A STUDY ON BRACHIAL BIRTH PALSY.

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HISTORICAL INTRODUCTION AND CRITICAL DIGEST OF THE LITERATURE OF BRACHIAL BIRTH PALSYES (L. P. CLARK).

Notwithstanding the fact that Duchenne first described brachial birth palsy due to traction in his work on localized electrization in 1872, there is evidence that arm palsies occurred in the process of delivery nearly two hundred years ago. Indeed, a careful review of obstetric works of a still earlier date would probably disclose cases of brachial birth palsy. The palsy is undoubtedly as old as forcible intervention in obstetric practice. Indeed, the association of the two facts early presaged the cause and effect relationship which is known to exist between them in our own time.

A case of compression paralysis of the arm is recorded in an old obstetric report as early as 1768 (Smellie). The labor in which it occurred was a face presentation. Owing to prolonged compression to which the child had been subjected both arms remained paralyzed

1 Grateful acknowledgment is made to Dr. E. A. Sharp for photographs of the cases, and to W. Peterson for the anatomical drawings of the operative field. A preliminary report was made before the Neurological Society of New York in April, 1904. A special paper on the pathology was presented before the same society in November, 1904. This paper reports the cases only to January, 1905. Final results will be reported in a future communication.
for several days. Discussions and theses at an early date bear testimony of the needs of classification of the causes and the resultant types of obstetric birth palsies. Thus some cases which apparently showed a wide range and severe degree of palsy at birth recovered in a few days, where others of slighter apparent defect recovered but little or not at all after years of medical treatment. A significant case of the former type is that of Jacquemier (1846), in which the palsy of the upper arm recovered in twenty days, while the first case of Duchenne-Erb palsy reported by Danyon in 1851 illustrates the severe destructive nature of the typical lesion. In this case, after an apparent simple compression which induced the palsy, the child died on the eighth day. A profound and extensive hemorrhagic infiltration was found in the entire brachial plexus. The condition found at autopsy was strongly suggestive of a lacerating lesion of the brachial plexus. Still other cases antedating Duchenne's report are those of Doherty (1844), Mattei (1862), Guenoit (1864), and Depaul (1864). The case by the two latter authors was reported in 1864 by each separately, and, owing to error of subsequent writers, has done double duty, being counted as two cases. Although compression was alleged as the cause, the unfavorable outcome leads one to suspect that it too, as in Danyon's case, was the result of a stretching and lacerating of the plexus. While Duchenne recognized three forms of brachial palsy in the newly born, he expressly outlines the clinical syndrome of the type classed in this study as "laceration brachial birth palsy."

(In this study the cases are classified as (1) "compression birth palsy," the result simply of pressure; and (2) "laceration birth palsy," from overstretching of the nerves with resulting laceration in varying degrees of the nerve sheaths and their contained vessels as well as of the nerve fibres themselves.)

Duchenne saw a few cases of compression palsy and relatively few of a subspinous dislocation of the humerus. As Duchenne had no definite conception of the nature of the nerve lesion present in any of these palsies, a more exact determination of the relationship of the different causes and effects was not possible at that time. He had no doubt, however, that in his five cases of obstetric palsy traction was the sole factor in its production, inasmuch as no forceps were used in the delivery and great pulling of the head by hand was employed in the process of extraction. Two of his cases were breech presentations. Duchenne saw all of the five cases in consultation with the obstetricians in whose practices these nerve accidents occurred.

Immediately following Duchenne's work upon these conditions, four cases were reported by Nadaud, including a case each of Bailly's, Tarnier's, Chantreuil's, with one of his own.

After Erb and others had described this same type of paralysis in adults, cases of obstetric palsy were reported by Schultz, Schu-
Following Duchenne's work, Seeligmüller (1874) presented the next case of laceration brachial birth palsy. Although Erb (1874) reported one case of this type in his original presentation of the adult lesion, the case was not published until after that of Seeligmüller. A fact of greater interest than the simple report of cases at this time was brought up by Fritsch, who in the discussion of Erb's thesis cites a case of arm paralysis in a child two days old, associated with a haematoma at the lower portion of the sternomastoid muscle (Erb's point). The case possibly foreshadowed the hemorrhagic nature of the lesion, which until in the present thesis has never been mentioned in the literature of the subject. If so, it must have been a very gross form of the lesion, as the cases here presented gave no history of such palpable birth injury. Moreover, the paralysis in Fritsch's case disappeared with the absorption of the hemorrhagic mass. The accident occurred in a head presentation with forcible forceps delivery. The case is all the more interesting as it was but a single illustration of a series studied by Fritsch in connection with hemorrhagic extravasations in this locality. He had repeatedly seen superficial haematoma about the shoulder in breech cases and had inferred that deeper lesions of the same hemorrhagic character should have existed. With the exception of the case mentioned above, his series consisted of stillborn infants; therefore, paralysis could not appear. No histopathological study of the lesion was made. Had this been done the exact nature of the lesion in laceration brachial birth palsy must have long since been demonstrated. The gross appearance of hemorrhage mentioned by Fritsch was not present in either Erb's or Seeligmüller's cases, although the latter was a bilateral lesion of the plexus, occurring after a difficult extraction. No traumatism or complications were associated in the case. Seeligmüller (1877) reported three cases of lower arm type of brachial birth palsy, in which a paralysis complementary to that of Erb was present—i.e., paralysis of the muscles supplied by the lower roots of the plexus. The palsy was associated with ocular symptoms such as narrowing of the pupil and palpebral fissure on the same side as the lesion. This type of brachial palsy was first described in the adult by Flaubert (1827). In Seeligmüller's case the infant was born unaided, but after a very protracted labor. Probably the lesion was purely a pressure one, as the child completely recovered in a few weeks. It is of interest to note that Erb's single case of laceration brachial birth palsy reported in 1874 and published in 1877 was thought to be due to pressure of the hooked finger in the axilla, as practised in the Prague method of version and forcible extraction. The inconsistency of a permanent palsy (over two years old at time of report) being induced in the fifth and sixth nerve root by pressure in the axilla was apparently not appre-
dated by Erb, notwithstanding the fact that his thesis was specially
directed toward proving that his type of adult palsy was caused by
none other than pressure of the clavicle upon the fifth and sixth
cervical roots in the neck.

Nothing essentially new is contained in the report of cases of
Bernhardt (1880) and Tborburn (1886). The first monographic
consideration given to the subject was that of Hamond (1881); but
the work sheds no new light upon the nature of the lesion. The
same may be said of Roulaud’s (1887), although a number of new
cases were reported. The elaborate work of Kustner (1889) still
repeated the dictum that the persistent Duchenne’s obstetric palsy
must be secondary to bone injuries, especially fracture at the upper
epiphysis of the humerus. The absence of all subsequent evidence
of a birth fracture in these many cases did not seem to have rendered
the author any the less certain of the etiology of the palsy. He
believed, however, that the cases which recovered spontaneously
were due to forceps compression. No mention is made of stretching
or rupture of the plexus. This reactionary view appeared to sup¬
press research work for some time, as but little was done on the sub¬
ject in the next few years. Schultz published the first article directed
specifically to pathogenesis. Erb’s theory was generally accepted
at the time. Schultz reported a case of arm paralysis in a child
seen when two years old, with a history of breech extraction and
bringing down of the right arm behind the head. The case was
typical of the laceration palsy herein described. Schultz applied
Erb’s theory of clavicle compression and elaborated a defence of
this view. The inaugural dissertation of Arens (1889) at Göttingen
upon “Obstetric Paralysis” is worthy of passing mention, as it was
a monographic treatment of the subject at the hands of an American.
But one new case was reported. It was a breech presentation deliv¬
ered by the Veit-Smellie method. A bilateral Duchenne-Erb palsy
resulted. The left side recovered rapidly. Arens assumed the pres¬
ence of a deep-lying hæmatoma on the left side which, as recovery
took place, underwent absorption. He conceived that the right
plexus had sustained a more severe injury (rupture?). There
appears to be a gap in the literature between 1889 and 1897, the
date of Fieux’s essay upon the etiopathology of obstetric palsies.
The experimental work of this author leads him to depart strongly
from Erb’s theory of compression. He believes that overstretched
is the chief causal factor. (The experimental work on the etiology
described later was done and the conclusions formulated before the
thesis of Fieux had been discovered in the literature.)

