OBSTETRIC PARALYSIS—ITS CAUSE AND TREATMENT

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OBSTETRIC paralysis, a paralysis produced during birth, is due to an injury of greater or less extent to the nerves of the brachial plexus. The resultant paralysis is characteristic; the whole arm hangs vertically, the elbow extended, the forearm pronated, and the whole arm inwardly rotated. The paralysis is a flaccid one.

Obstetric paralysis was first described by Smellie[1] in 1768, who believed the condition due to long pressure on the arm while the child was in the pelvis; but it was first brought prominently to the notice of the medical profession in 1872 by Duchenne, who described four cases in infants and attributed the condition to pressure of forceps or fingers in the axilla on the nerve trunks.

Duchenne recognized that the lesion might occur in obstetric operations, such as disengaging the upraised arm in a breech or footling presentation, in delivering after version, or in making traction on the arm of the child after the birth of the head, and quotes cases to support this theory. These procedures result in direct traction on the cords of the plexus, and when force is used probably cause injuries to the nerves. It was not until 1874 that Erb described the same type of paralysis in adults, since which time it has been commonly known as the Erb-Duchenne paralysis. Erb showed that pressure above the shoulder on the junction of the fifth and sixth cervical nerve roots, the so-called Erb's point, caused the characteristic grouping of the paralyzed muscles. He laid the occurrence of the paralysis especially "to the energetic application of the so-called Prague grip in which the fingers are applied like a fork over the back of the child's neck, with an after-coming head, and so endangering the integrity of the brachial plexus by energetic traction and compression".

Stransky[1], in a most careful review of the whole literature up

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to 1902, presents the subject in detail and most conclusively. He reviews Smellie (1768), Danyau (1851), Guéniot (1867), and Depauls' work, the latter cited by Seeligmuller. He reports ninety-four cases from various authors whose works he has reviewed. Stransky believed that pressure as well as hard pulling in some cases was an adequate cause, especially if ether had been used and the child was asphyxiated. The following authors are quoted from Stransky's article:

Seeligmuller thought that pressure from forceps often caused hæmorrhage about the plexus. Thorborn (1886) reported a case of lower arm paralysis, and believed the tearing of the nerves to be due to hyperextension of the shoulder as the arm was drawn above the head, but also ascribed it to pressure of the clavicle on Erb's point from the bad position of the arm.

Roulland (1884) gave all the various positions in which the condition could occur, and apparently believed it due to direct or indirect pressure on the plexus. Arens (1889) believed it due to hæmorrhage or tearing of the nerves.

Kustner (1888) advanced a theory that has been rejected at once by all other writers who have had any extensive experience with the cases, namely, that the trouble is usually due to a fracture of bones or separation of the humeral epiphysis.

Danchez (1891) believed the condition to be spontaneous, from pressure on the circumflex nerve of the arm while the child was caught in the pelvis, or that it might be traumatic from finger or instrumental pressure. He also believed that when the lower arm was involved, the condition was one of the "pseudoparalysis", as also did D'Astros (1892), that is, not a paralysis from nerve injury, but an arm held motionless on account of bruising and consequent pain, or as the result of bone injury. Gowers believed the paralysis to be due to pressure from forceps, and Weil (1896) that it was due to trauma, especially with an after-coming head. Peter thought it due to pressure of the forceps or strong lateral bending of the head, with a delayed shoulder, or turning of the head in breech cases. Guillemot (1896) likewise supported the theory that the condition was due to compression of forceps or a strong pull; and Jolly (1896) believed it due to pressure, chiefly with an after-coming head.

Stransky quotes the experimental work of Fieux (1896), Schoemaker (1899), Stolper (1901), Kustner (1888), and Landold, as follows:

Fieux opposed Erb's views, in that Erb's point was too small

and that the pressure would have to be too sharply localized, so that on the whole the theory that the finger pressure or forceps could produce it was unlikely. Pressure of finger he also rejects, for there was nothing for the finger to compress the plexus against. He comes finally to traction on the upper roots as the longest side of the triangle formed by the cords of the plexus, with lateral inclination of the head, as tending to increase the distance between the head and shoulder. He produced the paralysis in rabbits by pulling the head forcibly to one side. He showed that the amount of separation which occurred between the ends of the cut roots of the brachial plexus, when the shoulder was held down and the head carried to the opposite side with as much force as is used in ordinary labours, is as follows: The two upper cords, or fifth and sixth cervical, separated, from 26 to 28 mm., the third, or seventh cervical, only 12 mm., and the lower two, the eighth cervical and first dorsal only 8 mm. The point at which the rupture occurs is from a quarter to half an inch from the point of emergence from the spinal canal near the junction of the fifth and sixth cervical roots. Fibres of the suprascapular nerve always ruptured among the first.

Schoemaker also conducted experiments on cadavers with the plexus exposed, and could always tear the fifth and sixth cervical, but never the seventh and eighth. He also thought that the clavicle could cause pressure on the plexus by having it caught between the clavicle and first rib and spine. He was opposed to the theory that pressure from the fingers caused the injury. Kustner (second paper) and Landold also did experimental work and believed the injury due to traction. Stolper agreed in the main with Fieux and Schoemaker, but rejected the possibility of pressure on the plexus in breech cases, and believed that calvicular pressure might cause the paralysis. However, he believed that stretching was the main factor.

Other authors, such as Lovett[2], Carter[3], Walton[4], J. J. Thomas[5], Warrington and Jones[6], Stone[7], Bullard[8], Fairbanks[9], Taylor,[10] Osterhaus,[11] Frazier and Skillern[12], and Sharpe[13] and others, all believe in the theory of plexus injury due to traction, and support the known pathology as shown by operation and experiment.

Robinson[14] (1899) reports seventeen cases, in only one of which was the birth reported as normal. All the others had a definite history of the labour being tedious and difficult. In eleven the presentation was cranial; in three special mention was made of difficulty in delivering the arms; four others had forceps applied.

