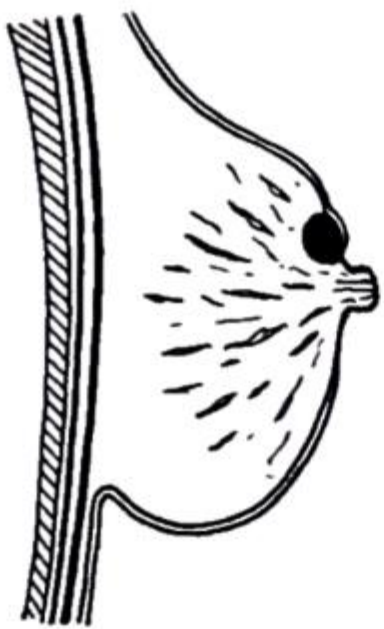


FIG. 1377.—Subareolar abscess.

Chronic intramammary abscess is often a very difficult condition to diagnose: when encapsulated within a thick wall of fibrous tissue, the condition cannot be distinguished from carcinoma. Consequently it is not rare for the central pus to be discovered only after the excised breast has been transected.

Chronic Subareolar Abscess.—A recurrent subacute or a chronic abscess of this variety usually occurs apart from lactation, but in women of the child-bearing age. The condition is a frequent complication of long-standing retraction of the nipple. The abscess ruptures and

subsides, only to repeat the cycle over and over again at intervals of a few months, or a chronic bottle-neck sinus (fig. 1378) continues to discharge, and flares up when the sinus closes.

Treatment.—Antibiotic therapy followed by incision and drainage is useless, the reason being that the abscess communicates with a lactiferous duct at the base of the nipple and reinfection of the dense fibrous tissue occurs along the associated duct.

Operation.—The only treatment that succeeds is, during a quiescent stage, to slit up the abscess (fig. 1379) or the sinus, together with the communicating duct to its orifice on the nipple, which often lies in the sulcus of an inverted nipple. The next step is to incise thoroughly the fibrous walls of the abscess. This can be followed by primary closure or, as some prefer, by packing and delayed closure. A plastic operation on the nipple, if inverted (see p. 1056), can be performed at the time of the excision or (preferably) at the time of the delayed closure.



Fig. 1379.—Slitting up a chronic subareolar abscess. In this case the patient has a retracted nipple of long standing. (After H. T. Casswell and A. W. E. Burnett.)

Tuberculosis of the breast, which is comparatively rare among Western races but fairly common in some other parts of the world, is, as a rule, associated with active pulmonary tuberculosis, or secondary to tuberculous cervical adenitis¹. Tuberculosis of the breast (fig. 1380) occurs more often in women who have borne one or more children and usually takes the form of multiple chronic abscesses. The diagnosis rests on bacteriological and microscopical examinations. Treatment with streptomycin, isoniazid and P.A.S. should be given. If healing does not occur within two months, in most cases it is advisable to amputate the breast.

Actinomycosis of the breast is rarer still, except among peasant women who work in the fields of Continental Europe. The lesions present the essential characteristics of facio-cervical actinomycosis (see p. 202). If healing does not occur as a result of the systemic treatment of actinomycosis recommended on pp. 25 and 203, the affected breast should be amputated.

Syphilis of the Breast.—A primary chancre of the nipple has been referred to on p. 27. Secondary lesions of syphilis in the form of mucous patches are sometimes found in the submammary fold. In the second stage also both breasts may become swollen and painful, the condition being known as diffuse syphilitic mastitis. Gumma of the breast is very rare, and almost impossible to diagnose unless there are other evidences of syphilis.

Submammary Intertrigo.—On lifting up large, pendulous breasts in fat women, it is not uncommon to find patches of intertrigo on the abutting skin surfaces of the breast and the chest wall.

¹ In 1829 Sir Astley Cooper, Surgeon to Guy's Hospital, London, described scrofulous swellings in the bosoms of young women, most of whom suffered from tuberculous cervical adenitis.



FIG. 1378.—Sinus connected with a chronic subareolar abscess.



FIG. 1380.—Tuberculosis of the breast with secondary suppurating axillary lymph nodes. (Professor A. K. Toufeeq, Lahore, Pakistan.)

Retromammary Abscess (fig. 1381).—Here the pus is situated in the cellular tissues behind the breast, and in the great majority of cases the abscess has no connection with the breast proper. Usually a retromammary abscess originates from a tuberculous rib, infected hæmatoma, or possibly from a chronic empyema necessitatis, and treatment must be directed to the relief of these conditions. A submammary incision allows the breast to be retracted as necessary from the field of operation.

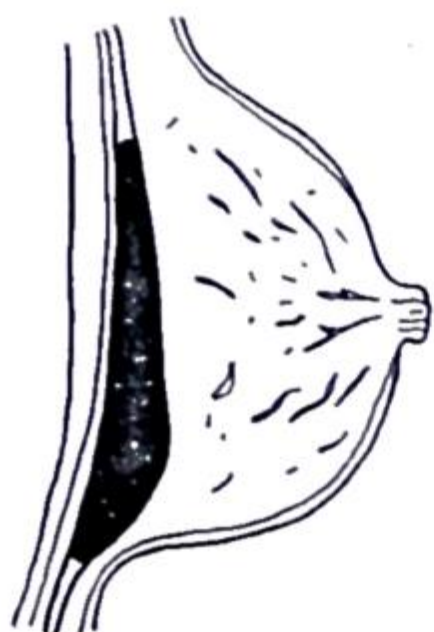


FIG. 1381.—Retro-mammary abscess.

MASTODYNIA

Slight discomfort in the breasts is not unusual in the premenstrual phase. When breast discomfort amounts to pain, it is termed mastodynia. On palpation the breasts feel normal, but they are tender. Mastodynia is sometimes associated with a neuropathic temperament.

Treatment.—Androgen therapy, such as methyltestosterone 15 mg. by mouth daily for two months, has been followed by an amelioration of symptoms. In the case of young girls a much smaller dose is advised. Androgen therapy is contraindicated during pregnancy. At all times (because of undesirable side-effects) this hormone must not be ordered indiscriminately. In a comparatively small proportion of cases mastodynia is a precursor of fibroadenosis.

FIBROADENOSIS¹

Ætiology.—Fibroadenosis is an aberration of those physiological changes that occur in mammary tissue at puberty (evolution) and at the menopause (involution).

Pathology.—When sectioned with a knife the affected areas in the breast are white or yellow, but they never present the grey tones of carcinoma. In cases of long-standing, cysts of varying sizes filled with dark mucoid material are often seen. Microscopically, it will be found that the interstitial tissues are swollen, and there is a round-celled infiltration. Fat and elastic tissue have largely disappeared. Later the interstitium is replaced by dense white fibrous trabeculæ. It is this fibrous tissue which compresses the ducts, thus favouring cyst formation. Often the epithelial lining is so compressed that it atrophies; occasionally epithelial hyperplasia occurs and distends the acini.

After decades of discussion many surgeons and pathologists are now convinced that fibroadenosis as such, is not a precarcinomatous condition (Hedley Atkins). Others are emphatic that fibroadenosis *with epithelial hyperplasia* is definitely a precarcinomatous condition. Both fibroadenosis and carcinoma of the breast are common conditions; by coincidence, they can coexist, which in point of fact occurs in 3 per cent. of cases of fibroadenosis.

Clinical Features.—Fibroadenosis may occur at any age after puberty; it is particularly common about the time of the menopause (fig. 1382). Spinsters, childless married women, and

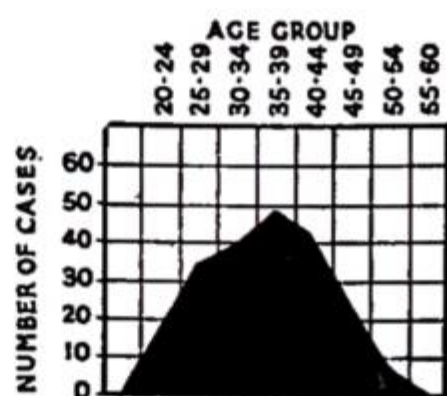


FIG. 1382. — Age incidence of patients reporting with fibroadenosis of the breast or breasts. (C. F. Geschickter's statistics.)

¹ Fibroadenosis must not be confused with fibroadenoma, the most common benign tumour of the breast.

multiparous women who have not suckled their children are the usual sufferers. This suggests that the condition is prone to appear in breasts that have been denied their intended function. The patient usually complains of pain in *one* breast, worse about the time of menstruation, or after using the arm. On examination both breasts are inclined to be what can be described as 'finely nodular'—the nodules being about the size of hemp seeds. As a rule it is possible to define the saucer-like edge of the periphery of the breast. When the breast complained of is examined between finger and thumb, more often than not an indefinite lump can be made out, but with the flat of the hand this can be felt only vaguely. The lump is neither adherent to the pectoral fascia nor to the skin. There is no recent retraction of the nipple, but very occasionally there is a serous or dark-green discharge therefrom. Fibroadenosis is sometimes more in evidence in one quadrant of the breast (fig. 1383) than in the remainder. The presence of a palpable cyst or cysts is inclined to obscure the clinical findings of fibroadenosis *per se*. Frequently the axillary lymph nodes are slightly enlarged, but they are not hard and are often tender.



FIG. 1383.—Sector-shaped fibroadenosis. The patient, a spinster of twenty-eight, had a retracted nipple on the left side for many years.

Treatment.—In early cases without cyst formation and where the possibility of carcinoma does not arise, reassurance of the patient and strapping the breast (fig. 1384) is the first step in treatment. Fourteen days later,



FIG. 1384.—A method of supporting the breast by adhesive strapping.

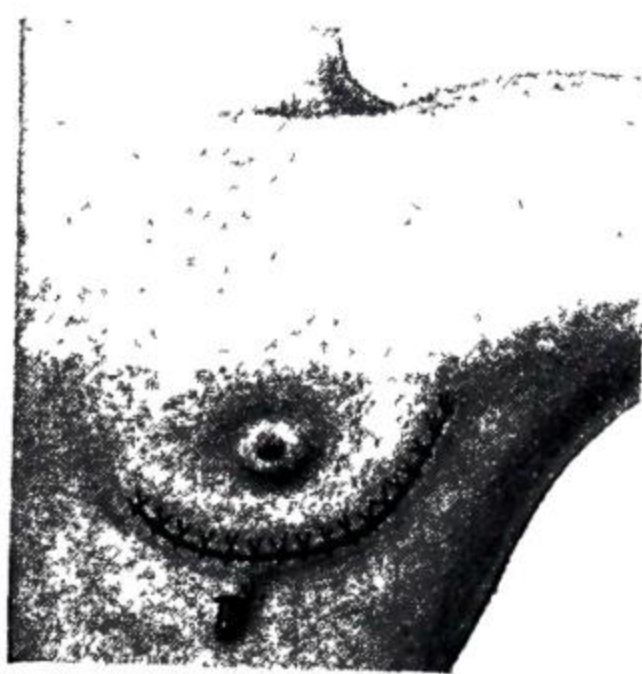


FIG. 1385.—Submammary excision of the breast completed.