During this quiescent period (1889-1897) Comby and Jaffroy
(1891) reported cases, as did also several American authors (Lovett
and Burr, 1892). Burr’s report ignored all the work previously
done, as well as that of Lovett, which was published in the same
volume ofTransactions of the Boston Obstetrical Society. Burr
styled the disease under a new name, "spinal paralysis," and regarded it as due to a "rare type of anterior poliomyelitis." The discussion failed to correct the diagnostic error. Ten cases were reported under this head, which were all typical of laceration brachial birth palsy. A paper of extreme interest is that of Guillemot (1897), in which he reports a veritable epidemic of obstetric birth palsy in a particular locality covering a term of years. There were no less than 30 cases in all delivered by the same midwife by podalic version. Guillemot saw 12 of these cases, most of whom suffered from the permanent or laceration type of palsy. They were all adolescent or adult cases. Two of the cases were bilateral in type. In his research 2 cases in each of two families were noted. In those days no particular explanation seems to have been expected from the obstetrician to account for any of these accidents. A sufficient number of cases had been reported by 1897 for Cibert to collect a series of 66, but nothing new was brought out. Studies upon the different types of obstetric palsy soon began to appear. Seeligmuller and Thorburn reported the "Klumpke paralysis" (1885), which should properly be called after Flaubert, who first described the condition in 1827. The type consists of a lower brachial plexus lesion. In 1896 Weil published a valuable article upon the differentiation of superior arm, lower arm, and mixed-arm types of birth palsies and their various combinations in the same case. He gives a very clear account for the first time of an entire cervicobrachial lesion.

In relation to the possible extent of the lesion, aside from that in the plexus nerves, the work of Barbarosa di Grovellona may be mentioned here. The possibility of there being a cord lesion associated as the result of the heavy traction employed in delivery is worthy of attention. Barbarosa places on record an entirely new form of obstetric palsy. The brachial paralysis he reports is accompanied by cord lesions. The cases illustrating this type consisted of double brachial monoplegia and amyotrophy as a result of the cord lesion (?). The condition was not common. It would seem that an error of diagnosis had been made. He inferred that the violent stretching in laceration birth palsy may exceptionally produce a tearing of nerve roots at or in the cord itself. The possibility of this occurrence will be dealt with in the experimental work on etiology in this research.

Inaccurate as the early statistics must have been it is of interest to note that of the 95 cases collected by Schumacher (1899), 53 were head and 40 breech cases; of the 53 head cases, forceps were used in 28; spontaneous births, 10; history of finger hooked in axilla, 10; history of traction with head laterally inclined, 8. Of the 40 breech cases 6 were of spontaneous delivery and 34 assisted.

In a careful review of the literature it is evident that with very few exceptions obstetric palsy is due to manipulation in delivery.
Obstetric palsies form a class entirely by themselves and have nothing to do with cerebral or other congenital palsies. As a rule, they occur in superior arm most frequently. More rarely the lower-arm type has occurred; very rarely total palsy is reported (10 cases). Now and then a case of individual muscle paralysis has been reported in obstetric palsy.

**ETIOLOGY (A. S. TAYLOR).**

The predisposing factors in the production of this lesion are such disproportion between the size of the child and the maternal pelvis as would delay the easy progress of the labor, and especially as would hinder the rotation and descent of the shoulders after descent and extrusion of the head, rigidity of the maternal soft parts, maternal exhaustion, and any other cause which will delay labor and therefore lower the vitality of the fetal tissues.

Apparently, from the cases on record, transverse and face presentations have not been responsible for the production of many of these cases.

They occur with about equal frequency in vertex and breech presentations. (Schümmacher, 93 cases: 50 vertex, 43 breech.)

Brachial birth palsy occurs in about one in two thousand labors (Duvall and Gullian, 1901). If one admits that laceration birth palsy occurs in but one-half of all the cases, the ratio stands one in four thousand for that type of palsy which is the one under consideration here.

It is erroneous to suppose that laceration birth palsy occurs only in mismanaged labor; it may easily result in highly skilled hands, as shown by its occurrence at the birth of Emperor William of Germany, on which occasion Sir William Jenner was the accoucheur.

It is manifestly important to determine the usual site, extent, and nature of the lesion, as well as the etiological factors concerned as exciting causes of the lesion.

Those factors commonly mentioned are:

I. Backward pressure on the nerves by the clavicle, (a) on transverse processes of the vertebrae; (b) on first rib.

II. Hyperextension of the arms in breech cases.

III. Pressure of forceps.

IV. Tension on the nerve roots.

It is noticeable that, while so many different causative factors are cited, the results are invariably the same in type, though differing in degree. This strongly suggests that one fundamental type of nerve injury underlies all the cases.

To determine which of these factors is the essential one, twenty dissections were made upon ten infants within three to ten days after death. The skin, fasciae, and fat were removed from the lower part of the posterior cervical triangle to fully expose the clavicle and
nerve roots. Also the pectoralis major and deltoid muscles, with skin, fat, and fascia were removed below the clavicle. This gave a free exposure of the brachial plexus, vessels, and bony structures.

The following anatomical facts were noted:

(a) The clavicle is small, has a smooth, rounded, posterior surface, is so curved as to fit around the side of the neck without localized pressure, is somewhat flexible, and the ligaments of its articulations at both ends are so loose as to allow free play of the bone in any direction.

(b) The first rib is small, flat, and very flexible.

(c) The nerve roots come out between the transverse processes of the cervical vertebrae, of which the anterior tubercles lie well forward of the nerve roots.

(d) The nerve roots lie between the scalenus anticus in front and scalenus medius muscle behind, which form a protecting muscle cushion.

(e) There is a thick layer of fat and fascia behind and below the clavicle.

(f) The clavicle lies well below the usual site of lesion in brachial birth palsy (i.e., fifth and sixth roots) and can be pushed up to that site only with some difficulty.

(g) When the clavicle is pushed directly backward with the arm at the side, or when it presses backward during hyperextension of the arm, (1) the nerves slide outward away from the lines of pressure; (2) the nerves are pressed upon so little that they slide up and down behind the clavicle with the greatest freedom when traction is applied to them.

(h) In hyperextension of the arm the clavicle rotates backward and slightly downward. It does not rise to the level of the lesion commonly found in brachial birth palsy. The nerves are not rendered tense by this manipulation.

Reasoning from these data, backward pressure by the clavicle is not a factor, inasmuch as the bone does not reach to the level of the usual lesion; the anterior tubercles of the transverse processes prevent it from pressing the roots at their exit from the spine; the first rib is so flexible as to give scarcely any resistance to pressure; the nerves are surrounded and protected by muscle and fat cushions, and the clavicle is so curved, so smooth posteriorly, and so loosely attached at either end that when it is displaced strongly backward the nerves can still be easily moved either sideways or up and down, showing absence both of pressure and tension.

If, however, in exceptional cases, the nerve should be compressed by the clavicle, the result would be a narrow transverse lesion of moderate degree which would always go on to spontaneous regeneration. Moreover, if the lesion were the result of compression between the clavicle and first rib, the lower roots of the plexus should show most damage because they are so placed as to sustain the
major part of such pressure. In all cases, however, the fifth and sixth roots are the ones most damaged.

Hyperextension is not a factor, inasmuch as it neither causes pressure by the clavicle nor causes the nerves to be stretched tightly around the clavicle.

Forceps cannot be a factor of moment because the blades will not reach as low as the site of the lesion when traction is applied. Moreover, if they could cause a lesion it would be a narrow transverse one, which would recover spontaneously as do the facial palsies resulting from forceps pressure.

Another fact against any of these kinds of pressure being the cause of the lesion is that in the seven cases thus far operated upon 1 to 2 cm. of the length of the nerve were involved, whereas any lesion the result of pressure from the clavicle or forceps would not involve more than 3 to 7 mm. of the nerve length.

There remains the consideration of tension as the causative factor. Some authors say it is a factor; some that it is one of the chief factors. In the dissected specimens above mentioned the only factor which caused damage to the nerve roots was tension, and tension sufficiently great caused lesions in the same situation and of like nature to those found in the seven cases operated upon. Therefore, tension is the only factor concerned in the production of persistent (laceration) brachial birth palsy of the Erb type. When tension is present certain other factors may increase the amount of damage to the nerves, as we shall see later.

The dissected infants were placed in all the attitudes incident to delivery in either vertex or breech presentations, and it was found that only one thing caused stretching of the nerves, namely, increase in the distance from the head and neck to the shoulder. Also, in six living infants from three to ten days old, it was found that pushing the head and shoulders apart causes the upper nerves of the plexus to stand out under the finger like fiddle-strings, while in any other position they were either relaxed or not palpable at all.

