SUBLUXATION AND DISLOCATION OF THE RADIAL HEAD.

A COMPLICATION OF ERB'S OBSTETRICAL PARALYSIS.

by

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C O N T E N T S.

1. INTRODUCTION.

While subluxation of the humeral head is a well-known complication of Erb's obstetrical paralysis, the etiology of which appears to have been satisfactorily determined, associated subluxations and dislocations of the radial head have been commented upon so infrequently that it would appear either that the condition is practically unknown or that the less obvious degrees are escaping detection.

The discovery of several instances of the condition some years ago at an out-patient clinic of the Royal Hospital for Sick Children, Glasgow, at routine follow-up examination of older children, who had been treated in infancy for Erb's obstetrical paralysis, prompted a survey of the literature on the subject. This, however, threw little light on the complication, either from the point of view of etiology or of treatment, what few references there were dismissing it in a few lines as being an uncommon and unimportant complication of doubtful etiology occurring in the older child.

In/

In 1948 four cases of posterior subluxation of the radial head were presented at a meeting of the Scottish Surgical Paediatric Club at a preliminary stage of this investigation in the hope of gaining more information on the incidence and other aspects. The indications of this meeting were, that up to date no series of cases had been reported, nor had any serious attempt been made to account for the occurrence of the complication, and it was suggested that such bony deformities only occurred in the neglected case. Subsequent communications, however, from the various Scottish Centres reported the occurrence of subluxations not previously noted in children who had been treated in the routine fashion. Accordingly, a review of all cases of Erb's obstetrical paralysis attending at the hospital over the past fifteen years was undertaken to arrive at conclusions concerning the incidence, etiology, treatment, and, in particular, the possibility of prevention of the associated subluxation, as, judging from the few cases which had been seen up to this time, the subluxated radial head appeared to be causing a very much greater degree of disability than the literature would/

would lead one to expect in cases in whom recovery otherwise had been good.

Eighty-seven cases of Erb's obstetrical paralysis were examined during this survey, and a further nineteen have attended since the investigation began and are included in the series, bringing the total to one hundred and six cases. This paper reports on thirty-two cases of subluxation or dislocation of the radial head, an incidence of 30% of the series.

During the investigation it became clear that these subluxations and dislocations were of two types, totally different in every respect; firstly, a posterior type of which there were twenty-seven cases, an incidence of 25.4%; and secondly, an anterior type, of which there were five cases, an incidence of 4.7%.

2. LITERATURE PERTAINING TO THE CONDITION.

In most of the papers on Erb's paralysis which were read there are no references whatever to radial subluxation. The following references are to those papers in which the condition is mentioned or discussed.

Most articles mention the fact that impairment of supination and of function of the elbow joint of the affected arm is a feature in some older cases, but only a few papers describe the occurrence of radial head dislocation, again confined to the older child. In spite of the fact that this is admitted to cause a residual disability, the condition is dismissed in a few words, and there is little if any expression of opinion regarding the incidence, age of onset, causation, or treatment preventive or corrective, of the condition.

Bullard (1907) states that in some old cases extension of the elbow is limited. He is of the opinion that this is due to contracture of ligaments and tissues surrounding the joint or sometimes to bony malformation. A radiograph of a posteriorly dislocated radial head of a child of about six years is illustrated, and/

and its abnormal shape is attributed to the dislocation. Limitation of extension of the elbow, he says, is due sometimes to lack of development of the olecranon process of the ulna. As will be shown later, his interpretation of these radiographs is incorrect.

Thomas (1914) reporting on nine old cases of Erb's paralysis mentions that in several with limited elbow movements there was "undue prominence" of the radial head, but this finding is not enlarged upon. In this series one case of anterior dislocation was noted, and, having already attributed the paralysis to a dislocation of the shoulder at birth, he is of the opinion that all associated dislocations of the radial head are also due to birth injury.

Sever (1925) in a series of 1,100 cases of Erb's palsy found that a subluxation or dislocation of the radial head had occurred in many instances. He admitted that he was unable to classify these cases correctly.

Gilmour (1925) divided cases of Erb's paralysis into three groups. First, the typical mild case with complete or almost complete recovery; second, the "irritable" type which at birth shows some degree of neuritis/

neuritis of the brachial plexus; and third, the type showing contractures and deformities, this last type, naturally, belonging to an older age group than the preceding two. He is of the opinion that babies in whom the original lesion has been neither too slight nor too gross are liable to become Type 3 cases in due course. Six out of a series of eight "irritable" type cases were eventually classified in this third group. He mentions that limitation of elbow movements and radial subluxations occur in this third group, and suggests that the subluxation is due to the combined paralysis of the supinators and the pull of pronator teres. The similarity of Gilmour's findings with those of some cases of the present series, except for the important aspect of age incidence, will be evident later.

Jepson (1930) states that in the older case, extension of the forearm on the arm is often impaired, but that no bony deformities are to be found radiologically, at any rate in the first year of life. He attributes the limitation of movements to soft tissue contractures and, in some older cases, to bony malformations, which are unspecified in the paper.

Mc.Farland/

Mc.Farland (1936) describing a series of eleven anterior dislocations of the radial head in children, unassociated with paralysis or trauma, considers that this deformity is congenital in origin, as distinct from "subluxations of the radial head occurring in Erb's paralysis as a result of muscle imbalance". Radiologically, the appearances of his cases are identical in every detail with the anterior dislocations in this series, but, judging from the findings to be set out later in this paper, the description of this condition as being of congenital origin appears to be incorrect.

Morison (1938) states that in his series of twenty-eight cases of Erb's palsy, although more than half had deficient extension of the elbow and deficient supination, no demonstrable bony changes were found radiologically. Although no mention is made of the occurrence of radial subluxation, one case of the series had his radial head removed "to improve the position of the forearm". It would seem probable that this was a subluxated or dislocated head.

Moore (1939) says that "contractures in turn lead to joint deformities, especially in the shoulder, where a/

a subluxation is often seen and in the elbow where a displacement of the radial head is seen. In the moderate cases there is frequently some flexion contracture of the elbow joint. Occasionally the radial head is dislocated upwards from its normal position."

As far as could be ascertained these authors treated their Erb's paralysis cases in full correction, either by a splint or by tying the hand behind the head. Some cases who had no early treatment are reported as having developed bony deformity of the elbow region. In papers where this deformity is described it appears to have been an anterior dislocation which was present. No instance was found in the literature of a typical posterior dislocation occurring in a child whose paralysis had been untreated or neglected.

3. OBJECTIVES OF THIS THESIS.

In contradistinction to the papers quoted above it is proposed to show that:-

1. Two distinct and separate types of subluxation and dislocation of the radial head may be encountered as complications of Erb's paralysis, an anterior type and a posterior type.

2. The etiology of the two types is completely different.

3. The posterior type is not a simple dislocation or subluxation of a normal radial head caused by the pull of contractures and occurring in the older child, as suggested in the literature, but commences in infancy in certain cases of Erb's paralysis, and is due to the position in Fairbank's splint of an arm, whose muscles are grossly unbalanced, setting up stresses and strains which give rise to alterations in metaphyseal growth.

4. Evidence of bony malformation and incipient posterior subluxations of the radial head can be seen radiologically as early as two to four months of age, long before there is any clinical evidence of deformity.

5. The anterior type is a simple traumatic dislocation occurring at birth, which may or may not be associated with/

with an Erb's paralysis.

6. In cases with a posterior subluxation, limitation of elbow movements is primarily due to bony deformity. Soft tissue contractures play a minor part at first, but accentuate the effects of the bony deformity as the child becomes older.

7. The complication can be modified and possibly prevented, with consequent improvement in the functional result as a whole, by the assumption of a modified splint, which has been evolved as a result of this investigation.

In order to attain these ends a great deal of detailed clinical and radiological material is of necessity included.

4. PATHOLOGY OF ERB'S OBSTETRICAL PARALYSIS.

The condition was first described by Smellie in 1768 (quoted by Abt, 1923) who thought that the paralysis was due to long-continued pressure of the foetal arm on the maternal pelvis. Since Duchenne's description in 1872, however, it has been recognised that the paralysis is due to injury at birth.

Thomas (1914) believed that the paralysis was secondary to a traumatic dislocation of the shoulder at birth, and caused by the resulting haemorrhage tracking up the nerve sheaths of the plexus, but since this time sufficient number of cases have been operated upon or examined at autopsy to prove that the lesion is a definite birth injury to the plexus itself, and that a shoulder dislocation, if present, is a secondary feature.

The concensus of opinion to-day is that the condition is due to trauma to the upper trunk of the brachial plexus at or near the junction of C5 and C6 nerve roots, and that this trauma is caused by an increase in the neck-shoulder angle during birth (Boorstein 1923, Taylor 1920, Platt 1920). Mc.Fadden (1928) is of the opinion that the mechanism of nerve injury is traction on the affected arm with flexion and rotation of the head to the/

the opposite side. He demonstrates that in this position the transverse process of the seventh cervical vertebra impinges on the plexus at "Erb's point".

Classification of Cases.

The amount of nerve injury can be of any degree of severity from a slight perineural haemorrhage to complete division of the plexus trunk or even avulsion of the nerve roots from the spinal cord. The signs, symptoms, and prospects of recovery naturally depend on the amount of nerve damage. Unless the case be operated upon at an early age, when the injury to the plexus can actually be seen, the true amount and type of nerve damage that there has been can only be assessed when the child is some years old and all recovery has ceased. In any series of cases, therefore, only those who are old enough can be grouped according to fundtional recovery and to what the probable pathology has been. Even so, such groups merge into one another, and cannot be sharply demarcated.

The following classification has been adopted in order to co-relate the incidence of subluxation and dislocation of the radial head with the amount of recovery,length of time of splinting, and probable pathology of the whole series.

Type 1./

<u>Type 1</u>. Mild pathology. Complete to good recovery.

Failure of conduction is due to stretching of the nerve fibres and associated perineural haemorrhage causing a physiological blockage.

(a). In the mildest cases the haemorrhage is absorbed and recovery is early and complete.

(b). In the less mild cases cicatrisation occurs, recovery is therefore slower, and is incomplete to a variable degree, resulting in slight residual weakness.

Normal growth of the limb occurs in these cases.

<u>Type 2</u>. Moderate pathology. Fair to Poor recovery.

Failure of conduction is due to stretching of some nerve fibres and tearing of others, with associated intra and extra-neural haemorrhage. This is followed by cicatrisation and neuroma formation and results in a permanent loss of conduction in some of the affected fibres. Recovery is slow and partial to a varying degree depending on the number and situation of the fibres involved.

Frequently this type of case is complicated by a "neuritis" of the plexus causing irritability and tenderness of the non-paralysed muscles, and tenderness can/

can also be elicited in the neck over the plexus itself. The arm is held firmly in the classical position by spasm of these muscles. This "neuritis" is probably due to irritation caused by haemorrhage amongst the frayed-out nerve fibres.

Interference with the nutrition of the limb is demonstrated at an early age by imperfect ossification and slowing up of growth of the bones, by delay in the appearance of the abnormally small epiphyseal centres, and later by their late fusion with the metaphysis and with one another.

Type 3. Severe pathology. Poor to minimal recovery.

Failure of conduction is due to complete or almost complete rupture of the upper trunk of the plexus at "Erb's point" or, in the most severe cases, to actual avulsion of the nerve roots of C5 and C6 from the spinal cord, this being frequently accompanied by varying degrees of injury to the rest of the plexus, and is followed by a complete and permanent flaccid paralysis of the muscles supplied. Recovery is minimal or nil. The bones are decalcified, smaller than normal in all dimensions, and epiphyseal ossification and fusion are much delayed. Trophic and sensory disturbances are frequently/

frequently associated.

Incidence of Recovery.

There is considerable divergence of opinion in the literature as to the proportion of cases making a complete recovery. Trainor & Crother (1923) consider that full recovery is exceptional, whereas Fleming (1931) obtained complete recovery in twenty-one out of twenty-eight cases. Jepson (1930) states that complete recovery is rare, and occurs only in the mildest cases. In our experience also, complete recovery is uncommon - out of this series of one hundred and six cases only seventeen showed no residual disability whatever.

Most authors agree that between 40% and 60% of cases show a good functional recovery, that is to say, although evidence of the original lesion is still present, the patient is not inconvenienced by it, nor is it strikingly obvious. Such cases belong to pathological Type 1(b). About 35% make a fair recovery, and these are of Type 2. The remaining 25% show only a minimal improvement and therefore are of Types 2 and 3.

The length of time that splinting is required is, of course, directly dependent on the extent of the pathological lesion. It appears to be agreed that if recovery/

recovery is to be complete it will be so after three to six months of treatment (Fairbank 1913, Jepson 1930, Taylor 1920), and that cases requiring up to one year of treatment make a fair recovery, whereas those who require longer than one year show only minimal improvement over their original condition.

These figures correspond closely with the findings in this series, as can be seen in <u>Table 1</u>, in which eighty-seven cases of the series have been grouped according to functional recovery to correspond with the foregoing pathological types. The number of cases in each type, the criteria by which the cases were grouped, and the incidence of the two types of subluxation and dislocation are also shown.

The remaining nineteen cases have not been classified, as they are as yet too young to assess, being still under active treatment. None, however, are of pathological Type 3, as all the paralysed muscles are showing some degree of recovery. Six instances of posterior radial subluxation are present.

It is notable that the great majority of cases of posterior dislocation fall into the moderate group, whereas/

TABLE I.

PATHOLOGY.	RECOVERY.	CRITERIA FOR GROUPING.		AVERAGE TIME OF SPLINTING.	EIGHTY-SEVEN CASES.		
		MUSCLES	GROWTH ETC.		No.	POST.R DISLOC.	ANT.R DISLOC.
MILD. TYPE I. STRETCHING — WITH OR WITHOUT ABSORPTION OF HAEMORRHAGE.	A. COMPLETE	NO RESIDUAL SIGNS OR SYMTOMS	NORMAL.	3 MTHS TO 6 MTHS	17	0	0
	B. GOOD.	SLIGHT WEAKNESS.	NORMAL	54%	29.	0	2
MODERATE TYPE II. RUPTURE OF A FEW FIBRES WITH HAEMORRHAGE.	FAIR TO POOR	DEFINITE WEAKNESS MILD DEGREE OF CONTRACTURES.	AFFECTED LIMB SHORTER THAN NORMAL BY ½" TO 1½"	6 MTHS TO 12 MTHS 28%	25	18	2
SEVERE TYPE III. RUPTURE OF MANY FIBRES WITH HAEMORRHAGE OR AVULSION.	POOR TO MINIMAL	RESIDUAL PARALYSIS. DEFINITE CONTRACTURES	AFFECTED LIMB SHORTER THAN NORMAL BY OVER 1½" MUSCULAR WASTING TROPHIC DISTURBANCES	INDEFINITE 15%	16	3	1
CASES STILL UNDER TREATMENT — UNCLASSIFIED.					19	6	0

whereas the cases of anterior dislocation are spread evenly throughout the three groups.

5. SCHEME OF TREATMENT
IN THE ROYAL HOSPITAL FOR SICK CHILDREN,
GLASGOW,
PRIOR TO THIS INVESTIGATION.

The treatment of obstetrical paralysis had been along the lines adopted in most clinics and followed that suggested by Fairbank in 1913, which sets out to relax paralysed muscles and prevent contraction brought about by unopposed muscle groups.

1. Application of a Fairbank type fibre splint as early as possible. The affected arm is thus fixed in full external rotation and 90^{o} abduction at the shoulder, 90^{o} flexion at the elbow, full supination of the forearm, dorsiflexion of the wrist and extension of the metacarpo-phalangeal joints. Fig. 1.

2. Massage and limited passive movements when recovery is apparent.

3. Encouragement of active and purposeful movements at as early an age as possible. The splint is discarded during the day and reapplied at night when the following conditions are fulfilled.

(a)/

FIGURE I.

FIG. I. Typical case of Erb's paralysis in a Fairbank's splint. (R.H.S.C. Pattern.)

(a). When the infant can raise his arm from the splint.

(b). When the external rotators of the shoulder have recovered sufficiently to balance the internal rotators.

(c). When the flexors of the elbow are voluntarily contracting.

4. The splint is discarded completely only when recovery is well advanced.

5. Continuation of physiotherapy until the child is some years old, depending on the amount of recovery.

Table 2 lists the twenty-seven cases of posterior radial subluxation or dislocation with particular details regarding the duration of employment of the Fairbank splint, in order to emphasize the fact that neither was the duration of splinting unduly short or prolonged, nor was treatment begun at an unduly late date in most cases.

It will be noted that the patients' ages at the date of discovery of the condition are, in most instances, well advanced beyond infancy. Previous to this investigation/

TABLE 2.
POSTERIOR SUBLUXATIONS AND DISLOCATIONS.

Nº	SEX	SIDE	AGE AT 1ST VISIT SPLINT APPLIED AFTER 1 WEEK	REMOVAL OF SPLINT IN DAY-TIME. AGE.	DISCOVERY OF DEFORMITY AGE.	REMOVAL OF SPLINT. AGE.	PRESENT AGE.	RESULT.
1.	M	L	1/365	6/12	7/52	—	7/12	—
2.	F	R	16/365	—	2/12	—	6/12	—
3.	M	L	3/52	—	4/12	—	9/12	—
4.	M	L	3/52	11/12	4/12	—	11/12	—
5	F	L	3/52	11/12	7/12	—	11/12	—
6	M	L	9/365	10/12	3/12	1 YR	1 YR	GOOD.
7	M	L	4/365	8/12	1 YR.	10/12	1 1/12 YR.	FAIR.
8	M	R	3/52	10/12	1 11/12 YR.	1 YR	1 1/12 YR	FAIR.
9	M	L	5/365	9/12	2 5/12 YR.	1 6/12 YR.	2 5/12 YR.	FAIR.
10	F	R	2/52	8/12	3 YRS.	11/12	3 YRS.	FAIR.
11	F	R	3/52	10/12	3 6/12 YRS.	1 6/12 YR	3 6/12 YRS	FAIR
12	M	L	10/52	9/12	5 YRS.	1 YR.	5 YRS.	BAD.
13	M	L	8/365	10/12	5 YRS.	1 2/12 YR.	5 YRS.	FAIR.
14	M	L	8/365	11/12	6 YRS.	1 1/12 YR	6 YRS.	FAIR.
15	F	R	2/52	9/12	6 1/12 YR	1 1/12 YR	6 1/12 YRS	FAIR.
16	F	R	4/365	10/12	7 YRS.	1 YR.	7 YRS.	FAIR.
17	F	R	11/365	6/12.	7 YRS.	7/12	7 YRS.	FAIR.
18	M	R	3/52	6/12	7 YRS.	7/12	7 YRS	FAIR
19	F	L	1/365	10/12	7 YRS	1 YR.	7 YRS.	FAIR
20	M	R	2/52	8/12	8 YRS.	11/12	8 YRS.	FAIR
21	M	R	2/52	10/12	8 YRS.	1 YR	8 YRS	BAD.
22	F	R	11/365	9/12	10 YRS.	10/12	10 YRS	FAIR
23	F	R	10/365	DID NOT REPORT AGAIN ? SPLINTED FOR 6/12.			15 YRS	FAIR
24	M	R	TREATED ELSEWHERE. NO RECORDS. ADDED FOR COMPLETENESS.				30 YRS	BAD.
25	M	L	2/52	10/12	6 YRS.	RADIAL HEADS REMOVED WHEN DEFORMITY WAS DISCOVERED. FIRST CASES SEEN.		FAIR
26	M	R	3/52	11/12	6 1/12 YRS.			FAIR
27	M	L	8/365	9/12	7 YRS			FAIR

PRE- AND POST-OP.

investigation there had been no routine X-ray examination of all cases, but since this has been instituted it has become evident that in some cases bony alterations were occurring not only in the radius but also in the ulna, and that by early X-ray examination these changes could be diagnosed long before they were clinically apparent. This routine radiography at an early age accounts for the comparatively early diagnosis in the first six cases. Cases 25, 26 and 27 were those dislocations which originally focussed attention on the condition, and Case 24, although not treated in this hospital, is included, as by so doing the condition in the adult can be studied, a point not otherwise possible in a fifteen year survey.

Table 3 lists the five anterior dislocations found in the series. It will be noted that in contra-distinction to the posterior type these cases do not follow a standard pattern. Treatment was irregular and the functional result variable. All five had extremely complicated births.

Despite the routine radiography previously mentioned, no new case showing this deformity has been found since the investigation began, although diagnosis should/

TABLE 3.

ANTERIOR DISLOCATIONS.									
Nº	SEX	SIDE	AGE AT 1st VISIT SPLINT APPLIED AFTER 1 WEEK	REMOVAL OF SPLINT IN DAY-TIME. AGE	DISCOVERY OF DEFORMITY AGE	REMOVAL OF SPLINT AGE	PRESENT AGE	RESULT.	BIRTH COMPLICATIONS.
28	M	R	6/12	DID NOT ATTEND AGAIN.	9 YRS	?	9 YRS.	FAIR	BREECH. ? EXTENDED ARM (S)
29	M	R	5/52	DID NOT WEAR SPLINT	4/12	—	11 YRS.	BAD	FORCEPS. ? OTHER COMPLICATIONS
30	F	R	8/52	DID NOT ATTEND AGAIN TILL 2 YRS OLD. SPLINTED THEN.	8 YRS	3 YRS.	8 YRS.	GOOD	FORCEPS ? OTHER COMPLICATIONS
31	M	R	12/365	3/12	9 YRS.	6/12	9 YRS	FAIR	BREECH EXTENDED ARMS.
32	F	L	2/52	3/12	9 YRS.	6/12	9 YRS.	GOOD.	BREECH EXTENDED ARMS.

should be possible at birth. This complication is obviously much less common than the posterior type.

6. DESCRIPTION OF THE POSTERIOR SUBLUXATIONS AND DISLOCATIONS.

1. CLINICAL DESCRIPTION.

The cases, (27 in all, see Table 2) will be divided for convenience into four groups, three based on age.

Group A. Cases 1 - 6, who have been seen and treated as new cases since the investigation began. (Present age 7 weeks - 1 year).

Group B. Cases 7 - 11, whose period of splinting had been completed before the investigation began, but who were still having physiotherapy. (Present age 1 year - $3\frac{1}{2}$ years.)

Group C. Cases 12 - 24, whose treatment had been completed, who had been discharged and were recalled for the purpose of the investigation. (Present age 5 years - adult).

Group D. Cases 25 - 27. Treated by operation prior to investigation.

A clinical summary only will be given of each of these/

these groups. Full clinical details of each case will be found in Appendix I.

<u>Group A. Cases 1 - 6</u> (at first visit aged 1 day to 3 weeks.)

All six were typical cases of injury to Cervical 5 and 6 nerve roots following a difficult labour, either forceps or breech deliveries.

The affected arms were held firmly in the classical position of adduction and internal rotation of the arm at the shoulder, extension of the elbow and pronation of the forearm. The position of the hands was variable.

As far as could be ascertained the following muscles were paralysed - Supra- and infraspinatus, deltoid, biceps, brachialis, brachioradialis and supinator in all, rhomboids in three and radial extensors of the wrist in five. A posterior subluxation of the shoulder was present in one case.

The three youngest cases (1, 9 & 16 days old) showed a well-marked "irritable neuritis" of the brachial plexus. The babies were extremely irritable and cried lustily when the affected arm was touched or moved, there/

there was an obviously tender area to pressure over the site of the plexus in the neck. The unparalysed muscles, especially triceps and the internal rotators of the arm, were extremely tender and in a state of spasm. The arms were placed in the Fairbank splint with difficulty and obvious resentment on the part of the baby, and difficulty was experienced in persuading the mother to keep the arm splinted.

The three older cases (all 3 weeks old) had a history very suggestive of an early "neuritis", but the unparalysed muscles and neck were no longer tender. There was spasm of the unparalysed groups, especially triceps and the internal rotators of the arm. The Fairbank splint was again fitted with difficulty.