FIG. 1386.—Result of submammary excision of both breasts for fibroadenosis.

when the breast is re-examined, there is often a substantial improvement, but in a large percentage of cases further applications are required. Iodine in milk therapy, similar to that employed in actinomycosis, is harmless and often beneficial. Methyltestosterone 15 mg. by mouth daily for two months reduces mammary pain, but is rarely necessary. Improvement often follows pregnancy.

If severe symptoms persist for more than a year, or if the breast is riddled with cysts, local mastectomy should be undertaken.

Submammary Excision of the Breast.—A satisfactory method of removing the mammary gland in these cases is through a submammary incision. The breast, including its axillary tail, is dissected out, leaving the skin and nipple intact. After the mammary gland has been excised, a purse-string suture on the under-surface of the areola ensures eversion of the nipple. This operation (fig. 1385), originated by Gaillard Thomas, gives a very good cosmetic result (fig. 1386), especially in women with comparatively small, firm breasts.

When the Diagnosis of Carcinoma is in Doubt.—There will always be cases where the clinician cannot be sure whether a particular lump in the breast is a patch of fibroadenosis or an early carcinoma. In doubtful cases it is wise to advocate operation without delay. The first step is to excise¹ that part of the breast containing the lump, and to look at its cut surface (fig. 1387). In many cases a naked-eye inspection will suffice to indicate

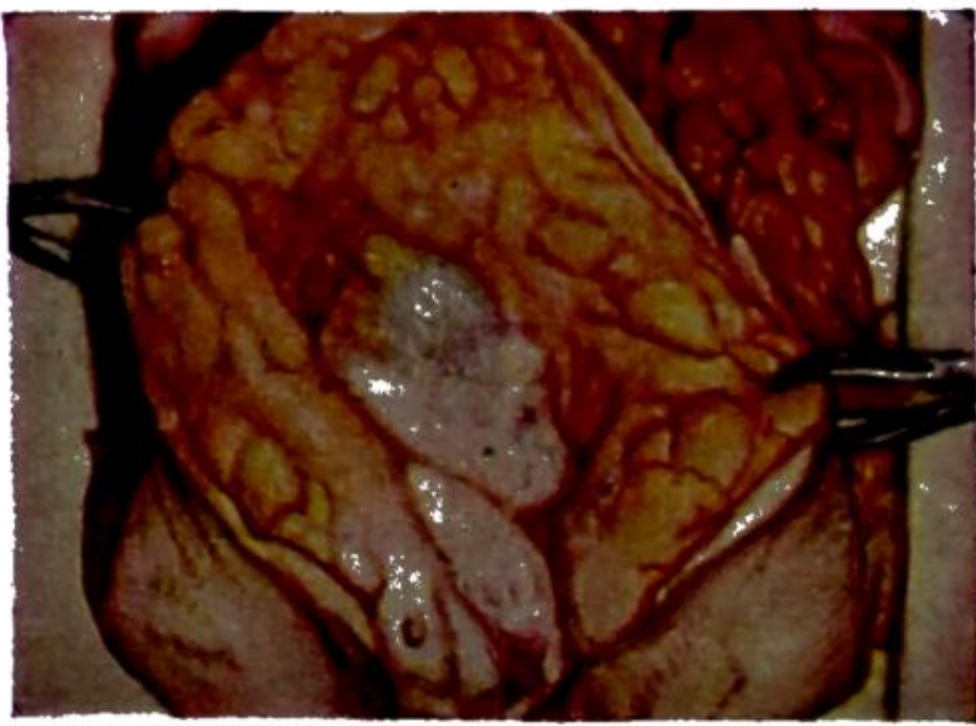


FIG. 1387.—Macroscopic examination of a doubtful lump in the breast. In the lower part of the specimen the dead-white appearance of fibroadenosis is evident. In the upper $\frac{1}{4}$ of this area there is a small carcinoma which is greyish-white in colour and cuts like an unripe pear.

the nature of the tumour. *If it is fibroadenosis*, local removal of the affected area is indicated. *If it is carcinoma*, the incision is closed, gloves and instruments are changed, and the operator proceeds to perform a radical excision of the breast.

There remain a small number of instances when, by looking at the cut surface, no conclusion can be reached. If facilities for immediate histological diagnosis by frozen section are not available, the surgeon must either proceed to treat the case as one of carcinoma, or close the incision and await a histological report. The latter course frequently necessitates a second operation, that possibly may be refused.

CYSTS OF THE BREAST

Usually a cyst of the breast is due to blockage of some part of the secretory mechanism, either by fibrosis from without or by obturation within the lumen of a duct or ductule. Exceptionally, a cyst arises in the stroma.

CLASSIFICATION OF CYSTIC SWELLINGS OF THE BREAST

1. Cystic disease of the breast { Solitary cyst.
Multiple cysts.
2. Cystadenoma (p. 1069).
3. Cystosarcoma phylloides (serocystic disease of Brodie) (p. 1070).
4. Intracystic papilliferous carcinoma (p. 1074).

¹ Pre-operative aspiration biopsy should be condemned because: (1) the procedure is open to the grave possibility of disseminating carcinoma; (2) the needle may miss a neoplastic area altogether; and (3) often it is difficult to give a positive diagnosis on the tiny specimen procured.

5. Colloid degeneration of a scirrhous carcinoma (p. 1071).
6. Chronic abscess (p. 1062).
7. Hæmatoma (p. 1059).
8. Galactocele.
9. Lymph cyst.
10. Hydatid.

Probably 75 per cent. of mammary cysts belong to group 1. That the swelling is a cyst usually can be confirmed by transillumination ; exceptionally aspiration is required to establish the diagnosis.

Cystic disease of the breast is a complication of fibroadenosis. Clinically evident cysts of the breast are often multiple. In a series of 205 patients with this condition, two-thirds had more than one cyst, while in 13 per cent. both breasts were involved (C. D. Haagensen).

(a) *Simple Solitary Mammary Cyst*.—The size of the cyst varies from $\frac{1}{4}$ inch to 2 inches (6mm.—5 cm.) in diameter, the seat of election being the upper and outer quadrant. Macroscopically the unopened solitary variety (fig. 1388) presents as a blue-domed cyst (J. C. Bloodgood), the colour being due to its fluid content. Although, clinically, the condition is called (correctly) a solitary cyst, as a rule the breast parenchyma contains a number of tiny satellite cysts (see fig. 1388).



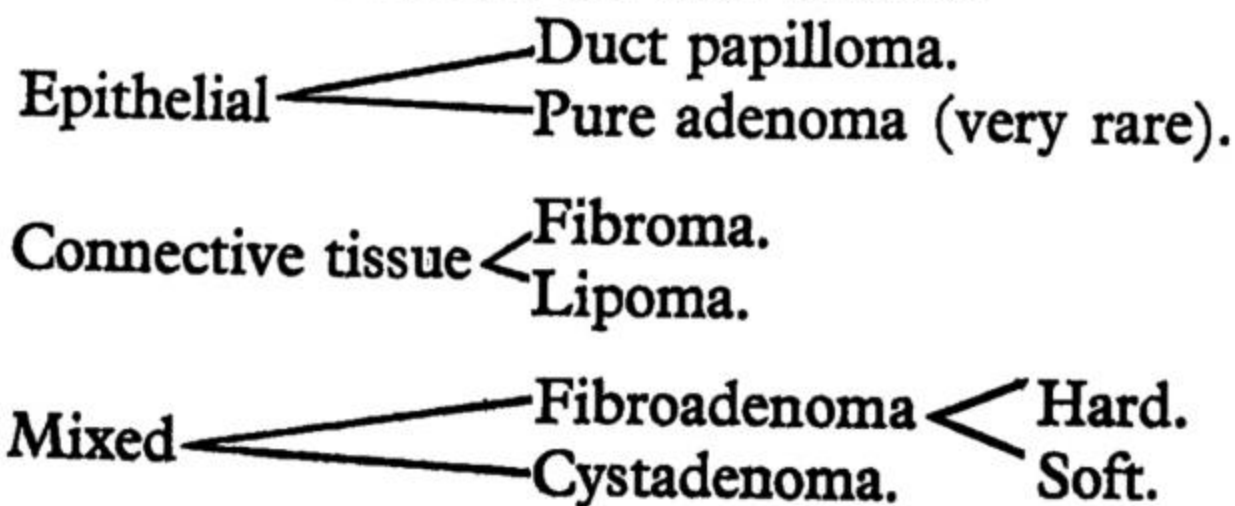
FIG. 1388. — The blue-domed cyst of Bloodgood. (After C. F. Geschickter.)

(b) *Multiple Cysts*.—The breast is riddled with cysts, and more often than not the condition is bilateral. Less often, one sector of the breast is affected alone, when obstruction to a main duct near the nipple by a duct papilloma should be suspected.

Treatment.—Aspiration, if necessary repeated, is sometimes successful. If the aspirate is blood-stained, if the cyst refills rapidly, or if a residual lump is present after aspiration, aspiration should be abandoned in favour of excision, lest an intracystic neoplasm be overlooked. A solitary cyst can be excised through an incision over the swelling following one of Langer's lines (see fig. 1392). Multiple cysts are best dealt with by submammary excision of the breast.

Galactocele, which is extremely rare, usually presents as a solitary cyst, and always dates from lactation. It contains milk or cream, and in long-standing cases its walls tend to calcify.

BENIGN NEOPLASMS OF THE BREAST



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 John Colt Bloodgood, 1867-1935. Surgeon, Johns Hopkins Hospital, Baltimore, Maryland, U.S.A.

Duct Papilloma.—The majority of these tumours are single, but bilateral examples are not rare, and occasionally two or more ducts of the same breast are the seat of a papillary growth. The usual single papilloma often has a stalk, and is situated in one of the larger lactiferous ducts.



FIG. 1389.—Staining of the patient's vest with blood from the nipple is conclusive evidence of the presence of a duct papilloma (or duct carcinoma).

Clinical Features.—The condition is rare before the age of twenty-five, and usually occurs in women between thirty-five and fifty. In the majority of cases bright red blood (fig. 1389) or, less often, a dark blood-stained discharge from the nipple is the only symptom. Rarely, the discharge is serous and not blood stained. On examination,

a cystic swelling sometimes can be felt beneath the areola; pressure upon it will cause a discharge from the mouth of the affected duct on the nipple. No greater tragedy is enacted than when this eminently curable condition is neglected, or submitted to X-ray therapy, and, after months or years, the duct papilloma is transformed into a highly malignant duct carcinoma, as we have witnessed on several occasions.

Treatment.—Amputation of the breast is usually unnecessary. To coat the nipple with tinct. benzoin co., and let it dry, and thus block the duct for fourteen days prior to the operation, is an advantage—the duct becomes distended with blood.