In vertex presentations this attitude occurs when the shoulder is obstructed either at the brim of the pelvis or by the symphysis pubis, and the head is pulled upon by the accoucheur with instruments or hands. If rotation or oscillation of the head and neck be added the strain is increased and more damage is apt to occur. A

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1 The connective-tissue overgrowth found at autopsy in some of these palsy cases was described in one case as a "tumor growth" (Eversmann); in another as "neuroma" (Parry); and in a third was considered as the result of a "maternal impression" (Bachrach). A few observers still believe the essential cause to be a form of congenital dislocation of the shoulder from which they deduce a plan of manipulative replacement therapeutics.

2 H. L. Taylor reports that some form or degree of palsy occurs in about 25 percent of reduction of congenital hip dislocations by Lorenz's method. The lesion in such is undoubtedly of a like character to that shown here in obstetrical palsy. Probably the irreparable lesion of the sciatic nerve which he reports is comparable to the very severest lesions of brachial birth palsy in which the nerve and sheath have suffered complete loss of continuity. It is next necessary to determine how the tension is brought about.
very few cases are known where, after a normal vertex labor with neither instrumental nor manual traction, a temporary birth palsy has occurred.

In breech presentations the lesion occurs in the delivery of the after-coming head. The fingers hooked over the back of the neck pull both shoulders down and away from the head and neck. Here again rotation or oscillation increases the strain on the nerve roots. Moreover, the tips of the fingers, hooked over the shoulders, lie upon the stretched nerves and add a lateral strain to the tension they already suffer from.

It is evident then that any form of traction which pulls the head and neck away from the shoulder is the exciting cause of the lesion. As a natural corollary the lesion may occur with any "presentation."

It was most interesting to note the nerve area involved and the sequence of events in the production of the lesion on the cadaver.

It was invariably the case that the fifth root gave way first, then the sixth, and so on down the plexus in regular order if the force used was sufficient. From the lay of the plexus it is perfectly obvious that the fifth root must bear most of the strain until it yields, then the sixth, and so on downward.

This same fact is borne out clinically, inasmuch as the mildest cases show only paralysis of muscles belonging to the fifth root and progress from that to cases involving rupture of the entire plexus.

The nerves do not give way in a limited transverse section, but fray out over a considerable linear area, just as does a rope when it is overstrained. This fact accounts perfectly for the pathological pictures found in our seven cases at the time of operation.

The location of the lesion is important and will be more easily understood if it is remembered that the fifth and sixth roots fuse about 1.5 to 2 cm. (in infants) from their spinal exits. Their junction is from 0.5 to 1 cm. long, and from its distal end pass two nerves to form part of the outer and posterior cords of the plexus respectively. For convenience sake, these may still be called the fifth and sixth nerves, and in locating the lesion the terms "above," "at," and "below the junction" will be used.

In the twenty experiments cited the lesion was produced:

<table>
<thead>
<tr>
<th>Location</th>
<th>Fifth nerve</th>
<th>Sixth nerve</th>
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<tbody>
<tr>
<td>Above junction</td>
<td>16 = 80 per cent.</td>
<td>17 = 85 per cent.</td>
</tr>
<tr>
<td>At junction</td>
<td>2 = 10 &quot;</td>
<td>2 = 10 &quot;</td>
</tr>
<tr>
<td>Below junction</td>
<td>2 = 10 &quot;</td>
<td>1 = 5 &quot;</td>
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In the case of the sixth nerve, 7 (35 per cent.) of the ruptures consisted in avulsion of its root, including the root ganglion from the spinal cord.

Great force must be employed to cause the lesion, which accounts for the relative infrequency of its occurrence.

Of the 7 operative cases, 1 (Fig. 6, Case I.) involved rupture of the entire plexus. Of the remaining 6, 5 (83 per cent.) showed the
maximum damage above the junction and 1 (17 per cent.) below it, about the same percentages as in the experimental cases. In all the cases the cicatricial sequelæ of the injury involved the "junction."

In 1 case (Fig. 6, Case VII.) the fifth root was torn across above the junction, the ends separated about 1 cm., and bound down by connective tissue.

In 1 case (Fig. 8, Case III.) the fifth root was torn across just below the junction, and the distal end displaced inward and downward about 2.5 cm. to the front of the scalenus anticus muscle, where it was adherent.

There was no case of avulsion of the sixth root.

It will be seen in these cases that the maximum damage is to the fifth root.

A nerve of special importance which is always involved is the suprascapular. It is a small nerve arising from the distal and outer aspect of the junction of the fifth and sixth roots and supplies the external rotator muscles of the shoulder.

PATHOLOGY (T. P. PROUT).

To properly appreciate the lesion in these cases the etiological importance of the overstretched process in its production at birth must be borne in mind. Furthermore, a study of the lesion should demonstrate not only the characteristics of the degenerated areas, but the reasons for the failure of complete regeneration following the accident. The severed ends are in apposition in the vast majority of instances; when such condition is brought about surgically, union, regeneration, and recovery of function occur without incident. Why are these cases exceptional in this particular?

In this connection several points must be borne in mind:

1. The force producing the lesion is variable; the lesion therefore varies in extent with the variation in the extent and character of the force producing it, as has been pointed out. In the milder (most usual) cases only the fifth and sixth cervical roots suffer (Case VI.), while the severer cases present a literal severing of the roots of the plexus, varying in number from one (Case VII.) to three or even more (Case I.).

2. The nature of the force producing the lesion is such that the nerve roots are pulled apart rather than severed clean at a given point. The lesion, therefore, is incomplete at any given cross-section of the nerve bundle and involves different fibres at different levels.

3. The nerve bundle is surrounded by a dense sheath of connective tissue, the perineurium, which supports it and the vessels supplying it. In any lesion of the nerve roots resulting from an overstretched process this supporting sheath must first give way. In these cases it is torn asunder and the arterioles belonging to it and supported by it are ruptured. A hemorrhage into and beneath the
perineural sheath and infiltrating the strands of nerve fibres and the meshes of the epineurium results. In the recent state a small hematoma infiltrating these structures forms at the point of rupture, as shown in the accompanying schematic diagram (Fig. 1).

**Fig. 1**

Schematic representation of a rupture of the perineural sheath and hemorrhage into its substance and into the meshes of the epineurium resulting in the formation of a hematoma: a, epineurium; b, perineurium; c, nerve bundles; d, hemorrhage.

4. This accident occurs at birth, a period of life when the vascular and nervous structures are susceptible of injury of a far-reaching character.

Among these various points only those of immediate import in the production of the lesion interest us here. Of the immediate lesion little has been written. Strange to say, it is scarcely mentioned in medical literature, there being no adequate description of the gross lesion, and none whatever of its microscopic appearances. The gross appearances vary much with the duration and severity of the case.

In all of the operative cases here detailed the deep cervical fascia was invariably found greatly thickened, especially over the plexus, and irregularly adherent to the nerve roots. The thickening of the fascia was of an irregular and variable character, depending upon the severity of the case.

**Fig. 2**

Schematic representation of the position of the gross lesion in Case VI. The dotted line represents the area excised, and the dark areas within it the lesions in the perineural sheath.

In cases of the milder grade, such as Case VI, for example, the outward appearance of the nerve strand at the point of the lesion may be normal, but in this particular instance a distinct nodular mass could be felt in the upper and outer aspect of the nerve strand (Fig. 2).
In this instance also the duration of the lesion was such that the gross abnormality was reduced to a minimum. In Case VII., on the other hand, the lesion had existed but eleven months and was, therefore, relatively fresh, and may be taken as presenting some of the more characteristic points of a relatively recent lesion of the severer grade. In this instance there was a severance of the fifth cervical root just before its junction with the sixth root (Fig. 3).

![Fig. 3](image)

Schematic representation of the gross lesion and its extent in Case VII. The dotted lines show the area excised. The actual size and shape of the larger piece is shown in Fig. 4. The dark spots represent the positions occupied by the various haematomata resulting from the rupture of the perineural sheath and hemorrhage into its substance and the meshes of the epineurium.

In this case the severed ends were more or less rounded and embedded in a haematomatous mass, as shown in Fig. 4, which is a drawing of a section through the entire length of the larger piece excised in this case. The larger of these haematomata is represented at a in the figure, while there are smaller ones at b and c, all of which represented nodular masses in the gross specimen quite distinct in each instance.