He states that J. E. Simpson has shown that the heads of boys are larger than the heads of girls, and therefore the heads of the latter would not dilate the way for the shoulders as well as the former. In his own series, thirteen babies out of seventeen were girls, which would bear out this theory that there was an insufficiently dilated canal for the shoulders and that they therefore caught, or were with difficulty delivered, and in so doing there was a strain put on the cords of the plexus.

T. T. Thomas[15] (1914), following Lange's theory, in an interesting theoretical discussion of the problem, based on a study of nine cases averaging 6·5 years, concludes that the paralysis is secondary to a primary traumatic dislocation of the shoulder occurring at birth, associated with a tear in the joint capsule, and a consequent involvement of the plexus in the exudate. He does not explain why the exudate always avoids the major portion of the plexus in the region of the shoulder joint, or why it practically always works its way at least two inches above the clavicle and picks out the junction of the fifth and sixth cervical nerves to produce the characteristic paralysis. This theory of his is not reasonable, nor is it based on clinical or pathologic evidence. Erb's point is small and it requires definite injury at this point to produce the characteristic paralysis, as well as injury above this point on the fifth cervical root to produce the paralysis of the supraspinatus and infraspinatus from trauma to the suprascapular nerve which comes off the fifth cervical just above or below Erb's point.

Ashhurst[16] in a recent paper defends the theory advanced by Lange and adopted by T. T. Thomas that the condition is not primarily due to injury to the brachial plexus, but is due to an unrecognized dislocation of the shoulder occurring at birth. I I might add that Thomas and Ashhurst so far are the only two individuals whose manual dexterity has been developed to such an extent that they can of all others determine this dislocation. Thomas, as you may remember, developed his original contribution as the result of the study of nine cases, seen late, that is, after several years, and Ashhurst reports about forty cases most of which were well by the early stages.

The statement is also made by Ashhurst that these cases all get well because no neurologist of his acquaintance has ever seen an adult with the condition. This is hardly a fact on which to base a scientific pathology. If a child is born with an obstetrical paralysis, the condition exists to a varying degree until death. Few cases every wholly recover and most carry always the well-known

mark of the so-called "policeman's tip" position through life, unless adequately treated for the deformity. Ashhurst considers the whole condition as to ætiology obscure, and cannot reconcile the resultant paralysis to the known distribution of the brachial plexus, overlooking the fact that many of the muscles have their supply from more than one spinal root. A further study and adequate observation on a sufficient number of cases with a willingness to accept proved pathology would at once clear the ground for him.

Pathology

There are generally two well-recognized types of paralysis seen. The more common one consists of a lesion which involves the fifth and sixth cervical roots and the suprascapular nerve and produces a paralysis of only the muscles of the upper arm, with the exception of the supinators. This type is known as the upper arm type as we have observed it in five hundred and thirteen cases. The less usual type, the so-called lower arm, or whole arm type, is the result of injury not only to the fifth and sixth cervical roots, but the seventh and eighth and possibly the first thoracic as well. Here the whole arm is flaccid; there is a wrist-drop and paralysis of the small muscles of the hand. There occasionally occurs the pure lower arm type of paralysis without any involvement of the upper cords of the plexus, the so-called Klumpke's paralysis, several cases having been reported by J. J. Thomas, Jolly, Guillemot, Seeligmuller, Thorburn, Raymond, Comby, and Danchez. These cases show a paralysis usually the result of stretching of the plexus from overextension of the arm in cases of face presentation, and due to injury to the lower cords of the plexus, namely, the seventh and eighth cervical and first dorsal roots. They may at times be bilateral. It is in this type that one often sees inequality of the pupils, owing to the fact that the sympathetic fibres from the deep cervical ganglionic plexus enter the spinal cord through the first dorsal and at times through the eighth cervical roots. Injury therefore to these roots leads to an unopposed action of the motor occuli nerve.

Pathologically, in the milder cases the stretching or tearing forces result in a greater or less degree of hæmorrhage or œdema into the nerve sheaths. In others there may be a rupture of the perineural sheath, accompanied by hæmorrhage into the substances of the nerve trunk, associated with the tearing apart or separation of the nerve fibres. This latter condition leads, of course, to per-

manently impaired function and the formation of scar tissue in the nerve track. In the more severe cases of the upper arm type there is a partial or complete division of the fifth and sixth cervical roots, which leads to a more permanent form of paralysis than usual, and the formation of a more extensive area of scar tissue.

The force producing these lesions is variable and so the lesions are variable. The nerve roots are often frayed out inside the sheath instead of being torn across evenly, and in this way the lesion may be incomplete at any given cross section of a nerve, but involves different fibres at different levels. This scar tissue contracts in time, and not only effectually prevents the regeneration of the nerves, but may by its contraction press on and destroy the few fibres which may have excaped the original injury.

The other type, known as the lower arm or whole arm type, is the result of either a lesion involving all the nerves of the plexus, or, in the distinctly lower arm type, in which the lower arm and hand are alone involved, the so-called Klumpke's paralysis, in which the lesion probably involves the eight cervical and first dorsal roots alone. This type generally results from traction applied in a breech case with the arm extended, or to traction in the axilla in a vertex presentation. It may be seen also in adults, when the first dorsal root is overstretched, as evidenced by some of the cases reported by T. T. Thomas. Pathologically, the conditions are similar to those seen in the other types, depending on the severity of the injury. No case in which operation has been performed has failed to show a definite pathologic lesion of the brachial plexus, definitely corresponding to the muscles involved.

Danyau (quoted by Stranksy[1]), in 1851, showed by necropsy that the nerves of the plexus had been torn and were surrounded and invaded by scar tissue. Practically all observers, especially those who have operated in these cases, have found definite changes in the plexus due to injury and scar tissue formation. Among these, for detailed study, may be mentioned Boyer[17], Fairbank, Warrington and Jones, Osterhaus, J. J. Thomas, Stone, Taylor, and Prout[18]. Prout's description of the pathology is classic and will be quoted freely as follows:

Prout states that the nerve sheath in any overstretching process must give way before the nerve itself as it supports the nerve. When the sheath is torn, as it always is in cases of birth palsy, the arterioles belonging to it and supported by it are ruptured, and a hæmorrhage into the substance of the nerve and its sheath results. These facts are of the greatest importance, since they determine

the ultimate extent and final character of the lesion. Were it not for the obstructive features of the repair process in the nerve sheath, we might expect a more or less complete recovery in the vast majority of cases.