Operation (Lee McGregor's).—The skin of the breast is washed with ether, and then with alcohol. With the eyed (blunt) ends of a graduated series of round-bodied sewing needles, the orifice of the affected duct is dilated sufficiently to allow admission of a probe-pointed grooved director (fig. 1390 A). The duct is slit up, and

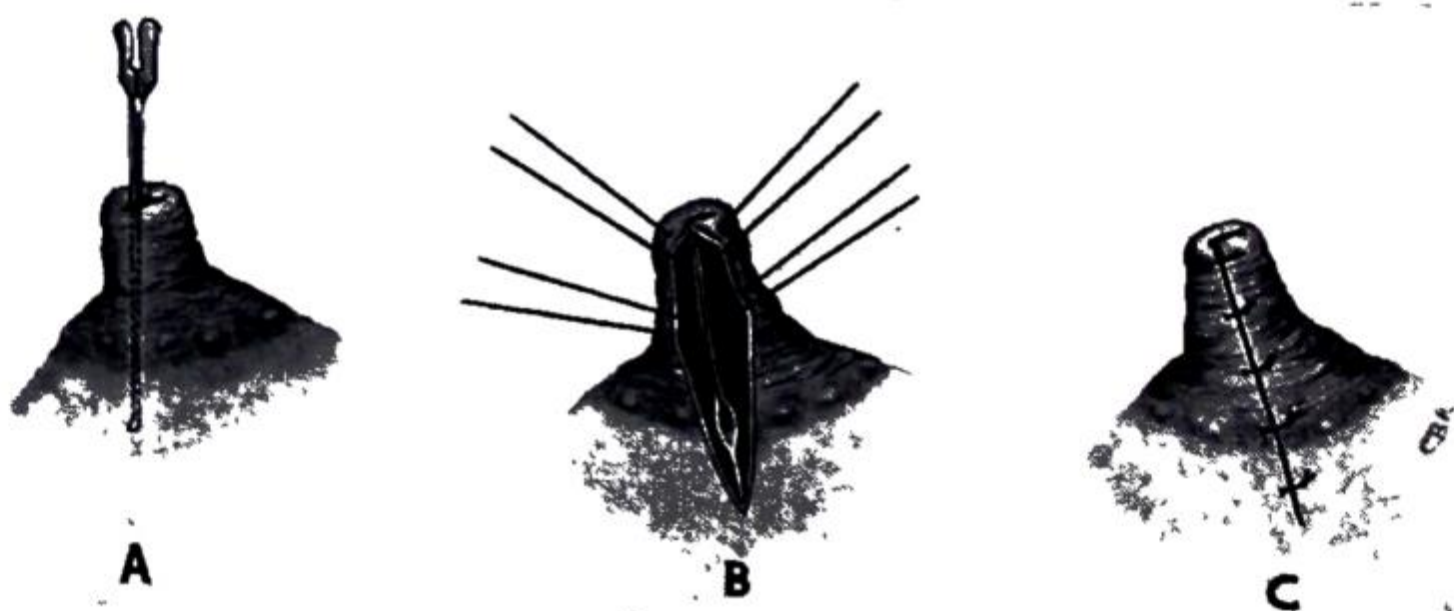


FIG. 1390.—(A) Grooved probe-ended director inserted into the affected duct, after dilatation of its orifice. (B) The papilloma has been excised. (C) The wound sutured.

to avoid the possibility of implantation of detached neoplastic cells, the resulting wound is flooded with 60 per cent. alcohol. The stalk of the papilloma is found and traced to its origin, which, together with a small portion of neighbouring tissue, is excised, preferably with a diathermy knife. When possible the excised tissue should be submitted to frozen section and histological scrutiny. The wound (fig. 1390 B) is closed (fig. 1390 C), but at the summit of the nipple a stitch is omitted, to provide for drainage.

Nearly all excised specimens are reported upon by the pathologist as "Papilloma. No evidence of malignancy"—a major triumph resulting from a comparatively minor surgical procedure.

Fibroadenoma of the breast is divided clinically into two varieties, the hard and the soft.

Hard fibroadenoma is again re-divided from the histological standpoint into *pericanalicular* fibroadenoma, which is rare, and *intra-canalicular* fibroadenoma, which is common: both have an exceptionally well-defined capsule.

Clinical Features.—As a rule the patient is between fourteen and thirty, the peak being about twenty-one years of age, and she complains of a lump in the breast. Exceptionally, there is more than one of these neoplasms present. On examination the lump is smooth, hard, and so freely movable that it has been termed a 'breast mouse.' In more than two-thirds of the cases the tumour is situated in the upper half of the breast.



FIG. 1391.—Fibroadenoma of the breast enucleated.



FIG. 1392.—Langer's lines in the skin over the breast. (After C. D. Haagensen.)

Treatment is enucleation of the tumour (fig. 1391) through an incision following one of Langer's lines (fig. 1392); this is accomplished easily, because this neoplasm is entirely encapsulated and can be shelled out without difficulty.

Soft fibroadenoma, like the foregoing, is a definitely localised tumour. Much rarer than the hard variety, soft fibroadenomata occur in women about the age of thirty-five or forty. They are inclined to be bilateral and usually lie deeply in the breast. To the examining fingers a soft fibroadenoma has a consistency of a lipoma.

Treatment.—As a soft fibroadenoma usually lies at some depth from the surface, it is best removed through an ipsilateral submammary incision (fig. 1393).

Cystadenoma is in all probability not a specific entity, but the outcome of cystic degeneration of a soft fibroadenoma. There is good reason to believe that in some cases the cystic degeneration proceeds apace, and a cystosarcoma phylloides results. Thus the metamorphosis is: Soft fibroadenoma → cystadenoma → cystosarcoma phylloides.

Treatment.—Like the above, a cystadenoma should be removed through a submammary incision. If it is large, submammary resection of the breast can be performed or, if the breast is pendulous and especially if the patient is past middle life, simple mastectomy is sometimes advisable.

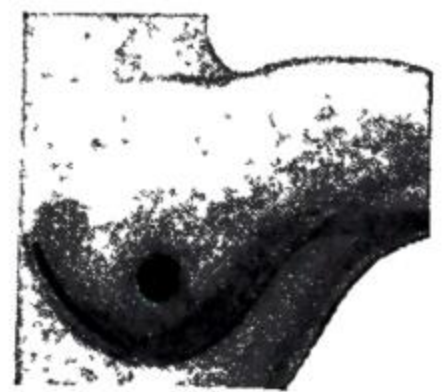


FIG. 1393.—Incision for removing a soft fibroadenoma in the medial half of the breast.

MASSIVE TUMOURS OF THE BREAST

This will be a convenient point at which to tabulate the massive tumours of the breast. They are :

1. Diffuse hypertrophy, which is usually bilateral (p. 1058).
2. Cystosarcoma phylloides¹ (*syn.* serocystic disease of Brodie).
3. Sarcoma.

Cystosarcoma Phylloides (*syn.* serocystic disease of Brodie). The probable origin of this tumour has been set out on p. 1069. While a cystosarcoma phylloides can appear at any age above sixteen years, it frequently does so between the fortieth



FIG. 1394.—Serocystic disease of Brodie.

and fiftieth year, which is about a decade later than a fibroadenoma. The striking clinical feature of this neoplasm is its tendency to grow rapidly and to attain a great size ; nevertheless it is surrounded by a capsule, and is not nearly so malignant as its official name implies. The surface of the tumour is unevenly bosselated (fig. 1394), with areas of softening and even fluctuation in the larger convexities. The overlying skin is thin and tense, and large veins can be seen coursing beneath the integument. Occasionally, in very large tumours, due to rubbing or pressure upon it, the overlying skin ulcerates where tension is greatest, and if the capsule becomes eroded the tumour protrudes as a fungating mass. But as a rule the tumour is adherent neither to the skin nor to deeper structures. On occasions there is a serous discharge from the nipple. The axillary lymph nodes are not enlarged, except secondarily to infection. In about a quarter of cases the tumour becomes sarcomatous, and gives rise to distant metastases. It is the

stroma, rather than the glandular tissue, that takes on a malignant change.

Treatment.—Most authorities advise simple mastectomy, but at the Memorial Hospital, New York, radical mastectomy is performed for this condition. Post-operative radiotherapy is often given, but its value is doubtful.

Sarcoma of the breast is usually of the spindle-celled variety, and accounts for about 1 per cent. of malignant tumours of the breast. Some of these growths arise in a pre-existing cystosarcoma phylloides. It is often supremely difficult, if not impossible, to distinguish clinically a sarcoma of the breast from a medullary carcinoma, but extremely rapid growth and the softness of the lump should suggest the possibility of sarcoma. On incising the neoplasm its pale, friable consistency is characteristic. Sarcoma of the breast is met with most often in women between the ages of thirty and forty. Metastases occur early, and usually determine a fatal issue in a comparatively short time. Even when radical mastectomy has been performed at an early stage of the disease, the prognosis is almost hopeless. Consequently, in the present state of our knowledge, simple mastectomy followed by radiotherapy seems to be the best course.

CARCINOMA OF THE BREAST²

There is no known cause of mammary cancer, and although the patient frequently attributes the lump to a knock, it is extremely improbable that injury plays any part in the production of the condition. Cancer very rarely attacks both breasts simultaneously. Only 1.5 per cent. of all cases occur in males. Women between forty and fifty years of age (fig. 1395) who have

¹ Phylloides—from the Greek *φυλλωδης* = leaf-like. There are branching projections of the tumour tissue into the cystic cavities of this neoplasm.

² The importance of this subject becomes more evident when it is realised that 7,500 women die annually from this condition in Great Britain. This is the highest incidence of any country in the world, except Austria.

Sir Benjamin Brodie, 1783–1862. Surgeon, St. George's Hospital, London.

suckled children are its most frequent victims, but the disease is not rare in spinsters. It is estimated that about 2 per cent. of all women of the cancer age will develop malignant disease of the breast. While any portion of the

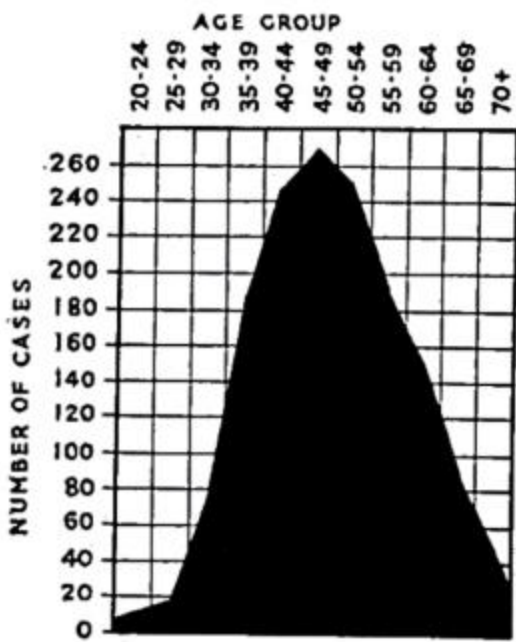


FIG. 1395.—Age incidence of carcinoma of the breast. (Nathanson and Welch's statistics.)

breast may be attacked, the disease commences most frequently in the upper and outer quadrant (fig. 1396). Unfortunately, so often the patient states that, although she noticed a lump in her breast while washing herself, she "took no notice of it" because it was painless. It is computed that the average time between the patient finding the lump and reporting it is eight months. Women should

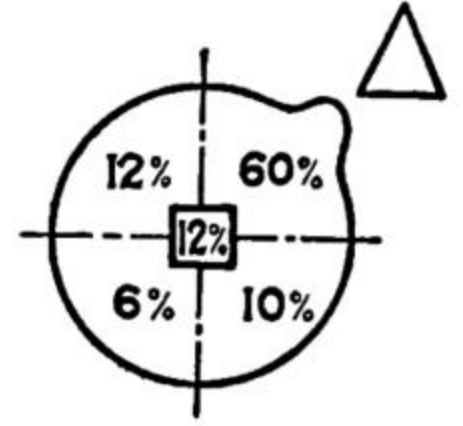


FIG. 1396.—The relationship of carcinoma of the breast to the quadrants of the breast. (Marshall and Higginbotham's statistics.)

be urged to report to their doctors as soon as a lump in the breast is discovered.