Group A. Cases 1 - 6 (at age of discovery of the deformity, aged 7 weeks to 7 months.)

All six cases were beginning to show recovery.

Shoulders. The one subluxation had remained reduced and was stable. All muscles showed a fair degree of recovery except Deltoid in two cases. No contractures and all passive movements of the joints full.

__Arms.__ No contractures. Biceps and brachialis still paralysed in five cases, flicker of recovery in one.

__Forearms.__ No contractures. Supinators still paralysed in two cases, slight recovery in four.
Radial extensors, full recovery in four cases, slight in one.
Passive extension of elbow limited in all six by $15^{\circ} - 20^{\circ}$.
Passive supination full.
Radial heads clinically normal in the three youngest cases and ? abnormally palpable in the three older ones.
Radiological diagnosis of incipient posterior subluxation of the radial head was made and their treatment altered.

It should be noted in this group that the flexors of the elbow show a slow recovery and are lagging behind those of the shoulder, and that limitation of passive extension of the elbow joint has already appeared, despite the fact that full passive movements of the shoulder joints and full passive supination, were possible.

__Group B.__ Cases 7 - 11/(at..

<u>Group B. Cases 7 - 11</u> (at first visit and aged 4 days-3 weeks).

These five cases very closely resembled the previous six. The youngest cases (4 days and 5 days old) showed typical "irritative neuritis" symptoms and signs. One case had a very suggestive history and in two the history was indefinite. All had definite spasm of the non-paralysed muscles especially triceps and the internal rotators of the arm.

<u>Group B. Cases 7 - 11</u> (at age of discovery of the deformity, aged 1 year - 3 years 6 months).

All these cases had had their splints removed but were continuing with physiotherapy.

<u>Shoulders</u>:- Rhomboids - recovery.
Deltoid & spinati - quite good recovery.
Active external rotation and abduction fair.
Passive abduction and external rotation limited in terminal degrees by slight contractures of pectorals and subscapularis.
No humeral subluxations.

<u>Elbows</u>:- Biceps and brachialis are still markedly weak, even in the oldest case.
Passive/

Passive flexion limited by slight contracture of triceps.

Active and passive extension limited by $20^{\circ} - 30^{\circ}$ although biceps and brachialis were fully relaxed.

__Forearms__:- Active supination less than 90°.

Passive supination not more than 100°.

Wrist movements and hands normal.

The affected arms were slightly smaller in all dimensions than normal.

The radial heads were all abnormally palpable.

In this group the elbow flexors are still very weak and passive extension of the elbow and passive supination are more limited than in the previous younger group. Slight contractures are developing in the non-paralysed muscle groups.

Note:- With regard to the foregoing clinical findings it must be stressed that in children as young as 2 weeks to 3 years of age the amount of voluntary movement of an individual muscle and even of a limb is extremely difficult to assess with any great degree of accuracy.

Electrical/

Electrical reactions are of little help in assessing degrees of recovery.

Group C. Cases 12 - 24. (aged 5 years to Adult).
See Fig. 2.

Early records of these cases were not very helpful with regard to irritability, sequence of muscle recovery etc. It is proposed, therefore, only to summarise their clinical condition at the time of recall for this investigation, assessing them as BAD or FAIR.

In this group of twelve cases the result of three was BAD, one of these being the adult, who had been treated elsewhere. These three had fairly marked disability with pronounced contractures and muscle wasting; all had a completely paralysed deltoid muscle, and one, a posterior subluxation of the humerus. Two had sensory and vasomotor disturbances of the affected hand, and the affected limbs of all were more than 2" ahorter than normal. Extension of the elbows was limited by 50° - 55°, and there was no effective supination of the forearm. All three had an extremely obvious posterior dislocation of the radial head.

In nine with a FAIR result, function was good on the/

FIGURE 2.

OLD CASE OF ERB'S PARALYSIS (R) WITH DISLOCATION OF THE RADIAL HEAD — AGED 6 YRS.

The right forearm shows maximal supination which is considerably less than 90°. The right elbow is fully extended. The prominence on the lateral side of the right elbow is the dislocated radial head.

the whole, especially that of the shoulder muscles. The principal disability, that of which the patients complained, was the semi-flexed elbow and the inability to supinate the forearm to any extent. In order to bring the hand palm-upwards the arm had to be abducted, externally rotated and flexed at the shoulder, a very awkward series of movements. Those patients whose right arms had been affected had taught themselves to become left-handed for all fine movements.

Shoulders:- In five cases the previously paralysed muscles were normal, two of these had slight contractures of the non-paralysed muscles. In four, the previously paralysed muscles were slightly weak and two of these had contractures of the unparalysed groups. Abduction varied from 60° to full and external rotation from 100° to full.

Elbows:- Biceps and brachialis were weaker in all cases than one would have expected, considering the recovery of the shoulder muscles. Triceps showed a varying degree of contracture, none was very severe. Limitation of extension varied from 20° to 50°. Limitation of flexion varied from full to 15°. Capsular contractures appeared to be present in all cases./

cases.

<u>Forearms</u>:- Contractures of the pronators were present in all cases though in varying degree. Active supination varied from 10° to 85°, majority about 70°.

Passive supination varied from 35° to 95°, majority about 85°.

Movements of the hands, vasomotor control and sensation were normal in all cases, and all the radial heads clinically were dislocated. The affected arms were from $\frac{1}{2}$" to $1\frac{1}{2}$" shorter than normal.

It should be noted in the FAIR cases of this group that biceps and brachialis are still noticeably weak, that active and passive extension of the elbow and active and passive supination are yet more limited than in the younger age groups.

<u>Group D. Cases 25 - 27</u>. (Aged 6 years - 7 years.)

These cases were typical FAIR results. They were operated upon prior to the investigation and the abnormal radial heads removed. The results were disappointing in that there was no improvement in extension/

extension of the elbow and only about 5° of improvement in supination.

Summary of Resulting Disability.

It will be seen from the foregoing clinical notes that the condition results in the following sequence of disabilities in cases in whom muscular recovery has been good on the whole.

Group A. 7 weeks - 7 months (at age of discovery of deformity).

At this age paralysis is still present so that limitations of passive movement only can be elicited.

Passive extension of elbow	- limited by 15 - 20° and gradually becoming more limited.
Passive supination	- Full at first but gradually decreasing.

Group B. 1 year - $3\frac{1}{2}$ years.

Passive extension of elbow	- becoming limited up to 20 - 25°.
Active " " "	- becoming limited up to 20 - 25°.

Passive/

Passive supination - about 100° and gradually decreasing.

Active supination - less than 90° and gradually decreasing.

Group C. 5 years upwards.

Passive } Extension of elbow becoming limited by as
Active } much as $30 - 40^{\circ}$.

Flexion becoming limited by 15° or so.

Supination becoming more and more limited down to 5° to 20° of movement.

The Adult.

Passive } Extension of elbow - grossly limited.
Active }

Flexion markedly limited.

Active } Supination practically nil.
Passive }

2. OPERATIVE DESCRIPTION.

The following are the operative appearances of the affected elbow joints applying to cases 25, 26 and 27. (Group D). All three were essentially the same.

Fig. 3(1). The elbow joint has been opened on its lateral aspect, exposing the radial head and capitellum. The orbicular ligament was present but was thin, stretched and attenuated. The original capitellar articular surface of the radial head faces posteriorly and upwards, (the forearm is semi-pronated). A new articular facet has formed on its anterior aspect and this articulates with a deformed capitellum, the latter concave where it articulates with the radius.

Fig. 3(2). The radial head has been removed. This clearly shows the concave capitellum and the new facet on the side of the radial head.

FIGURE 3.

OPERATIVE APPEARANCES.

1. HEAD IN SITU.

2. HEAD REMOVED.

3. RADIOLOGICAL DESCRIPTION.

An endeavour has been made to illustrate representative films of each year of age in order to show the development of the deformities until growth is complete. Considerable pains were taken by the radiologists to photograph the two arms and forearms in the same position and at the same distance from the tube. This is by no means easy with these infants and young children, who strongly resent attempts at passive movement, and, in some few cases, it was found to be practically impossible.

An essential part of the findings to be elucidated later is that the upper one fourth of the ulna of the affected side is curved to a variable degree. As this curvature is an exaggeration of the normal and is so near the proximal end of the bone it is not at all obvious even on comparison of the two lateral views and can very easily be missed. Superimposition of film negatives is necessary to enable a close comparison of the two forearms to be made. In this thesis contact prints of one or other lateral view have been reversed in order to approach as far as possible this requirement. This is essential, as, in the youngest cases, little abnormality is immediately evident if the/

the radiograph of only the abnormal limb is studied.

The curvature can be demonstrated in two ways:-

(1). By superimposing the films of the lateral views of the affected and normal ulnae (provided these have been taken in the same plane), so that the outlines of the trochlear notches coincide. This has been done in each case and the accompanying line drawing is a tracing of the ulna of the affected forearm (continuous lines) superimposed on that of the normal forearm (dotted lines).

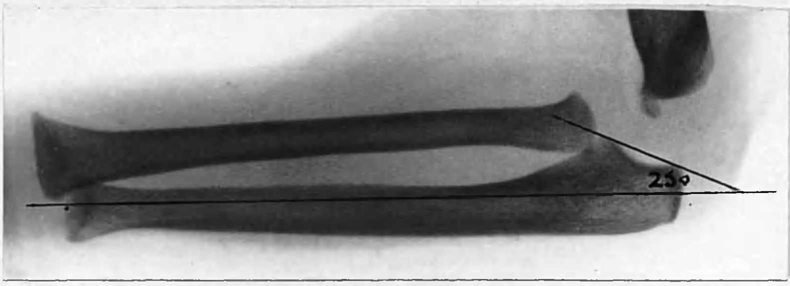
(2). By measuring the angle between a line joining the centre of the distal end of the shaft of the ulna with the centre of the olecranon process and a line joining the two apices of the trochlear notch. The resulting angle on the affected side is always considerably less than that on the normal side. See Fig. 4.

The term "metaphyseal line" will be used to denote the extreme limit of the shadow of the ossified metaphysis.

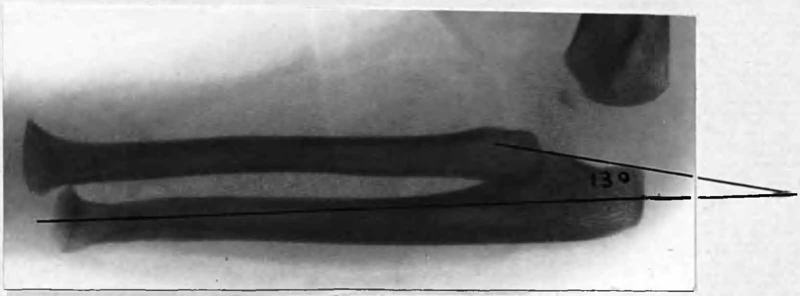
In the radiographs of some of the older cases the axis of movement of the radius on the ulna, which runs from the centre of the radial head to the radial side of the ulnar styloid process, has been drawn in.
Alterations/

FIGURE 4.

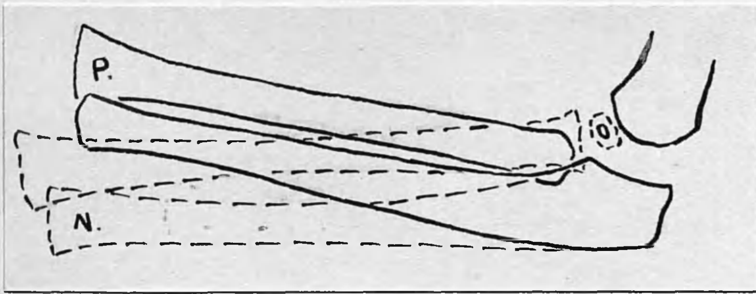
1. MEASUREMENT OF ANGLE



NORMAL SIDE



PARALYSED SIDE.



2. SUPERIMPOSED RADIOGRAPHS.

METHODS OF MEASURING THE EXAGGERATION OF THE NORMAL CURVE OF THE PROXIMAL FOURTH OF THE ULNA.

Alterations in its position relative to the interosseous border of the ulna on the affected side should be noted.

CASE ONE.

7 weeks old. Left Erb's paralysis.

Lat. View: Ulna. Exaggeration of the normal curvature of the upper fourth.

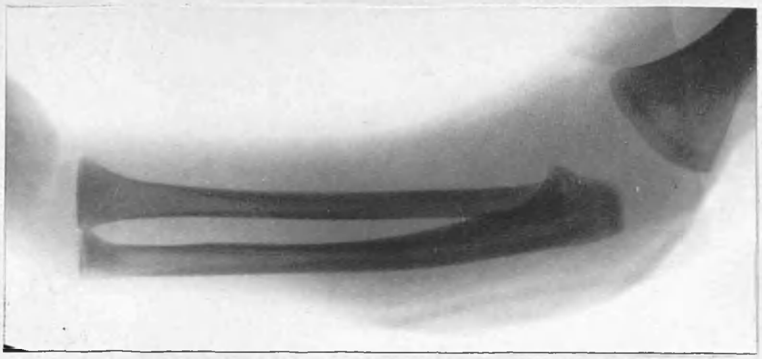
Radius. Broadening of proximal radial metaphysis and adjacent shaft. ("Clubbing").

P.A. View: Ulna. Normal.

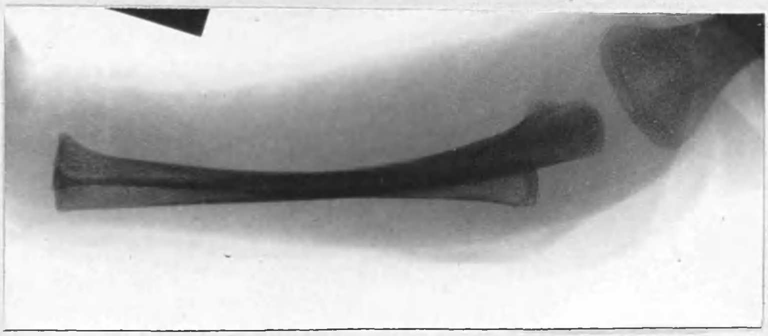
Radius. Clubbing of proximal radial metaphysis, especially on its medial side.

Line Drawing: Superimposed trochlear notches of ulnae of normal and paralysed limbs show exaggeration of normal curvature in the upper fourth of the ulna of the affected side.

CASE ONE

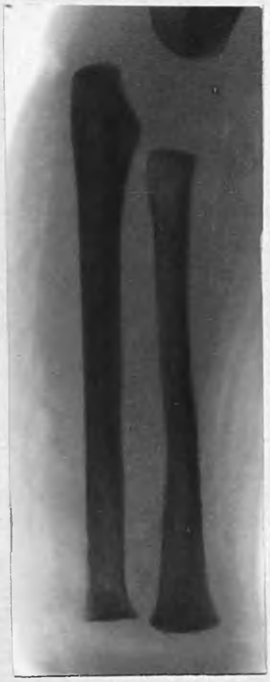


NORMAL.

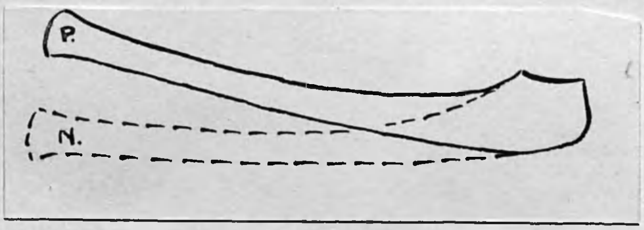


PARALYSED.

NORMAL.



PARALYSED.



CASE TWO.

2 months old. Right Erb's paralysis.

Lat. View: Ulna. Curvature as before.

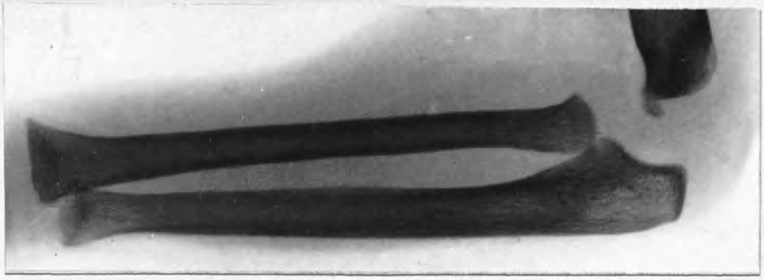
Radius. Proximal metaphysis and shaft clubbed, with flattening of the anterior part of the metaphyseal line.

P.A. View: Radius. Proximal metaphysis clubbed, especially on its medial aspect.

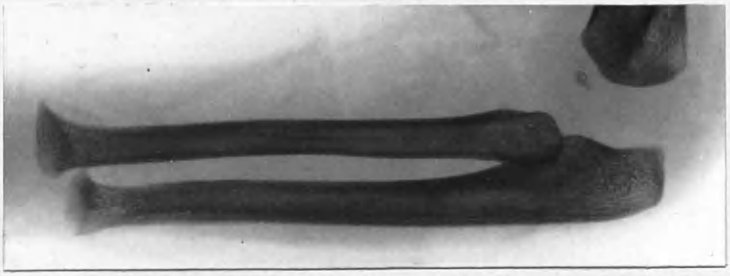
Both bones smaller than normal in all dimensions. The affected capitellar epiphyseal centre is smaller than on the normal side.

Line Drawing: Curvature as before.

CASE TWO



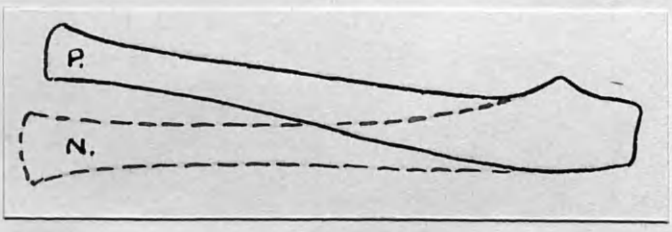
NORMAL.



PARALYSED

PARALYSED

NORMAL.



CASE THREE.

3 months old. Left Erb's paralysis.

Lat. View: Ulna. Curvature as before.

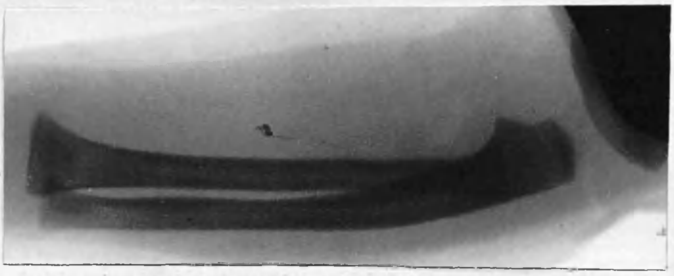
Radius. Proximal metaphysis and shaft markedly clubbed.

P.A. View: Radius. Prxoimal metaphysis slightly clubbed.

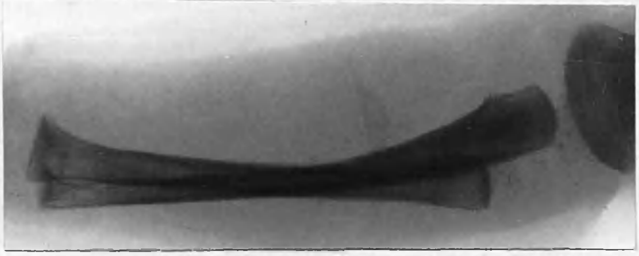
Both bones slightly smaller than normal in all dimensions, especially at their distal ends.

Line Drawing: Ulnar curvature not so marked as in Cases 1 and 2.

CASE THREE



NORMAL.



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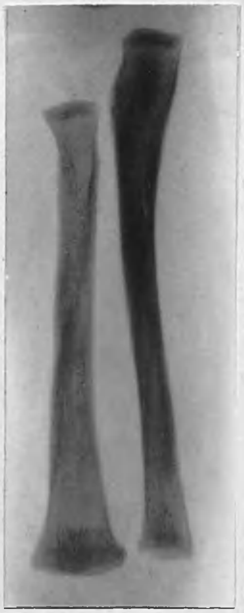
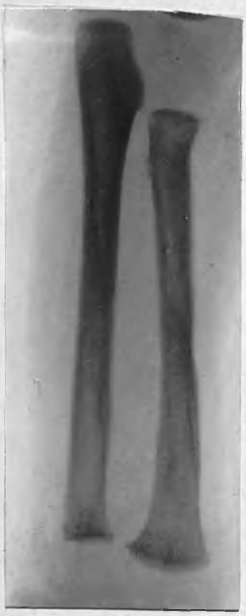
NORMAL.





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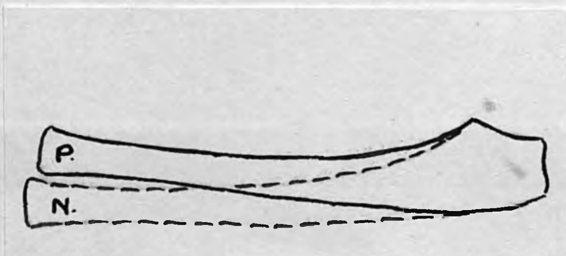


CASE FIVE.

7 months old. Left Erb's paralysis.

Lat. View: Ulna. Curvature as before.

Radius. Proximal radial metaphysis and shaft clubbed, a distinct notch is present in the anterior aspect of the metaphyseal line. The posterior part of the metaphysis is at a more proximal level than normal.

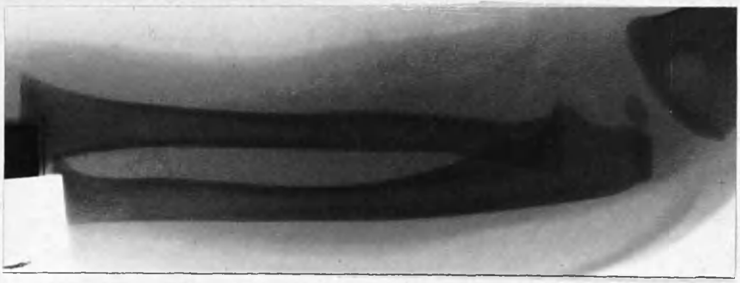
P.A. View: Radius. Proximal radial metaphyseal line appears to be oblique. This appearance is due to the notching in an antero-posterior direction, the postero-medial part of the metaphysis being at a more proximal level than the anterior aspect.

Both bones are smaller than normal in all dimensions.

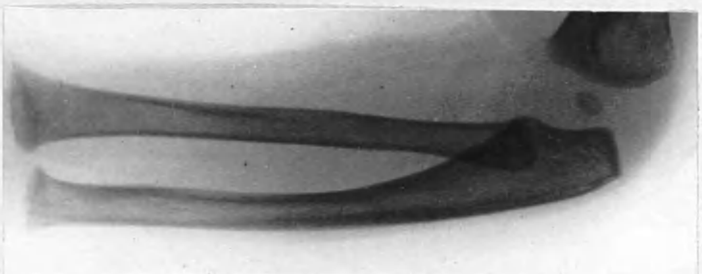
Line Drawing: Ulnar curvature as before.

Head of radius - findings detailed.