![Fig. 4](image)

Actual size of piece excised in Case VII. a, small haematoma in the perineural sheath and epineurium; b, smaller hemorrhage with marked infiltration beneath the perineural sheath; c, strands of nerve fibres.

The recognition of the importance of the rupture of the perineural sheath and the resulting hemorrhage into its substance and the substance of the nerve bundle is not mentioned in works upon this subject.

These are points of great importance, since they are the determining factors in the production of the ultimate lesion. Were it not for these, we might reasonably expect a recovery more or less complete in all cases except those few presenting an actual rupture of the roots of the plexus. These factors, however, determine the ultimate extent and final character of the lesion.

The extent of the lesion varies greatly with the severity of the
case. Fig. 2 presents in schematic form the extent of the lesion in one of the milder cases. In this instance the lesion occurred at the customary site at the junction of the fifth and sixth cervical roots. The dark areas in the figure represent the extent of the lesion in the nerve sheath as developed in a series of sections lengthwise through the piece excised. A drawing of the entire section slightly magnified, showing the distribution of the lesion, follows in Fig. 5.

![Fig. 5](image)

Longitudinal section of piece excised from Case VI., magnified 2: a, perineural sheath; b, pigment deposits and connective tissue infiltrating the substance of the nerve bundle.

In Case VII. there was a severance of the fifth root. The extent of the lesion and the area excised is shown in Fig. 3. In this instance the lesion was comparatively recent and fairly well organized haematoma were present in the nerve sheath, as already mentioned. Fig. 4 shows the larger of the excised pieces, actual size. The position of the various haematomata is also indicated. In Case III. the lesion was still more decided, the fifth root being severed below the junction with the sixth and the excised mass (junction of the fifth and sixth roots) being involved in a ruin more or less complete. In this instance the cells of the neurilemma which represent the remains of the nerve fibres are thrown into folds, one of which is shown at A in Fig. 12, 3. The fibres A come to an abrupt ending in a connective-tissue mass, C, an old organized hemorrhage, with some masses of pigment still remaining in the interior.

The types of lesions depicted in these three cases represent fairly well the varying grades usually met with.

A conception of the ultimate lesion is to be obtained only by a study of the sequence of events in the nerve trunk following the primary lesion described and depicted above.

Organization of the blood clot or haematomatous mass and a union of the severed perineural sheath take place before any attempt at regeneration of the nerve fibre itself. The new connective tissue formed in this process contracts upon the nerve bundles and prevents regeneration of the nerve fibres. If the lesion in the perineural sheath is considerable, resulting in the formation of hematoma at the points of rupture, as in Case VII., the effect of the organization of the blood-clot will be such as to prevent the regeneration of a relatively large number of nerve fibres in the nerve bundle. Such points of compression are illustrated in Fig. 11, Cases II. and V. In the latter instance the lesion was too recent to show the disfiguring effect of its contraction upon the nerve fibres.
In all of the cases thus far examined the evidences of an old hemorrhage still persist in the tissues (Fig. 12, 1, B, and 4, A). In some of these areas the section presented a fairly large vessel in the immediate neighborhood of the old hemorrhage which may easily have figured in the production of the original lesion.

A further possibility following the rupture of the perineural sheath is shown in Fig. 12, 2 and 4. In the first a dense band of connective tissue, A, crosses the nerve bundle and strangles it. In the latter there has been a hucking inward of the perineural sheath as shown at A, and also in Fig. 13, 2, A. This huckle in the sheath effectually strangulates the nerve bundle and has prevented its regeneration.

As regards the behavior of the nerve fibre caught in lesions of this character, its appearance varies very much with the extent and duration of the lesion at a given point. Fig. 13, 1 and 3, present areas of extreme compression. In the unstained areas nothing remains except the cells of the neurilemma, together with some old fragments of the myelin sheath. 3 presents in particular the results of an incomplete compression of the nerve trunk.

From a study of these sections it is evident that the lesion in these cases is not confined to any one given level, but even in the milder grades of palsy extends over quite a wide area.

Some special features in connection with particular cases deserve notice:

In Case VI. there were two lesions in the perineural sheath separated by a short distance (shown in text, Fig. 5) and varying greatly in consistency. The mass at b was a hard nodule quite readily felt in the gross specimen; while the lesion at b' was more diffuse and the tissue of looser arrangement. Both of these areas contain some pigment deposits, the remains of an old hemorrhage which originally involved the nerve trunk diffusely and has since undergone organization, choking the involved nerve fibres in a contracting connective-tissue mass.

Case VII. belonged to the severer type and differed from the other cases in which the tissue has thus far been examined in being of comparatively recent origin. In the area excised there were two haematomata, each about the size of a small pea, which had developed in the substance of the epineurium (Fig. 4, a).

The sequence of events in the production of the laceration brachial birth palsies may be summarized as follows:

The lesions produced are (a) immediate and (b) remote.

The immediate lesion consists in the tearing of the perineural sheath surrounding and supporting the nerve trunk and the incidental rupture of the bloodvessels belonging to it. Hemorrhage occurs into and beneath the perineural sheath, and in many instances into the substance of the epineurium. There is, furthermore, a severance of the nerve strands more or less complete, depending on the severity of the case.
The remote lesion is brought about and its extent determined by (a) the healing of the rent in the perineural sheath; (b) the size of the blood clot and its ultimate organization; (c) the ultimate contraction of the cicatrix upon the nerve strand, which not only prevents its regeneration, but determines a neuritis in certain of those, not severed, upon which it may chance to impinge.

SYMPTOMATOLOGY AND DIAGNOSIS (L. P. CLARK).

The “laceration palsy” dealt with here is so characteristic in type that in severe cases its clinical recognition, from the attitude alone, is easy; thus the arm hangs powerless by the side, and cannot be abducted at the shoulder because of the palsy of the deltoid and supraspinatus muscles; the forearm is extended, and cannot be flexed on account of paralysis of the hiceps, brachialis anticus, and supinator longus; the hand is in extreme pronation, caused by palsy of the supinator brevis and hiceps, and the entire arm is so rotated inward that the palm of the hand may look backward and outward. The humerus is markedly rotated inward as a result of paralysis of the supraspinatus and infraspinatus and teres minor muscles.

Where laceration of the nerve roots has occurred there is present a factor of very great clinical importance not heretofore recognized and of fundamental significance in the early treatment and prognosis of the condition. When an infant remains peevish and fretful for a considerable period after this accident at birth, and when handling of the extremity greatly increases the pain and irritability, there is present a traumatic neuritis aggravated by pressure incident to the organization of the blood clot and repair of the rent in the perineural sheath.

Cases that do not present this symptom will show a more or less complete spontaneous recovery; while in those cases presenting these signs of a neuritis a considerable palsy will follow, depending on the severity of the lesion.

In severe cases after several months the internal rotators, especially the pectoralis major, become markedly contractured, further increasing the deformity of the arm at the shoulder-joint, and this, combined with the paralysis of the external rotators, may lead to more or less posterior displacement of the head of the humerus (as in Case III.). There are present also some contracture at the elbow preventing full extension and more or less flexion contracture and ulnar adduction at the wrist. These attitudes are well seen in all the case pictures. The limits of motion are well shown in Figs. 7 and 8.

In some cases of extreme laceration brachial birth palsy, both congenital torticollis and spasmodic wryneck are also present. From the nature of laceration birth palsy and its pathogenesis it is probable that the lesion in the above conditions is a nerve injury resulting from compression or stretching, and not a lesion of the muscles as Stromeyer contends. The spasmodic character of these affections can be explained on the basis of incomplete nerve regeneration, as is true of the spasmodic conditions in chronic facial palsy.
The clinical picture of laceration brachial birth palsy (chronic) is well shown in Figs. 7 and 8, 1. The muscles affected do not belong to the distribution of any single nerve trunk of the arm involved. Erb indicated the exact point at which the lesion could be demonstrated, and this point has been called by his name. The site is about 2 cm. outside the sternomastoid and the same distance above the clavicle, as shown in Fig. 8, 4. Erb demonstrated that by means of electric stimulation at this point one may evoke contraction in all the muscles found affected in this type of paralysis. This point corresponds to the junction of the anterior divisions of the fifth and sixth cervical nerve roots. It has been shown by Erb experimentally, and later by others through clinical study, that the motor fibres to the deltoid, biceps, brachialis aniceps, supinator longus, and sometimes supinator brevis muscles run in the junction of the anterior divisions of the fifth and sixth nerve. The palsy resulting from an injury of the nerves at this point is obvious. Orientation of the site of the lesion may be facilitated by referring to the semidiagrammatic scheme of the cervical nerve roots and the formation of the brachial plexus by their union (Fig. 9).