Pathological Classification of Varieties of Carcinoma of the Breast.—For practical purposes¹ all carcinomata of the breast are of duct epithelium origin (Hedley Atkins). However, in regard to behaviour they can be segregated into two main classes :

- (a) Those that spread within the ducts and are relatively benign.
- (b) Those that pay no regard to these preformed pathways, but 'bulldoze' their way through all structures they encounter.

(A) Those that tend to remain intraductal :

1. Columnar celled. Generally papilliferous in form.
2. Spheroidal celled, forming plugs of tissue, so-called 'comedo cancer.'
3. Paget's disease.

(B) Those that break the confines of the duct :

1. Acute carcinoma of pregnancy and lactation.
2. Medullary.
3. Scirrhus (can develop colloid degeneration).
4. Atrophic scirrhus.

Clinical Types of Carcinoma of the Breast.—Commencing with the most malignant and (assuming that a diagnosis is made reasonably early) passing to the least malignant, the following clinical varieties are encountered :

Mastitis Carcinosa.—(2 per cent.)²—Notwithstanding the widespread belief, and contradicting current teaching, pregnancy and lactation do not predispose to the inflammatory type of carcinoma of the breast. Two types of this terrible affliction are encountered: (a) a mass in the breast and signs of inflammation appear simultaneously; and (b) signs of inflammation commence in a breast already the seat of a

¹ The exception to the rule is an epidermoid carcinoma, which is exceedingly rare.

² The percentages are culled from the Ministry of Health reports on Carcinoma of the Breast, Nos. 28, 32, and 34.

carcinoma. The average age of patients suffering from mastitis carcinosa is forty-seven, or about three years younger than the average for breast carcinoma in general (C. D. Haagensen). The diseased breast is often painful—an uncommon symptom in ordinary carcinoma of the breast. In 50 per cent. of cases there is retraction of the nipple. The reddened skin (fig. 1397) feels abnormally warm and cutaneous œdema,



FIG. 1397.—Mastitis carcinosa of the left breast.

which indicates blockage of the subdermal lymphatics with carcinoma cells, usually extends over a considerable area, i.e. over one-third or more of the breast. Enlargement of the axillary lymph nodes is present regularly. This galloping form of mammary cancer, which is the result of an unbridled proliferation of cancer cells with very little fibrous reaction, sometimes is mistaken for an abscess, and incised. The main distinguishing features between the two conditions are that in mastitis carcinosa there is (1) more widespread œdema, (2) (with few exceptions) an absence of pyrexia and leucocytosis, and (3) the inflammation fails to respond to antibiotic therapy.

Treatment.—The widespread teaching that operation—radical mastectomy in particular—is always contra-indicated in cases of inflammatory carcinoma, is untenable. The only patients with this condition who have survived five years—and they are few enough in all conscience—have been subjected to radical mastectomy followed by radiotherapy. In many instances palliative treatment is all that is possible, and usually the patient is dead within a year.

Medullary (syn. anaplastic) carcinoma (17 per cent.) is usually found in women between twenty-five and thirty-five years of age with well-developed breasts (fig. 1398). While presenting many characteristics of the scirrhous



FIG. 1398.—Medullary carcinoma of the left breast. The nipple on the affected side is elevated. The breast contains an irregular firm mass. The axillary nodes are impalpable.



FIG. 1399.—Medullary carcinoma fungating through the skin. Note the *peau d'orange*.

variety, the epithelial element of the growth is in excess of its fibrous stroma. As a consequence the tumour does not feel so hard, and in advanced cases (fig. 1399) it may present semi-solid areas due to degeneration of masses of

ill-nourished cells. This variety of carcinoma is not so intensely malignant as one was often led to believe. Statistics from all clinics show that the survival rate after operation is very little worse, or even a little better, than that of scirrhous carcinoma. Perhaps the relatively large size and rapid growth of the tumour impel the patient to seek relief earlier than in the case of scirrhous carcinoma.

Scirrhous carcinoma (60 per cent.) is met with principally in middle-aged and elderly women. Owing to an abundance of fibrous tissue the lump feels very hard, while its contour tends to be irregular. In its early stages it can be moved freely upon underlying structures, and the skin can be made to glide over it (fig. 1400). Later it becomes tethered to the skin or to the underlying muscle, or to both (fig. 1401). The importance of recent retraction of the nipple has been alluded to already (p. 1056). *Peau d'orange* of the skin overlying the tumour (see fig. 1405) is another important sign. Both these manifestations are comparatively late. In the early stages the axillary nodes are impalpable. Notwithstanding, it must ever be before one that these nodes are invaded microscopically a considerable time before they can be felt clinically.

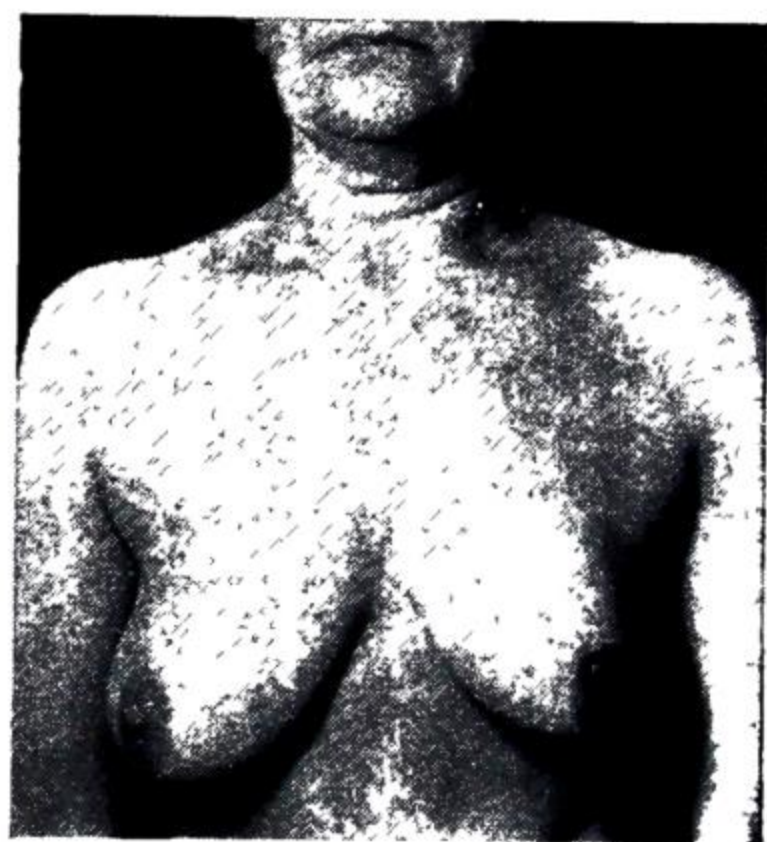


FIG. 1400.—Scirrhous carcinoma of the breast; Stage I. Nipple commencing to retract.

Untreated, the growth invades (fig. 1402), and eventually ulcerates through the skin and it may extend into the thorax, while dissemination via the lymphatic and blood-streams finally determines the fatal issue.

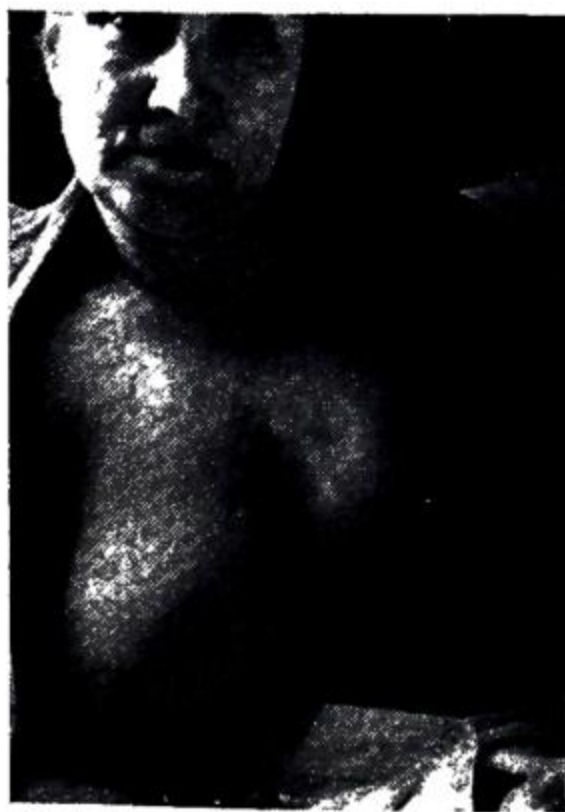


FIG. 1401.—Scirrhous carcinoma; Stage III. Nipple almost out of sight.



FIG. 1402.—Scirrhous carcinoma; Stage IV. Nipple submerged, skin involved by the growth, tumour adherent to chest wall. (For staging of carcinoma of the breast, see p. 1075.)

If a breast containing a scirrhous carcinoma is cut with a knife so as to section the tumour, the following macroscopical characteristics will be noticed :

1. The growth cuts like an unripe pear, and may grate whilst being cut.
2. Usually *both* cut surfaces are found to be concave.
3. The colour of the cut surface is definitely grey (see fig. 1387), and its appearance has been likened aptly to the interior of an unripe pear. A most important gross finding is small granular chalk-like streaks within the tumour tissue.
4. On viewing the periphery of the sectioned tumour it will be found that there is not the slightest indication of a capsule. True to its namesake, the crab, its claws have penetrated hither and thither into the breast tissue, and it is impossible to separate the tumour from the breast.

Atrophic scirrhous carcinoma (5 per cent.) is seen principally in aged, thin women with small breasts. The cellular element of the growth is comparatively sparse, its main constituent being the fibrous stroma. Although steadily progressive, the disease runs a very chronic course, perhaps taking ten years to ulcerate through the skin, when it is inclined to grow somewhat more rapidly.