Four pathologic specimens showed on study the following conditions: The usual seat of the lesion was at the junction of the fifth and sixth cervical nerves. The perineural sheath presented many old dense pigment deposits, the site of old hæmorrhages. In some portions the perineural sheath was buckled inward on the nerve fibres, strangulating them and preventing their regeneration. Evidences of strangulation were present not only at these points, but also in the nerve fibres underlying these pigment deposits. There was an obliteration of the myelin sheath above and below. In the more severe cases the strands of the plexus involved came to an abrupt termination in a mass representing an old organized hæmorrhage. In these cases there was a severing of the nerve fibres, which were often thrown into folds for some distance from the primary lesion. Repair of the nerve sheath takes place before the regeneration of the nerve fibres, and if this has buckled inward on the nerve bundles following relief of tension, the nerve fibres are inevitably going to be strangulated and their regeneration prevented.

Writer's Experiments

The writer, by numerous dissections on infantile cadavers, has shown that traction and forcible separation of the head and shoulder puts the upper cords, the fifth and sixth cervical roots of the brachial plexus, under dangerous tension. This tension is so great that the two upper cords stand out like violin strings. Any sudden force applied with the head bent to the side and the shoulder held would without question injure these cords. Further observation shows that forcible abduction and elevation of the arm and shoulder put the lower cords of the plexus, the eighth cervical and first thoracic on a stretch, and when much force is applied it may well lead to a tear, rupture, or other injury to these segments. This condition is seen in breech cases, with arms extended. It may also follow sudden strain when the arm is elevated, such as the so-called hostler's paralysis, caused by the sudden elevation and strain of the arm which occurs when a hostler holds a rearing horse. With the shoulder held and the head carried to one side, with the clavicle intact, considerable force was necessary to injure the plexus. The suprascapular nerve always snapped first, apparently for the

reason that it had not so much freedom of play as the others. Even with considerable force the fifth and sixth cervical nerves could not be completely torn across at Erb's point, but frayed out inside the sheath, following a partial tearing or rupture of the sheath, which always gave way first. In some cases there could be produced an evulsion from the spinal cord of the fifth and sixth cervical roots.

With the clavicle removed, the whole weight of the shoulder came practically directly on the plexus, and less force had to be exerted to cause an injury, which under these conditions was generally greater in extent, but presented the same general characteristics. It was most difficult to put the eight cervical and first thoracic roots on a stretch unless the arm was abducted or hyperextended with great force.

With the clavicle intact there was apparently always enough room, even with the arm elevated and hyperextended forcibly between the clavicle and plexus so that direct pressure from the intact clavicle on the plexus did not seem a possible cause of the paralytic condition. A fractured clavicle of course allows the weight of the shoulder to drag on the plexus, and so predisposes to greater injury from traction. Rotation of the head combined with forcible abduction apparently does not increase the degree of tension greatly, certainly not enough to cause additional damage. In no case, even with all the force I could apply with my hands, could I rupture the joint capsule, or even separate the humeral epiphysis. Neither could I dislocate the head of the humerus. The clavicle can be broken without great force, but fracture of the other bones which go to make up the shoulder joint is practically impossible. Most birth fractures occur in the clavicle, or in the humerus, at about the junction of its upper and middle third. Stone states in the experimental work which he did that the humeral epiphysis could be easily separated, but I failed to confirm this.

At birth the shaft of the humerus is nearly wholly ossified, but the two extremities are cartilaginous. The scapula at birth is largely osseous, with the exception of the glenoid fossa, the coracoid and acromial processes, and the posterior border and inferior angle, which are still cartilaginous. It is on account of these conditions that fractures in these regions at birth are practically non-existent. It is not possible to produce a paralysis of the Erb type by the fracture of any bone but the clavicle.

In order to get a clear idea as to what happened to an exudate

from a ruptured capsular ligament of the shoulder, in studying Lange's theory, I injected the shoulder joints of several infants with methylene blue, and then caused a rupture of the anterior portions of the joint capsule. The infants were then allowed to lie in a preserving solution on their backs for several weeks, following which time a dissection was made. In no case did the methylene blue go above the clavicle, but completely surrounded and invaded the plexus in the axilla. This would in life lead to a paralysis of the whole arm below the joint, but would in no way affect the nerves above the clavicle, and in no case would there be the typical picture of obstetric paralysis, that is, paralysis of the fifth and sixth cervical nerves. As I have stated before, why the exudate should leave the nerves alone in immediate proximity of the shoulder joint and seek out Erb's point, the junction of the fifth and sixth cervical segments, at least two or three inches above the clavicle, Lange, Thomas, and others have not made quite clear. It evidently does not happen. Why also should the suprascapular nerve always be involved, which generally arises from the fifth cervical at about Erb's point? One thing impressed me, and that was the evident vulnerability of the upper cords of the plexus under any degree of traction and I was surprised that the paralysis was not of much more frequent occurrence.

Roentgen-Ray findings. About two hundred cases have been *x*-rayed. These patients varied in age from two days to eighteen years. In only two cases had there been fracture, one of the clavicle and one of the upper third of the humerus. Both fractures had healed without incident.

A study of the roentgenograms taken in these cases shows the following conditions:

In the first year there is usually nothing seen of bony deformity. There may be a slight posterior sublaxation of the shoulder joint, but there is never any acromial deformity evident by roentgenogram or clinically. No case has been observed in which the epiphysis has been displaced primarily so far as could be seen by comparison with the normal shoulder. The epiphysis, as well as the shaft of the humerus, is always smaller than the unaffected side, which condition is undoubtedly due to atrophy from disuse. The scapula is practically always elevated and outwardly rotated, due apparently to the pull of the intact inward rotators and the levator anguli scapulæ.