CASE FIVE



NORMAL



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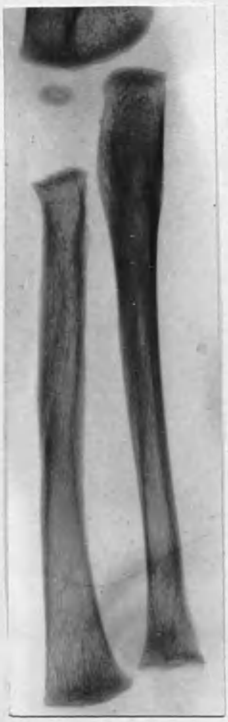
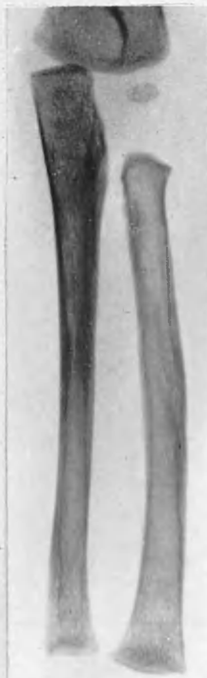
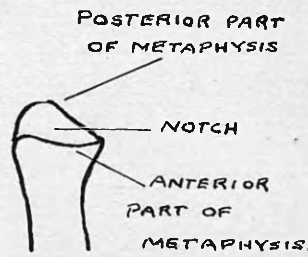


NORMAL





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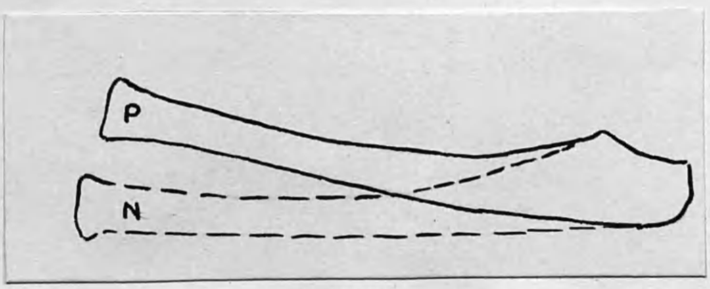


CASE SIX.

3 months old. Left Erb's paralysis.

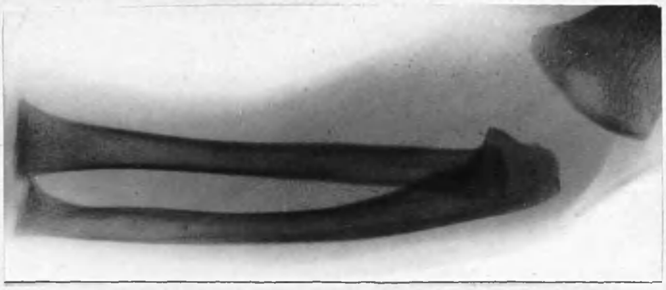
Lat. View: Ulna. Curvature as before but nore exaggerated.

Radius. Proximal metaphysis and adjacent shaft clubbed. Radial neck bent posteriorly. Shaft has swivelled posteriorly about the inferior radio-ulnar joint, resulting in the proximal metaphysis being more posterior than normal.

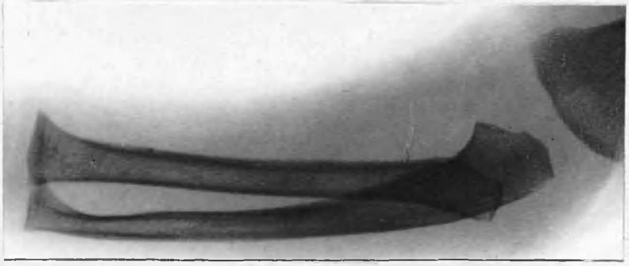
Radius appears too long, relative to the ulna.

P.A. View: Radius. Proximal metaphysis clubbed.

CASE SIX

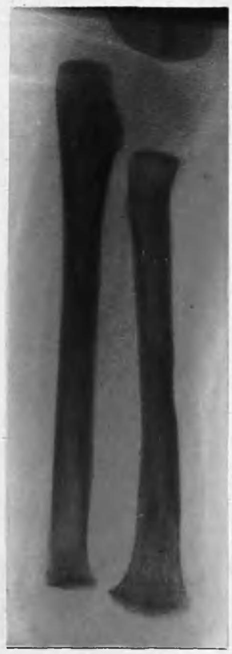


NORMAL.

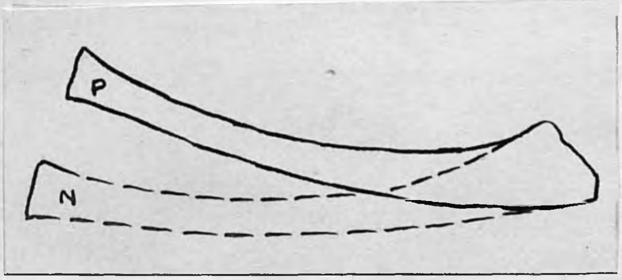


PARALYSED.

NORMAL



PARALYSED.



CASE EIGHT.

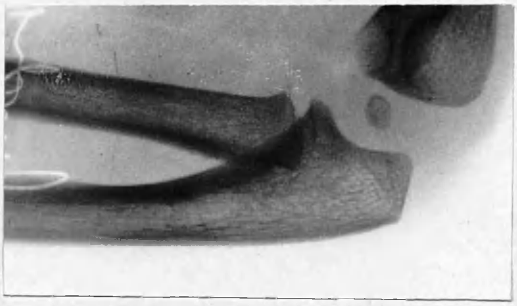
1 yr. 11 mths. old. Right Erb's paralysis.

Lat. View: Ulna. Well marked curvature.

Radius. Metaphyseal line markedly oblique and upper shaft thickened. The upper radial shaft is displaced backwards due to "swivelling" as before, resulting in the abnormally posterior position of the posterior part of the metaphysis. The metaphysis is at a more proximal level than normal making this bone appear too long.

P.A. View: Metaphyseal line is abnormally oblique for the same reasons as in Case 5.

CASE EIGHT.

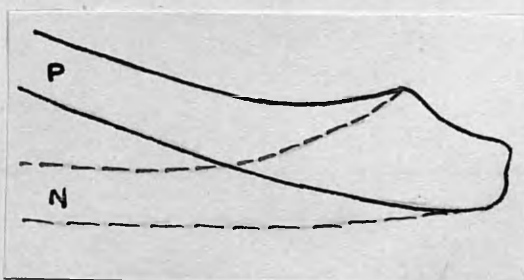


NORMAL.

PARALYSED.

PARALYSED

NORMAL.



CASE NINE.

2 yrs. 5 mths. old. Left Erb's paralysis.

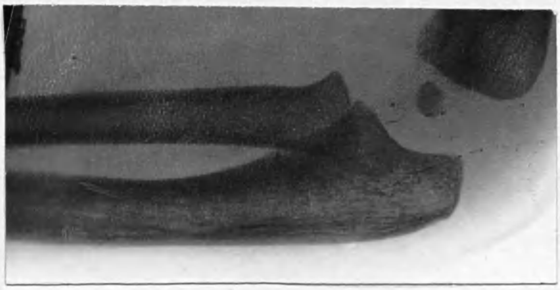
Lat. View: Ulna. Curvature as before.

Radius. Clubbing of metaphysis and upper shaft. Metaphyseal line oblique and at a more proximal level than normal.

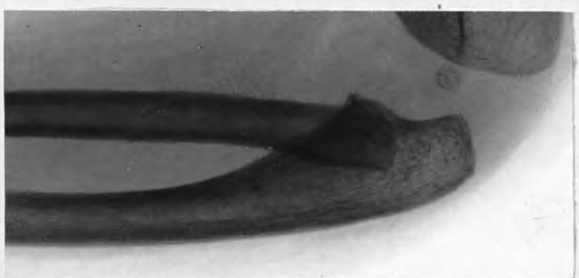
Both bones smaller than normal in all dimensions.

(P.A. View: Unsatisfactory owing to limited supination.)

CASE NINE.



NORMAL.



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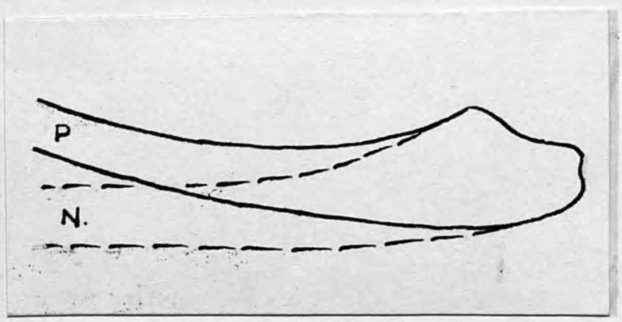


CASE TEN.

3 yrs. old. Left Erb's paralysis.

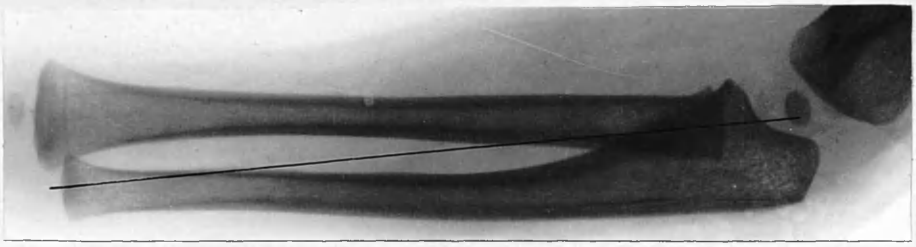
Lat. View: Ulna. Curvature upper fourth as before. A curvature of the distal third in the opposite direction is present.

Radius. Obliquity of metaphyseal line and clubbing of metaphysis. Radial shaft posteriorly swivelled. Metaphyseal line at a higher and more posterior level than normal. Radius therefore appears too long. The cartilaginous radial head is subluxated.

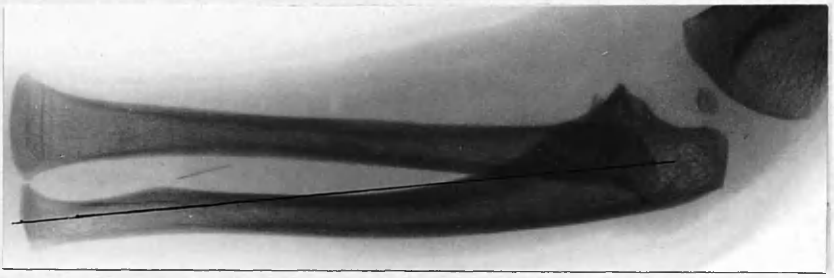
The axis of movement of the radius on the ulna has been drawn in. It is more posteriorly situated than normal and lies on the interosseous border of the ulna. The distal ulnar curve is parallel to the displaced axis.

P.A. View: Radius. Metaphyseal line appears to be oblique for the same reasons as in Case 5. Both bones are smaller than normal in all dimensions, as is also the capitellar centre.

CASE TEN



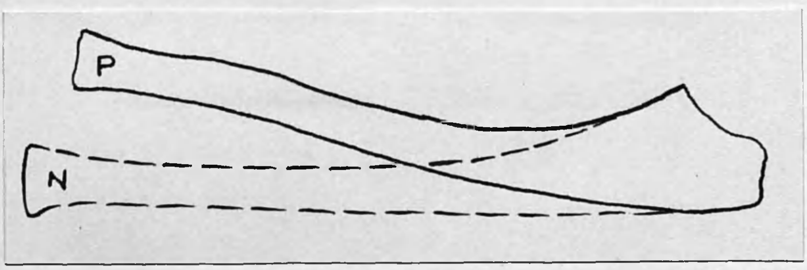
NORMAL



PARALYSED.

PARALYSED.

NORMAL.



CASE TWELVE.

5 yrs. old. Left Erb's paralysis.

Lat. View: Ulna. Double curvature as in the previous case.

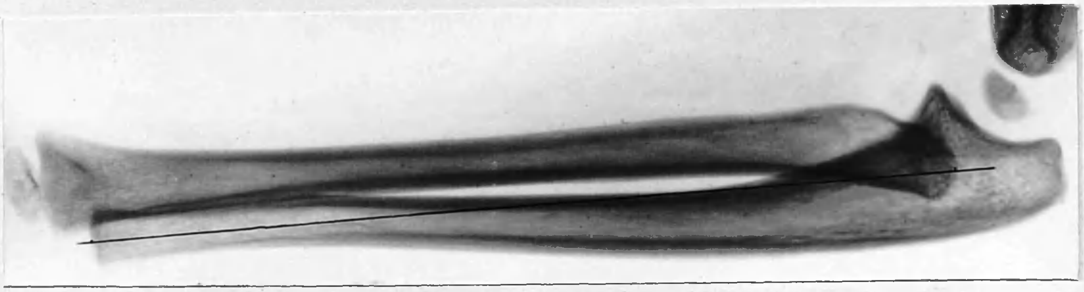
Radius. Shaft posteriorly swivelled. Radial neck bent posteriorly and thickened. Metaphyseal line at a higher and more posterior level than normal. Head dislocated. The line of radial axis lies well behind the interosseous border of the ulna and the distal ulnar curve is parallel to it.

P.A. View: Radius. Metaphyseal line appears to be oblique for the same reasons as in Case 5.

Both bones smaller than normal in all dimensions. The medial epicondylar centre has not yet appeared on the affected side.

CASE TWELVE

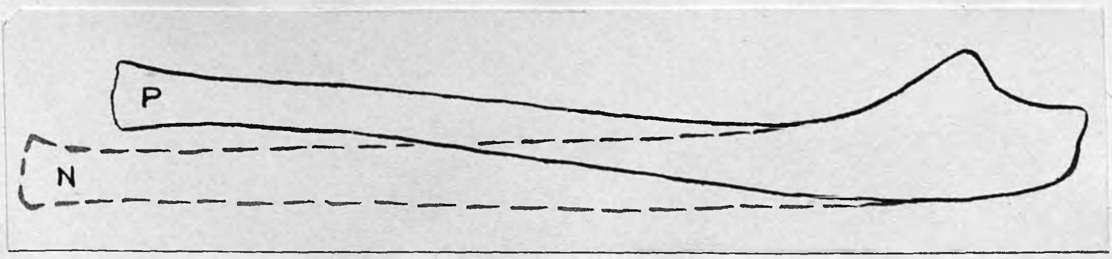
NORMAL.



PARALYSED

NORMAL

PARALYSED.

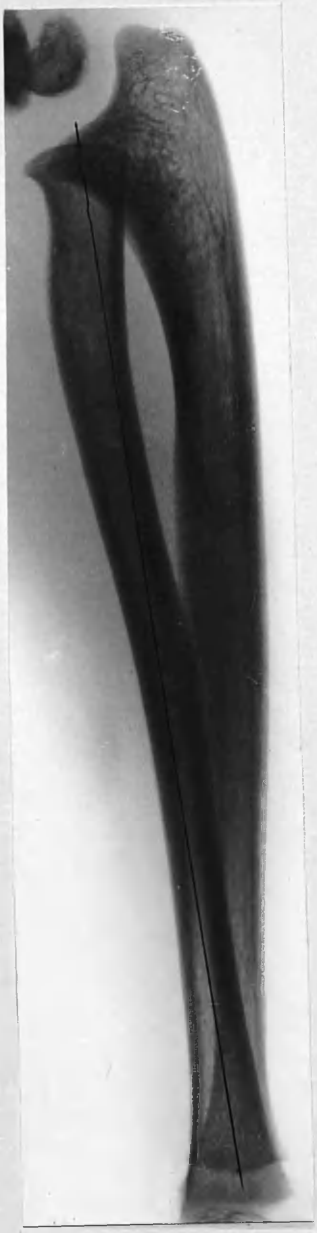


CASE FOURTEEN.

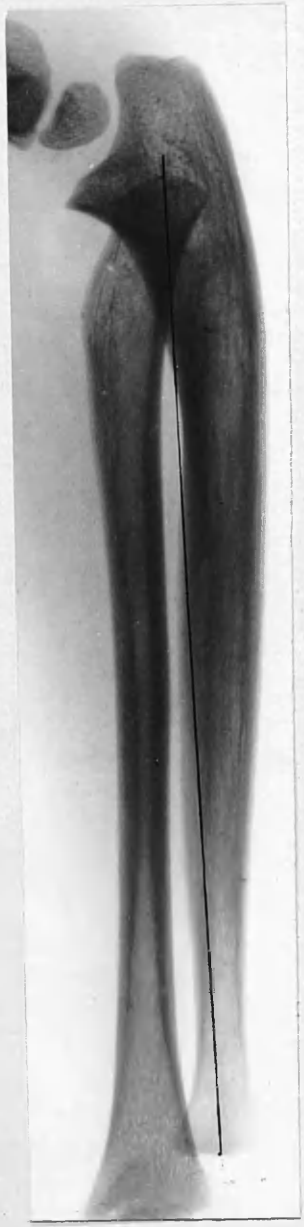
6 yrs. old. Left Erb's paralysis.

The appearances in this case are essentially the same as in Case 12 except that the distal ulnar curve is less obvious.

CASE FOURTEEN.



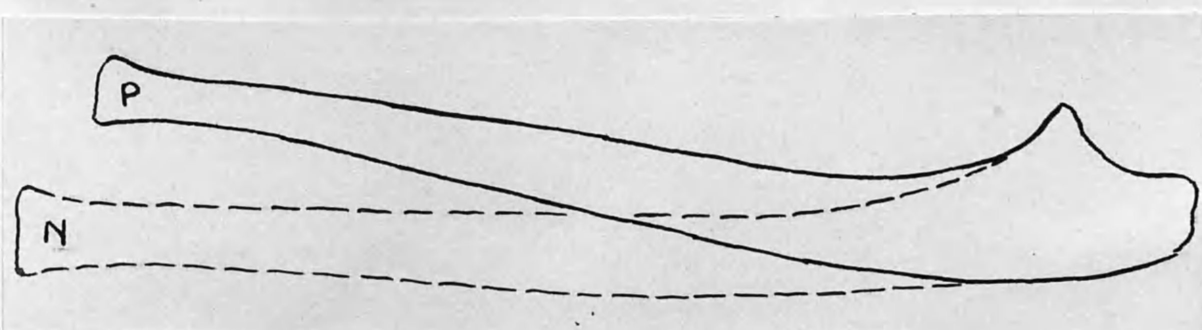
NORMAL.



PARALYSED

NORMAL

PARALYSED.



CASE SIXTEEN.

7 yrs. old. Right Erb's paralysis.

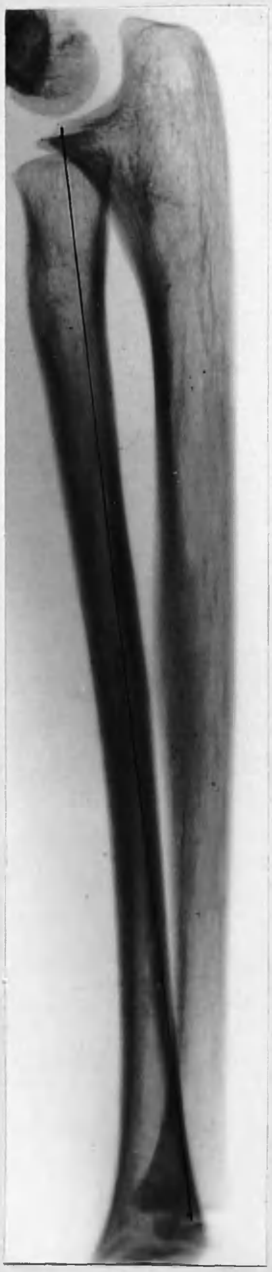
Lat. View: Ulna. A proximal curve but no distal curve, is present.

Radius. No posterior swivelling of shaft. Neck and upper shaft thickened. Metaphyseal line oblique. The small conical epiphyseal centre is set far back on the metaphysis.
Head only subluxated.
Radial axis is practically in the normal position.

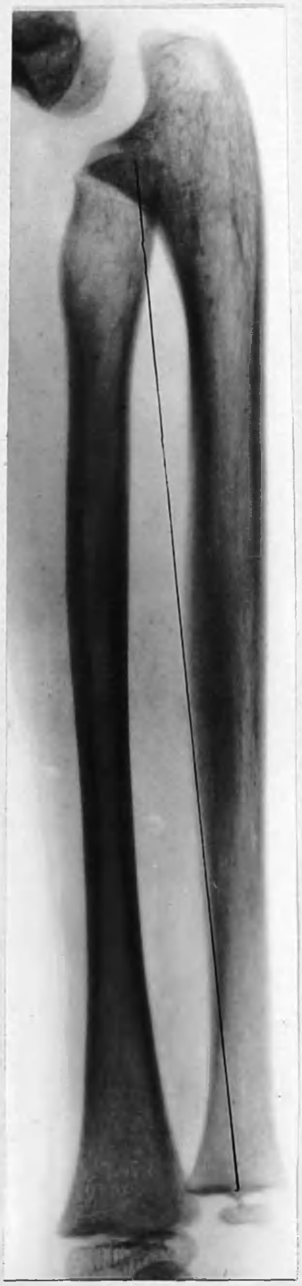
P.A. View: Radius. The posterior bending of the neck is obvious.

Both bones smaller than normal in all dimensions.

CASE SIXTEEN.



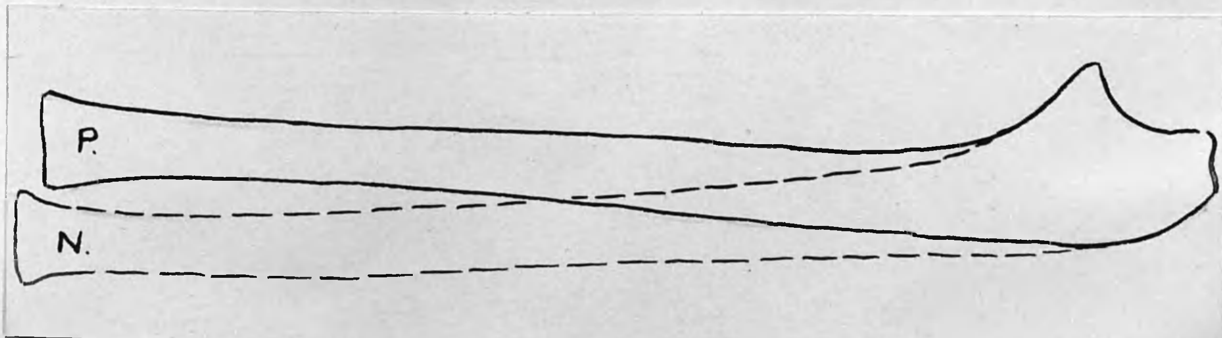
NORMAL



PARALYSED

NORMAL

PARALYSED.



CASE TWENTY.

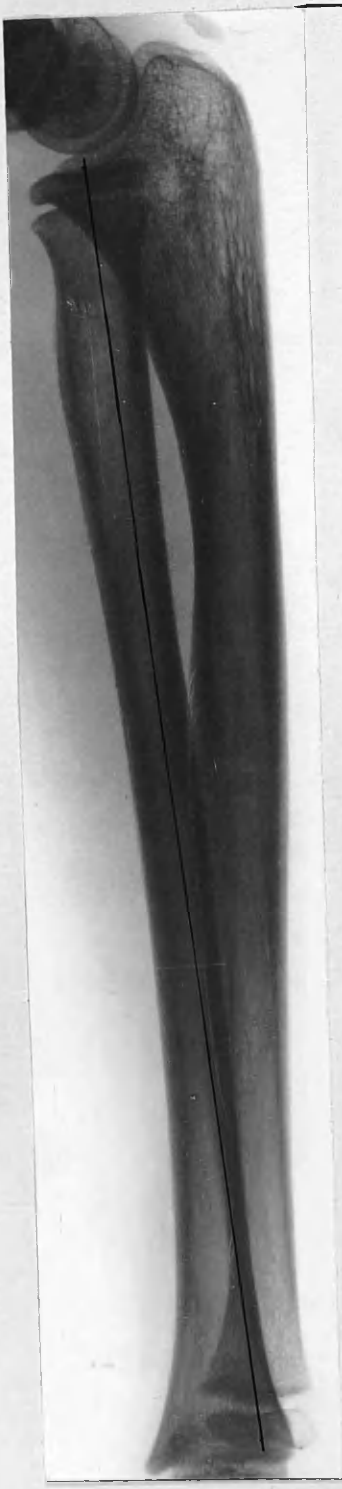
8 yrs. old. Right Erb's paralysis.

Lat. View: Ulna. Proximal curve present as before, also well marked distal curve parallel to the radial axis, which is grossly displaced posteriorly.