Duct Carcinoma (8 per cent.).—As the leading symptom in both conditions is a blood-stained discharge from the nipple, it is often impossible to distinguish a duct papilloma from a duct carcinoma without additional help. In the case of a duct carcinoma sometimes a small lump can be palpated behind the nipple or areola, and emerging from this there is usually a sector-shaped area of induration, viz.:

Obviously the cause of the latter is distension of those alveoli drained by the duct that is blocked by the growth.

Radiographic Diagnosis.—Punctate areas of calcification are pathognomonic.

Exploration in a Doubtful Case—On slitting up a lactiferous duct containing a duct carcinoma often it is possible to trace the main stalk of the neoplasm arising from the wall of the duct. From this stalk delicate tendrils, like fine seaweed, can be traced along smaller ducts, the latter and their corresponding alveoli being dilated into a fine sponge-work by the growth and blood-stained serous exudate.

The reason for the relative benignity of this form of carcinoma is that the lymph nodes are involved somewhat late in the course of the disease, and as a duct carcinoma gives rise to alarming symptoms (bloody discharge from the nipple), which impel the patient to seek advice early, the prognosis after radical mastectomy is usually good.

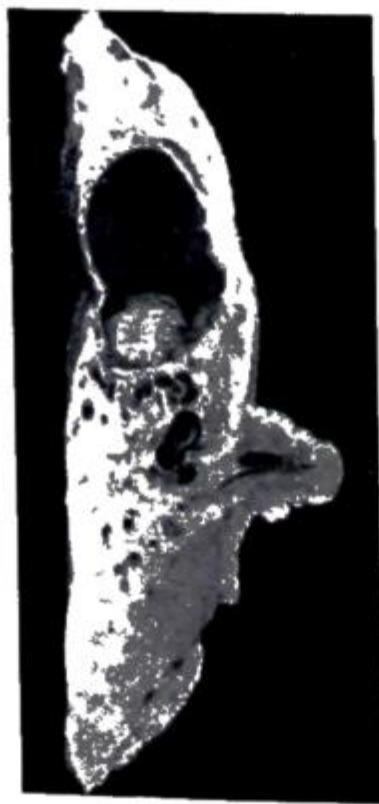


FIG. 1403.—Intracystic papilliferous carcinoma. The breast is also the seat of fibroadenosis with multiple small cysts.

Intracystic Papilliferous Carcinoma (*syn.* Disease of Réclus) (2 per cent.).—It is usually impossible to differentiate this condition from a simple cyst until its interior has been displayed. Within the cyst there is a cauliflower-like growth (fig. 1403). The prognosis after early operation is good.

Comedocarcinoma of the Breast (3 per cent.).—If on inspection of the cut surface of the specimen prominent lactiferous ducts can be seen, and if on compression of the specimen from side to side vermiform plugs of inspissated secretion emerge from the ducts in a serpiginous manner, the growth is a comedocarcinoma. The resemblance of these plugs to cutaneous comedones ('black-heads') is striking, and over fifty years ago the term comedocarcinoma was coined by J. C. Bloodgood. The ages of patients with this condition range from the

late twenties to the evening of life. Having become aware of the existence of this form of carcinoma, sometimes the clinician can diagnose it preoperatively, or at least put forward a tentative suggestion that it is present, by reason of the following clinical features. Half the patients complain of a heaviness in the breast, sometimes amounting to pain. On enquiry, about a third of them remember that there has been a serous discharge from the nipple from time to time: the main complaint in a few is a discharge tinged with blood. In 80 per cent. of cases there is a lump present, nearly always centrally placed, and seldom large. As one would expect of a growth arising within the larger ducts, the lump cannot be moved freely, or apart from the nipple. In 20 per cent. of cases a distinct lump cannot be defined. The results of treatment—radical mastectomy followed by radiotherapy is advised by all authorities—are better than those of carcinoma of the breast in general. In cases without lymph-node involvement the five-year survival rate is 90 per cent. It would appear that comedocarcinoma has more than a casual relationship to Paget's disease of the nipple.

Paget's disease of the nipple (1 per cent.) is a persistent eczematous condition that usually commences in patients over fifty years of age and does not respond to treatment. The nipple is eroded slowly and eventually disappears. As the disease progresses the areola becomes involved (fig. 1404), and the eczema continues to spread peripherally for about two years, by which time a carcinoma within the breast becomes manifest. After many years of controversy it is now agreed that Paget's disease of the nipple is due to a



FIG. 1404.—Paget's disease of the nipple and an obvious carcinoma of the breast co-existent.

slowly growing duct carcinoma that infiltrates the epithelial covering of the nipple.

Microscopically the eczematous area is characterised by the presence of large vacuolated cells with small deeply staining nuclei in the epidermis. In the majority of cases an exhaustive microscopic search reveals the presence of malignant changes in the ducts (Donald Teare). Sooner or later a carcinoma develops in the breast itself.

Differential Diagnosis:

Eczema	Paget's Disease
Bilateral.	Always unilateral.
Lactation.	Menopause.
Vesicles.	None.
Always itches.	Sometimes itches.

Treatment should always be radical mastectomy. As a rule the prognosis is extremely good. Naturally, if the patient has a palpable lump as well as the eczema, the prognosis is less favourable. On no account should patients with this condition be subjected to radiotherapy alone, as the evidence is that Paget's disease of the nipple is radio-resistant.

CLINICAL STAGING OF CARCINOMA OF THE BREAST

When the patient is first examined, instead of categorising the growth in such vague terms as 'early,' 'moderately advanced,' or 'advanced,' it is highly desirable to have some conventional method of expressing the stage which has been reached in an explicit manner. There is no better method than the Manchester¹ classification:

¹ Evolved by the staff of the Christie Hospital, Manchester.

Sir James Paget, 1814-1899. Surgeon, St. Bartholomew's Hospital, London.
Donald Teare, Contemporary. Pathologist, St. George's Hospital, London.

Stage I.—Growth confined to the breast. An area of adherence to the skin smaller than the periphery of the tumour does not effect staging. Even ulceration of the skin in the area defined does not alter it.

Stage II.—Same as Stage I, but (a) palpable mobile lymph nodes; (b) tethering of growth to the pectoral muscle.

Stage III.—(a) Skin involvement larger than the tumour; (b) tumour fixed to the pectoral muscle; (c) if nodes are palpable they must be mobile.

Stage IV.—(a) Skin involvement as Stage III; (b) tumour fixed to the chest wall; (c) axillary nodes not mobile; (d) palpable nodes in supraclavicular fossa; (e) secondary deposits in skin wide of the tumour; (f) secondary deposits in the opposite breast; (g) distant metastases.

It must be understood that any one of the phenomena (a) to (g) is sufficient to affect the staging. When Stage II has been passed, the prognosis deteriorates appreciably.

PHENOMENA RESULTING FROM LYMPHATIC OBSTRUCTION IN CASES OF MAMMARY CARCINOMA

Peau d'orange (fig. 1405) is due to cutaneous lymphatic œdema. Where the infiltrated skin is transfixed by the sweat ducts it cannot swell. The characteristic pitted appearance, so well likened to orange peel by French observers, has become a classical physical sign of advanced carcinoma of the breast. But it should be noted carefully that occasionally the same phenomenon is seen over an abscess, particularly a chronic abscess, of the breast.



FIG. 1405.—Early *peau d'orange* is made more obvious by pinching up the skin as shown.

Early Post-operative œdema of the Arm.—œdema occurring within a matter of days after radical mastectomy must be regarded as the consequence of some fault in surgical technique. It is due to infection, and as the lymphatic drainage is impaired, a mild infection is prone to cause considerable swelling. With a view to preventing infection, C. D. Haagen-sen undertakes the post-operative dressing himself.

Prompt treatment with antibiotics results in rapid subsidence of the swelling.

Late œdema of the arm (*syn.* elephantiasis chirurgens) is a frequent and troublesome complication: the swelling (fig. 1406) appears at a varying time from several months to many years after radical mastectomy. Once again it is due to infection of an arm with a defective lymph drainage system, obese patients being especially susceptible to it. In some cases the whole arm becomes obviously inflamed. If a careful search is made, the portal of infection often can be demonstrated, e.g. paronychia. In a number of instances X-ray dermatitis is the cause.

When commenced before the condition has become chronic, antibiotic therapy is often successful in reducing, if not eliminating the swelling. Should it fail, a course of hyaluronidase into the affected area, followed by bandaging the whole arm with gauze over which an elastic bandage is applied, and elevating the limb for eight hours often reduces the swelling. The treatment is repeated daily for five days; further courses can be given, when necessary. In obese patients drastic reduction in weight is helpful. Various operations to enhance lymphatic drainage have been advocated, but all fail in their purpose.

Brawny arm can result from advanced neoplastic



FIG. 1406.—Late œdema of the arm following radical mastectomy three years previously.

infiltration of unremoved or incompletely removed axillary or supraclavicular lymph nodes. The œdema, which is persistent and brawny (it does not pit), is due to lymphatic blockage, but in some cases venous obstruction is a contributory cause.

A forequarter amputation is merciful in selected cases, especially in order to relieve the intense pain caused by involvement of nerves in the axilla.

Cancer en Cuirasse.—Here, in addition to a brawny arm, the affected side of the thoracic wall is studded with carcinomatous nodules and the skin is so infiltrated that it has been likened to a coat of armour (fig. 1407). Usually, but not necessarily, the condition appears in cases with local recurrence after amputation of the breast. Various palliative measures can be tried, but the main objective is to relieve pain, if present, for the few remaining months of the patient's life.

Lymphangiosarcoma has been recognised recently as a complication of post-mastectomy lymphœdema. Unless there is awareness of the condition, it is likely to be confused with recurrent carcinoma of the breast.

Occasionally deep X-ray therapy postpones the inevitably fatal course of this complication. The only alternative is to perform an interscapulo-thoracic (fore-quarter) amputation.

Serous effusion into the peritoneal or pleural cavities may be classed as one of the terminal events in hopeless cases, although occasionally, as a result of paracentesis and endocrine treatment, temporary remission occurs.

THE SPREAD OF MAMMARY CARCINOMA

(a) **Local Spread.**—The tumour increases in size and invades other portions of the breast. It tends to involve the skin (see fig. 1402) and to penetrate the pectoral muscles, and even the chest wall.

(b) **Lymphatic spread** occurs in two ways: *by emboli*, composed of carcinoma cells, being swept along the lymphatic vessels by the lymph stream; and *by permeation*, that is, actual growth of columns of cancer cells along the lumen of the lymphatic channels. By these means the axillary lymph nodes (see fig. 1365) and sometimes the internal mammary lymph nodes are involved comparatively early. Later, the supraclavicular nodes, the opposite breast, and the mediastinum, are all possible resting places for itinerant carcinoma cells journeying by this route. Finally, they may be found in lymph nodes even farther afield.

(c) **Spread by the Blood-stream.**—It is by this route that skeletal metastases occur (in order of frequency) in the ribs, lumbar vertebræ, femur, thoracic vertebræ, and the skull, a pathological fracture occurring most often in a rib or a vertebra. In most instances it is also by way of the blood-stream that metastases arrive in the liver from the breast. It cannot be denied, however, that secondary deposits may also be carried to the liver via the lymphatics within the rectus sheath and the falciform ligament.