As time goes on and the child gets older, one begins to see increasing evidences of bony deformity, occasionally more joint

subluxation than at first, increasing outward displacement and elevation of the scapula, and acromial deformity. The deformity of the acromion consists of a bending downward and forward or a hooking of its outer end, which, apparently, having no bony resistance to meet as normally in the head of the humerus, projects downward in front of the subluxated and inwardly rotated head. This hooking seems to vary directly with the degree of posterior subluxation and inward rotation of the humerus and tends to increase as the child gets older, provided subluxation is present. No case has been observed in which there has been a total subluxation or dislocation of the shoulder joint backward. The clavicle usually is shorter and its curves are more acute than its normal fellow.

Clinical Findings. When the child is first seen, if within a few days or weeks after birth, the following picture is classic. The arm lies limp at the side, extended and inwardly rotated, with complete inability to abduct, elevate, outwardly rotate or supinate. The muscles paralyzed in the typical upper arm type are as follows: Deltoid, supraspinatus, infraspinatus, teres minor, biceps, triceps, supinator longus, and occasionally the subscapula, the serratus magnus, coracobrachialis and supinator brevis. The arm cannot be actively flexed at the elbow, but as a rule the lower arm is not affected so far as flexion and extension of the wrist and flexion and extension of the fingers go.

The greater part of the motor nerve supply to these paralyzed muscles depends on one root alone, although fibres from more than one root, especially the sixth cervical, can be traced to individual muscles of the arm.

It should be noted that a number of these muscles have more than one source of supply. Expressed in terms of motion the condition is as follows:

Flexion of the elbow is carried out by the fifth cervical; extension of the elbow by the seventh cervical; pronation of the hand by the sixth cervical; supination of the hand by the fifth cervical; flexion of the wrist by the eighth cervical, and extension of the wrist by the seventh cervical.

In the upper arm type then, the nerves involved are the suprascapula, from the fifth cervical root and outer cord of plexus, going to the supraspinatus and infraspinatus muscles. The musculocutaneous from the fifth and sixth cervical roots and outer cord of the plexus, going to the coracobrachialis, biceps and brachialis anticus. The circumflex from the fifth and sixth, and possible the seventh and eighth and posterior cord of the plexus, going to the

deltoideus and teres minor. The musculospiralis from the fifth, sixth, and seventh, and also possibly some fibres from the eighth cervical and posterior cord of the plexus, going to the supinator longus and brevis, brachialis anticus, triceps, anceœus and extensors of hand.

The fact that in the upper arm type practically the only muscles supplied by the musculospiralis which are paralyzed below the elbow are the supinators goes to show that either the injury is not extensive or that the nerve root supply is well divided. No two diagrams of the brachial plexus among all that I studied were alike. The two best that I could find are, one from Cunningham's "Anatomy" and the other quite different is from Kocher.

In order to get this definite and constant paralytic muscle grouping, the injury would have to be located at about the junction of the fifth and sixth cervical nerve roots, just above the point of origin of the suprascapular nerve. This junction point is called Erb's point, from his classic description of the type of paralysis seen following injury at that point.

The inability to raise or abduct the arm at the shoulder is due to the paralysis of the deltoideus and supraspinatus. Outward rotation cannot be accomplished because of the paralysis of the infraspinatus and teres minor, and the arm cannot be internally rotated owing to the internal rotators, namely, the teres major, subscapularis and latissimus dorsi, being already fully contracted, due to lack of opposition.

The arm cannot be flexed at the elbow, owing to the paralysis or weakness of the biceps, brachialis anticus, coracobrachialis and supinator longus; and supination cannot be carried out owing partially to the inward rotation in which the arm is held and the weakness or paralysis of the biceps and supinator longus and brevis.

In regard to sensation, it may be stated that it has been impossible in the early cases to determine any changes from the normal, on account of the age of the patient.

During the first week, in the early cases, the child may cry if the arm is handled or moved, especially in abduction, but this soon disappears. In one or two cases there has been some swelling and tenderness noted by palpation over the plexus above the clavicle. This condition, however, apparently had no connection with the degree of paralysis present. The hand grasp is usually good and the child flexes and extends the wrist and fingers well. Occasionally there is a wrist drop present which in the upper arm cases was

only temporary. The later developments in the upper arm cases, as the child grows and gets older, with or without exercises and massage, are as follows: The persistence of the inward rotation and abduction deformity, the so-called policeman's tip position; the inability in most cases to fully or freely supinate; the inability to get the hand to the mouth without raising the elbow, due to inability outwardly to rotate; the inability to put the hand to the head or behind the back of the head.

In the lower arm type all these conditions hold besides the additional ones due to the paralytic conditions of the lower arm and hand, resulting generally in a useless dangle arm.

Atrophy of the muscles in these cases of obstetric paralysis is never very marked, except in some cases of the lower arm type. One practically never sees the extreme atrophy so noticeable in cases of infantile paralysis. This lack of marked atrophy is undoubtedly due to the fact that the nerve impulses are rarely fully blocked and that the muscles practically never, except in rare cases, wholly lose their entire enervation. Some normal nerve impulses pass through the scar tissue at the site of the lesions, owing to incomplete destruction or injury of the nerve, and so keep the muscle tone up to a certain point. There is always a definite shortening of the arm, however, in all cases, due probably as much to nerve injury as lack of use.