In laceration birth palsy the fifth and sixth cervical nerve roots suffer first. Frequently the seventh and occasionally the eighth cervical and first dorsal nerve roots are involved, thus constituting a lesion of the entire plexus as shown clinically in Fig. 6, 1. In not a few cases of the laceration palsy the entire arm is paralyzed, but for a time only. In such, the milder degree of lesion in the lower cervical nerve roots is recovered from in the course of a few months. Sufficient data are not yet at hand to declare the exact nature of the stretching lesion in these lower cervical nerve roots which recover in part. It seems probable, however, that temporary palsy results here in consequence of simple stretching of the nerve strands without causing rupture of the bloodvessels or the perineural sheath itself. Certainly a lesion of the severe type hereafter to be described could not be present in any marked degree and spontaneous recovery take place.

The sensory changes in brachial birth palsy are very slight and do not aid in the diagnosis. The overlapping of the segmental cord supply to the skin in the affected parts may account for the absence of sensory changes. Although careful tests were made, no detectable sensory changes were present in this series of cases either before or after operation.

The amount of atrophy is moderate, but the developmental defect which is noticeable after a time may be slight or severe, and apparently it is more dependent upon the extent of the brachial lesion than upon any degree of local damage to the plexus nerve. A case now under observation shows extreme dwarfing of the entire upper limb, although all the muscle that is now present seems of good quality, and there is but slight limitation of the motions of the ex-
tremity. The diagnosis is based on the history of traction used at delivery, followed immediately by paralysis of the upper extremity, with the assumption of the attitude and characteristics mentioned just previously in the symptomatology. The degree and extent of lesion in any birth palsy case cannot be determined immediately after its occurrence. There is no definite test to determine whether the nerves have been divided, simply compressed, or lacerated and contused by overstretching. Electric tests are only possible in the palsied child when it is placed under anaesthesia, and even then the results of such tests are contradictory and misleading, a fact early recognized (Stransky, Soltman, Westphal). The diagnosis of the range of nerve injury may be made approximately by analysis of the resulting muscle palsy, the atrophy and extent of growth defect. The electric reactions of the muscle (R. D. of paralyzed muscle) also assist in this particular. In the course of a few months one may detect by palpation a thickening and induration of the nerve roots at Erb's point. By palpation a fairly accurate knowledge of the state of the whole plexus may be obtained in those children who are not fat and who assist the examiner by moderately shrugging the shoulders. By practice one soon gains expertise in this diagnostic aid. The following table embraces the most recent data of the neuromuscular anatomy of the parts affected in birth palsy, and aids much in determining the distribution and degree of lesion present in a given case. It should be used in connection with Fig. 9.

This table shows the immediate nerve supply, plexus division, and nerve-root origin of the muscles of the shoulder, arm, forearm, and hand.

**Muscles Moving Scapula and Arm.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Immediate nerve supply</th>
<th>Root origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>Spinal accessory.</td>
<td>C. II to VI.</td>
</tr>
<tr>
<td>Rhomboidicus</td>
<td>Spinal accessory.</td>
<td>C. IV and V.</td>
</tr>
<tr>
<td>Levator angulus scapulae</td>
<td>Spinal accessory.</td>
<td>C. III, IV, V.</td>
</tr>
<tr>
<td>Serratus magnus</td>
<td>Posterior thoracic.</td>
<td>C. IV, V.</td>
</tr>
<tr>
<td>Deltoide</td>
<td>Circumflex (posterior cord).</td>
<td>C. IV, V.</td>
</tr>
<tr>
<td>Supraspinatus and infraspinatus</td>
<td>Supracapular.</td>
<td>C. V.</td>
</tr>
<tr>
<td>Teres minor</td>
<td>Circumflex.</td>
<td>C. V, VI.</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Short subscapular.</td>
<td>C. VII.</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Long subscapular (posterior cord).</td>
<td>C. V. and VI.</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Anterior thoracic (outer and inner cords).</td>
<td></td>
</tr>
<tr>
<td>Teres major</td>
<td>Supracapular (posterior cord).</td>
<td>C. VI, VII.</td>
</tr>
</tbody>
</table>

**Muscles Moving Forearm.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Immediate nerve supply</th>
<th>Root origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triceps</td>
<td>Musculospinal (posterior cord).</td>
<td>C. VI, VII.</td>
</tr>
<tr>
<td>Brachialis anticus</td>
<td>Musculospinal and musculocutaneous (outer and posterior cord).</td>
<td>C. V, VI, VII.</td>
</tr>
<tr>
<td>Biceps</td>
<td>Musculocutaneous (outer and posterior cord).</td>
<td>C. V, VI, VII.</td>
</tr>
<tr>
<td>Supinator longus</td>
<td>Musculospiral (posterior cord).</td>
<td>C. V, VI, VII.</td>
</tr>
<tr>
<td>Supinator brevis</td>
<td>Musculospinal (posterior cord).</td>
<td>C. V.</td>
</tr>
<tr>
<td>Pronator (teres and quad.)</td>
<td>Median (outer and inner cord).</td>
<td>C. VI, VII.</td>
</tr>
</tbody>
</table>
### Muscles Moving the Hand

- **Flexor carpi uln.**
- **Flexor carpi rad.**
- **Extensor carpi rad. longior.**
- **Extensor carpi rad. brevis.**
- **Extensor carpi rad. brevis.**
- **Flexor carpi rad. brevis.**
- **Extensor carpi rad. brevis.**
- **Extensor carpi rad. brevis.**
- **Interoesel and lumbricales.**
- **Two outer lumbricales.**
- **Flexors of Wrist.**
  - Ulnar (inner cord).
  - Median (inner and outer cord).
- **Extensors of Wrist.**
  - Median (inner and outer cord).
- **Musculospiral.**
- **Extensors of Fingers.**
  - Musculospiral.
- **Flexors of Fingers.**
  - Median (inner and outer cord).
  - Median and ulnar (inner, outer, and posterior cord).
  - Ulnar (inner cord).
  - Median (inner and outer cord).

### Prognosis (L. P. Clark)

The prognosis in birth palsy depends upon the (a) nature and degree of the nerve injury; (b) the treatment.

(a) In the mild cases where possibly compression alone (rare) or at least only the slightest grade of laceration occurs, spontaneous and fairly prompt recovery may be expected (three to nine months). However, even in these cases there may be a persistent atrophy and retarded development through life of a part or the whole of the extremity, although the range of motions may be little or not at all restricted.

In more decided lacerations of the nerves the outcome depends on how much the cicatricial contractions in and about the nerves (see Pathology) obstruct the anatomical and functional continuity of their fibres. There may, then, result any condition from nearly complete recovery to the total loss of function of a part or the whole of the extremity.

Inasmuch as it is impossible, just after the injury (diagnosis), to determine the exact distribution and degree of the lesion, only time (six to twelve months) will permit a fairly accurate prognosis to be made.

In those cases presenting definite “traumatic neuritis” of the nerve roots (symptomatology) the prognosis is relatively bad from the outset, and it may be positively stated that there will be some degree of permanent damage to the extremity, although here again only time can determine its exact extent. In many cases the lesion consists of several foci scattered through the nerves at the site of injury. Therefore the prognosis is influenced by the distribution as well as the degree of the lesion.

The deep cervical fascia overlying the nerve roots is injured in all the severer cases, and by its cicatrization and adhesions to the
nerve roots (noted in all 7 operated cases) interferes with their regeneration.

(b) Proper treatment greatly influences the prognosis even in those cases which will suffer from permanent nerve damage, for, as stated in the symptomatology, there is always some recovery in the nerves which have been only moderately damaged about the periphery of the maximum laceration. During the recovery of these nerves and muscles, unless proper treatment (see Treatment later) is carried out, there occur contractures of muscles and ligaments, with resulting deformities of the joints which very greatly limit the functional value of such muscles as regain power.

Only 26 per cent. of all forms of brachial birth palsy recover (Bruns).

It has been stated (Comby) that cases which occur in head presentation have much the better chance of recovery. While this statement is borne out by statistics, yet one can understand that as less stretching force is apt to be applied in vertex labor, these cases would naturally show less serious lesions.

TREATMENT (CLARK AND TAYLOR).