BIOPSY FOR THE CONFIRMATION OF THE DIAGNOSIS OF CARCINOMA OF THE BREAST

In a high proportion of cases (estimated at 25 per cent.) even an experienced clinician cannot be certain of the diagnosis of a lump in the breast. Biopsy,

S.P.S.—68



FIG. 1407.—Cancer en cuirasse in a patient with untreated carcinoma of the breast.

therefore, assumes a position of importance unrivalled in any other part of the body. The unwarranted dangers and disadvantages of needle biopsy (which include trephine biopsy) have been alluded to already (see p. 1066).

Open biopsy is undertaken in the operating theatre, with the patient prepared for mastectomy. After the specimen has been obtained, the operative area is redraped, gloves are changed, and fresh instruments are put out in readiness for mastectomy should the pathologist report that the section reveals carcinoma.

Excision is Safer than Incision.—Neoplastic tissue should never knowingly be incised *in vivo*. If the lesion is not small enough and superficial enough to be excised with a margin of apparently healthy tissue through an incision following one of Langer's lines (see fig. 1392), simple mastectomy will provide the best biopsy material. Such a step is justified in older women when the clinical diagnosis weighs in favour of carcinoma. In other circumstances excision of the lesion through a submammary incision is advisable.

Macroscopical Examination of the Lump (see p. 1066).—On bisection of the specimen, in eight out of ten cases it will be apparent to an experienced surgeon whether the lump is definitely malignant or definitely innocent.

Frozen Section.—When a pathologist especially skilled in interpreting frozen sections microscopically is in attendance in the operating theatre he is able to give an opinion as to whether or not the growth is carcinomatous within a matter of minutes. In some cases, of course, he will be doubtful. When the services of a pathologist with special experience in this work is not available, or when he cannot express a definite opinion, it may be considered to the patient's advantage to close the wound and await the result of an examination of paraffin sections, which can be ready in forty-eight hours.

METHODS OF TREATMENT OF CARCINOMA OF THE BREAST

At the present time most authorities consider that radical mastectomy or extended radical mastectomy offers the best prospect of long survival, provided the neoplasm can be categorised as belonging to Stages I or II. When Stages III and IV are reached, the interests of the patient are best served by simple mastectomy, radiotherapy and, provided the tumour is hormone stimulated, endocrine therapy.

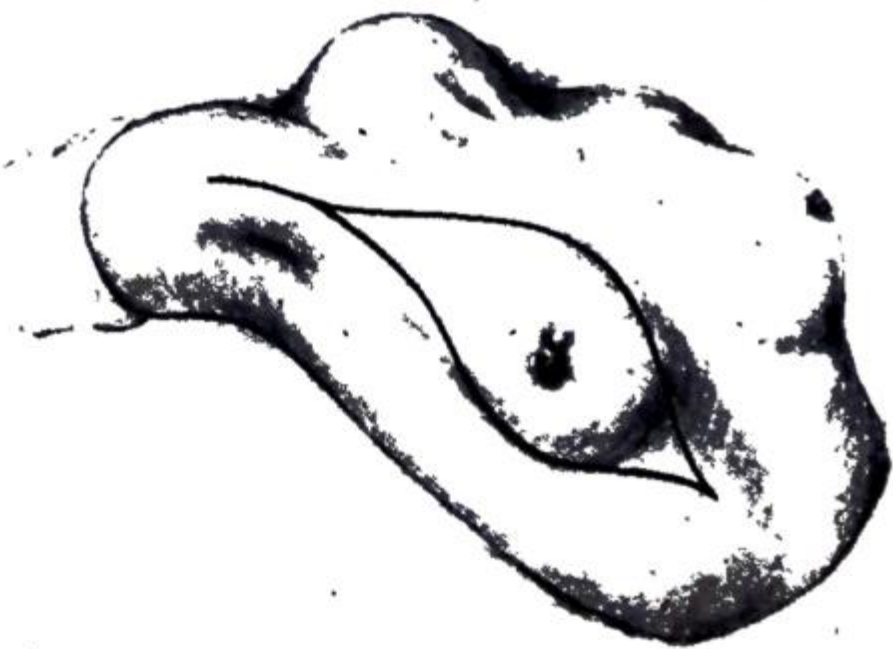


FIG. 1408.—Incision for radical mastectomy. FIG. 1408a.—By temporarily retaining the portion of skin shaded, sufficient is left for providing skin for an immediate full-thickness graft, if required. (After R. H. Gardiner and A. D. Roy.)

Sir William Mitchell Banks, 1842–1904, Surgeon, Liverpool Royal Infirmary in Britain, and William S. Halsted, (1852–1922), Professor of Surgery, Johns Hopkins University, Baltimore, were responsible for evolving the radical amputation of the breast as performed to-day. The operation is often known as 'a complete Halsted.'

Radical Mastectomy.—The breast and associated structures are dissected *en bloc*, and the mass excised is composed of :

1. The whole breast.
2. A large portion of skin, the centre of which overlies the tumour, but always includes the nipple (fig. 1408). When there is much skin involvement more skin must be sacrificed (fig. 1408a).
3. The fat and fascia from the lower border of the clavicle to, and including, the upper quarter of the sheath of the rectus abdominis, and from the sternum to the anterior border of the latissimus dorsi.
4. The pectoralis major and its fascial sheath (usually its clavicular head is left).
5. The pectoralis minor and its fascial sheath.
6. The costocoracoid membrane.
7. All the fat, fascia, and lymph nodes of the axilla.
8. The fascia over, and a few of the more superficial muscle fibres of, the anterior part of the external oblique, serratus anterior, the subscapularis, the latissimus dorsi (except its posterior surface), and the upper quarter of the rectus abdominis (fig. 1409).

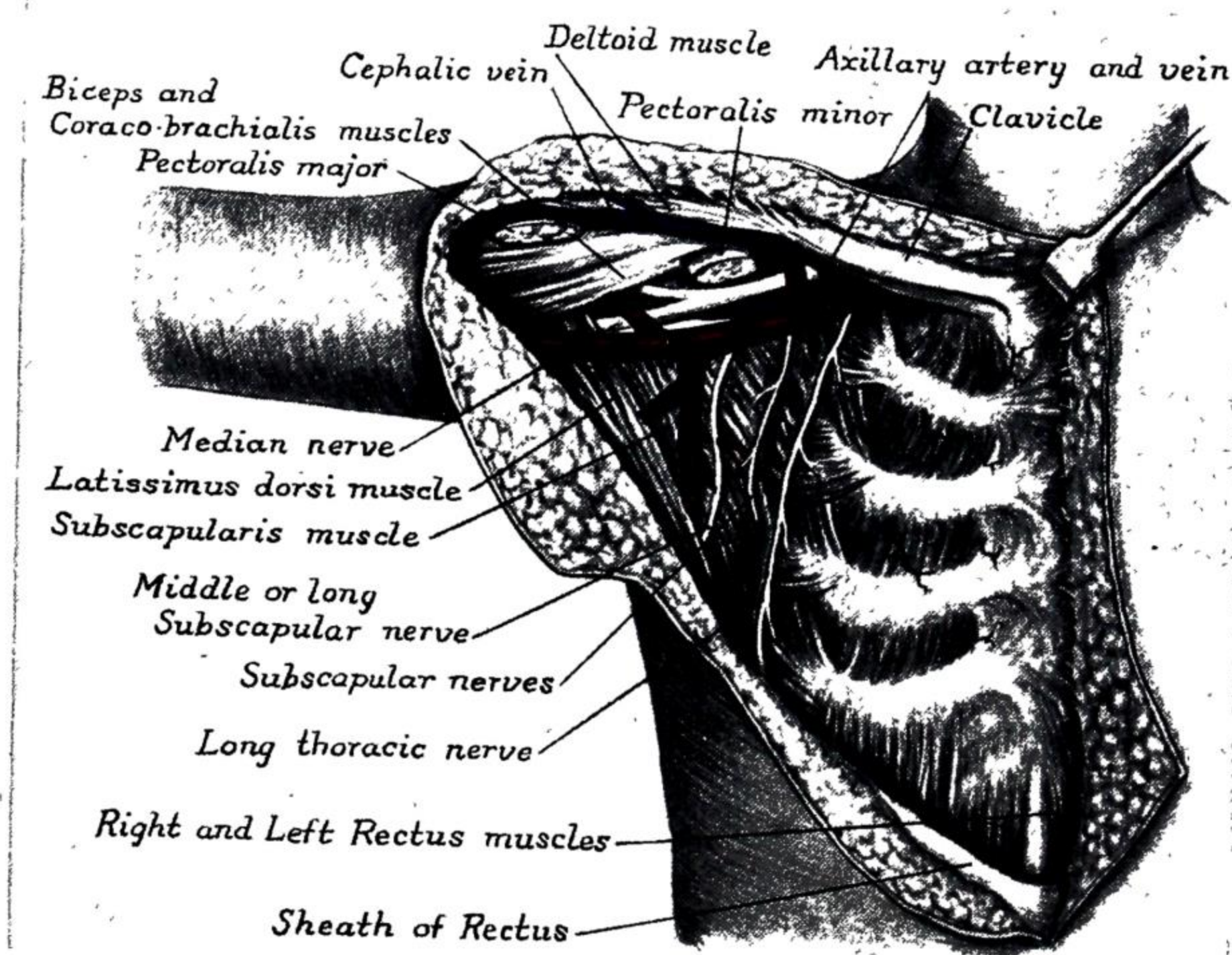


FIG. 1409.—Radical mastectomy completed. It is desirable, but not essential, to preserve the nerves proceeding in a downward direction.

During the operation every effort should be made to preserve :

1. The axillary vein.
2. The cephalic vein.
3. The long thoracic nerve of Bell (nerve to serratus anterior).

The middle or long subscapular nerve (nerve to latissimus dorsi) can be sacrificed without ill effect, and this should be done without hesitation if its division enables a more thorough dissection to be carried out.

During the operation the exposed chest wall must be protected by towels wrung out in hot saline. At the completion of the operation the wound is drained in order to prevent blood accumulating.

If a wide area of skin has been sacrificed, it may not be possible to approximate the skin edges completely. A deficiency is left which is treated by immediate or more remote skin grafting.

Sir Charles Bell, 1774–1842. Surgeon, Middlesex Hospital, London, and founder of its Medical School.

After operation the arm is supported upon a pillow until the wound has healed, when early movement of the arm is encouraged. The movements of the arm after so extensive a loss of muscle are surprisingly good.