Subsequent Developments

Whole arm type, lower arm type. There were seen ninety-seven cases of this type in this present series. In this classification those cases which showed any nerve involvement beyond that usually shown by an injury of the fifth and sixth cervical roots were placed. These cases represented those injuries mainly to the whole of the plexus, or at least the seventh and eighth cervical and the first dorsal roots. Pupillary inequality and narrowing of the palpebral fissure were not unusual with this type. Occasional facial paralysis was present. Wrist-drop was the usual condition, associated with the usual inability to supinate and the additional inability to extend the lower arm. Paralysis of the flexors and extensors of the wrist and fingers were common, associated with paralysis and atrophy of the intrinsic muscles of the hand. Often the proximal phalanges are hyperextended, and the distal ones flexed, due to paralysis of the interossei or lumbricalis namus muscles. There is, of course, no power to grip and the fingers cannot be freely moved. There is

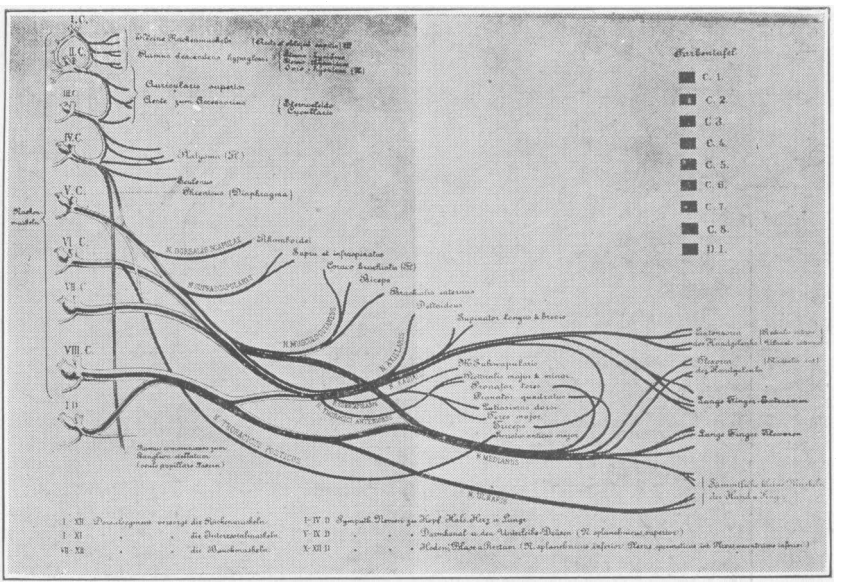
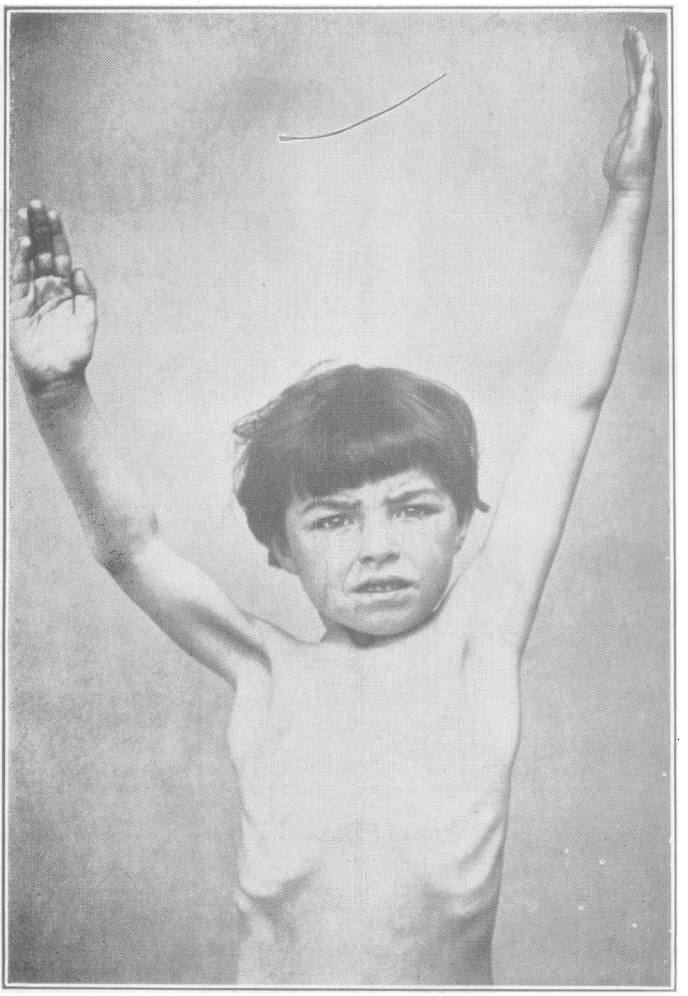
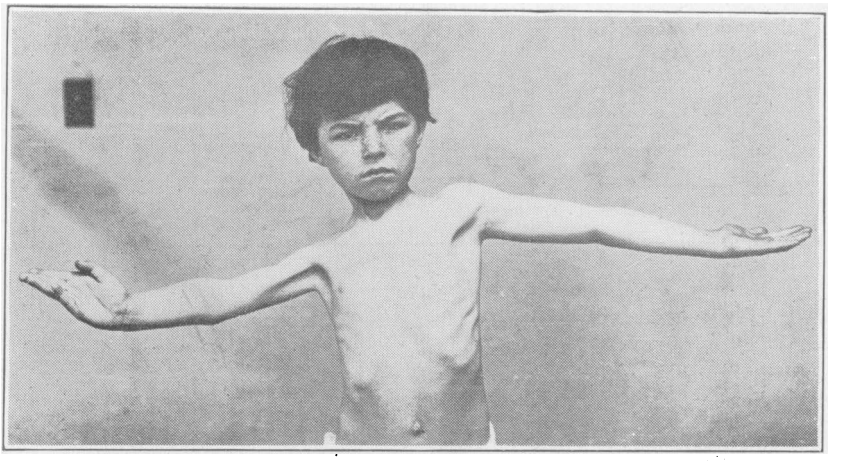