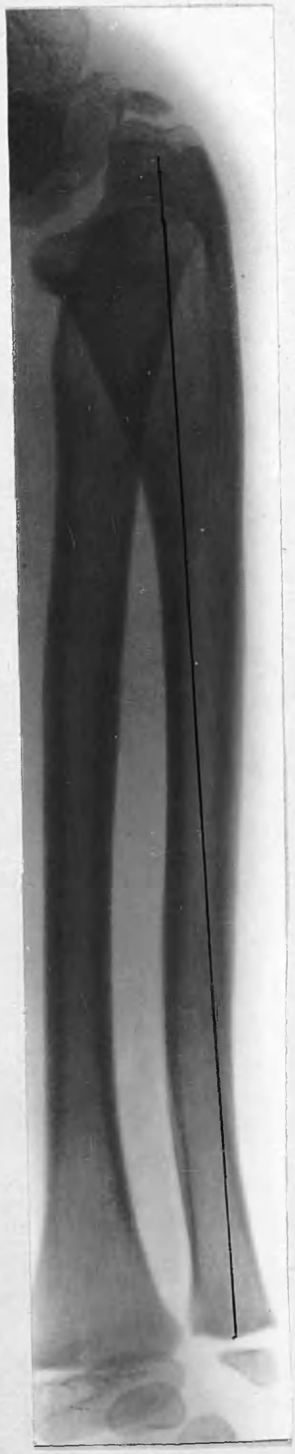
Radius. Shaft posteriorly swivelled. Metaphyseal line oblique. Neck and upper shaft much thickened. Small conical epiphyseal centre set far back on the metaphysis.
Radius appears much too long, head is completely dislocated and articulating with the deformed and flattened capitellum by its anterior surface.

P.A. View: Radius: Head tilted posteriorly and slightly laterally. The epiphyseal centre is disc shaped in this view and fully encompasses the width of the metaphyseal line.

CASE TWENTY.



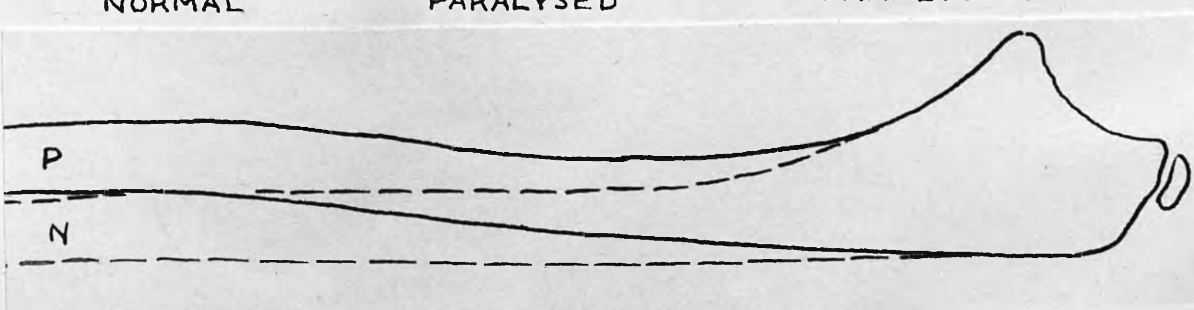
NORMAL



PARALYSED

NORMAL.

PARALYSED.



CASE TWENTY-TWO.

10 yrs. old. Right Erb's paralysis.

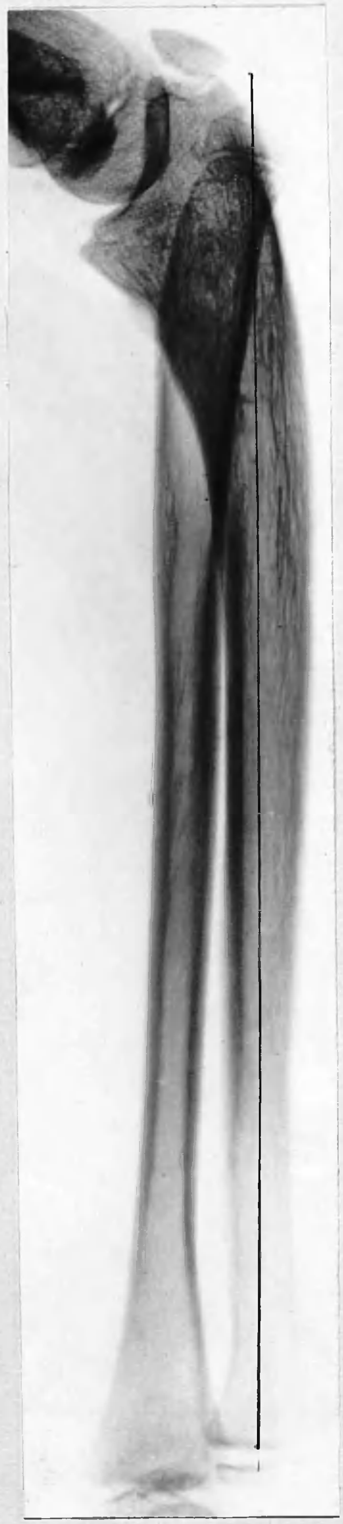
Lat. View: Ulna. Double curve as before. Distal curve not very well marked.

Radius. Shaft posteriorly swivelled. Whole upper third of shaft bent posteriorly and thickened. The epiphyseal centre of the head is conical, posterior to and above the normal position. The bone appears much too long. The axis is grossly displaced posteriorly. The cartilaginous head is articulating with the capitellum by its anterior surface and is completely dislocated.

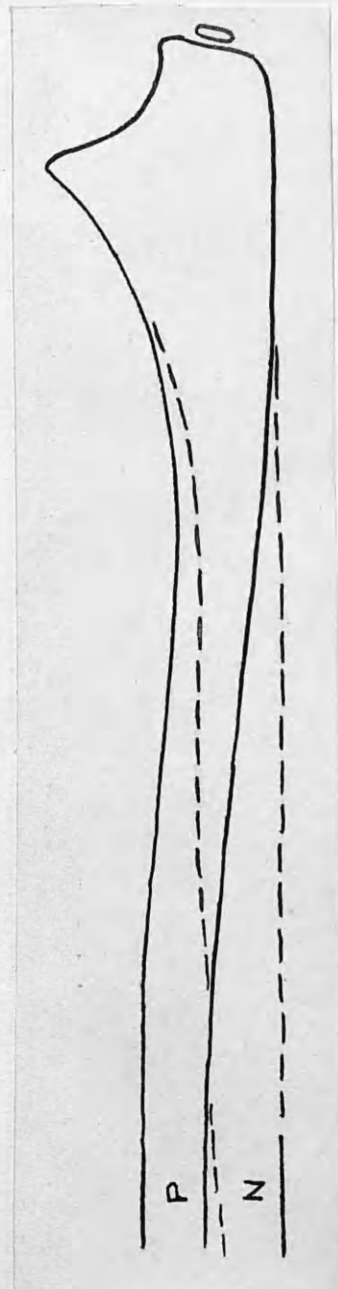
(P.A. View: Unsatisfactory).

CASE TWENTY-TWO

NORMAL



PARALYSED.



CASE TWENTY-THREE.

15 yrs. old. Right Erb's paralysis.

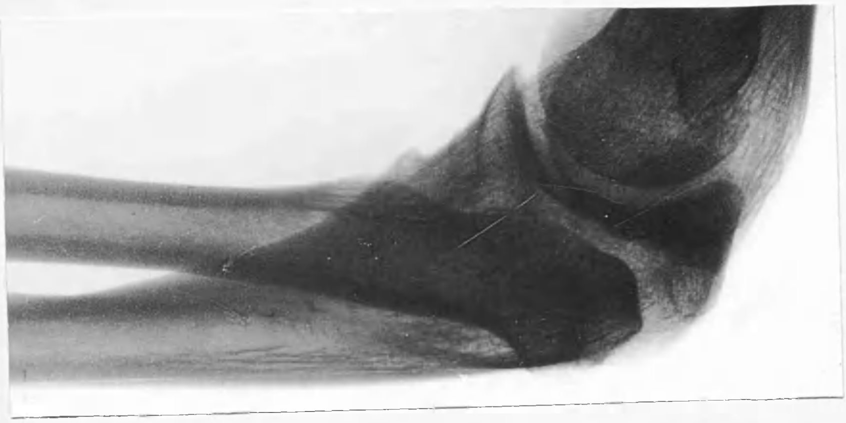
Lat. View: Ulna. Curved as in previous cases. There appears to be overgrowth of the extremities of the trochlear notch.

Radius. Posterior swivelling of shaft present. Metaphyseal line widened, neck and upper shaft thickened. Epiphyseal centre is the shape of a truncated cone and is about to fuse with the oblique metaphyseal line. The abnormal articular facet on the anterior surface of the head is clearly seen as is the flattened capitellum with which it articulates. The radius is much too long and the head grossly dislocated.

P.A. View: The grossly deformed radial head and capitellum are obvious.

CASE TWENTY-THREE

NORMAL.



PARALYSED

NORMAL.

PARALYSED.

CASE TWENTY-FOUR.

Adult. Right Erb's paralysis.

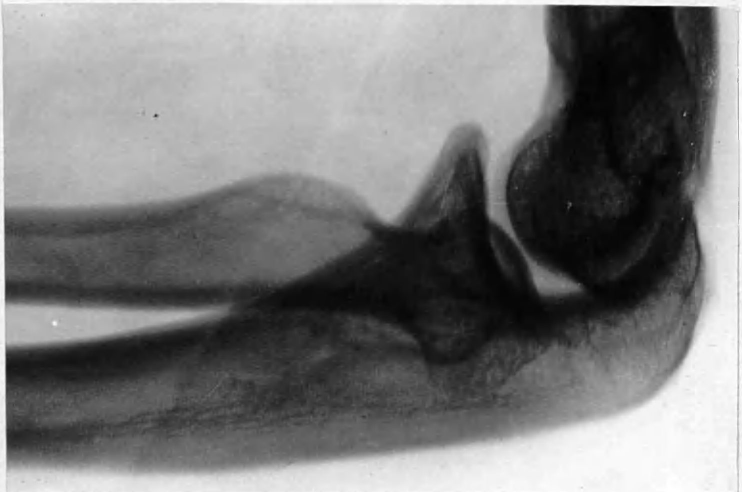
These radiographs show the end result of the series of events.

Lat View: Ulna. Curved as before, and the extremities of the trochlear notch are again overgrown.

Radius. Head grossly deformed. The true articular facet faces practically posteriorly and the head articulates with the flattened capitellum by its anterior surface.

P.A. View: The grossly deformed radial head and capitellum are well shown.

CASE TWENTY-FOUR



PARALYSED.

PARALYSED.

From this series of radiographs it is possible to demonstrate the sequence of the deformities and the ages at which they occur.

Account has to be taken of the fact that deformities of the epiphyses, while yet cartilaginous, do not show radiologically. The shape of the metaphyses, however, gives a clue to the shape of the cartilaginous epiphyses as does the shape of the epiphyseal centre when it eventually appears.

The direction and rate of growth of the metaphysis is shown by the way in which the shape and relationship of the metaphyseal line with the long axis of the radius varies with advancing age.

<u>Age and Sequence of Deformities (Summarised.)</u>

<u>0 - 7 months</u>. <u>In splint</u>. <u>Cases 1, 2, 3, 5, & 6</u>.

Deficient growth of bones. Small size of affected epiphyseal centre.

Increased curvature of upper fourth of ulna, obvious at 2 - 3 months of age.

Thickening of upper radial metaphysis giving it a club shape, followed by notching of its anterior aspect.

Slight backward displacement of upper radial shaft.

<u>1 - 3 years</u>./

1 - 3 years. Splint removed. Cases 8, 9, and 10.

Curvature of upper part of the ulna is more marked.

A second curve in the opposite direction develops in the distal third of the ulnar shaft.

Upper radial shaft becomes more markedly displaced backwards and the greater the proximal ulnar curve the more marked is this backward displacement.

The metaphyseal line becomes oblique from before backwards and upwards owing to spreading of the notch. Normally, of course, this line should be at right angles to the axis of the shaft.

The radial metaphysis is at a higher and more posterior level than normal, making the radius appear abnormally long.

The cartilaginous head is subluxated.

The radial axis is posterior to the interosseous border of the ulna.

4 - 7 years. Cases 12, 14 and 16.

Ulnar curvatures as before.

Radial neck thickened and bent posteriorly.

Upper radial epiphyseal centre is conical in shape in lateral views and disc shaped in A.P. views, and is placed far back on the metaphysis. The upper end of the/

the radius is too high and far back, giving the impression that the radius is relatively too long. The cartilaginous head is obviously dislocated.

As seen from the operation photographs, the cartilaginous head and the capitellum are developing abnormal articular facets, that of the capitellum being concave, and that of the radius convex, from side to side - a reversal of the normal order.

8 - 10 years. Cases 20 and 22.

Ulnar curvatures as before.
The radial head is now posteriorly dislocated.
The abnormal shape of the upper radial epiphyseal centre is more obvious, and the radius appears to be much too long. Radiological evidence of the deformity of the capitellum appears.

15 years - adult age. Cases 23 and 24.

The deformed epiphyseal centres have become completely ossified and are uniting with the metaphyses so that the appearances of the elbow of the adolescent of fifteen are almost the same as those of the adult.
The final deformity is therefore as follows:-

Radial neck thickened and angulated posteriorly.
Radius/

Radius is apparently too long in proportion to the ulna so that the upper end lies behind and above the capitellum. A new facet convex from side to side has developed on the anterior aspect of the side of the head and articulates with a new concave facet on the capitellum.

The original articular surface faces posteriorly, and plays no part in the joint.

The double ulnar curves remain stationary and the radial axis remains behind the interosseous border of the ulna.

7. DESCRIPTION OF THE ANTERIOR DISLOCATIONS.

It is impossible to summarise the clinical findings of these five cases as the features of each are so different, unlike the posterior type.

1. CLINICAL.

(a). At first visit.

All five cases showed a typical Erb's paralysis at their first visit and the parents remembered no symptoms suggestive of an irritative neuritis. In two cases the accoucheur "had to bring down an arm". (Cases 31 and 32). Case 28 was apparently a breech with ? extended arms, the presumption being that again the arms had to be brought down. Cases 29 and 30 were both notably large babies, and one was overdue. Considerable difficulty appears to have been encountered in all five births.

Cases 28 and 29 did not attend or wear their splints regularly and made slow recoveries. Case 30 remained unsplinted until two years of age when she reappeared with a mild residual paresis of the shoulder abductors which took a year to recover completely. Cases 31 and 32 made a rapid recovery and/

and the splints were discarded after six months.

(b). <u>At age of discovery of deformity</u>.

<u>Case 28</u>. <u>M. 9 yrs</u>. <u>Rt. Erb</u>. <u>Result FAIR</u>.

Limitation of abduction and external rotation of the shoulder.

Elbow flexion limited. Extension normal. Supination limited by 20°.

The radial head could be felt slipping in and out on flexion and extension of the elbow and on supination and pronation of the forearm.

<u>Case 29</u>. <u>M. 11 yrs</u>. <u>Rt. Erb</u>. <u>Result BAD</u>.

Gross residual paralysis of many of the affected muscles with contractures of their opponents. Biceps and brachialis functioning fairly well. Radial head felt displaced anteriorly. Flexion of elbow limited actively and passively by contracture of triceps. Forearm held firmly pronated. Supination 10° only.

<u>Case 30</u>. <u>F. 8 yrs</u>. <u>Rt. Erb</u>. <u>Result GOOD</u>.

Slight limitation external rotation of shoulder due to mild contractures of pectorals. Other movements practically normal.

Full flexion and extension of elbow active and passive.

Biceps/

Biceps and brachialis normal.

Supination to 160°.

Radial head palpable anteriorly and could be replaced in approximately the normal position by pressure but became dislocated again as soon as pressure was relaxed.

<u>Case 31</u>. <u>M. 9 yrs</u>. <u>Rt. Erb</u>. <u>Result FAIR</u>.

Limitation of abduction and external rotation of the shoulder.

Biceps and brachialis normal.

Flexion of elbow limited. Gross contracture of pronators. On active flexion and extension of the elbow the radial head could be felt slipping anterior to and into the normal position.

<u>Case 32</u>. <u>F. 9 yrs</u>. <u>Lt. Erb</u>. <u>Result GOOD</u>.

Slight limitation external rotation of shoulder due to contractures of pectorals. Full flexion and extension of elbow. Other movements full.

Biceps and brachialis normal.

Radial head could be felt slipping in and out of the normal position on flexion and extension of the elbow and on supination and pronation of the forearm.

2. RADIOLOGICAL DESCRIPTION.

The appearances in all five anterior dislocations are essentially the same, the radiographs of two cases only therefore, have been reproduced.

Case 29. 11 yrs. M. Rt. Erb.

Radiographs at the age of four months show:-

Curvature of the upper third of the ulna concave posteriorly (the normal outline of the posterior edge of the ulna is slightly convex posteriorly). The projected lines, detailed on page 42, give an increase in the angle of measurement over the normal, a reversal of that found in the posterior dislocations.

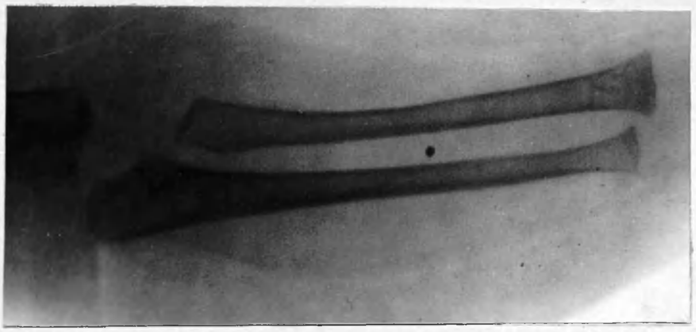
The radial head is dislocated anteriorly, leaving a wide space between the head and the ulna.

Radiograph at the age of 11 years shows:-

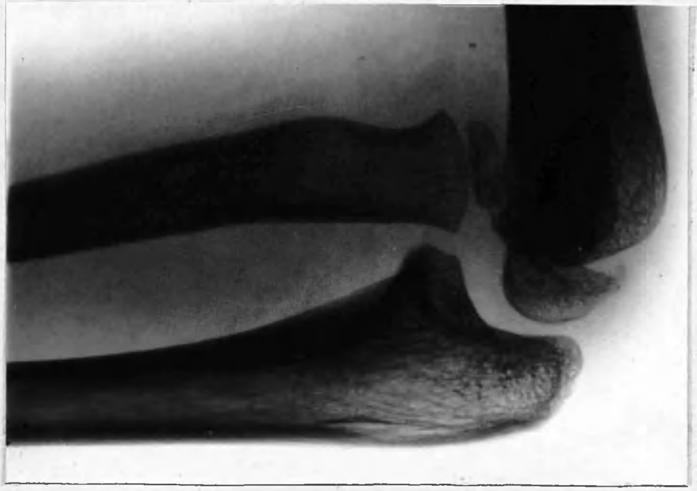
The abnormal curvature of the upper third of the ulna is more obvious. The radius appears too long. The head is dislocated anteriorly to and above its normal position.

The radial head is smaller than normal and the epiphyseal centre is dome-shaped rather than disc-shaped.

CASE TWENTY-NINE.



AT 4 MTHS OF AGE



AT 11YRS OF AGE.

CASE THIRTY-ONE

Case 31. 9 yrs. M. Rt. Erb.

The appearances are similar to those of Case 29 except that the radial head has a more abnormal appearance, the epiphyseal centre being more obviously dome-shaped.

8. THEORY OF THE CAUSATION OF THE DEFORMITIES.

A. THE POSTERIOR SUBLUXATIONS and DISLOCATIONS.

1. Type of case in which the deformity occurs.

In the twenty-seven posterior subluxations and dislocations, eighteen were classified in the "Fair" recovery group, and six were unclassified, being still under active treatment. Recent observation, however, indicates that these six cases, following altered treatment, will eventually be either "Good" or on the borderline between "Good" and "Fair" recoveries.

The deformity is largely confined to cases in whom the pathology is neither mild enough to allow of a complete recovery, nor severe enough to allow of little or no recovery. There is residual and permanent weakness of certain muscles, notably biceps and brachialis, due to loss of nerve supply to a varying number of their individual fibres, the remaining innervated fibres eventually hypertrophying and compensating for this weakness to a variable degree.

An/

An important feature of many of these cases is the occurrence of an "irritative neuritis" of the brachial plexus dating from birth. As has been mentioned, this is due to haemorrhage and subsequent inflammatory reaction among the frayed-out nerve fibres and affects the unparalysed muscle groups. Pain and tenderness in the observed cases appear to last from one to two weeks but muscular spasm persists for a matter of months. Cases 1 to 8 had had a definite "neuritis", but regarding the other cases, the parents were indefinite in their answers concerning their early history and no helpful notes had been made in the case records.

Since the actual investigation began, nineteen cases of Erb's paralysis have come under observation. Only six of these showed an irritative "neuritis". These latter all developed signs of subluxation of the radial head and are listed as Nos. 1 to 6 in Table 2.

It therefore seems likely that this neuritis of the plexus with the concomitant spasm of the unparalysed muscles is a factor in the etiology of the condition. This hypothesis is in accord with the findings of Gilmour (1929).

2./

2. Deficient Bony Growth.

Atrophy is a common finding in cases of nerve section in a growing limb, but the actual cause appears to be doubtful. Sever (1920) and other authors dismiss the deficiency in growth as being "Neurotrophic".

Le Gros Clark (1945) states that it is the opinion of most workers that atrophy in paralytic cases is the result of factors other than destruction of so-called trophic nerves. Nerve section experiments by Tower (1937) tend to show that bony atrophy is the result of disuse following muscular paralysis.

Lewis (1946) states that it is unnecessary to introduce the idea of a trophic factor to explain atrophy, and that the idea of vasomotor disturbance can be entertained only in so far as to signify that disuse causes decreased blood flow, that it is still unknown if narrowing of the vessels in disuse is a response to a low concentration of local metabolites or to a change in vasomotor tone, and that few trophic changes can be regarded as due to withdrawal of the direct influence of nerve cells on the affected cells.

Morison (1938) in his series of Erb's paralysis cases could find no changes other than could be accounted for/

for by disuse and diminished blood supply.

Moore (1939), however, is of the opinion that bony changes are a direct trophic effect of the nerve injury. Nerve endings in close relationship with the osteoblastic cells of the zone of ossification in the metaphysis have been demonstrated by de Castro (1925) and Hurrell (1932) using special staining methods, and the latter tentatively suggests that the nerve fibres and endings so found may be the two ends of a reflex arc governing bone growth and maintainence.

Although it is the concensus of opinion that, in a growing limb rendered inactive both by muscular paralysis and splinting combined with elevation, atrophy is largely due to diminished blood supply, it seems very probable that in the series under consideration some trophic factor has played a part, as disparity in length and thickness of radius and ulna and in size of the capitellar epiphyseal centre of the normal and paralysed arms has been obvious even in a case of two months of age. (Case 2). Whatever may be the cause of the deficient growth of the bones, atrophy must also affect the paralysed and unparalysed muscles and the ligaments of the joints. The atrophic condition of these/

these tissues will render them susceptible to the action of stresses and strains, which would not affect the growth or stability of a normal limb.

3. Factors causing exaggeration of the proximal ulnar curve.

The earliest actual bony deformity apart from deficient growth is an exaggeration of the normal posterior curve of the proximal one-fourth of the ulna and is found to be present in certain cases after one to three months' immobilisation in the Fairbank type splint. Incidentally these eventually prove to be the cases which develop a subluxation. The increase in curvature is not obvious clinically, and at first it is only evident when the radiographs of the two forearms are compared, either by superimposition of the films or by measurement.