(a) Prophylactic. The necessity of prophylaxis is obvious and it can easily be deduced from a consideration of the "etiology."

(b) Palliative. Inasmuch as the degree of spontaneous recovery which will occur in any given case cannot be determined until after many months, treatment should be directed to maintaining the nutrition of the muscles, to preventing contractures and resulting deformities, and to assisting the spontaneous repair of the damaged nerves by means of massage, passive motion, douches (hot and cold), electricity, and such apparatus (if necessary) as will overcome a tendency to deformity.

It must be remembered, however, that in the cases showing marked evidences of traumatic neuritis, complete immobilization is demanded until the inflammatory reaction has subsided (often two to four months). During this period means should be taken in the immobilization to hold the extremity in normal position (i.e., overcome the internal rotation) and so prevent contracture of the pectoralis major muscle and the anterior ligaments in that attitude. The attempt to use the active measures above detailed tortures the child and aggravates the inflammatory reaction. When the neuritis has subsided the active measures may be employed.

Electricity not only helps keep the muscles in good condition, but also aids materially in the nerve regeneration by stimulating "neurofibrillation" in the regenerated homogeneous axis cylinders (Bethe).

(c) Radical. The length of time through which palliative treatment should be continued is still a matter for discussion. If, by the
end of the year, complete recovery has not occurred, a prognosis of permanent lesion may be definitely made, although some slight improvement occurs after this time in certain cases.

Kennedy counsels operation at the end of three months, but that would seem too early, inasmuch as, at that time, none of the spontaneous regeneration, which occurs to some degree in nearly all cases, would have had time to show itself and to permit of a more accurate diagnosis of the distribution and degree of the lesion.

If the palliative treatment be systematically employed there would seem to be no disadvantage in waiting a year before proceeding to radical measures, although in certain selected cases a shorter time limit might be chosen (where electric responses show no tendency toward spontaneous improvement after four to six months).

The advantages of waiting lie in the increased size of the operative field, the more definite localization of the lesion, and the lessened danger to life from shock and hemorrhage.

The clinical demonstration that there is to be a permanent lesion in any given case means that there must be a cicatricial lesion preventing complete nerve regeneration, as has been proven in the consideration of the pathology of the condition.

Here then, as in other traumatic lesions of the peripheral nervous system, the only rational treatment lies in the excision of the damaged tissue, with following nerve suture.

There have been but few secondary operations upon the brachial plexus. Excision of the lesion in a case was advised several years ago (Starr), but owing to the extent of the lesion found the operation was abandoned.

In 1900 Kennedy operated upon a case in which the brachial plexus was involved in a cicatrix causing total palsy of the arm. An operation for the relief of the nerve from adhesions resulted in a practically complete recovery fourteen months after operation. The same author reported operations upon three additional cases of birth palsy in February, 1903. Case I. made a nearly complete recovery in nine months after operation. Case II. five months after operation showed improved electric reaction, but no return of voluntary power. Case III. only three months after operation showed returning faradic response. He recently reported three additional cases, but the time was too short for results to have appeared.

OPERATIVE TECHNIQUE (A. S. TAYLOR).

The patient is anæsthetized and brought to the table with the field prepared for operation. A firm cushion is placed beneath the shoulders, the neck is moderately extended, and the head held toward the sound shoulder. This position gives a good exposure of the operative field.

The incision passes from the posterior border of the sternomastoid
muscle, at the junction of its middle and lower thirds, downward and outward to the clavicle at the junction of its middle and outer thirds. After the skin, platysma, and deep fascia are divided, the omohyoid muscle is exposed near the clavicle, and lying beneath it are the suprascapular vessels. These structures may be retracted downward, or, if the case requires the extra room, the omohyoid first and then the vessels, between double ligatures, may be divided. The transversalis colli vessels are encountered a little below the middle of the wound and divided between double ligatures.

The dissection is rapidly carried through the fat layer to the deep cervical fascia covering the brachial plexus. In all the cases this fascia was thickened at the site of lesion of the nerve trunks. This fascia is divided in the direction of the original incision, is dissected away from the nerve trunks to expose them freely (Fig. 10, 1). The damaged portions of nerve are usually noticeably thickened and of greater density than the normal nerves. The extent and distribution of the paralysis, determined before operation, gives the clue as to which roots are at fault. Usually the junction of the fifth and sixth roots is the site of maximum damage. The thickened indurated areas are determined by palpation and are excised by means of a sharp scalpel. Scissors should never be used for this purpose as they pinch the nerve ends so much as to seriously interfere with their later regeneration.

The nerve ends are brought into apposition by lateral sutures of fine silk involving the nerve sheaths only, while the neck and shoulder are approximated to prevent tension on the sutures. Cargile membrane is wrapped about the anastomosis to prevent connective-tissue ingrowth. The omohyoid muscle, if it has been divided, is sutured with catgut. The platysma and skin are sutured with silk. A firm sterile dressing is applied, and the bandage is made to approximate the shoulder to the head (Fig. 6, Case VI., 2). This position must be maintained for from two to three weeks to permit of firm union between the nerve ends. In the first five cases it was very difficult to maintain this position by bandages, especially during the struggling incidental to recovery from the anesthetic. It must be remembered that a single moment's separation of head and shoulder after the nerve sutures are tied will spoil the operation. Preceding Case VI. a plaster splint was moulded to the head and paralyzed extremity so as to maintain them in the desired relative position. After hardening it was removed and lined with soft material. At the operation, as soon as the nerve sutures were tied, the cast was slipped on and the skin wound sutured without danger of tension on the nerves (Fig. 6, Case VI., 2). The child could readily be lifted about later without danger to the suture. A neater splint was designed later, with buckles and weehing straps to eliminate the necessity for bandages (Fig. 6, Case VII., 2).

It will be noticed that (Fig. 10, 2) (a) the tissues to be excised l
in close proximity to the phrenic nerve and internal jugular vein, and to the junction of the cervical sympathetic communications with the spinal nerve root. (b) The suprascapular nerve comes off from the junction of the fifth and sixth cervical nerve roots, which, as already stated, is usually the site of maximum damage. This nerve is very small in children, but it should be sutured with the greatest care to proximal nerve stump, since it innervates the external rotators of the shoulder, the paralysis of which permits the posterior dislocation of the shoulder often seen in the older cases.

In cases where the lesion is more extensive, especially where it lies beneath the clavicle, a wider exposure is necessary (Fig. 10, 2). It is obtained as follows: The first skin incision is carried downward along the line between the pectoralis major and deltoid muscles, which are then separated. The clavicle is divided in the line of the skin incision by a Gigli saw; the subclavius muscle is divided as are the omohyoid muscle and suprascapular vessels if they have been spared in the earlier steps of the operation. When the outer fragment of the clavicle and the shoulder are retracted outward the entire brachial plexus, with more or less fat in front of it, is exposed down to the upper margin of the pectoralis minor muscle. (If this muscle is divided a still wider exposure is given, but this is seldom required.)

When the nerve suture is completed the divided muscles are repaired, the clavicle is sutured with chromic gut, and the skin closed with silk as before.

This operation, because of its length, the loss of blood, and the shock involved, is applicable only to older children.

Where the lesion involves the whole plexus it would be wise to do only a portion of the repair work at the first operation and complete the repair at a later operation, thus avoiding too long and exhausting a procedure at one time. (See Case I.)

After-treatment. When the immobilization is removed, three weeks after operation, the measures indicated in Palliative Treatment are systematically employed. As soon as evidence of returning voluntary power appears in the paralyzed muscles, attention should be given to encouraging voluntary motions in all directions, thus educating the motor centres of the brain to control muscles that were up to that time beyond their influence. Improvement, though slow at first, will continue for a number of years until more or less complete recovery occurs.

A definite prognosis as to the amount of recovery that will follow operation cannot be given until several months have elapsed.¹

¹ In the older cases where contracture deformities are already present the procedures advocated by Whitman (New York Surgical Society, March, 1905) are of great assistance in regaining the usefulness of the limb. The method consists in forcible reduction of the deformities under ether in several sittings, and the maintenance of improvement, so gained by forcible passive motion in the interval, based on the principle of Lorenz's reduction of congenital dislocation of the hip.
During the past two years seven cases have been operated upon by the method detailed. Their histories are as follows:

Case I.—I. H., aged twenty-five months. Patient is a girl who presented complete paralysis of the left arm, as shown in Fig. 6, Case I., 1. A complete lesion of the entire brachial plexus was diagnosed. She was a first child, vertex presentation. Labor was prolonged and difficult. Instruments were used and strong traction exerted on the head. Complete paralysis of the left arm was noted a few days after birth. No spontaneous improvement resulted during the first two months after birth. After four months, however, slight flexion of the fingers and wrist was possible. In every other way the child was perfectly healthy. There was R. D. in all the muscles of the upper extremity. Contractures produced the deformity shown in the case. An indurated area corresponding to the site of the sixth, seventh, and eighth cervical nerves were found on palpation.