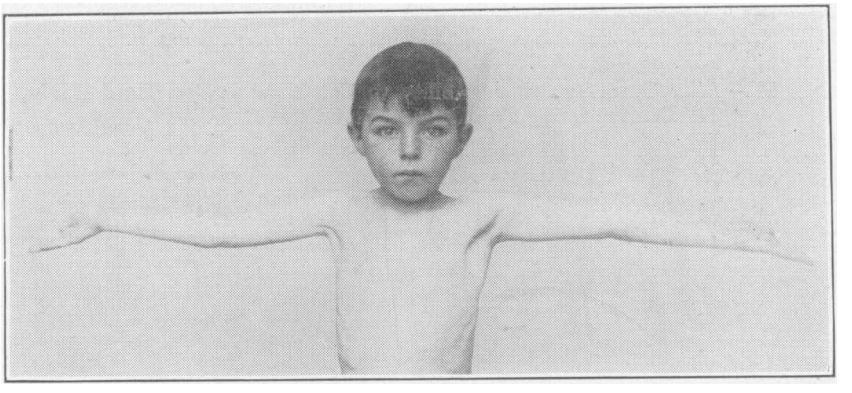
Diagram of Brachial Plexus



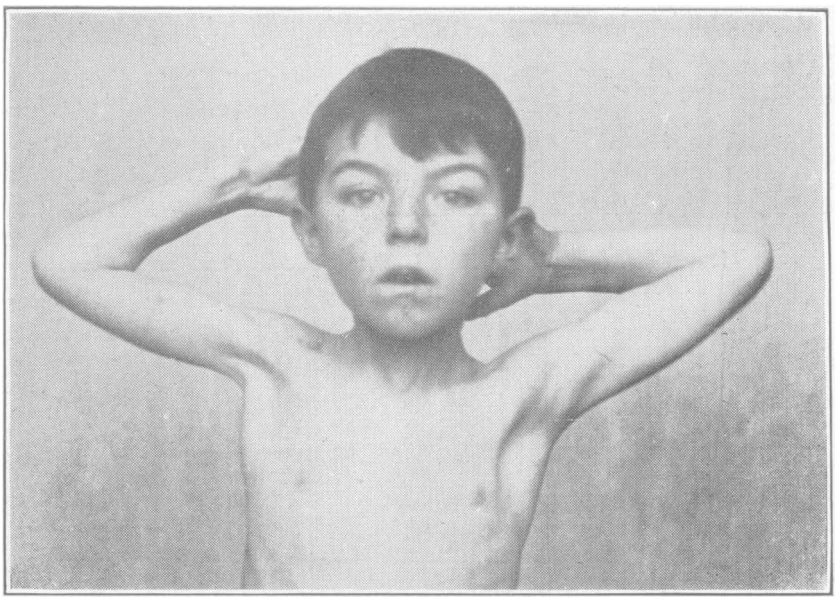
No. I.—Before Operation. Note Inability to Outwardly Rotate and Supinate Right Arm.



No. II.—Before Operation. Note Limited Abduction and Supination.



No. III.—After Operation. Note Free Abduction of Right Arm and Normal Supination.



No. IV.—After Operation. Note Ability to Put Hand Behind Head Easily, Demonstrating Free Outward Rotation—Right Arm.

usually ulnar displacement or abduction of the hand. These cases, almost without exception, represent severe tearing injuries to the roots of the plexus, and although some of the muscles may recover in part, particularly the upper arm and shoulder groups, the lower arm ones practically never recover from the point of view of function, even after attempted operative repair of the plexus. It is in these cases that sensation is more apt to be impaired than in the usual upper arm type. A not uncommon type seen is one showing simply a wrist-drop, associated with the usual picture of upper arm paralysis and evidence of injury to the fifth, sixth, and seventh cervical roots. These cases, as far as results go, should be classed with the simple upper arm type. Few cases have been recorded in which the two lower roots alone have been involved. These have been reported fully by J. J. Thomas.

The complications may be divided into two classes, early and late. The early complications are those accompanying the paralysis and present at birth. The following may be mentioned:

Facial paralysis is usually mild and on the same side as the paralyzed arm and is probably from forceps pressure on the facial nerve.

Fracture of clavicle is not rare.

Separation of epiphysis of the head of the humerus may occur, but no case is noted in this series; it might be grouped under the pseudoparalysis of D'Astros and Danchez.

Dislocation of the humerus sometimes is present, usually infraspinatus. This complication is not noted in this series, but is recorded by other observers.

Fracture of the upper third of the humerus may also occur.

As late complications the following may be mentioned:

Posterior subluxation of the humerus is common and due to contraction of unparalyzed pectoralis major, subscapularis and teres major.

Hooking of the acromion may occur, as had been already noted above.

Anterior subluxation of the humerus, due to the pull of the contracted pectoralis major and the stretching of the subscapularis, is not uncommon. Paralysis of the subscapula muscle is not rare.

Contraction of the biceps and the brachialis anticus, leading to some degree of permanent flexion deformity at the elbow and occasionally dislocation of the head of the radius, may occur, Persistence of marked loss of power in the triceps is common.

An analysis of the figures may be of interest. In the first

place, there is no reason to expect any difference in regard to the sex, unless one is ready to accept Simpson's theory that girls' heads, being smaller, and so not dilating the canal sufficiently, would subject them to a more difficult labor, and so to a greater percentage of occurrence of injury to the brachial plexus. These figures, representing by far the largest number of cases so far reported, and outnumbering all others reported by all observers, do not confirm his theory.

The right arm was affected three hundred and fifty-nine times and the left two hundred and forty, about 66 per cent. in favour of the right arm. This bears out Sharpe's figures in his series of fifty-six operative cases. Fourteen babies had both arms affected.

The types of paralysis differed, the most usual one being the so-called upper arm type, five hundred and thirteen being recorded, as against the so-called lower or whole arm type, in which, beside the fifth and sixth cervical cords being injured, the seventh and eighth cervical and first dorsal were injured. Of the latter type, ninety-seven cases were recorded. In fourteen cases with both arms affected, the lower or whole arm type of paralysis showed generally.

It has been conceded by practically all authors that a difficult labour was a predisposing factor in the causation of paralysis. In this series, five hundred and forty-one cases were definitely recorded as long, laborious and difficult; four hundred and sixty-two at least had ether and three hundred and sixty-one had forceps used; forty-four were apparently normal labours and two hundred and one were recorded in which the child was asphyxiated.