The theory now to be propounded suggests that the exaggeration of the normal posterior curvature of the upper ulna is caused by forcing the upper limb, some muscles of which are spastic and others paralysed, into a too fully corrected position imposed by the use of a Fairbank type of splint, and comes about in the following way:-

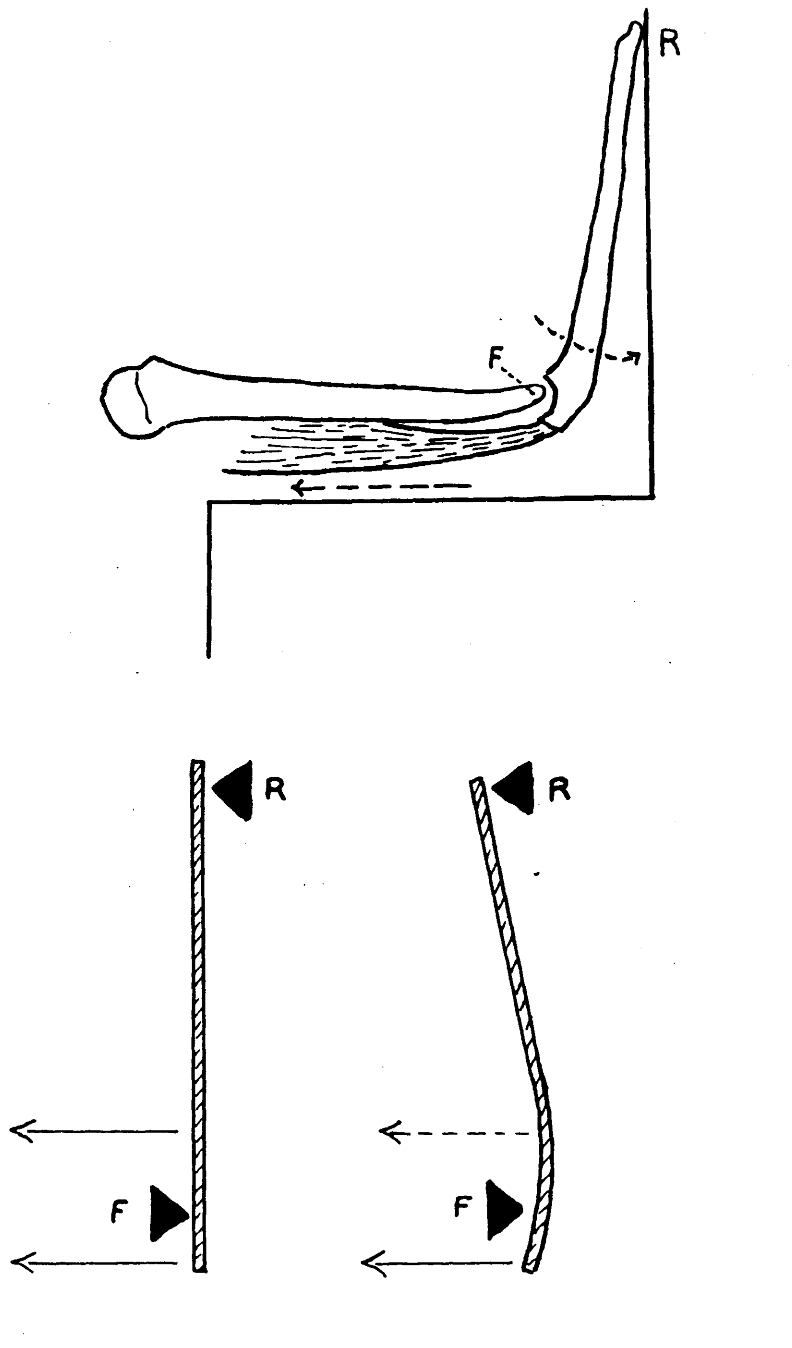
In/

In <u>Fig. 5</u> the ulna is considered to be a non-rigid lever, its fulcrum (F) is at the trochlea, and there is a point of resistance (R) at its distal end. If a force is applied at right angles to the short arm, the lever will become curved at the fulcrum or at a point in the long arm immediately distal to it and will then assume the same shape as the ulna of the cases under discussion.

The force on the short arm of the lever is the continuous state of tension of an unbalanced triceps, which is at first spastic and later tonic and voluntarily contracting, the muscles of a baby being in a state of continuous movement whether the limb be splinted or not.

The point of resistance is against the vertical limb of the splint, and, as the fit of a splint is never perfect, no matter how well made, the main thrust is taken on the back of the wrist on the distal end of the ulna, thus leaving the rest of the forearm more or less unsupported and adding to the length of the lever and consequently its tendency to bend. There is no balanced opposition to this force as biceps and brachialis are paralysed. Had the biceps and brachialis been acting, the arm would lie in the splint without stress, with a short lever acting equally against a short lever instead/

FIGURE FIVE



The effect of forces on a non-rigid lever comparable to those acting on the ulna of a paralysed arm in Fairbank's splint.

instead of a short lever opposing a long one.

The corrective effect of functioning elbow flexors is much delayed in these particular cases, and in fact, never becomes sufficient to balance the triceps completely. The clinical findings in the older child and even in the adolescent showed that the elbow flexors had not recovered to the same degree as the previously paralysed shoulder muscles, some indication of the relative severity of damage to the nerve supply to biceps and brachialis.

When the splint is finally removed the distorting forces disappear but the ulna remains abnormally curved and with growth the most acute part of the curve becomes somewhat more distal. Reference to the radiographs demonstrates that, whereas in the infant and young child the most acute part of the curve is at or just distal to the trochlear notch, in the older cases it is somewhat farther down the shaft.

Patrick (1946) suggests that an ulnar curvature resulting from Erb's paralysis is due to the infant being unable to supinate and pronate, thus losing the traction and moulding effects of the interosseous ligament. It seems unlikely that this explanation plays a major part in the causation of this deformity, as normal infants, seldom/

seldom if ever, supinate the forearm past 90° until they are at least old enough to make purposeful movements. In the babies who developed a subluxation, the ulnar curvature had appeared long before this capacity had been attained, and moreover, the curvature involves the proximal one fourth of the bone, to which the interosseous membrane has no attachment. Were this inability to pronate and supinate the cause of the curve, it would appear in the first instance at a later age, and secondly the curve would affect the part of the ulna to which the membrane is attached, i.e. the distal two thirds.

4. Factors causing subluxation and dislocation of the Radial head and its alterations in shape.

Appleton (1934) in a large series of experiments on the bones of immature rabbits, came to the following conclusions:-

(a). Increase in pressure is sufficient to hinder growth of a metaphysis in length in the direction of pressure.

(b). There is evidence to show that when a metaphysis fails to exhibit its normal growth, as a result of pressure, it may develop an excessive growth in a different direction. Experiments tend to show that this/

this overgrowth is directed at right angles to the direction of pressure.

(c). During growth there is continuous remodelling of the bone shaft as shown by dye (Madder) experiments and the remodelling process is modified by abnormal stresses and strains.

(d). Modifications of normal course of growth in the form of a limb bone of healthy animals are caused by the persistent adoption of postures which fall within the normal range of a normal individual.

(e). These modifications occur only in immature animals.

Appleton's findings explain the changes in bone growth in this series throughout the age groups. The forcing of the paralysed limb of certain cases of Erb's paralysis into the exaggeratedly corrected position imposed by the Fairbank splint gives rise to forces which lead to increases in pressure and alterations of pressure points on epiphyses and metaphyses in the elbow region. These areas react by alteration of their direction and speed of growth and evidence that this occurs, can be seen radiologically.

When/

When the splint is applied the forces at work are those set up by muscular imbalance. Unparalysed muscle groups are not only unopposed but are also in a state of spasm due to brachial plexus neuritis, so that their individual action is much enhanced. The position of splinting adds to this imbalance by stretching the spastic muscles, to a considerable extent in the case of triceps and to the fullest capacity in the case of pronator teres. The action of the former in causing the ulnar curvature has already been described and it is now necessary to consider the role of the latter.

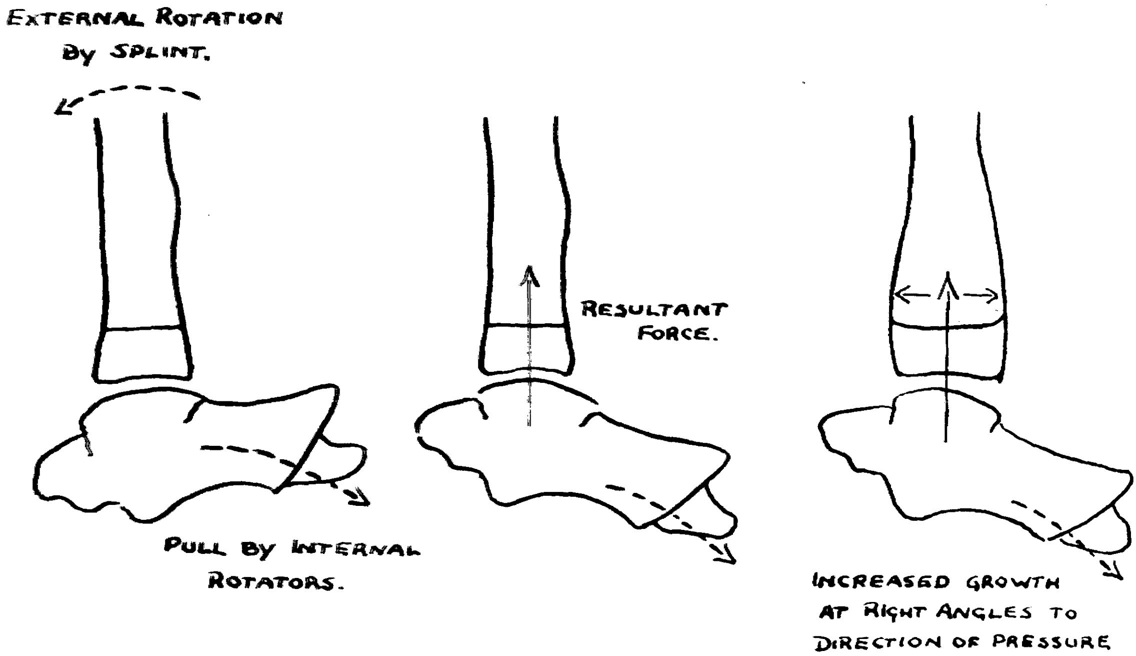
Pronator radii teres, besides being a pronator of the radius, is also a flexor of the forearm, and this latter action comes into play after flexion of the elbow has been initiated by biceps and brachialis. In the paralysed limb with the elbow flexed and splinted at right angles the pull of this muscle, which is almost in the long axis of the radius, is increased by further spasm induced by full supination of the forearm. Its action, which continues throughout the period of splinting, therefore, accentuates the other forces acting on the radial head by pulling the bone in a proximal direction.

The progress of the deformity can be divided into two/

two distinct phases; firstly, the stage of muscular imbalance in the splint; and secondly, the stage of developing contractures after the splint has been removed.

Phase 1. In the Splint. When the splint is applied, owing to the unopposed action of the spastic internal rotators of the arm, there is a constant tendency for the arm to rotate medially and this movement is prevented by splint pressure on the ulnar side of the forearm and hand. The effect of the resulting thrust of the capitellum against the radial head is increased by a converse thrust of the radial head against the capitellum caused by the pull of pronator teres, as already discussed. Growth in a longtitudinal direction is slowed up but continues at an enhanced speed at right angles to the direction of pressure so that the metaphysis becomes broadened or clubbed. Fig. 6. At the same time or very shortly afterwards, under the strain of the spastic triceps, the upper fourth of the ulna begins to bend, rendering the two bones of the forearm disproportionate in length. Pressure on the radial head is still further increased by the upward movement of the head against the capitellum due to the relative increase in/

FIGURE SIX.



The distal end of the humerus is represented with the forearm flexed as in the Fairbank splint. The forces set up by the constant pull of the internal rotators are shown, and their action on the radial head. In the last figure the metaphysis and upper shaft are shown "clubbed" due to overgrowth at right angles to the line of pressure.

in the length of the radius.

As time goes on, posterior bending of the ulna continues, and this backward movement is communicated to the radial shaft via the interosseous membrane. The upper end of the shaft and head are gradually pulled backwards into line with the distal ulna, a movement hinging about the <u>distal</u> radio-ulnar joint. This backward and upward movement of the head results in an alteration of the situation of the point of maximum pressure from the whole articular surface of the head to a point anterior to its centre. Growth slows up or ceases beneath this point but continues on either side of it, causing at first a flattening and later a notch, in the metaphyseal line.

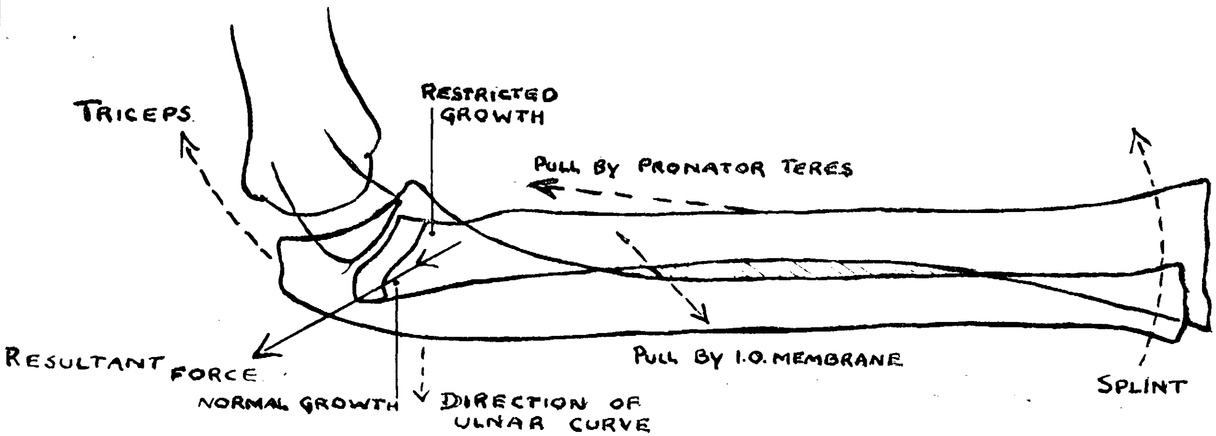
With continued backward and upward movement of the head the point of maximum pressure travels anteriorly and distally enlarging the notch in that direction, giving rise to the appearance of an oblique metaphyseal line. The posterior part of the metaphysis, unaffected by the notch, continues to grow in an upward and posterior direction. These alterations in pressure and alignment, as the radius grows with course of time, cause the posterior angulation and thickening of the radial neck which/

which is such an obvious feature of the radiographs of the older children. At the same time growth of the rounded capitellum is affected by pressure and at first it becomes flattened and later actually concave. Fig. 7.

The combined effect of these forces in bringing about a subluxation is enhanced by the abnormal malleability of the bones, by laxity of atrophic ligaments due to disuse and poor blood supply, and by paralysis of some of these muscles which aid in joint stability by their tone.

Phase 2. After removal of the splint. From clinical observation and examination of the series of radiographs at different ages it is evident that disruption of the radio-humeral joint goes no further than a subluxation of the radial head while the limb is in the splint and that actual dislocation does not occur until this is discarded. The disruption process is a continuous one but the causes of the conversion from a subluxation to a dislocation must be sought elsewhere than in the immediate effects of splinting. Damage to the head and capitellum by pressure continues as shown by the conical shape of the epiphyseal centre of the radial head/

FIGURE 7.



This diagram shows how the ulna becomes bent and how the forces set up by its bending affect the radial head, its metaphysis and the capitellum.

head and its posterior position on the metaphysis, indicative of inhibition of growth of this centre in an antero-posterior direction.

In this second phase the limb is held with the elbow semi-flexed and the forearm fully pronated. The forces at work are those of muscles and ligaments becoming shortened by the development of contractures, and act on the radial head, which, being subluxated, is in an unstable position.

The principal structures and their actions to be considered in this phase are as follows:-

<u>Pronator Teres:</u> The muscle of the upper limb which is most affected by contracture, not only does it hold the forearm in pronation but, the elbow being semi-flexed, it also pulls the radius in a proximal direction.

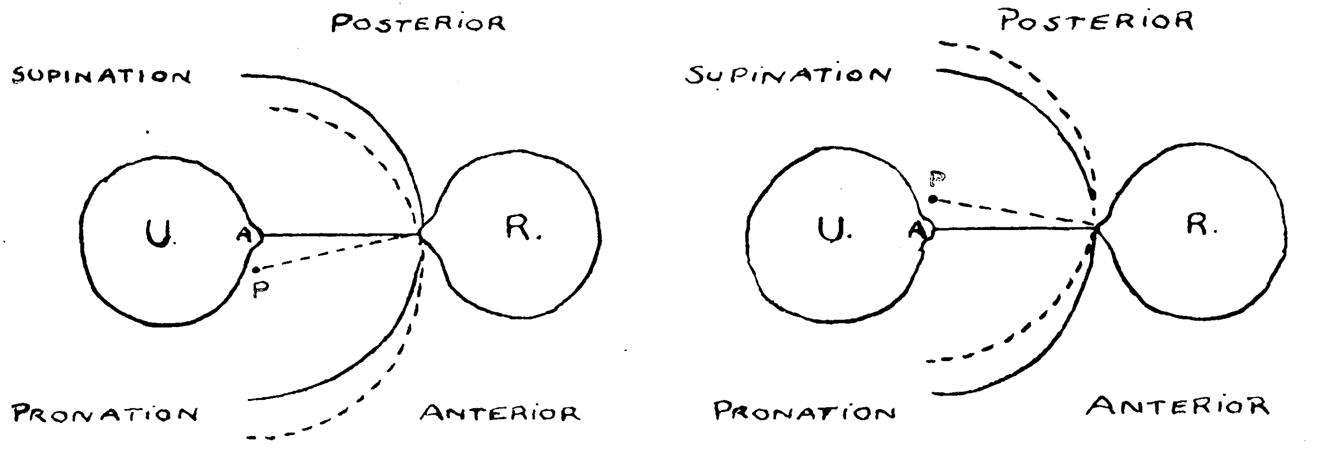
<u>The interosseous membrane:</u> This structure has its role reversed and causes the formation of a curve in the distal third of the ulna, the ulna thus becomes farther shortened and the radius proportionately increased in length. The following mechanism is explanatory of this alteration in function of the interosseous membrane.

Owing/

Owing to the posterior displacement of the upper radial shaft and to the head being posterior to its normal position, the axis of pronation and supination movements of the radius on the ulna, which normally runs from the centre of the radial head to the lateral side of the ulnar styloid process, is displaced posteriorly and now lies behind the interosseous ridge of the ulna instead of immediately in front of it as in the normal forearm. This alteration in the position of the axis results in the membrane being taut on supination instead of on pronation. Fig. 8. By this time, power has returned to some extent to the supinator muscles and the child, now being old enough to make purposeful movements, attempts to pronate and supinate the forearm. The forces mentioned by Patrick tending to mould the interosseous ridge of the ulna into alignment with the radial axis come into play. The interosseous membrane, which now has its role reversed, tightening on supination, moulds the distal ulna into line with the displaced axis, causing it to become curved in the length of the shaft to which the membrane is attached.

The forces set up by these major diversions from normality/

FIGURE 8.



P = AXIS OF MOVEMENT OF RADIUS ON ULNA.

NORMAL.

CASES WITH SUBLUXATION OF RADIAL HEAD.

To show that the interosseous membrane normally tightens on pronation but that this action is reversed in cases with a posterior subluxation of the radial head. The dotted semicircle is the true path of movement of the radius around the fixed point P. The solid line indicates what its path would be were it to move round the attachment of the membrane - point A. (Reproduced by courtesy of Mr. J. Patrick and the Journal of Bone and Joint Surgery).

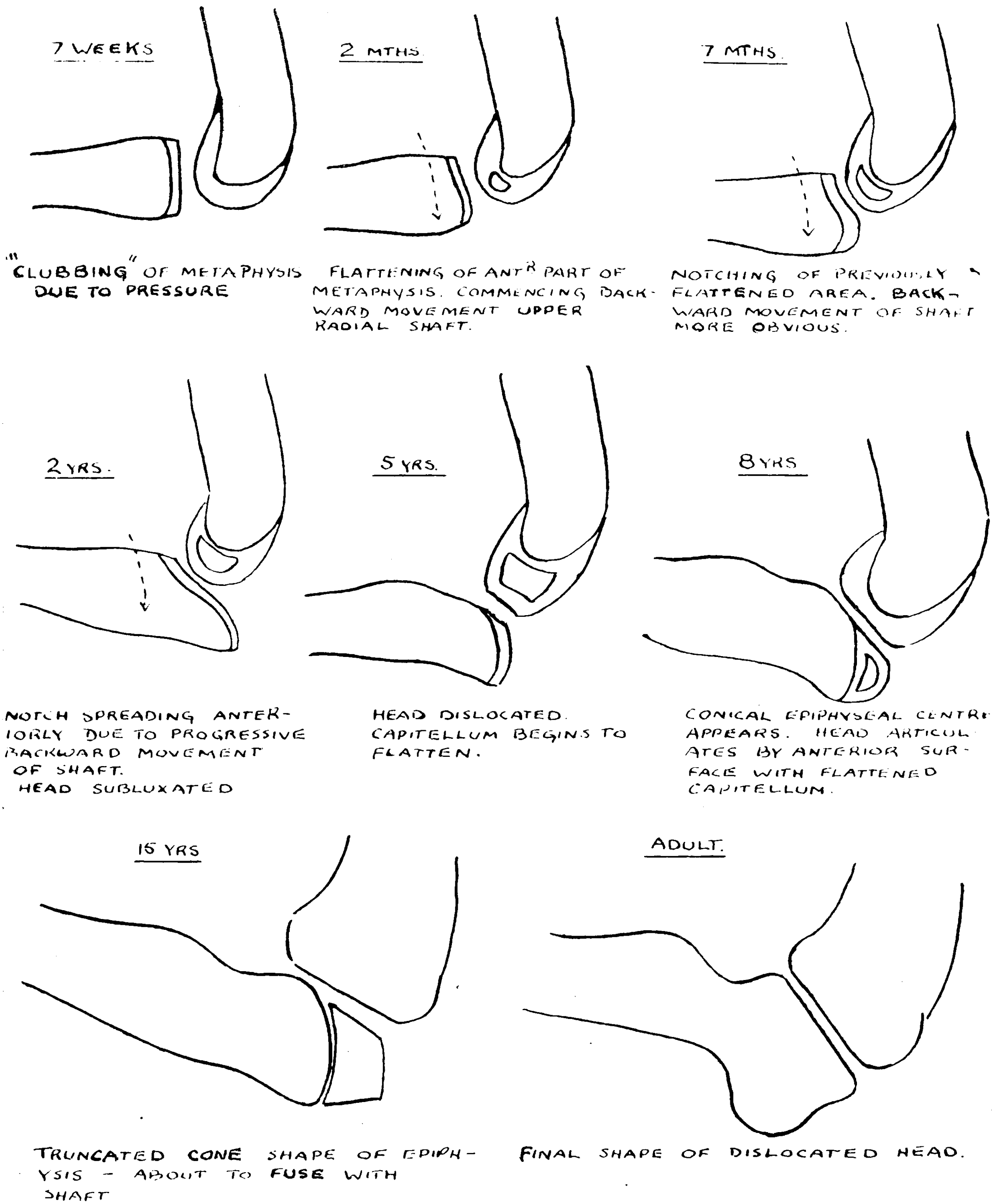
normality act directly on the radius, pressing the head against the capitellum, causing deformity of both and converting the unstable subluxation into a dislocation. The effects of all these forces on the radial head, from the age of 7 weeks until maturity, are depicted in Fig. 9.

5. Mechanism compared with that of a Flexion Monteggia Fracture.

The causative mechanism and final bony deformity of a posterior or flexion Monteggia fracture are closely comparable to those of a dislocated radial head due to Erb's paralysis in the older child, taking into account the fact that the former occurs in a matter of seconds in a normal arm but that the latter is the result of forces acting over a period of many months on a growing arm already weakened by trophic disturbances.