Operation May 18, 1903; chloroform. The more extensive exposure as described above (Fig. 10, 2) was made in this case. The region of the normal brachial plexus was occupied by dense fibrous tissue, in which it was difficult to make out any nerve trunk. After some dissection the proximal ends of the nerves were identified, and the nerves were divided near the outer border of the scalenus anticus muscle. Distally, the nerves were identified and the division made just beyond the cicatricial area, which was in all about 2.5 cm. wide (Fig. 11, Case I.). The nerves were sutured to the proximal stumps with silk, the clavicle was united with chromic gut, Cargile membrane was wrapped around the anastomoses. The wound was closed without drainage. The operation lasted somewhat over one and one-half hours; a moderate amount of blood was lost. The child was returned to bed in fair condition about 3 p.m. Five hours later the temperature was 106°; pulse, 180; respirations, 68. In spite of bathing, rectal irrigation, and stimulation, the temperature rose to 108.5° the following morning. The pulse was imperceptible, and the child died at 10 A.M., about nineteen hours after operation. Cultures taken from the wound immediately after death were sterile and the wound appeared all right.

Case II.—Annie H., aged ten years. Typical birth palsy of milder grade was present, as shown in Fig. 7, Case II., 1. The patient was a fourth child, vertex presentation, markedly asphyxiated after a dry labor of seven hours' duration. Forceps were used and great force employed in delivery. Palsy of the right arm was at once noticed. At the end of four months improvement began and continued for a year. Slight contractures have occurred in all the muscles paralyzed, producing the characteristic deformity.
Palpation disclosed a cicatricial induration, most marked at the juncture of the fifth and sixth cervical roots.

Operation June 17, 1903; chloroform. The lesser operation was done as described above (Fig. 10, 1). The deep fascia was thick-
enched in front of the nerve lesion, which involved the fifth and sixth nerves, of which the damaged portion (about 1 cm.) was excised (Fig. 11, Case II.). The nerves were sutured and the wound closed as usual. The operation lasted one hour. Very little blood was

FIG. 7. Case II.

1. (Typical laceration brachial birth palsy.) Ordinary position in which the patient held the right arm before operation.
2. The amount of possible supination of the hand before operation.
3. Amount of elevation of arm possible before operation.
4. Showing patient's ability to place the hand on the top of the head eighteen months after operation. (Compare with 3.)
5. Showing patient's nearly normal ability to elevate the arm eighteen months after operation.
6. Showing the amount of supination of the right hand eighteen months after operation.

lost. There was no reaction. The wound healed by primary union. After three weeks the dressings were removed and the limb left free. Marked return of power began in the third month and has continued to the present time. (Compare Plate II., Case II., Figs. 1, 2, and 3 with Figs. 4, 5, and 6.) These show the improvement in range of
muscle action. The muscle power in the distribution of the fifth and sixth cervical nerve roots has been fully doubled.

Case III.—F. G. C., aged eight years. Birth palsy of the right arm, as shown in Fig. 8, Case III., 1. The habitual position charac-

Fig. 8. Case III.

1. (Typical laceration brachial birth palsy.) Ordinary position in which patient held right arm before operation.
2. Amount of supination of the right hand possible before operation.
3. Showing extent of muscle power in the biceps and deltoid before operation.
4. Showing great reduction in deformity of the right arm nine months after operation. (Compare with 1)
5. Showing extent of muscle power in the biceps and deltoid nine months after operation. (Compare with 3)
6. Showing still greater return of muscle power ten months after operation. (Compare with 3 and 5)

teristic in this lesion. He was the third child (the two preceding confinements were normal), vertex presentation, dry labor, lasting fourteen hours, in which instruments were finally used. After pro-

longed and forcible traction he was born asphyxiated and with total
Semidiagrammatic scheme (Kocher) to show the formation of the brachial plexus and the nerve supply to the muscles of the upper extremity.
paralysis of the right arm. During the first year there was some slight return of power, but there has been no improvement since that time. The right upper extremity and half of the shoulder girdle are distinctly undeveloped compared to the left side, as shown in Fig. 8, Case III., and the x-ray pictures. Palpation of the lesion shows the fifth and sixth nerves involved in a cicatricial mass. There is loss of reaction to the faradic current and R. D. in all muscles of the fifth and sixth distribution. The shoulder is a flail-joint. The elbow cannot be extended nearer than 30 degrees to a straight line. The wrist is markedly flexed and ulnar adducted. The extremity is cooler than the normal one and the hand is purple colored. The bones of the damaged extremity are from 12 to 20 per cent. shorter than the corresponding bones on the opposite side. There is a pronounced posteroinferior dislocation of the shoulder. The coracoid and acromion processes are longer, more pointed, and bend more downward and forward than normal.

Operation June 24, 1903; chloroform. The simpler procedure was resorted to; the fascia in front of the plexus was much thickened and adherent to the nerves. When the plexus was exposed, a most interesting condition was found; the external nerve division derived from the junction of the fifth and sixth cervical roots was torn away and displaced downward and inward 2.5 cm., and was adherent to the front of the scalenus anticus muscle by firm fibrous tissue. The nerve was dissected free and its damaged end removed. The junction of the fifth and sixth nerve and the posterior division derived from them was the seat of cicatricial induration. The damaged tissue was excised (Fig. 11, Case III.), the freshened ends sutured, Cargile membrane used, and the wound closed as usual. The operation lasted one hour. Primary union resulted. After three weeks the extremity was allowed free mobility. The recovery was complicated by a severe bronchitis lasting two weeks. The return of power began decidedly at the end of the fifth month. At the end of the ninth month the patient was able to move the arm as shown in Fig. 8, Case III., 5. One month later, as shown in 6. He continues to improve steadily, but slowly.

Case IV.—Joseph B., aged eight months. Typical birth palsy (Fig. 6, Case IV., 1). He was the third child. The two preceding labors were normal and easy. Vertex presentation. Labor seventy-two hours, conducted by a midwife, who, when the head was born, pulled forcibly upon it to deliver the shoulders, which were caught. Two days later the paralysis of the right arm was noticed. No improvement occurred up to the time of operation. The child was small, frail, poorly nourished, and had diarrhoea; no signs of other disease. He was kept in the hospital for two months, until his diarrhoea had disappeared and his general condition had very greatly improved.

Operation July 22, 1903. Cocaine 1 per cent. and adrenalin
1:4000. As the dissection in this case would be slight, it was thought that cocaine and adrenalin would avoid the risk of a general anaesthetic. The mixed solution was injected into the skin, which after five minutes was divided, and the dissection carried quickly through the fat to the plexus. The cicatrix was localized at the junction of the fifth and sixth nerves and the overlying fascia. The solution
1. Longitudinal section through piece excised from case: A, degenerated nerve fibres; B, hemorrhages in the perineural sheath; C, buckling inward of perineural sheath upon the nerve strands.
2. Band of connective tissue, A, lying across nerve bundle B.
3. Kink, B, in nerve fibres, A, which terminate in connective-tissue mass, C, containing pigment (blood clot).
4. Buckle in perineural sheath, A, which compresses the nerve fibres. Broken-up remains of the myelin sheath shown at B.
was injected into the fifth and sixth nerves proximally. After five minutes the cicatrix was excised (Fig. 11, Case IV.) and the operation completed as before. The operation lasted fifty minutes, and with very slight loss of blood. The child was returned to bed in fair condition, although the temperature had risen to 103°; pulse 154; respiration 80 during the operation. A few hours after the operation the diarrhoea, which had been absent for a month, recurred. The temperature remained 103° continuously and the child was very restless. In spite of treatment the temperature mounted slowly. On the third day there was suppression of urine and the child died. Cultures from the wound were sterile and there were no complications in the chest.