All the conditions noted above imply the application of force combined with greater muscular relaxation of the child, conditions peculiarly favourable for the production of such an injury. A moderately large number, it is recorded, had the head delivered naturally, but the shoulders stuck, and at that time force was applied.

In regard to the presentations, three hundred and twelve at least were vertex or face presentations and ninety-four were breech. The latter classification includes versions and footlings. In two hundred and eleven the position was not recorded, but a large majority of these were probably vertex. These figures do not bear out either Tubby or Sherren (quoted under Fairbank), who state that the paralysis occurs equally in head or breech presentations. Fairbank's own figures refute this also, for he reported in forty cases thirty-two vertex and seven breech. These figures cover

four hundred and six cases of the author's in which the presentation was definitely known.

The other conditions occurring at birth may be noted in the table and I want to add a word about only one of them, namely, that of unequal pupils. This condition is probably overlooked in some cases, and is a most important symptom, in that it means that through injury to the cervical sympathetic there may be definite injury to the plexus either of the lower cords, the eighth cervical or first dorsal, which have communicating bands with the cervical sympathetic, or injury in the spinal cord itself to the fibres of the sympathetic system. The prognosis in these cases is usually not so good as in those which do not show this sign.

Treatment

As to treatment, these cases at once resolve themselves into two divisions, namely, those to be treated with massage and exercises, principally those of the upper arm type; and those to be treated by operation on the plexus, usually those of the lower arm type. Unless the early treatment has been adequate, the upper arm type will also come to operation, not for plexus repair, but to correct contraction deformities. This operation, which I have devised, will be spoken of later.

At first, in order to prevent contraction of unparalyzed muscles, it seems best to put the arm at rest in such a position that the muscles cannot become contracted. This may be done by holding the arm in a plaster cast, or by the use of a light wire or aluminum splint, in an abducted, elevated and outwardly rotated position, with the hand supinated. This position can be maintained between massage and gymnastic treatments, and insures a better subsequent position of the arm. It also takes the drag off the paralyzed muscles, allowing them to regain their strength more quickly, and prevents subsequent shoulder joint deformity, such as subluxation and acromial hooking and overgrowth.

Massage and exercises are of the greatest importance and should be done daily if possible. It is most unwise to allow a child to become obsessed with the fact that it has an arm which cannot be used. Exercises which have been described in detail by J. J. Thomas are most satisfactory, and have been developed during the past twenty years in the neurologic department of the Children's Hospital. The treatment should be continued for several years at least, and if contractures develop in the subscapularis and

pectoralis major, they must be divided before any further range of action in the arm is to be hoped for.

In regard to the operation on the plexus in the usual upper arm type of case, it might be said that in the experience of this clinic it has not been found necessary. In the lower arm type of cases the situation is quite different, but it cannot be too strongly emphasized that no operation on the plexus will be of any great use in restoring functional activity to the arm, unless contracted and restricting muscles are divided, and careful after-treatment persisted in for a long period.

In regard to the operative treatment on the plexus in the lower arm type of case, it may be stated that it has been done a number of times without any benefit. The plexus in all cases was found to be so badly torn and so bound down and invaded by scar tissue that any kind of repair was impossible. In spite of the work done by A. S. Taylor, Stone, Fairbank, and others, there has been no case as yet which has shown an anatomic or physiologic cure, or even a marked improvement. This may be due to the fact that in in the first place the plexus was impossible to repair, and secondly, granted that the plexus repair was in part possible, the muscular contractions and joint deformities were not recognized and properly treated, without which the attempt to obtain plexus repair would be a waste of time and effort.

The following operation was devised, following suggestions made by Fairbank. It differs from Fairbank's operation principally in that the shoulder joint is not opened. Opening this joint leads to adhesions of the capsule, which are troublesome and fatal to the best functional results. In addition, I have found that complete division of the pectoralis major is always advisable, in that it is practically always tightly contracted, and so holds the arm adducted and prevents abduction and outward rotation. The subscapularis tendon can usually be easily found with the arm abducted and outwardly rotated after the division of the pectoralis major, and can be divided without opening the joint capsule.

Operation

An incision is made on the anterior aspect of the arm, beginning at the tip of the acromion and carried down to below the insertion of the pectoralis major. The cephalic vein is found generally in the outer edge of the wound and tied or drawn aside. The tendinous insertion of the pectoralis major is defined, raised on an

instrument, and divided all the way across near the bicipital groove. The pectoralis major muscle is then retracted inward out of the way, giving one a clear view of the axilla and shoulder joint. The arm should now be abducted fully and rotated outward as far as possible. Following the division of the pectoral, the range of motion in abduction will be found to be greatly increased. Outward rotation will, however, be somewhat limited. With the arm fully abducted and outwardly rotated, the insertion of the tendon of the subscapula is to be defined. This tendon is inserted on the lessor tuberosity of the humerus at its inner aspect, and its fibres run at right angles to those of the joint capsule, into which they merge. Just below the lower edge of the tendon may usually be found two or three small veins, running parallel to the lower edge of the tendon. The tendon of the coracobrachialis obscures the insertion of the subscapula tendon at times. It is then necessary to separate the origin of the coracobrachialis from the coracoid process by means of an osteotome, which gives one a much clearer field to see the insertion of the subscapula. The hole in which the surgeon is working is quite a deep one, and the tendon cannot be easily found unless the arm is in the position above described. The best way to divide the tendon is to pass under it some blunt instrument, and personally I have found a No. 18 French sound the most useful, not only because it is smooth and round and pointed, but also because its curve allows the point to present above the upper edge of the tendon and so defines it well. It is of the utmost importance that the shoulder joint should not be opened. The tendon of the subscapula should always be found, identified and lifted up before it is divided. Blind cuts along the capsule do more harm than good and should never be practised, even if following division of the capsule; the outward rotation is better. Eventually these capsular incisions lead to troublesome adhesions, and the results are never as good as when they are avoided. Following the division of the subscapula the outward rotation is perfectly free, as well as abduction. If at this stage there is still some subluxation of the head of the humerus which cannot be fully reduced, an osteotomy of the acromion should be done, and the loose distal piece either removed or tilted up so as to allow the head of the humerus to slip back into the glenoid. The wound is then closed with a few deep stitches and a continuous catgut stitch to the skin. No drainage is required. Very little bleeding usually takes place. The arm is then placed on a wire spint, which holds it elevated to or above the shoulder level, abducted and fully rotated outwardly

with the hand in full supination. At the end of ten days, massage, baking and exercises are begun, and continued daily, or at least four times a week. The splint should be worn night and day for at least three months, and daytime for at least three months longer.