In the case of the injury, there is a posteriorly angulated fracture of the upper third of the ulna combined with a posterior and upward dislocation of the radial head. A lateral radiograph of the elbow and forearm in such an injury shows similarity with that of the Erb's cases, the essential difference being that in the latter the ulnar fracture is replaced by an ulnar/

FIGURE 9.



Diagramatic representation of the alterations in shape and position of the radial head and upper shaft as growth proceeds.

ulnar curvature and the radial head is abnormal in shape; this suggests that the causative forces will also be comparable as is found to be the case. See Fig. 10.

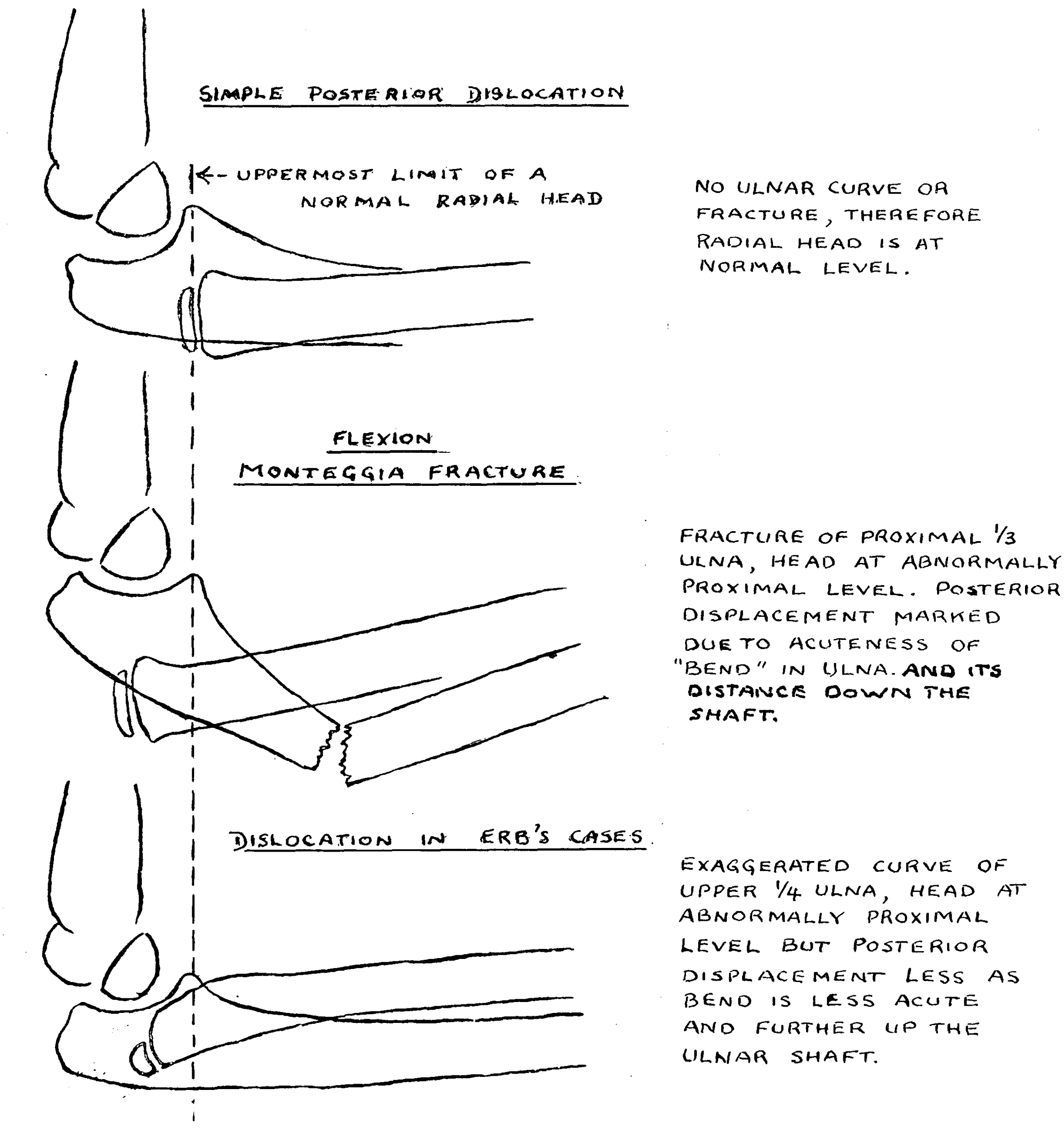
The fracture occurs as a result of a fall on the hand with the elbow flexed and the forearm pronated. Triceps, being under protective tension at the time, causes the backward angulation of the ulnar fracture, the radial head having been levered forwards out of the joint by pressure on the radial shaft by the ulnar shaft, the forearm being in full pronation and the bones crossed, is then dislocated posteriorly by the interosseous membrane pulling the upper radial shaft posteriorly into line with the distal two thirds of the ulnar shaft to which it is attached. (Evans 1949). The similarity between this mechanism and that postulated as causing the dislocation in the Erb's cases is evident from Table 4.

6. Factors causing limitation of movement of the elbow joint and the forearm.

Causes of limited movements fall under three heads:-

(a). Muscular - Residual paralysis or paresis of originally paralysed groups. Contractures of unparalysed/

FIGURE 10.



Comparison with a Flexion Monteggia fracture. The proximal position of the radial epiphysis indicates shortening of the ulna. There is probably an element of overgrowth in the Erb's cases also.

TABLE 4.

DEFORMITY COMPARED WITH A FLEXION MONTEGGIA FRACTURE.

SEQUENCE OF EVENTS	FLEXION MONTEGGIA FRACTURE	POSTERIOR RADIAL DISLOC^N IN ERB'S CASES.
1.	PROTECTIVE TENSION OF TRICEPS	SPASM OF TRICEPS & LATER ITS UNBALANCED ACTION.
2.	WEIGHT OF BODY FALLING CAUSES FORCES ACTING ON THE HAND.	PRESSURE OF VERTICAL LIMB OF FAIRBANK SPLINT ACTS MAINLY ON HAND.
3.	DISRUPTION OF RADIO-HUMERAL JOINT BY FORCED PRONATION. HEAD DISLOCATED ANTERIORLY AT FIRST.	UNNECESSARY TO POSTULATE FORCE SUFFICIENT TO FREE HEAD. FORCES ACT OVER LONG PERIOD ON MALLEABLE GROWING BONES, ON JOINT WEAKENED BY PARALYSIS & ATROPHIED LIGAMENTS. DISLOC^N PROCEEDS SLOWLY POSTERIORLY FROM THE FIRST, LIGAMENTS STRETCH BEFORE DISLOCATING FORCES.
4.	SHAFT & HEAD PULLED POSTERIORLY INTO LINE WITH DISTAL 2/3 ULNA BY INTEROSSEOUS MEMBRANE.	AS FOR FRACTURE, BUT OVER LONG PERIOD OF TIME
5.	HEAD DISLOCATED PROXIMALLY AS WELL AS POSTERIORLY BY SHORTENING OF ULNA BY ANGULATION AT FRACTURE SITE. POSTERIOR DISPLACEMENT MARKED AS FRACTURE IS FAR DOWN THE SHAFT.	SHORTENING OF ULNA BY CURVATURES. POSTERIOR DISPLACEMENT LESS MARKED AS MAIN CURVE IS IN UPPER 1/4.
6.	SHORTENING OF ULNA GROSS, THEREFORE GROSS PROXIMAL & POSTERIOR DISLOCATION OF HEAD.	SHORTENING OF ULNA LESS MARKED THEREFORE PROXIMAL & POSTERIOR DISPLACEMENT OF HEAD LESS, AMOUNTING AT FIRST TO A MERE TENDENCY TO SUBLUXATION.

unparalysed groups.

(b). Ligamentous - Contractures of ligaments and joint capsules.

(c). Bony deformity and mal-alignment.

Most articles on Erb's paralysis mention that limitation of extension of the elbow and of supination of the forearm is a common finding in cases showing a fairly good recovery, and the theory is put forward that this is due to muscular contractures. In cases with a subluxation or dislocation of the radial head this theory is reasonable as regards pronation and supination, as contractures of the pronators undoubtedly occur. As regards elbow movements, muscular contractures, being confined to the unparalysed groups, can only affect triceps, an unparalysed muscle, and cause limitation of flexion. Extension of the joint must, therefore, be limited either by shortening of the anterior capsule, by bony deformity, or by both together.

<u>Extension of Elbow</u>. In the youngest case of the series (7 weeks old) no contractures were present in any muscle or joint capsule and yet extension of the elbow was quite obviously limited. Clinically, passive extension/

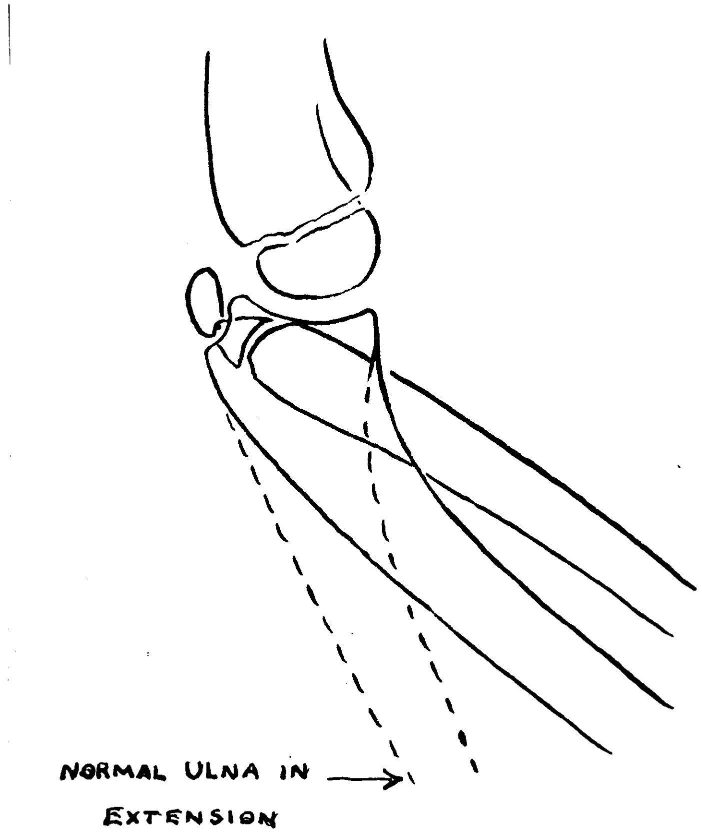
extension was smooth but suddenly and without warning, stopped short of full extension, a finding typical of a bony block. Owing to the curvature of the ulna, the olecranon process had locked in the olecranon fossa of the humerus before the forearm was in line with the upper arm.

In the older child this flexion deformity remains unchanged, but contractures of ligaments are developing elsewhere and so the anterior capsule of the joint accommodates itself by contraction, so that clinically the signs of a bony block are lost and full passive extension is now prevented by an elastic resistance. At the same time, in cases where the radial head is grossly displaced upwards and backwards, the head locks against the back of the capitellum of the humerus before full extension can occur. Fig. 11.

Supination of forearm. Loss of supination is due to the three factors in varying proportion according to the age of the child.

In the infant still under treatment, although there is an ulnar curvature, gross displacement of the radial axis has not yet occurred, nor has the radial head dislocated/

FIGURE 11.



To show how the exaggerated curve of the upper third of the ulna causes premature locking of the olecranon process in the olecranon fossa of the humerus. The dislocated radial head also locks against the back of the capitellum in the older child.

dislocated sufficiently to cause a bony blockage. There are as yet no muscular or ligamentous contractures, passive supination is therefore almost normal, but active supination is prevented by the paralysis of the supinators.

In the child of 2 - 4 years passive supination is usually more than 90°. This limitation is due to commencing displacement of the radial axis, so that the interosseous membrane tends to become taut on supination, and to commencing contracture of the pronator muscles.

In the older child limitation is much more marked and is usually considerably less than 90°. The radial axis is now definitely displaced backwards, the interosseous ligament tightens on supination, and the dislocated radial head probably locks against the ulna. Contractures of the pronator muscles are established. It is obvious that mere removal of the displaced radial head as was done on three occasions, would have little effect on these limitations of movement. A summary of the factors limiting movement is given in Table 5.

TABLE 5

ETIOLOGY OF LIMITATIONS OF MOVEMENTS.

MOVEMENT	0 – 1 YR.	1 – 4 YRS.	4 YRS ONWARDS.
EXTENSION OF ELBOW ACTIVE PASSIVE	EXAGGERATION OF CURVATURE OF UPPER FOURTH OF ULNA. LIMITED BY 15° TO 20°	ULNAR CURVATURE. CONTRACTURE OF ANTERIOR CAPSULAR LIGAMENTS. LIMITED BY 20° TO 25°.	ULNAR CURVATURE. CAPSULAR CONTRACTURE. DISLOCATION OF RADIAL HEAD. LIMITED BY 25° OR MORE
FLEXION OF ELBOW	PARALYSIS OF BICEPS AND BRACHIALIS	PARESIS OF BICEPS AND BRACHIALIS. CONTRACTURE OF TRICEPS.	WEAKNESS OF BICEPS AND BRACHIALIS. CONTRACTURES OF TRICEPS AND CAPSULE.
SUPINATION ACTIVE	PARALYSIS OF SUPINATORS	DISPLACED RADIAL AXIS. EARLY PRONATOR CONTRACTURE.	DISPLACED RADIAL AXIS. PRONATOR CONTRACTURE. DISLOCATED RADIAL HEAD.
PASSIVE	FULL — 180°	LIMITED BY 80°	LIMITED BY 130° TO 175°

THEORY OF THE CAUSATION OF THE DEFORMITIES.

B. THE ANTERIOR DISLOCATIONS.

In some few papers on Erb's paralysis the fact that an anterior dislocation of the radial head is occasionally found as a complication is mentioned, and, with the exception of Thomas (1914) who considers birth injury to be the cause, the etiology is considered to be "contractures" or "muscle imbalance", and there the subject has been left. To date no attempt has been made to work out the true etiology or mechanism of the condition, nor has any distinction been drawn between this condition and the posterior subluxation and dislocation.

It will be seen from the following that the etiology of this deformity is totally different from that of the posterior subluxations.

1. The occurrence of an identical type of anterior dislocation has been described in cases in which there has been no paralysis or other cause. (Mc.Farland 1936, White 1943, Bindman 1945), and has therefore been termed a "Congenital dislocation of the Radial head". The posterior type has only been described in connection with Erb's/

2. From this survey posterior subluxations and dislocations all occur in the same type of Erb's paralysis, one in which there is a pathology of medium severity, probably with brachial plexus "neuritis" and associated muscle spasm and slow and incomplete recovery especially of the elbow flexors, necessitating a long period of splinting. Be it noted, each and every case had been splinted. In the small series of anterior dislocations, however, this similarity of feature does not occur. Two cases hardly wore their splints at all, one was not splinted until two years of age, and two made quite a good recovery in six months.

3. The abnormal radiological appearances of the bones in the anterior dislocations are essentially the same in the baby of four months and the child of eleven years, but in the posterior type the appearances vary according to age, indicating that the former lesion is of sudden occurrence and is practically unaltered by and independent of growth factors while in the latter, growth enters largely into the etiology.

4./

4. Case 27 (see Table 2) whose radiographs at four months of age are reproduced, had a marked anterior dislocation, yet the splint provided was not used, nor was any other treatment given.

These facts show that splinting or other treatment for the associated paralysis can be exonerated as a causative factor in anterior dislocations. On the other hand, as numerous cases have been described as an isolated condition without obvious cause, neither the paralysis, hypothetical contractures nor muscle imbalance can be blamed.

This anterior dislocation has been described as "Congenital", but in view of the fact that instances occur in association with an Erb's paralysis it appears more likely that the etiology of the two conditions is similar, namely birth injury.

The theory to be presented suggests that traction on the hand and forearm, which in some cases, in conjunction with flexion and rotation of the head to the opposite side during birth, causes an Erb's paralysis, is responsible for the anterior dislocation, the mechanism being similar to that of the traumatic subluxation of the/

the radial head or "pulled elbow" of young children. In this condition the child falls while he is being led by the hand, is jerked to his feet again by the same arm, and the radial head is pulled partially or completely out of the orbicular ligament and thereafter may be felt to be abnormally prominent anteriorly. "Pulled elbow" is also suggested as a possible etiology by White (1933) describing a case of "Congenital dislocation of the Radial Head". He suggests, however, that the injury occurs during efforts at resuscitation of the baby.

This injury, occurring during birth, results in the radial head lying anterior to the now empty orbicular ligament, which collapses and forms a pad or distance-piece between the two bones, holding them apart under tension. The ulna becomes curved anteriorly in an attempt to overcome this state of tension but in so doing becomes proportionately shorter than the radius so that in course of time the radial head lies both anterior to and more proximal to its normal position, giving the impression that the radius is too long. See <u>Figs. 12 and 13</u>. The radiological appearances of an epiphyseal centre smaller than normal, convex rather than/

FIGURE 12.

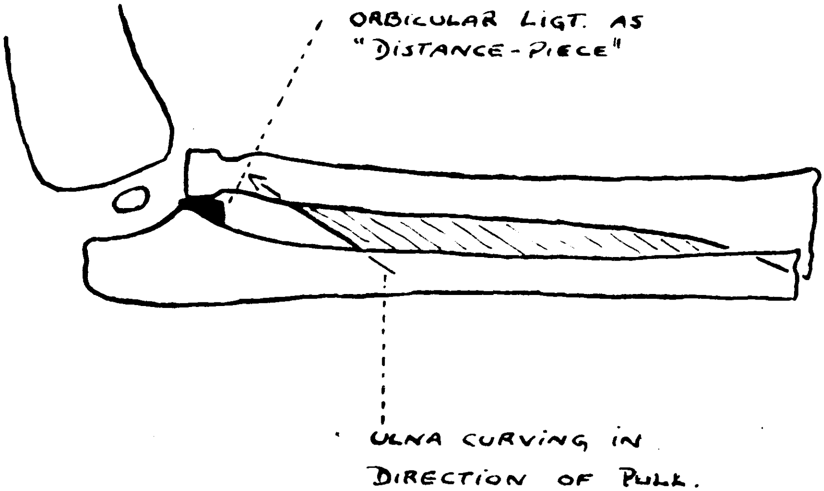
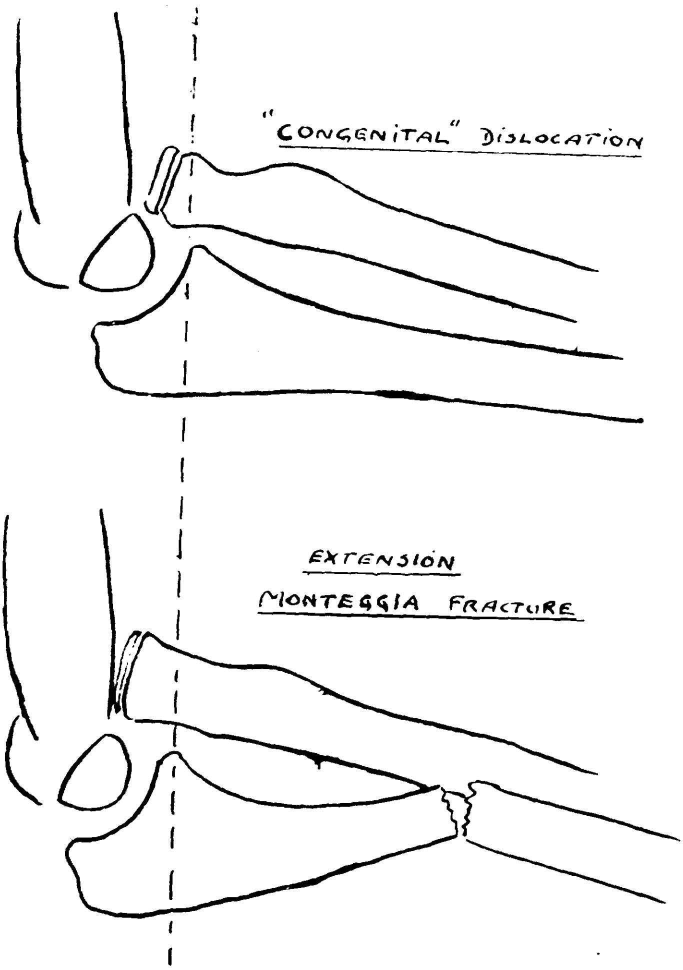


Diagram to show how the ulna becomes curved in an anterior direction by the pull of the interosseous membrane.

FIGURE 13.



Comparison between the anterior dislocation and an extension Monteggia fracture. The radial head is at a more proximal and more anterior position than normal owing to the shortening of the ulna by its curve. The anterior dislocation is more gross in the fracture as the angulation is greater and further down the shaft.

than concave, are those which one would expect where articulation with the capitellum has never occurred.

Mc.Farland (1936) in describing the removal of such a dislocated head in five cases, mentions that no orbicular ligament was to be found, thus supporting the theory that this structure lies collapsed behind the head and in course of time has become unidentifiable as a ligament. It will be noted that at operations on the posterior dislocations an orbicular ligament was present though stretched and attenuated.

9. TREATMENT.

A. THE POSTERIOR TYPE.

It is evident from examination of this series that bony deformity begins to appear after two to three months of splinting, and that the fundamental cause lies in forcing an arm, in which there is trophic upset and imbalance of muscle action, into a position of great strain. The progress of the deformity is due to keeping the arm thus splinted over a long period.

The deformity does not appear in the MILD cases because there is no initial spasm. By the end of two months of splinting muscle recovery is proceeding apace, including that of the elbow flexors, and nutrition of the limb is rapidly improving with voluntary movement; for these reasons twenty-four hour splinting is no longer required.

As these facts came to light during the investigation it became obvious that if the deformity were to be prevented or its progress checked, an alternative method of treatment would have to be adopted. The connection between the early "neuritis" and the later/

later development of the deformity was not at first appreciated, and, as it was not then known which cases would develop subluxation, alterations of treatment had to be deferred until there was radiological evidence at two to three months. Treatment until this age was therefore carried out in the routine fashion in Fairbank's splint.

In considering the best method to alter the treatment once the first radiological signs had appeared it was necessary to consider the theoretical etiology point by point:-

(a). Moderate damage to the plexus. Operation on the plexus in these cases was considered, but after reviewing the disappointing results in the literature and elswwhere this treatment was not considered suitable.

(b). Delay in recovery of the elbow flexors. As this feature is presumably due to the type and situation of the damage to the plexus the same objections as in (a), above, held good.

(c). Upset in nutrition of the limb. It was considered/

considered that from the point of view of treatment this was largely due to deficient blood supply and tissue oxygenation following prolonged immobilisation and that the subsequent muscular contractures were due to the same causes, after the fashion of a mild Volkmann's ischaemic paralysis. The solution appeared to be early and full passive mobilisation combined with splinting. Early physiotherapy has not been advocated in the literature from the somewhat theoretical fear of tearing the regenerating plexus and overstretching the paralysed muscles. This, however, should not occur provided the arm is not pulled downwards with the head flexed and rotated to the opposite side. No such ill effects have been seen in the cases so treated up to the present. On the contrary, it has been found that the blood supply has been improved and regeneration of the plexus enhanced.

(d). The method of splinting. The position enforced by the Fairbank's splint appeared to be quite unnecessarily extreme. In no other paralytic condition does treatment consist in splinting the limb in such a position so as to fully relax the paralysed groups while stretching the unparalysed ones to their fullest extent./

extent. (This is carried to an even more extreme degree in the treatment which is advocated by some authors, that of tying the limb behind the infant's head).

For these reasons a different type of abduction splint was evolved. Fig. 14. This is made to measure of fibre on a plaster cast of the individual baby and holds the limb in the following position:-

Shoulder: Abduction to 90° with the arm slightly flexed at the shoulder, thus holding the humeral head in a stable position in the glenoid fossa and preventing subluxation of the joint.