Case V.—George H., aged four and a half years. Second child. Vertex presentation. Very difficult labor. Instruments used after nineteen hours and “great pulling” was employed. The right arm was paralyzed at birth. Movements began to return at the end of three months, but after the end of six months improvements ceased. Paralysis, deformity, contractures, and atrophy typical of a medium grade of birth palsy, as shown in Fig. 6, Case V., 1, resulted. Electric reaction and palpation showed that the junction of the fifth and sixth nerves was the site of lesion.

Operation May 17, 1904; ether. The usual operation was done, and the fifth root from near the spine down to and including some of the junction of the fifth and sixth roots was removed (Fig. 11, Case V.). The sutures and closures were done as usual. Operation lasted thirty-five minutes. There was no reaction. Primary union resulted. The function of the muscles supplied by the fifth and part of the sixth cervical roots remained completely in abeyance for the first three months. Slow improvement has occurred since, until at the end of six months about two-thirds of the former muscle power and range of movement had returned. This child was very refractory and has followed none of the instructions as to after-treatment, and therefore the best results are not to be hoped for in his case.

Case VI.—Rose B., aged eleven years. First child. Vertex presentation. Delivered by a midwife, who pulled on the head. Partial paralysis of the left upper extremity was noticed within the first two days. After several months improvement began and continued for about two years, appearing first in the hand muscles and then extending upward. Finally, improvement ceased and the patient now has a typical birth palsy of mild degree (Fig. 6, Case VI., 1).

The nerve lesion could not be made out by palpation in this case as in the preceding ones, but was located by the type and range of palsy at the junction of the fifth and sixth cervical root, in the upper and outer part of the fifth cervical root principally.

Operation November 12, 1904; ether. The usual operation was done. The fascia lying just in front of the nerve roots was much thickened, was adherent to the front of the scalenus anticus muscle
and to the fifth and sixth nerve roots, from all of which it was dissected away. The lesion was found in the fifth root and in the outer part of the junction of the fifth and sixth root. The damaged tissue was excised (Fig. 11, Case VI.) and the operation completed as usual. Operation lasted thirty minutes. There was no reaction and the wound healed by primary union.
In this case and the succeeding one sufficient time has not elapsed for the return of power.

Case VII.—Edward A., aged sixteen months; fourth child. Labor was difficult; version was performed and the case was terminated as a breech. He weighed eleven pounds. Paralysis of the right arm was first noticed at the end of a week, and involved the whole extremity, which assumed the typical attitude. After about three months improvement began in the muscles of the hand and forearm, but finally ceased at fourteen months, leaving him with a typical birth palsy (Fig. 6, Case VII., 1). An induration about 1 cm. in diameter was easily palpable beneath the skin at Erb’s point on the right side. He was a sturdy, well-nourished child.

Operation November 19, 1904; ether. Usual operation. The deep fascia was found thickened in front of the nerves and adherent to them. On dissecting it away carefully it was found that the fifth root had been completely torn across, proximal to its union with the sixth root. The proximal end was bulbous, displaced to and adherent to the anteroexternal part of the scalenus anticus muscle. The distal end was bulbous, was adherent to and covered the sixth root. The suprascapular nerve was fibrous for a distance of almost a centimetre from its origin. The damaged tissue was excised (Fig. 11, Case VII.), the nerve sutured, and the operation completed as usual. Operation lasted forty-five minutes. The maximum postoperative temperature was 100° (twelve hours after operation). Primary union resulted.

RESULTS (A. S. TAYLOR).

Mortality. It will be noticed that of the seven cases the first and fourth died (about 30 per cent.). The first case was a well-developed, healthy blonde girl two years old. The operation lasted one and one-half hours; the loss of blood was moderate; all the roots of the left brachial plexus were divided at the outer edge of the scalenus anticus muscle. The clavicle was divided. This operation was of some magnitude.

The patient left the table in good condition, but within a few hours the temperature rose rapidly and steadily, as did pulse and respirations, until death occurred within twenty hours. (Temperature, 108.8°; pulse, over 200 and almost imperceptible; respirations, 68.) Cultures from the wound were sterile.

Unquestionably shock entered materially into this unfortunate result, but there was much in the clinical picture outside the realm of shock which closely identifies this case with those victims of "lymphatic diathesis," "acetonæmia," and similar little-understood conditions, in whom death occurs without reason even after trivial operations.
Infection does not enter into the problem, since the wound was dry and clean and cultures were sterile.

The fourth case was a poorly nourished child, which was in the hospital several weeks suffering from diarrhoea. During the month preceding operation there was no diarrhoea and the weight increased steadily. Immediately after the operation diarrhoea recurred in aggravated form; there was suppression of urine on the third day and the child died.

In this case death was due to the diarrhoea and the suppression of urine, but these unquestionably were precipitated by the operative procedure.

The other five cases recovered without the least evidence of shock or reaction. Even in Case VII., only sixteen months old, although the operation lasted forty-five minutes under ether anaesthesia, considerable manipulation was necessary and the fifth and sixth roots were divided, the maximum postoperative temperature was 100°, and there was no evidence of shock.

In spite of the two unfortunate cases in this series, there is every reason to believe that the mortality in a large number of cases will be very slight. Because of the complete absence of reaction in the other five cases it would seem as though the two deaths were not entirely due to the operative procedure.

Functional Improvement. The return of function in a divided and sutured nerve occurs only after months, and the longer the time elapsed between injury and operation the slower, relatively, it returns.

In cases of several years’ duration there will probably never be a development of limb equal to that of its opposite fellow. This could not be expected. But the disparity (due to growth and even hypertrophy from overuse on the sound side) between the two will either not increase at all or at least will increase in a less rapid ratio.

Only in Cases II. and III. has sufficient time elapsed to give definite results. In Case II. the nutrition of the arm was good before operation. The increased range of motion is indicated in the photographs (Fig. 7, Case II.). The muscles are decidedly stronger than they were.

In Case III. the increased range of motion is shown by the photographs (Fig. 8, Case III.). The extremity, instead of being cold and purplish, is now warm and of normal color. The flesh is firmer and the muscles stronger. In the shoulder, instead of a flail-joint, there is still a complete posterior dislocation, but the humerus is pulled well upward by the deltoid. The reduction of the dislocation is prevented by the distorted coracoid and acromion processes, as well as the contractures in the anterior soft structures.

He can now reach his face and head with his right hand and also button his clothing, a thing which he had never been able to do before operation.
Case V. is beginning to show return of power.
It is worthy of note that in Cases II. and III. operation was performed ten and eight years, respectively, after the injury, and yet regeneration with return of function is occurring. This is strong evidence in favor of the rule that nerve suture should be done regardless of the time elapsed since injury, provided there is muscle tissue left to be acted upon through regenerated nerve.

**Conclusions.**

This research embodies new facts in the etiology and pathology of the laceration type of birth palsy, the development of the relationship thereto of the symptomatology, and the establishment of a scientific basis for treatment.

1. The cause of the laceration type of birth palsy is tension on the nerve trunks, which first ruptures the nerve sheath and then the nerve fibres. The prevention of this serious lesion of the cervical nerve trunks rests with the obstetrician, who should not overstretch the child's neck in the process of delivery.

2. The persistence of the palsy is clearly explained by the pathological findings, viz.:
   
   (a) Rupture of the perineural sheath with hemorrhage into its substance, resulting in the formation of hematomata or hematomatic infiltration into the neighboring tissues.

   (b) The cicatricial contraction following organization of the blood clot and repair of the rent in the perineural sheath. The connective tissue thus formed indentes and presses upon the nerve bundles, strangulating them and preventing regeneration of the nerve fibres. In some instances the same result is accomplished by the turning inward of the perineural sheath upon the nerve bundles.

3. The nature of the lesion in all cases demands excision of the damaged areas and suture of the divided ends as soon as it is proven that spontaneous repair will not take place. The plan of treatment is then the same as that for peripheral nerve injuries elsewhere.

4. In all cases such treatment as will prevent contractures and deformities and maintain muscle tone in the paralyzed limb should be systematically used until either spontaneous recovery occurs or operation is done. (Traumatic neuritis is a contraindication to active treatment.) It is obvious that the above measures should be continued after operation.

5. The proper time for surgical interference is not yet definitely fixed. It appears, however, to be much later than two or three months after birth, as advised in Kennedy's report. At the present time one year would seem to be a reasonable delay before operation.

6. Sufficient time has not elapsed in the majority of the cases in this series for final results to have appeared.
At the end of eighteen months in two cases (II. and III.) the improvement in nutrition, range of motion, and muscle power in the paralyzed limb have been sufficient to demonstrate the value of the operative procedure.

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