The operation merely releases contractions, and gives the stretched and partly paralyzed muscles a chance to recover their tone and strength, and consequently the after-treatment is of the utmost importance. There have been thirty-two cases operated upon by this method.

The following questions have often been asked me in regard to this operation and while the number of cases operated upon is small, the results have been in the main so striking that I am going to try to answer them in detail.

1. What benefit, if any, has the operation caused?

In practically every case which has been operated on there has been free and full active outward rotation, as well as increased ability to elevate the arm at the shoulder, depending somewhat on the ability of the deltoid to regain its strength after long stretching and disuse, as well as more persistent residual paralysis in that muscle, which condition cannot be accurately determined beforehand, because of limitation of motion from contractures. Supination becomes either normal, or nearly so. The child can get the hand to the mouth easily, can put it on top of the head and behind the head, which in girls is all-important, so as to enable them to do their own hair. As a matter of fact, after following several hundred cases for several years, outward rotation and supination are never gained by the most persistent exercise treatment, even when stretching under ether is included.

2. What are the essentials for a successful operation?

A careful operation with free division of all contractures, and the utmost care in avoiding cutting the joint capsule. This cannot be too strongly insisted upon. Fixation in a splint and not plaster, which holds the arm elevated to above the shoulder level, abducted and outwardly rotated, with full supination. Fixation not continued for more than the time required to heal the wound, and then exercises, baking, and massage at least four times a week, wearing splint for at least six months.

3. On what cases should it be done?

The best results, as we see them, are on those cases who have had previous massage and muscle exercises, and who have some power in the deltoid and supraspinatus muscles. Treatment in all cases should be begun the first week of life, and the arm should be

put in the position of physiological rest—that is, abducted, elevated and outwardly rotated from the first, Cases should not have the arm tied to the side or across the chest, as so often is done at first, as this position encourages and develops contractures of the non-paralyzed muscles. Practically all cases, even those who have had no previous treatment, are distinctly improved, but the convalescence as far as active function goes is slower in those cases who have not had previous massage and exercise treatment. Any case which has contractures, even if only of the subscapula, is better if that contraction is divided. The operation does less harm than the contraction, and results in a more useful arm.

4. How long should the after-treatment be continued?

At least six months, wearing the splint night and day for at least three months and daytimes for three months more. Exercises, baking and massage at least four times a week.

5. What treatment before operation is necessary?

Every case should be given the benefit of the doubt, and should have a long course of at least a year of exercises and massage. In very young children it is better to wait until they are at least three years of age before operating. A splint should be worn during this period.

6. What can the child do after the operation that it could not do before?

The hand can be supinated, the arm can be outwardly rotated, and elevated to above the shoulder level, depending, as said above, on the strength in the deltoid. The hand can be put to the mouth naturally and on top and behind the head to do the hair. At first in some cases—that is, in the first six months or year—there is a persistent inability to adduct or inwardly rotate the arm. This clears up in time and unless the shoulder joint has been opened, is no cause of worry. Motion in the shoulder joint is always good in the end, unless the joint has been opened. A few cases where the joint has been opened have shown a persistent loss of motion in the shoulder and the arm has remained permanently abducted and outwardly rotated, with no motion in adduction. In these cases the free play of the scapula is of great benefit, and allows the use of the arm in a better position, at the expense of stretched rhomboids. The result, however, is not one to be desired, and can be avoided by leaving the capsule intact. Too long fixation following operation without exercises and massage will also lead to slow recovery of motion in rotation and adduction.

7. Is the gain permanent?

Yes. So far, at the end of about three years in some cases.

Prognosis

The prognosis in all upper arm type of cases is good, provided the case is watched from the start, and treatment property carried out. The patients are practically all able to raise the arm to the shoulder level and can use the hand and lower arm well, except for varying degrees of supination. Abduction and outward rotation are rarely regained without division of the contracted muscles, provided they have been allowed to contract.

In the lower arm type the outlook is not so good, although many of the patients regain use of the upper arm in spite of the persistent paralysis of the lower arm and hand. These cases should all be explored for repair of the plexus as far as possible, but even then very little hope can or should be held out to the parents. The general principles of treatment, however, should be carried out over a long period of time. Much can be done along orthopædic lines for these patients, and they should not be generally neglected as they have been in the past, with the statement that nothing can be done, or that they will get well of themselves.

Conclusion

Obstetric paralysis is due to stretching or tearing of the cervical roots of the plexus brachialis. It occurs in boys as frequently as in girls. It occurs more often on the right than on the left side.

The upper arm type is much more frequent than the lower arm type. It affects both arms very infrequently.

It is practically always associated with a difficult labour, in which ether and forceps have been used and force has been applied. Not uncommonly is the baby asphyxiated.

Head presentations show the larger percentage of occurrences of both types of cases.

It may rarely be associated with fracture of the clavicle but is not the result of a fractured humerus or a dislocated shoulder joint.

The prognosis for a useful arm is good in the upper arm type and bad in the lower arm type.

Table

Boys	298
Girls	319
	617

Right arm affected	359
Left arm affected	240
Both arms affected	14
Upper arm type	513
Lower or whole arm type	97
Labour difficult and long	541
Labor normal	44
Ether used	462
Forceps used	361
Asphyxiation of child	201
Presentation.	
Head (including face)	312
Breech (including foot and version)	94
Position not known	211
Severe operation	32

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