Arm: Externally rotated to between 90° and 135°, in order to relax the tension of the internal rotators and relieve pressure on the radial head.

Elbow: Forearm held at 45° short of full extension to relax the tension of triceps and reduce the mechanical advantage of pronator teres.

Forearm: Semi-pronated to relax the pronator muscles.

Hand: A shaped hand piece is provided with a gutter for the thumb, allowing of much greater control over the/

FIGURE 14.

ERB'S PARALYSIS CASE IN THE ALTERED SPLINT.

the position of the hand than in the Fairbank splint. Dropped wrist, ulnar deviation of the hand etc. can be easily corrected.

The following scheme of preventive treatment was instituted and carried out during the investigation.

1. Preventive treatment.

(a). All cases when diagnosed as Erb's upper arm paralysis were immobilised in a Fairbank type splint for the first two months.

(b). At two months of age or after two months of splinting all cases had both shoulders, both forearms and elbows X-rayed in true P.A. and Lateral views. An accurate clinical and electrical assessment of muscle recovery was also made at this time.

(c). Patients in whom the electrical reactions of biceps and brachialis were negative to Faradic current and/or in whom was present an ulnar curvature with or without clubbing or notching of the radial metaphysis, had the affected arm immobilised in the new pattern splint.

(d)./

(d). From the time that the splint was fitted the parent was instructed to put the limb through the full range of movements of all the joints for five minutes thrice daily, special emphasis being put on full passive extension of the elbow, and full supination of the forearm.

These movements were demonstrated on the baby in front of the mother, who then did them herself on the child so that one was certain she fully understood what was required. The child attended for physiotherapy twice weekly thereafter.

(e). A six-weekly check radiograph was taken.

(f). The splint was worn for twenty-four hours until biceps and brachialis were functioning reasonably strongly, thereafter only at night until general recovery was well advanced.

2. Results to Date.

Cases 1 to 6 have been treated in this way since the diagnosis of subluxation was made at 7 weeks, 2 months, 4 months, 4 months, 7 months and 3 months of age. The results have been very much better than anticipated both from the point of view of checking the deformity, and, unexpectedly/

unexpectedly enough, of increasing the speed of recovery of the paralysed muscles.

The shoulder muscles of all six cases show a complete recovery, as do all the other muscles, with the exception of the elbow flexors which are still rather weak. There are no contractures of the unparalysed groups or of joint capsules.

The posterior curvature of the upper one fourth of the ulna is very much less exaggerated and almost full active and passive extension of the elbow is possible. The ulnar curve has become sufficiently normal to prevent posterior traction on the radius by the interosseous ligament with the result that the axis of movement is in the normal position and active and passive supination are practically normal.

The radial metaphyses, however, remain deformed, principally due to "clubbing" and as this is one of the earliest deformities, the damage has certainly occurred during the initial period of full correction in the Fairbank splint; however, deformation of the head to the extent seen in these six cases at the present time does not appear to result in any functional disturbance. The six/

six cases can now be classed legitimately as "GOOD" recoveries, which would certainly not have been the case had treatment followed the standard scheme throughout.

As has already been mentioned, only towards the end of the investigation did it become obvious that there was a connection between the initial "irritative neuritis" and the appearance of the first signs of the deformity some months later, but now that this has been recognised, it is proposed to put such cases in the altered splint ab initio in the hope that the entire deformity may by prevented, and to keep a close radiological check throughout the course of treatment which will follow the scheme already described.

As this splint is rather more difficult and time-consuming to make, cases not showing an early neuritis will be treated in the standard Fairbank splint unless radiological evidence of deformity becomes evident. Full clinical details of these cases at the present time with their radiographs, will be found in Appendix II.

3. Treatment of Established Deformity.

Correction of the bony deformities has to be aimed at in these cases and therefore should only be considered under/

under the following circumstances:-

(a). If recovery, generally, is sufficiently good to enable the patient to take advantage of the correction.

(b). If the previously paralysed muscles are strong enough and sufficiently balanced to take advantage of of the bony correction and the forearm rotators are sufficiently strong and controlled.

(c). If the pronators do not show marked contracture.

There appear to be several possible lines of operative treatment:-

1. Osteoclasis of the middle third of both bones, as recommended by Blount (1940) for supination deformities in children. Possibly in an early case where the ulnar curvature is as yet minimal and where the head has not yet grossly subluxated this procedure may be of value. In the older case, while it would correct the ulnar curve, the radial head would be too deformed to reduce correctly.

2. Baldwin's operation. This is a useful procedure where loss of supination is due to ulnar curvature and backward displacement of the radial axis such as occurs in some cases of Spastic disease. In cases in/

in which in addition the radial head is subluxated or dislocated, however, it is likely that the procedure would result in an unstable forearm. The operation possibly has a place in cases in whom the ulna is curved but the radius shows only thickening of the neck and flattening of the head. (e.g. Case 16).

3. Subperiosteal osteotomy through the upper third of the ulna and excision of the deformed radial head, followed later by division of the contracted pronator teres if necessary. This operation was devised in the hope of obtaining a stable forearm with improved extension of the elbow and supination at the expense of some further shortening of the forearm.

The operation allows of:-

Straightening of the abnormally curved ulna by angulation backward at the osteotomy site.

Realignment of the ulnar interosseous border with the radial axis.

"Reduction" of the radial neck into the site of a normal radial head.

Prevention of the bony lock of the deformed head/

head against ulna and capitellum.

Later, removal of the binding action of the contracted pronator teres by its division.

This has been carried out to date in one case with quite a fair result, and seems to be a hopeful line of treatment.

Operative and clinical details of the case will be found in Appendix III.

B. THE ANTERIOR TYPE.

It will be seen from the notes on the clinical findings in these cases that this deformity does not cause anything like the amount of disability which is associated with the postero-lateral type. Only in one child, (Case 27) was there limitation of elbow movements and of supination to any very marked degree and this was due more to the effects of the paralysis than to the bony deformity. In cases in whom recovery from the paralysis has been good, the sole effect of the dislocation appears to be limitation of full flexion of the elbow, due to the displaced radial head locking against the front of the humeral shaft. Pronation and supination are/

are little affected because the radius, being free at its proximal end, is able to move to and fro and allow for any discrepancy in the position of the radial axis. Mc.Farland (1936) in his series of eleven cases, found that only in five was function interfered with sufficiently to warrant active treatment.

If the theory of causation be the correct one, all cases in whom traction on the arm during birth has been necessary, whether an Erb's palsy be present or not, should be examined for signs of a "pulled Elbow", and if this be present the dislocation should be reduced by manipulation.

In the older child, stable reduction of the dislocated head is not possible owing to the radius being proportionately too long. Resection of the displaced head is the correct treatment, but only if it is a source of disability.

10. DISCUSSION.

This thesis has dealt with a complication encountered in thirty-two instances out of a series of one hundred and six treated cases of Erb's obstetrical paralysis, an incidence of 30%, a very high figure for a condition which, up to date, has received so little attention. Taking into account the fact that the treatment of our cases of Erb's paralysis had been along the standard lines and the usual teaching followed with regard to splinting and physiotherapy until this investigation began, that cases are only now being discovered by the various Scottish centres following our preliminary report, and that references in the literature are few and far between, one is forced to the conclusion that the complication, certainly in its early stages, is being overlooked elsewhere. The omission may be due to an insufficient follow-up of Erb's paralysis cases, as the deformity may not become clinically obvious until some time after muscle recovery has ceased, or, as frequently happens, to treatment of the paralysis in the infant by a different individual to that treating its effects in the older child and adult.

Judging/

Judging from much of the literature on Erb's paralysis, radiographs have only been taken of the elbow region when there has been an obvious clinical deformity, which, as has been shown, does not occur until the patient is some years old. It seems possible that lack of detailed comparison of radiographs of both elbows and forearms may account for the statements in some papers that bony changes are not seen below the age of one year or in children with limitation of elbow and forearm movements. The early changes in the radiographs, which have been described, could easily be missed if a film of the affected limb only is examined.

It has been found possible to divide the complication into two types, a posterior one with an incidence of 25.4%, and an anterior one with an incidence of 4.7%, and it has been shown that these types are completely distinct, the posterior type starting as a subluxation and becoming a dislocation as growth proceeds, and being associated with a considerable degree of disability, and the anterior type, a dislocation from the outset, causing little or no disability.

<u>The Posterior Type</u>. Disability in this deformity consists of/

of limitation of extension of the elbow and of supination, such limitations of movement being regarded in most papers as being due to soft tissue contractures. It has been demonstrated in this thesis that, at least in cases with a subluxating radial head, other factors play a more important part.

Limitation of passive extension of the elbow is a feature in the youngest cases, even in infants of two months old or less, but, as no contractures of the shoulder joint capsule or associated muscles are present, as is shown by the full range of passive movements, it seems reasonable to conclude that neither are contractures present at the elbow joint, nor in its associated soft tissues. The uncontracted triceps, full passive flexion and full passive supination is proof of this assumption, and an explanation for the disability other than contractures must be sought. Radiographs of the elbow and forearm in these small babies show a club-shaped upper radial metaphysis and an easily demonstrable exaggeration of the normal anterior curve of the upper fourth of the ulna. The theory has been advanced that the growth changes in the metaphysis are due to abnormal pressures and that the ulnar curvature is the origin of the ensuing deformity. It has been suggested that the causes/

causes of this curvature are stresses and strains set up by the attitude of the limb in the Fairbank splint, in the following type of case:-

(1). One in which there is an initial brachial plexus neuritis with associated muscle spasm at birth.

(2). One in which the pathology is of medium severity.

(3). On in which a long period of splinting is required because of slow muscle recovery.

(4). One in which the recovery of biceps and brachialis is unduly delayed.

As limitation of passive supination is a later manifestation than limited elbow extension, as it appears gradually and at the same stage as soft tissue contractures begin to appear around the shoulder joint, it is likely that at least some of the limitation of this movement is due to pronator contractures. That this is not the sole cause, however, is demonstrated in the radiographs, where the axis of movement of the radius on the ulna is obviously displaced posteriorly causing the interosseous membrane to become taut on supination, thereby limiting this movement to a few degrees. In fact, it seems probable that the pronator contractures/

contractures are secondary to this bony deformity and merely accentuate the disability.

The end result of the sequence of events has been demonstrated and it is obvious that many such patients would have had a very much better functional result had it not been for the limitations of movement imposed by the bony deformities, actual muscle recovery having been good on the whole. For this reason a new scheme of treatment has been devised and details of the first six cases so treated have been included. A very definite improvement both clinically and radiologically is evident in all six. It is hoped that results will be even better when such cases are treated in this way from their first visit.

A method of treatment of the established deformity in the older child has been suggested but is unlikely ever to give very satisfactory results as by that age soft tissue contractures and gross bony deformity have occurred. The one case so far operated upon is evidence of this, but the fact that there was some clinical improvement encourages one to believe that operative treatment is of some value in selected cases.

The Anterior Dislocations. From this series this complication appears to be very much less common than the posterior type. It has been shown that the radiological and clinical appearances are identical with the so-called "Congenital dislocation of the Radial head", of which accounts of twenty-three cases unassociated with paralysis have already been published.

Mention of the occurrence of anterior dislocations in association with Erb's paralysis has been made in several papers, but no actual details have been discussed, nor does the etiology appear to have been considered in any way different from the posterior type. With the exception of Thomas (1914), who states that all types of radial head dislocation in Erb's paralysis are due to birth injury, authors generally are of the opinion that the condition is due to contractures and muscle imbalance.

The theory has been advanced that the condition is a simple traumatic dislocation caused by traction on the affected arm during birth, and, depending on the amount of traction and on the position of the child, may or may not be accompanied by an Erb's paralysis. The operative/

operative findings, the shape of the ulna and of the radial head are all compatible with this theory.

The condition, per se, causes no disability in most cases, but if limitation of movement be present it is confined to the last few degrees of flexion of the elbow and is due to the radial head impinging on the humerus. When disability in any patient is marked, it is due to the effects of the paralysis and not to those of the dislocation.

Removal of the dislocated head has been advocated only when it is the source of disability.

11. SUMMARY.

1. One hundred and two cases of Erb's obstetrical paralysis have been examined.

2. Subluxations and dislocations of the radial head were found in thirty-two instances - 30%.

3. These subluxations and dislocations were found to be divisible from every point of view into two distinct types. A posterior type - 25.4%, and an anterior type - 4.7%.

4. Radiologically typical primary signs of incipient posterior subluxation were found in cases as early as seven meeks of age, and those signs were followed by actual subluxation of the head which proceeded to a complete dislocation as age advanced.

5. The anterior type was found to be a complete dislocation from the outset, and did not appear to be affected by growth.

6. The clinical findings in the posterior dislocation cases have been set out and a series of radiographs of selected cases reproduced and discussed, showing the development of the deformity from seven weeks of age/

age until growth is completed.

7. The clinical findings of the five cases of anterior dislocation have been set out and radiographs of two reproduced and discussed.

8. Theories of causation of both conditions have been presented, it being suggested that the posterior type is due to the attitude of splinting in certain cases and the anterior type to birth injury.

9. A new type of splint and a scheme of preventive treatment for the posterior type have been described and the results in six recent cases following their application.

10. Operative treatment for the established posterior dislocation has been discussed. A suitable operation has been described and its results in one case.

11. Treatment for the anterior type is discussed.

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14. APPENDIX I.

Detailed Clinical Findings in Cases 1-24.

Cases 1 - 6 at first visit.

CASE 1. M. 1 day old. Breech delivery. Lt. Erb.

The baby was extremely irritable and cried lustily when the affected arm or the region of the brachial plexus in the neck was touched. The paralysed arm was held firmly at the side in the classical position and there was obvious spasm of the non-paralysed groups on putting the limb in the fully corrected position. This was especially noticeable in the internal rotators of the arm, triceps and pronators.

The following muscles were apparently paralysed:- Supra and infra-spinators, deltoid, biceps, brachialis, brachio-radialis, supinators of the forearm and radial extensors of the wrist.
All passive movements of the limb full.

CASE 2. F. 16 days old. Complicated Vertex delivery. Rt. Erb.

Condition exactly as for Case 1 with the addition of paralysed rhomboid muscles. A posterior subluxation of the affected shoulder joint was present but was easily reducible/

reducible and appeared stable after application of the Fairbank splint.

<u>CASE 3</u>. M. 3 weeks old. Forceps delivery. Lt. Erb.

A history suggestive of an early neuritis was obtained. There was still some tenderness in the neck but the non-paralysed groups were not tender. There was definite spasm of all unparalysed muscles. The same muscles were paralysed as in Case 1.

All passive movements of the limb full.

<u>CASE 4</u>. M. 3 weeks old. Forceps delivery. Lt. Erb.

A history suggestive of an early neuritis was obtained. The neck and the unparalysed muscles were no longer tender. Definite spasm of all unparalysed muscles. The same muscles as in Case 1 were paralysed with the addition of the rhomboids.

All passive movements of the limb full.

<u>CASE 5</u>. F. 3 weeks old. Forceps delivery. Lt. Erb.

Condition exactly as for Case 4 except that the rhomboids were not paralysed.

All passive movements of the limb full.

<u>CASE 6</u>. M. 9 days old. Breech delivery. Lt. Erb.

Condition exactly as for Case 1 except that spasm of/

of the unparalysed muscles and tenderness were if anything more marked. The rhomboids were paralysed but the radial extensors of the wrist were unaffected.

All passive movements of the limb full.

Cases 1 - 6 at age of discovery of deformity.

CASE 1. at 7 weeks old.

Recovery commencing. Spasm of triceps and internal rotators of the arm still present.

Shoulder: No contractures. All passive movements full and free.
Fair degree of recovery of paralysed muscles except deltoid, which was still paralysed.

Elbow: No contractures. Passive extension limited by 15°.
Full passive flexion.
Biceps and brachialis paralysed.
Triceps - spasm.

Forearm: No contractures. Full passive supination.
Supinator paralysed.
Radial extensors - slight recovery.
Radial head normal clinically. Early subluxation radiologically.

CASE 2./

<u>CASE 2</u>. at 2 months old.

As for Case 1. Subluxated shoulder now stable.

<u>Elbow</u>: Passive extension limited by 20^o.

<u>CASE 3</u>. at 4 months old.

Recovery quite well advanced. Spasm of triceps still present but other non-paralysed muscles seemed normal.

<u>Shoulder</u>: All muscles show early recovery, no contractures.

<u>Elbow</u>: Biceps and brachialis paralysed.
Triceps - spasm. Passive extension limited by 20^o.

<u>Forearm</u>: No contractures. Full passive supination.
Supinator recovering. Passive supination full.
Radial extensors recovered.
Radial head normal, clinically. Early subluxation radiologically.

<u>CASE 4</u>. at 4 months old.

As for Case 3.

<u>Elbow</u>: Passive extension limited by 15^o.
Radial head slightly more palpable than normal.

<u>CASE 5</u>./

CASE 5. at 7 months old.

Recovery well advanced. Still some slight spasm of triceps.

Shoulder: Recovery almost complete. No contractures.

Elbow: Biceps and brachialis - slight recovery.
Passive extension limited by 20°.
Supinators, slight recovery.
Passive supination limited by $10 - 15^{\circ}$.
Radial extensors - recovery.
Radial head more palpable than normal.

CASE 6. at 3 months old.

Early recovery. Spasm of triceps and internal rotators still present.

Shoulder: All muscles show early recovery. No contractures.

Elbow: Biceps and brachialis paralysed.
Passive extension limited by 20°.

Forearm: No contractures, full passive supination.
Supinators paralysed.
Radial head clinically normal. Early subluxation radiologically.

Cases/

Cases 7 - 11 at first visit.

CASE 7. M. 4 days old. Forceps delivery. Lt. Erb.

Marked tenderness and spasm of unparalysed muscles, tender area in neck, resembling Case 1.

The usual muscles were paralysed and included the rhomboids and radial extensors.

CASE 8. M. 3 weeks old. Breech delivery. Rt. Erb.

History suggestive of an early neuritis. Unparalysed muscles were no longer tender but showed marked spasm. There was a posterior subluxation of the shoulder joint which appeared stable when the splint had been applied.

The usual muscles were paralysed. Rhomboids and wrist extensors were unaffected.

CASE 9. M. 5 days old. Complicated Vertex delivery. Lt. Erb.

In this case only the triceps was spastic and tender. The usual muscles were paralysed including the rhomboids.

CASE 10. F. 2 weeks old. Forceps delivery. Rt. Erb.

CASE 11. F. 3 weeks old. Forceps delivery. Rt. Erb.

Case notes merely give the diagnosis as "Typical Erb's paralysis".

Cases/

Cases 7 - 11 at age of discovery of deformity.

CASE 7. 1 yr. old. Result FAIR.

Shoulder: Rhomboids - recovery.

Spinati and deltoid - good recovery.

Subscapularis) slight contracture.
Pectorals)

Abduction to 80°. External rotation to 100°.

Elbow: Biceps and brachialis - weak.

Triceps normal.

Active and passive extension limited by 20°.

Flexion full.

Forearm: Active supination to 80°.

Passive supination to 100°.

Wrist movements and hand normal.

Affected arm about $\frac{3}{4}$" shorter than normal.

Radial head abnormally palpable.

CASE 8. 1 yr. 1 month old. Result FAIR.

Shoulder: As for Case 7.

Abduction to 90°.

External rotation to 115°.

Elbow: Biceps and brachialis markedly weak.

Triceps/

Triceps - slight contracture.

Active and passive extension limited by 25°.

Flexion limited by 5 - 10°.

Forearm: Active supination to 45°.

Passive supination to 60°.

Wrist movements and hand normal.

Affected arm 1" shorter than normal.

Radial head abnormally palpable.

CASE 9. 2 yrs. 6 months old. Result FAIR.

Shoulder: Good recovery.

Abduction to 90°.

External rotation to 125°.

Elbow: Biceps and brachialis - weak.

Triceps - slight contracture.

Active and passive extension limited by 25°.

Flexion by 5°.

Forearm: Active supination - 50°.

Passive supination - 70°.

Affected arm 1" shorter than normal.

Radial head abnormally palpable.

CASE 10. 3 yrs. old. Result FAIR.

As for Case 7.

Shoulder/

Shoulder: Abduction to 50°.

External rotation to 95°.

The muscles appeared quite powerful, limitation was due to contractures of subscapularis and internal rotators.

Elbow: Biceps and brachialis weak.

Triceps - contracture.

Active and passive extension limited by 30°.

Flexion limited by 15°.

Forearm: Active supination - 45°.

Passive supination - 55°.

Affected arm $1\frac{1}{2}$" shorter than normal.

Radial head subluxated posteriorly.

CASE 11. 3 yrs. 6 months old. Result FAIR.

Shoulder: All muscles and movements practically normal.

Elbow: Biceps and brachialis slightly weak.

Triceps normal.

Active and passive extension limited by 20°.

Flexion limited by 5°.

Forearm: Active supination - 90°.

Passive supination - 100°.

Affected/

Affected arm 1" shorter than normal.

Radial head definitely subluxated posteriorly.

Clinical findings in Cases 12 - 24.

CASE 12. M. 5 yrs. old. Result BAD. Lt. Erb. Said by the parents to have been a very irritable baby for the first month.

Shoulder:	Rhomboids, Spinati	very weak.
	Deltoid	paralysed.
	Subscapularis, Pectorals.	contracted.
	Posterior subluxation of humeral head present.	
	Abduction to 5°.	
	External rotation to 25°.	
Elbow:	Biceps, Brachialis	very weak.
	Triceps	contracted slightly.
	Extension limited by 50°., Flexion almost full.	active and passive.
Forearm:	Held pronated.	
	Active supination to 10°.	
	Passive supination to 25°.	
	Radial/	

Radial extensors weak.

Radial head is very prominent postero-laterally in semi-pronation.

The affected limb is 2" shorter than normal.

CASE 13. M. 5 yrs. old. Lt. Erb. Result FAIR.

Shoulder: Rhomboids normal.

Deltoid) normal.
Spinati)

Pectorals) slight contracture.
Subscapularis)

Abduction - 80°.

External Rotation - 100°.

Elbow: Biceps) weak.
Brachialis)

Triceps - slight contracture.

Extension limited by 45°.

Flexion limited by 10°.

Active supination - 60°.

Passive supination - 80°.

Radial head prominent postero-laterally in semi-pronation.

Affected limb 1" shorter than normal.

CASE 14./

CASE 14. M. 5 yrs. old. Left Erb. Result FAIR.

Shoulder: Rhomboids normal.

Deltoid } weak.
Spinati }

Pectorals } some contracture.
Subscapularis }

Abduction - 70°.

External rotation - 100°.

Elbow: Biceps } weak compared to normal side.
Brachialis }

Triceps - slight contracture.

Extension limited by 50° active and passive.

Flexion limited by 10°.

Forearm: Held pronated.

Active supination 70°.

Passive supination 85°.

Radial head very prominent postero-laterally in semi-pronation.

Affected limb $1\frac{1}{4}$" shorter than normal.

CASE 15. F. $6\frac{1}{2}$ yrs. old. Rt. Erb. Result FAIR. (Fig. 2.)

Shoulder: Rhomboids normal.

Deltoid } weak compared to the normal side.
Spinati }

Pectorals/

Pectorals } normal.
Subscapularis }

Abduction to 85°.

External rotation to 120°.

Elbow: Biceps } very weak compared to normal side.
Brachialis }

Triceps normal.

Extension limited by 40°, active and passive.

Flexion full.

Forearm: Held pronated.

Active supination to 80°.

Passive supination 90°.

Other forearm muscles and hand normal.

Radial head very prominent postero-laterally in semi-pronation.

Affected limb 1" shorter than normal.

CASE 16. F. 7 yrs. Rt. Erb. Result FAIR.

Shoulder: All muscles and movements are practically normal.