Extended Radical Mastectomy.—As about 50 per cent. of cases of carcinoma in the medial quadrants and 25 per cent. in the lateral quadrants of the breast show metastases in the internal mammary lymphatic chain, an increasing number of surgeons feel that the internal mammary chain should be included in a radical mastectomy. A few incise the muscles of the second intercostal space and remove a node for frozen section; should it be involved, they regard the following step as not worth while. The second, third and fourth costal cartilages are divided with rib shears close to the sternum, and the intercostal muscles are severed vertically. A short lateral incision is made in the second and fourth intercostal spaces and the ribs are again divided half an inch (1.3 cm.) more laterally. The lower end of the trap-door thus fashioned is raised, and the internal mammary vessels are ligated as low as possible. The vessels, together with the lymphatics and adjacent tissue, are dissected upwards and are again ligated as high as possible in the second space. Sometimes these vessels lie in the shadow of the sternum, when the sternum must be split near its lateral border to give access. Towards the close of the operation I. M. Ariel drills holes through the ends of the severed bony structures and inserts stainless steel wire through them. While firm pressure is applied to the lateral aspect of the thorax by an assistant, the sutures are tied. The frequency with which the pleura is damaged makes it desirable always to insert a drainage tube through the sixth intercostal space, and attach this to a water-sealed bottle.

Super-radical mastectomy includes removal of the internal mammary chain in continuity with the supraclavicular lymph nodes after division of the clavicle. This procedure allows the 'Grand Central' terminal nodes near the jugulo-subclavian junction to be removed. The operation is of such magnitude that it finds favour with but very few surgeons.

THE RÔLE OF RADIOTHERAPY IN THE TREATMENT OF MAMMARY CARCINOMA

Pre-operative irradiation renders the tissues a little more vascular, but its main disadvantage is that the patient or her relatives hear that a 'mutilating' operation can be avoided, and consequently may refuse surgical treatment. On the other hand, pre-operative irradiation is especially valuable in Stage II cases where the skin is ulcerated, and occasionally it brings a Stage III case into the category of operability.

Post-operative irradiation is not recommended when the radical mastectomy specimen reveals no metastases in the axillary lymph nodes. On the other hand, when given to patients who had axillary lymph-node involvement in total amounts well over 3,500 r, there is a 5 per cent. increase in the five-year survival rate. Therefore, in all cases where the likelihood of recurrence can be predicted, post-operative irradiation, especially of the anterior mediastinum, is unquestionably a logical procedure.

Treatment of Recurrences and Secondary Deposits.—Deep X-ray therapy causes to disappear, or retards the progress of, recurrences and secondary deposits in about one-third of cases. Examples are encountered where extensive metastatic deposits are so radio-sensitive that they melt away with this form of therapy, unfortunately only to return in the same, or another, site.

McWhirter's Method of Treatment.—Because either the supraclavicular or the internal mammary lymph nodes are implicated also in 48 per cent. of patients with axillary lymph-node involvement (see p. 1077 and fig. 1365), R. McWhirter considers that it is illogical to clear the axilla of its lymph nodes and allow these oft-involved satellites to remain. He therefore advises simple mastectomy to rid the patient of the primary neoplasm, and relies on vigorous radiotherapy for the treatment of axillary,

supraclavicular and internal mammary lymph node involvement. His aim is to give a dose of not less than 3,750 r to the operative area and whole lymphatic field during the three weeks immediately following the operation. He stipulates that the method is contraindicated in (1) very obese patients, (2) aged patients, (3) those with advanced arteriosclerosis, (4) those with tuberculosis, and (5) those with a primary neoplasm in the axillary tail of the breast. As his published results refer only to five-year survivals, and not to patients who are clinically free from recurrence (see Royal Marsden Statistics, below), and as many of the patients have had the benefit of oophorectomy and other endocrine treatment in addition, it is difficult to compare the results of this method with those of radical mastectomy. What is not given prominence is that a number of patients treated by the McWhirter method show irradiation complications, and in a few of them these complications are so severe as to necessitate amputation of the arm. McWhirter has not proved that sterilization of carcinoma in the axillary lymph nodes is achieved (L. V. Ackerman). Equally good, and in some cases better, results have been obtained by radical mastectomy followed by radiotherapy in series that include fat, aged, arteriosclerotic, and, in fact, all patients who are fit to undergo radical mastectomy.

THE 'FOLLOW-UP' OF CASES OF CARCINOMA OF THE BREAST

It is the duty of the surgeon to examine all his cases periodically for life, so that in event of recurrence he can inaugurate such treatment as is applicable without delay. The following indicates a routine suitable for this periodic examination:

History.—This includes an enquiry as to the physical energy, general health, and the presence of an unexplained cough. Symptoms that the patient usually ascribes to rheumatism, lumbago or sciatica must be regarded with suspicion, for too often skeletal metastases announce themselves in this way.

Examination.—The operation field is examined for nodules. The axillæ, supraclavicular lymph nodes, and opposite breast¹ are palpated. The hand and arm are examined for œdema. The chest is percussed and auscultated and the abdomen examined for evidence of enlarged liver or ascites. If considered necessary, a rectal or vaginal examination is made in order to detect pelvic or ovarian metastases.

Radiography.—In doubtful cases a radiographic examination is made of the chest, or of any bones suspected of harbouring metastases.

Results.—Unlike some forms of malignant disease, where if the patient survives five years a permanent cure can be assumed, there is no such criterion in cases of carcinoma of the breast. Patients die of secondary mammary carcinoma as long as fifteen or twenty years after operation. It is, however, abundantly clear that when the axillary lymph nodes are not involved, the prospect of many years of freedom from recurrence is much greater.

Recurrence-free Rates (all forms of treatment)		
Stage	5 years	10 years
I	68 per cent.	54 per cent.
II	40 " "	25 " "
III	15 " "	4 " "
IV	2 " "	4* " "

* Includes several patients treated earlier but not accounted for in the five-year list. (Statistics from the Royal Marsden Hospital, London.)

¹ A few surgeons recommend early simple mastectomy on the contralateral breast because 7.5 per cent. of patients with carcinoma of the breast develop carcinoma in the contralateral breast.

THE ENDOCRINE TREATMENT OF INOPERABLE AND RECURRENT
CARCINOMA OF THE BREAST

Irrespective of their histological structure, mammary carcinomata fall into one of two categories :

1. **Hormone Stimulated**¹.—A large number (about 50 per cent.) of mammary carcinomata are hormone stimulated, that is to say that unless they

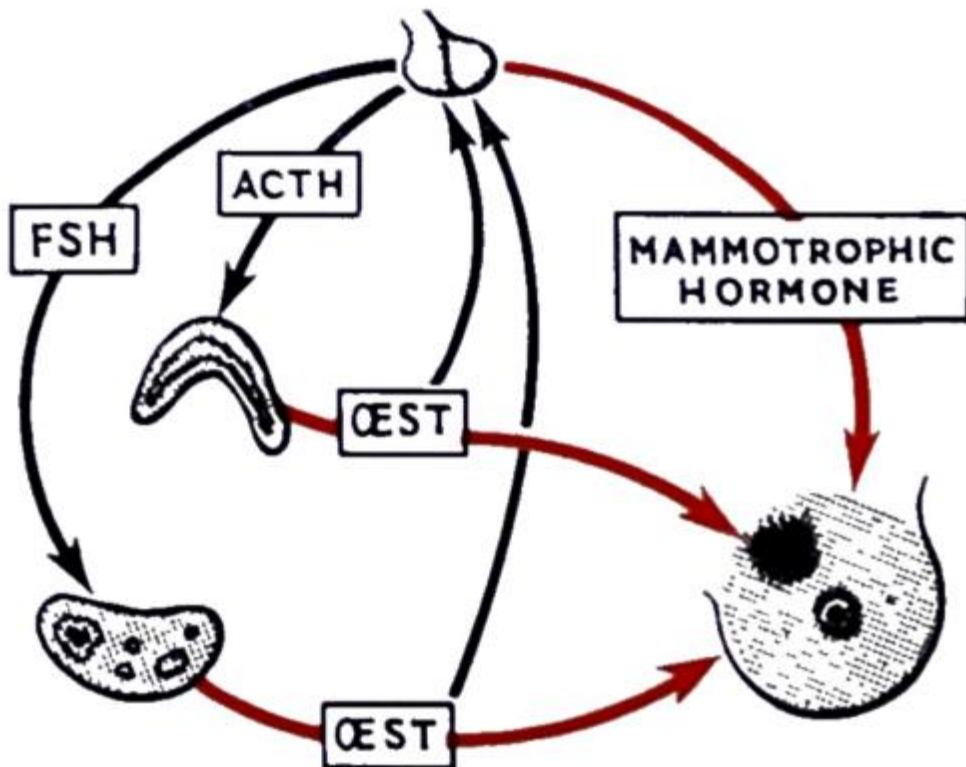


FIG. 1410.—The hormonal influences of normal mammogenesis. ACTH adrenocorticotrophic hormone; FSH follicle stimulating hormone. (After Jessiman and Moore.)

are nurtured by blood containing one or perhaps more than one of the hormones responsible for normal mammogenesis (fig. 1410), they cease to proliferate and metastasise, and many of their component cells perish. Unfortunately this regression following hormone deprivation is never permanent.

2. **Automatous**, i.e. the cells of which they are composed require no stimulus to enable them to thrive, multiply and metastasise.

If carcinomata belonging to Group I are deprived of the hormone or hormones that stimulate them, after a varying number of months they, too, become automatous.

2. **Automatous**, i.e. the cells of which they are composed require no stimulus to enable them to thrive, multiply and metastasise.

Oestrogen stimulated carcinomata comprise the largest group. It is true that, compared with the normal average, five times as many women over fifty years of age with carcinoma of the breast are found to be still menstruating more or less regularly.

Even so, quite frequently oestrogen stimulated mammary carcinomata occur in women long past the menopause (A. G. Jessiman). The ovaries of such patients are the seat of cortical stroma hyperplasia, which represents the response of an elderly ovary to gonadotrophic FSH stimulation (fig. 1411). Often such hyperplasia is so well marked as to be readily recognisable macroscopically as a yellow-brown rind of increased thickness. Thus it is quite clear that segregation of patients who are likely to benefit from oophorectomy and adrenalectomy cannot be



FIG. 1411.—(a) Normal senile ovary from a patient aged 65 years; (b) Ovary showing cortical hyperplasia from a patient also aged 65 years suffering from oestrogen stimulated carcinoma of the breast. (Dr. A. G. Jessiman and Dr. F. Moore, Boston, Mass.)

governed by the presence or absence of menses. Unfortunately, the estimation of oestrogen in the urine is technically difficult, and the results are unreliable.

¹ It is inaccurate to say that a mammary carcinoma is ever hormone-dependent, for all of these tumours, although enfeebled, continue to survive without hormones.

Occult Oestrogen Stimulated Carcinomata.—Even after the ovaries, the adrenals and the pituitary have been removed, in some cases after a time oestrogen again appears; the explanation is that adrenal tissue is present somewhere, either in accessory adrenals or ectopic adrenals that lurk around the coeliac axis or in the broad ligament.

Stilbœstrol Test.—10 mg. of stilbœstrol is administered by mouth for three days. If the tumour is oestrogen-stimulated there will be :

1. *Systemic response*—malaise, pyrexia, and perhaps vomiting. The tests should be stopped if there is a severe reaction or a decreased urinary output. Untoward reactions are rare except in patients who exhibit hypercalcæmia prior to the test, in which case the test should not be performed.

2. *Increased Calcium Output.*—In patients with oestrogen-stimulated skeletal metastases there is a 50 per cent. or more increase in urine calcium excretion two or three days after the last dose of stilbœstrol. The increased output of calcium is sometimes prolonged for as long as three weeks.

In patients giving a positive stilbœstrol test, oöphorectomy, or especially oöphorectomy plus adrenalectomy, is likely to bring about not only subjective improvement but a decided regression in secondary deposits, especially skeletal metastases. Neoplastic cutaneous lesions, lymphadenopathy and pleural and peritoneal effusions often respond well. Visceral deposits are less affected, those in the liver hardly at all.

Cortisone Inhibition Test.—When the patient has been subjected to bilateral oöphorectomy¹ and a relapse occurs, it may be that the relapse is due to a raised level of oestrogens of adrenal origin. 200 mg. of cortisone is administered by mouth for three days and maintained at 100 mg. for four days. Importance is attached to symptomatic relief, as well as to a fall in the urine calcium. A positive result indicates that the patient is likely to benefit by the performance of adrenalectomy. Adrenalectomy for recurrent and metastatic carcinoma of the breast is discussed on p. 264.

Mammotrophin-stimulated Carcinomata.—In all probability there is a group of patients whose tumours are stimulated by mammotrophic hormone alone. Mammotrophin can be demonstrated in the urine with comparative ease (G. Hadfield), and a high titre in a patient with carcinoma of the breast strongly suggests that the tumour is mammotrophin stimulated. In this type of case the only hope of a remission is to remove or destroy the pituitary gland.

Dual Hormone Stimulated Carcinomata.—Hypophysectomy has induced remission in some patients who have benefited for a time after oöphorectomy and adrenalectomy, and then relapsed. The rationale is as follows: removal of the Master endocrine gland (the pituitary) does away not only with the secretion of mammotrophin, but also with ACTH, which stimulates accessory and ectopic adrenals to physiological activity. As those who have benefited from oöphorectomy are likely to react favourably to adrenalectomy, so those who have responded to adrenalectomy will probably gain remission by hypophysectomy. Nevertheless this rule is not steadfast, and there are no hard and fast rules for the selection of cases for hypophysectomy, save to heed the great experience of H. Olivecrona, who advises against hypophysectomy in patients over sixty years of age and those with liver or brain metastases.

¹ Bilateral oöphorectomy for metastatic carcinoma of the breast was advocated in 1896 by Sir George Thomas Beatson, 1848–1933. Surgeon, Western Infirmary, Glasgow.

Geoffrey Hadfield, *Contemporary*. Director, Clinico-Pathological Research, Imperial Cancer Research Fund, London.
Herbert Olivecrona, *Contemporary*. Director, Neurosurgical Clinic, Serafimerlasarettet, Stockholm.

Hypophysectomy.—The pituitary is removed via the frontal route. After dividing its stalk with a diathermy knife and enlarging the orifice in the diaphragma sellæ, the pituitary gland is removed piecemeal. Zenker's solution is applied to the sella to necrose any remnants of the gland.

As an alternative procedure, implantation of gold or yttrium seeds into the pituitary fossa by the nasal route has been tried; however, the incidence of grave complications is higher than those of hypophysectomy, and the results are not as good.

Androgen therapy is sometimes useful in women below fifty-five years of age who have relapsed after adrenalectomy or hypophysectomy; 150 mg. of testosterone propionate is given intramuscularly three times a week for ten weeks or longer.

Side Effects.—Masculinisation effects are produced, and the patient must be forewarned of these distasteful sequelæ. Stimulation of the disease occurs occasionally.

Results.—Frequently there is obvious symptomatic improvement; relief of pain occurs in 80 per cent. of patients, in spite of the fact that healing of osseous lesions and decrease in the size of parenchymatous lesions are seen only in 20 per cent. of cases.

Œstrogen therapy should be reserved for women ten or more years past the menopause. Before prescribing an œstrogen, it is necessary to be certain that the tumour is not likely to be stimulated by the œstrogen. In this respect a negative stilbœstrol test is helpful, but a more certain method is an examination of vaginal smears; an absence of cornification of the epithelial cells over a month is proof of œstrogen lack.

Dangers and Untoward Effects.—Salt and water retention may lead to cardiac impairment. Not infrequently painful breasts and uterine bleeding occur. An increased dose of the hormone sometimes brings about cessation of uterine hæmorrhage. If it does not do so, and the bleeding is copious, the œstrogen must be stopped.

Results.—Relief of pain is often gratifying; 40 per cent. of soft tissue and 30 per cent. of osseous metastases undergo regression for a time.

Cortisone Therapy.—This last stronghold of endocrine therapy can be tried in patients who have relapsed after other forms of applicable therapeutics. It is believed that cortisone acts directly on the tumour cells, and occasionally remarkable remissions lasting for a few months eventuate.

Although as far as can be foretold, the surgical and medical endocrine treatment of susceptible carcinomata of the breast will always be a losing battle¹, further advances in this field are likely to be achieved in the not far distant future.

THE MALE BREAST

The mammary tissue of the male is the leading, if not the only, example of an external secretory mechanism that persists without actual or potential function.

Mastitis of puberty is frequently encountered. The boy, aged about fourteen, complains of pain and swelling in the breast. In 80 per cent. of cases the symptoms are mainly or entirely unilateral. The condition is due to a relative transient increase in androgens. The symptoms usually disappear in fourteen days, or less, but occasionally induration persists for several months.

¹ So far the maximum length of time of a remission following endocrine therapy is four years; usually such remissions are much shorter.

Fredrich Albert von Zenker, 1825–1898. Professor of Pathology, Erlangen, Germany.

Mastitis from local irritation is by no means rare in men; in civil life it usually occurs in manual labourers with ill-fitting braces (fig. 1412). It is not uncommon among soldiers carrying heavy equipment across their shoulders. The treatment is to remove the cause; substitution of a belt for braces is sound advice.

Gynæcomazia.—(a) *Idiopathic.*—Hypertrophy of the male breast may be unilateral or bilateral. The breasts enlarge at puberty, and sometimes present the characteristics of a well-developed female organ. The subjects of this deformity are often virile. Chengwayo, chief of the Zulus (fig. 1413), a gynæcomast, at the age of fifty-five, had forty wives and over a hundred children. Tribal tales of a father nurturing his motherless infant



FIG. 1413.—Chengwayo, from a photograph by Schujelot.

with milk from his own breast belong to the realms of mythology, but pseudo-lactation has been observed in rare instances, and fluid akin to colostrum has been expressed.

(b) *Hormonal.*—Enlargement of the breasts often accompanies stilbæstrol therapy, e.g. for carcinoma of the prostate (see fig. 1137, p. 857); it may also occur as a result of a teratoma or a chorion-epithelioma of the testis, in anorchism, and after castration.

(c) *Associated with Leprosy.*—Gynæcomazia is very common in male persons suffering from leprosy. Possibly this is the result of bilateral testicular atrophy, which is a frequent accompaniment of leprosy (C. Bowesman).

(d) *Associated with Portal Hypertension.*—Gynæcomazia sometimes occurs in patients with portal hypertension. Again, this is dependent upon testicular atrophy (see p. 414).

Treatment.—Provided the patient is healthy and comparatively young, the treatment of obvious gynæcomazia should be excision of the breasts, for their possessor is subject to ridicule.

Fibro-adenosis is the usual cause of unilateral gynæcomazia. The removed breast shows the same microscopical features as this condition in the female.

Fibroadenoma is not exceedingly rare, and presents the same clinical features as in the female.

Carcinoma, which accounts for about 1 per cent. of all cases of carcinoma of the breast, has an evil reputation: more than one-third of cases are totally inoperable when the patient first presents. In the first place this is due to the fact that so often he does not seek advice for months or years (fig. 1414). Secondly, the breast is so small that the enlarging growth reaches the extramammary tissues much sooner than in the female; this favours earlier metastasis.

Treatment.—In cases diagnosed during Stages I and II and treated by radical mastectomy and radiotherapy, the outlook should be favourable, but it is not as good as in the corresponding stages in the female.

In inoperable cases bilateral orchiectomy has an even more favourable effect than oophorectomy in the female, favourable results having been reported in as high as 70 per cent. of cases (A. G. Jessiman). Œstrogen therapy sometimes produces amelioration after the good effects of orchiectomy have waned. Conversely, prolonged œstrogen therapy employed in the treatment of men suffering from carcinoma of the prostate occasionally has resulted in mammary carcinoma, usually bilateral.

Sarcoma, although uncommon, cannot be categorised as a pathological curiosity.



FIG. 1412.—A braces button being lost, the remaining button draws the brace inwards, and the buckle rubs against the nipple.



FIG. 1414.—Carcinoma of the breast untreated for eight and a half years. The patient could not raise his arm completely because of cicatrization around the axillary lymph nodes.

The trachea and main bronchi with their lobar and first segmental divisions can all be examined visually by bronchoscopy. This investigation will demonstrate abnormalities in size (stenosis, obstruction or dilatation), movement (immobility or spasm), shape or position. The examination will also reveal the presence of a tumour or an intrabronchial foreign body. Material for biopsy and secretions for cytological or bacteriological examinations can be obtained. Only the proximal parts of the bronchial tree can be examined, even with the aid of the telescope, so that the examination has distinct limitations in the investigation of peripherally situated lesions.

A more detailed anatomical study can be made by bronchography, which consists of the introduction of radio-opaque material (iodised oil) into the bronchial tree. An attempt is made to fill all the branches of the bronchial tree on one side, and radiographs are taken in two or more planes. Bronchography provides information about the size and distribution of the bronchi, and will also demonstrate bronchial occlusion or narrowing.

INJURIES TO THE CHEST

Chest injuries are not common in civil practice; in war, however, they constitute nearly 10 per cent. of all wounds, whilst of those killed in battle, 25 per cent. have chest injuries. They can be divided into closed and open varieties. The former include crush and blast injuries; the latter are either simple or complicated.

First-aid Management

Chest casualties may require important and urgent life-saving first-aid measures not normally applicable to other casualties :

- (1) A sucking chest wound (open pneumothorax) should be sealed with an occlusive pad.
- (2) The paradoxical movements of a flail chest wall should be controlled by strapping.
- (3) A tension pneumothorax or hæmothorax should be relieved by aspiration.
- (4) The tracheo-bronchial tree should be kept clear of secretions by encouraging coughing or by bronchial aspirations.
- (5) A tracheostomy should be performed as an urgent measure if ventilation is inadequate or bronchial secretion uncontrolled.

Crush Injuries

These are common both in war and in civilian practice. The injury may be produced by a localised blow or a more extensive crushing force. Similar injuries can also be produced by concussion waves from explosions conveyed either through air or water.

The injuries may include contusion of the chest wall, simple or complicated rib fractures and contusion or laceration of the underlying lung.

Air and blood in the pleural cavity occur commonly; their removal may be a matter of urgency but usually the accumulation is not excessive and can be removed more leisurely.