Deltoid rather atrophied but functioning well.

Elbow: Biceps } slightly weak.
Brachialis }

Triceps/

Triceps - normal.

Extension limited by 20° active and passive.

Flexion full.

<u>Forearm</u>: Active supination to 85°.

Passive supination to 90°.

Radial head normal to palpation.

Affected limb 1" shorter than normal.

<u>CASE 17</u>. F. 7 yrs. old. Rt. Erb. Result FAIR.

<u>Shoulder</u>: All movements normal except for full external rotation due to contracture of pectorals and subscapularis.

<u>Elbow</u>: Biceps } weak.
Brachialis }

Triceps normal.

Extension limited by 30°.

Active supination - 70°.

Passive supination - 85°.

Radial head palpable postero-laterally in semi-pronation.

Affected limb 1" shorter than normal.

<u>CASE 18</u>. M. 7 yrs. old. Rt. Erb. Result FAIR.

<u>Shoulder</u>: As for Case 15.

<u>Elbow</u>:/

Elbow: Biceps) weak.
Brachialis)

Triceps - slight contracture.

Extension limited by 40°.

Flexion limited by 15°.

Active supination - 80°.

Passive supination - 95°.

Radial head prominent postero-laterally in semi-pronation.

Affected limb 1½" shorter than normal.

CASE 19. F. 7 yrs. old. Lt. Erb. Result FAIR.

Shoulder: All movements full and normal.

Elbow: Biceps) slightly weaker than normal only.
Brachialis)

Triceps - slight contracture.

Extension limited by 10°.

Flexion - slight limitation.

Active supination 80°.

Passive supination 90°.

Radial head palpable postero-laterally in semi-pronation.

Affected limb ¾" shorter than normal.

CASE 20./

CASE 20. M. 8 yrs. Rt. Erb. Result FAIR.

Shoulder: Rhomboids weak.

Deltoid, Spinati weak.

Pectorals, Subscapularis slightly contracted.

Abduction to 60°.

External rotation to 100°.

Elbow: Biceps, Brachialis markedly weak.

Triceps normal.

Extension limited by 30° active and passive.

Flexion full.

Active supination 10°.

Passive supination 20°.

Radial head palpable postero-laterally in semi-pronation.

Affected limb 1½" shorter than normal.

CASE 21. M. 8 yrs. old. Rt. Erb. Result BAD.

Shoulder: Gross limitation of all movements.

Deltoid paralysed.

Head of humerus posteriorly subluxated.

Elbow:/

Elbow: Biceps) very weak.
Brachialis)

Triceps contracted.

Extension limited by 50^o.

Flexion limited by 15^o.

Forearm held strongly pronated.

Active supination - 5^o.

Passive supination - 15^o.

All hand muscles weak, hand blue and clammy.

Sensation poor in whole hand.

Radial head very prominent postero-laterally in semi-pronation.

Affected limb $2\frac{1}{2}$" - 3" shorter than normal.

CASE 22. F. 10 yrs. old. Rt. Erb. Result FAIR.

Shoulder: Rhomboids normal.

Deltoid) weak.
Spinati)

Pectorals) some contracture.
Subscapularis)

Abduction to 75^o.

External rotation to 100^o.

Elbow: Biceps) weak.
Brachialis)

Triceps/

Triceps slightly contracted.

Extension limited by 35° active and passive.

Flexion limited by 15°.

Forearm: Held pronated.

Active supination to 10°.

Passive supination to 35°.

Hand normal.

Radial head grossly displaced postero-laterally on semi-pronation.

Affected limb $1\frac{1}{2}$" shorter than normal.

CASE 23. F. 15 yrs. old. Rt. Erb. Result FAIR.

Shoulder: Slight limitation of abduction and external rotation.

Muscles appear normal except for slight atrophy of the deltoid.

Elbow: Biceps) Brachialis) weaker than normal.

Triceps - some contracture.

Extension limited by 30° active and passive.

Flexion limited by 15°.

Forearm: Held pronated.

Active supination to 20°.

Passive/

Passive supination to 35°.

Radial head palpable above, lateral and posterior to its normal position in semi-pronation.

Affected limb 1" shorter than normal.

<u>CASE 24</u>. M. 25 yrs. old. Rt. Erb. Result BAD.

There are no early records of this case as he was treated elsewhere.

<u>Shoulder</u>: Deltoid ? paralysed.

Spinati and Rhomboids very weak and wasted.

Internal rotators contracted.

Gross limitation of abduction and external rotation.

<u>Elbow:</u> Held semi-flexed.

Biceps and Brachialis very weak.

Triceps contracted.

Extension limited by 55° active and passive.

Flexion limited by 20°.

<u>Forearm</u>: Held strongly pronated.

Active and passive supination practically nil.

The/

The whole limb is wasted and considerably smaller than the normal. Trophic disturbances of the skin are evident. The radial head is grossly displaced and palpable in the usual abnormal position.

15. APPENDIX II.

Detailed clinical findings in Cases 1 - 6 following treatment.

The following are the clinical details at their present ages of Cases 1 - 6 following alteration to their treatment along the lines previously described.

As the radiological details of all six cases are very similar, the radiographs of four only have been reproduced.

CASE 1. 7 months old. Altered splint worn 5 mths. 2 weeks.

Shoulder: Complete recovery, no contractures.
Biceps and brachialis - recovering, but still weak clinically and to Faradic current.

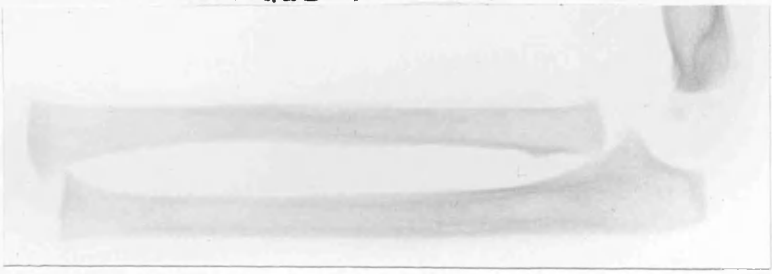
Elbow: Extension limited by 5^{0} active and passive.
Flexion normal.
Supination - passive 180^{0}.
active 160^{0}.
Wrist and hand normal.
Radial head not abnormally palpable.

X-ray findings - Ulnar curve much reduced.
Radius of normal length, i.e. metaphyseal line in normal situation.
No/

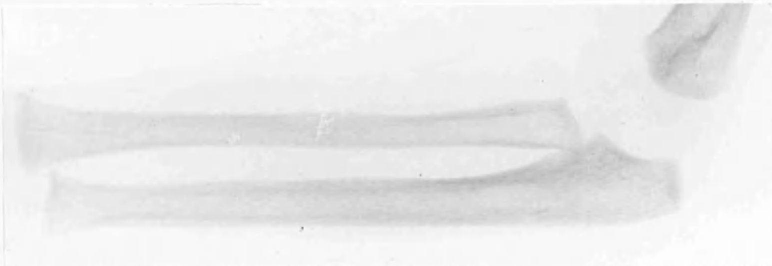
CASE ONE

AFTER ALTERED TREATMENT.

AGED 7 MTHS.



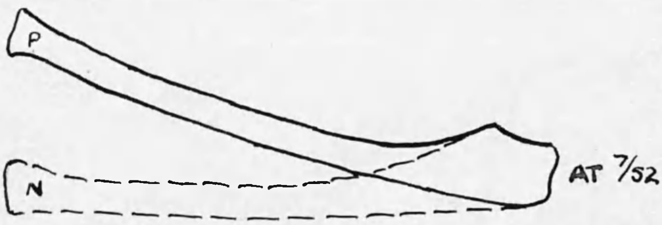
NORMAL.



PARALYSED

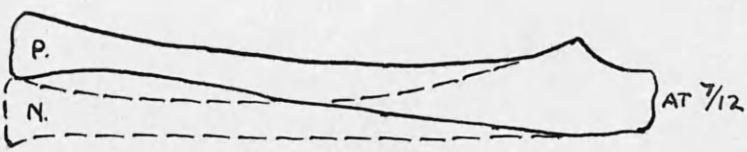
NORMAL

PARALYSED.



SEE P. 45.

ALTERED SPLINT WORN FOR FIVE MONTHS.



No posterior swivelling of radial shaft.
Notch in anterior part of metaphysis persists with slight thickening of radial neck.
Bones of almost the same length.

Splint to be worn at night only, physiotherapy continues. The line drawing shows the amount of reduction in the ulnar curve during 5 months of splinting and physiotherapy.

<u>CASE 2</u>. 6 mths. old. Altered splint worn 4 months.

<u>Shoulder</u>: Complete recovery. No contractures.
No subluxation present now.
Biceps and brachialis recovering but still weak clinically and to Faradic current.

<u>Elbow</u>: Extension limited by 10° active and passive.
Flexion normal.
Supination - passive 180°.
active 120°.
Wrist and hand normal.
Radial head not abnormally palpable.

<u>X-ray findings</u>: As for Case 1.

24-hour wear of splint and physiotherapy continued.

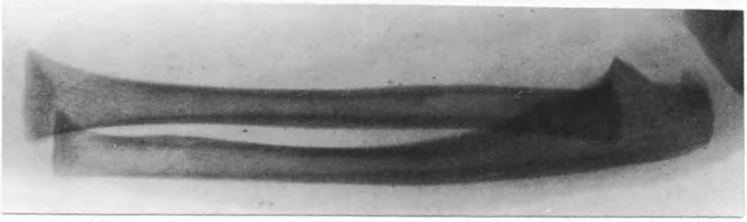
<u>CASE 3</u>. 11 mths. old. Altered splint worn 7 months.

<u>Shoulder</u>: Complete recovery. No contractures.
Biceps/

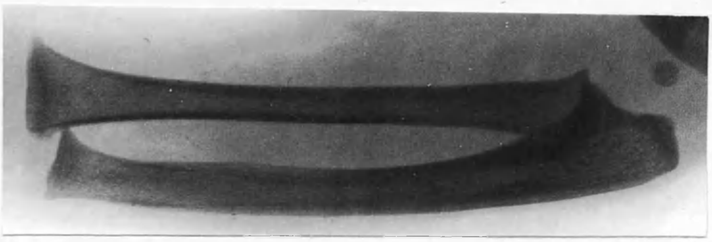
CASE THREE

AFTER ALTERED TREATMENT

AGED 11 MTHS.



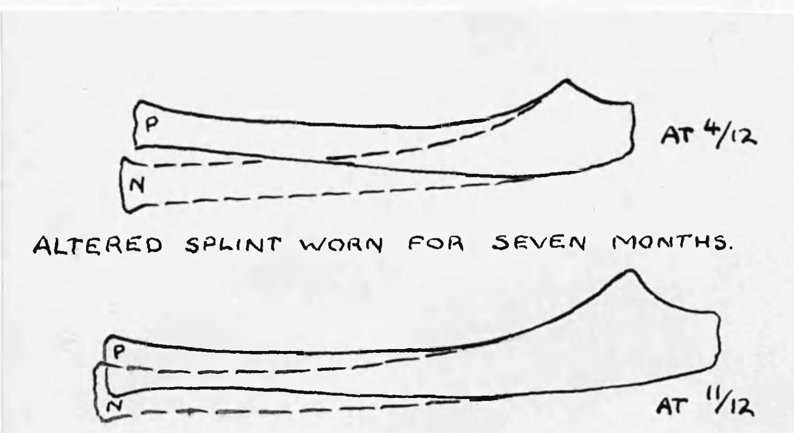
NORMAL



PARALYSED

PARALYSED

NORMAL



SEE P. 49.

Biceps and brachialis practically normal.

Elbow: Extension limited by 5° active and passive.

Flexion normal.

Supination - passive 130°.

active 110°.

Wrist and hand normal.

Radial head slightly more palpable than normal but in normal situation.

X-ray findings: Ulnar curvature much reduced.

Radius of normal length.

Upper fourth of radius thickened.

P.A. and Lat. Views: Metaphysis still shows an anterior notch.

No backward swivelling of radial shaft.

Bones of almost equal dimensions.

Splint to be worn at night only. Physiotherapy continues.

Line drawing shows improvement in curve as before.

CASE 4. 11 mths. old. Altered splint worn 5 months.

Shoulder: Complete recovery, no contractures.

Biceps and brachialis - practically normal.

Elbow: Extension limited by 5° active and passive.

Flexion normal.

Supination/

Supination - passive 180°.

Active 135°.

Wrist and hand normal.

Radial head slightly more palpable than normal but in normal situation.

X-ray findings as for Case 3.

Splint discarded. Physiotherapy continued.

CASE 5. 11 mths. old. Altered splint worn 4 months.

Shoulder: Complete recovery. No contractures.

Biceps and brachialis practically normal.

Elbow: Extension limited by 7° active and passive.

Flexion normal.

Supination - passive 180°.

active 140°.

Wrist and hand normal.

Radial head ? more palpable than normal but in normal situation.

X-ray findings: Ulnar curvature much reduced.

Radius ? relatively slightly longer than ulna.

Upper fourth of radius normal but the metaphyseal line has an anterior notch.

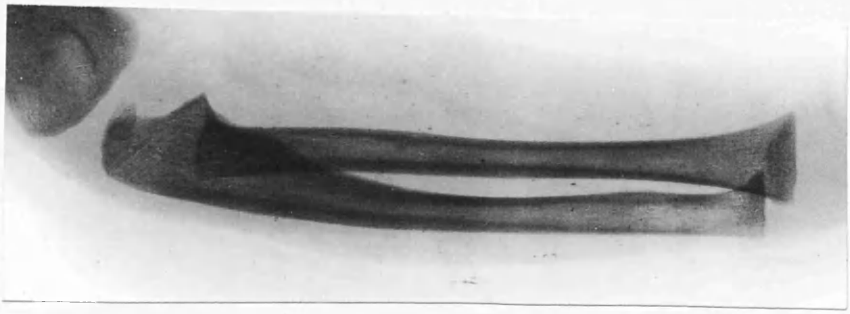
No posterior swivelling of radial shaft.

Bones/

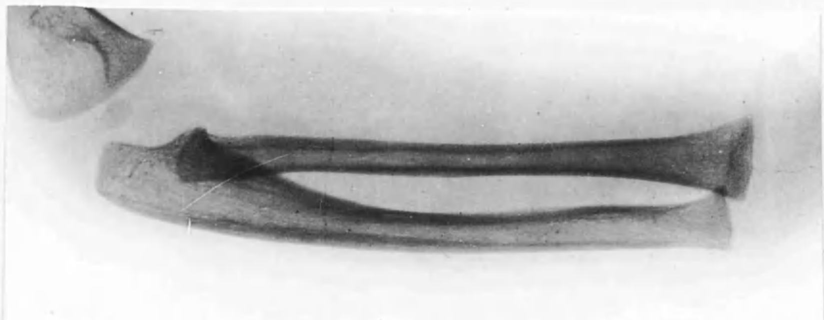
CASE FIVE

AFTER ALTERED TREATMENT

AGED 11 MTHS.



NORMAL



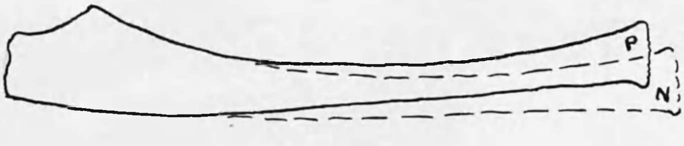
PARALYSED

PARALYSED

NORMAL

AT 7/12. SEE P.51.

ALTERED SPLINT WORN FOR FOUR MONTHS.



AT 11/12.

Bones of almost equal dimensions.

Splint discarded, physiotherapy continued.

CASE 6. 6 mths. old. Altered splint worn for 3 months.

Slight winging of scapula.

Shoulder: Recovery of all muscles except deltoid which is still weak.

No contractures.

Biceps and brachialis still definitely weak.

Elbow: Extension of elbow limited by 8° active and passive.

Flexion normal.

Supination - passive 180°.

active 120°.

Radial head slightly more palpable than normal in normal position.

X-ray findings: Ulnar curvature reduced.

Radius of normal length.

Upper fourth thickened and neck angulated posteriorly.

No backward displacement of radial shaft.

24-hour wear of splint and physiotherapy continued.

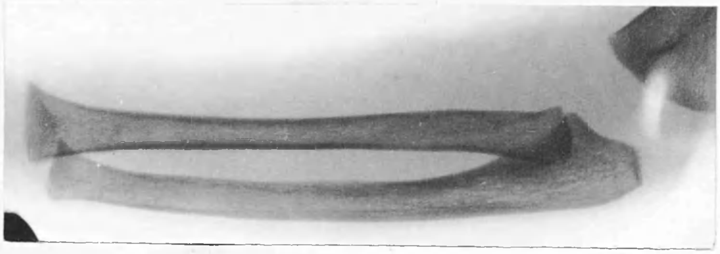
CASE 6. 1 yr. old. Altered splint worn for 9 months.

Shoulder:/

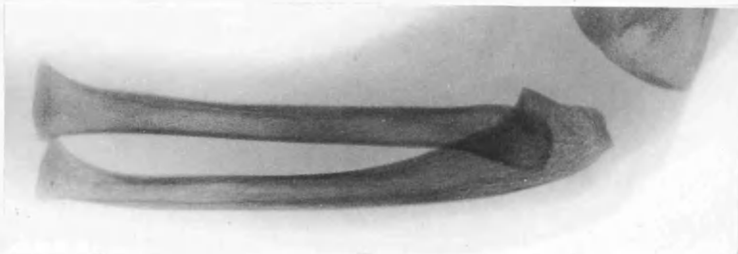
CASE SIX

AFTER ALTERED TREATMENT

AGED 6 MONTHS



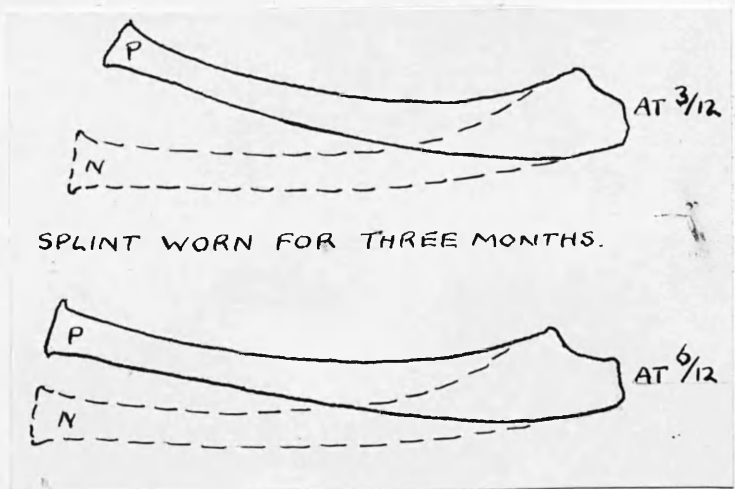
NORMAL



PARALYSED

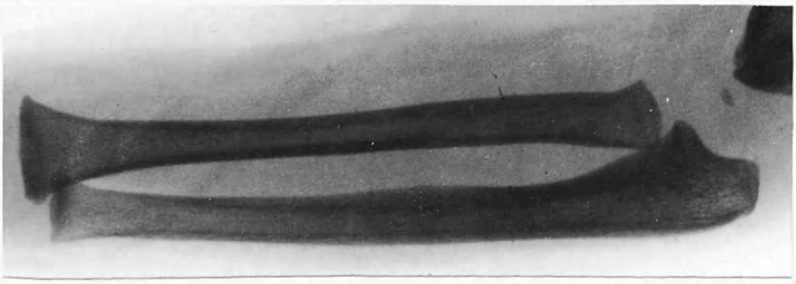
PARALYSED

NORMAL



SEE P. 53.

CASE SIX.
AFTER ALTERED TREATMENT
AGED 1 YEAR



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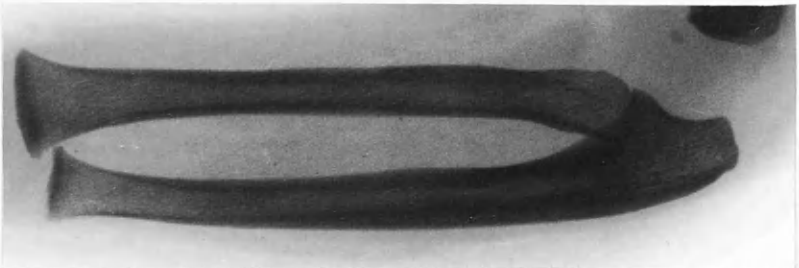

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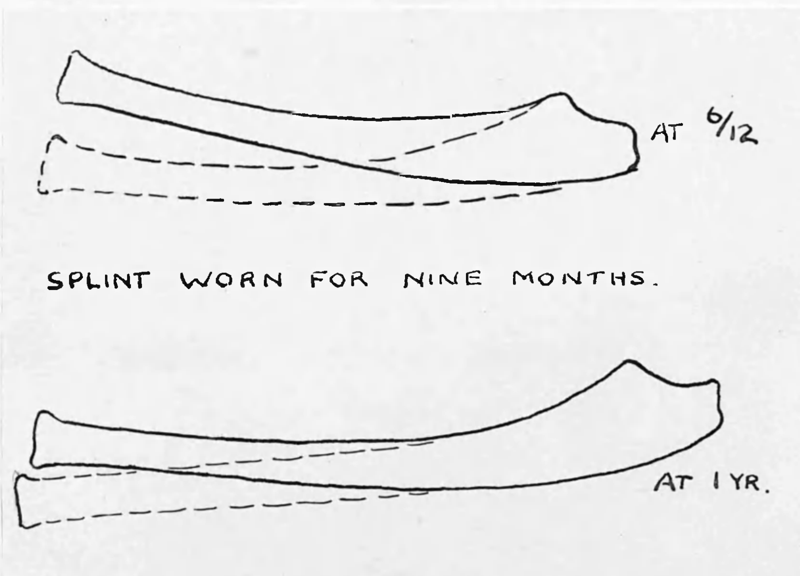

<u>Shoulder</u>: All muscles normal, no contractures.

Biceps and brachialis practically normal.

<u>Elbow:</u> Extension limited by 5° active and passive.

Flexion normal.

Supination - passive 180°.

active 150°.

Radial head as before.

<u>X-ray findings</u>: Further reduction in ulnar curvature. The condition of the radial head has not further deteriorated. It lies in approximately the normal position and there is no posterior swivelling of the radius. Bones slightly smaller than normal.

Splint discarded. Physiotherapy continued.

16. APPENDIX III.

Description of subperiosteal osteotomy of the upper fourth of the ulna and excision of the radial head.

This operation has been carried out to date in one case (Case 15 of the Series) with a fair result. Undoubtedly the result would have been better had there not been some errors in technique.

OPERATION: Through a lateral incision the radial head was exposed, the appearances being as in the operation photographs. The deformed head was removed and the periosteum turned over the stump. The wound was left open temporarily so that the effects on the radial stump of division of the ulna could be examined. Through a small incision over the subcutaneous edge of the ulna the bone was divided subperiosteally at the junction of upper and middle fourths. This was found to be rather difficult owing to the shape of the ulna at this site. The elbow was now extended past its previous limit by posterior angulation at the osteotomy and the radial stump was seen to slip into the position which would be occupied by a normal radial head. At the same time, and as the forearm was supinated, the lower/

lower ulnar fragment was pulled towards the radius, presumably due to the tight interosseous membrane.

The wounds were closed and the limb put in plaster in 135° extension of the elbow and full supination. This was an error as the elbow should have been fixed in full extension to maintain the correction.

The arm was immobilised for six weeks and thereafter physiotherapy was carried out.

Result:

Pre-operative:	Supination - passive	90°.
	active	80°.
Extension of elbow limited by		40°.
Post-operative:	Supination - passive	130°.
	active	120°.
Extension of elbow limited by		20°.

Some further improvement is to be expected following division of the contracted pronator teres.

The child unfortunately has left the district but latest reports indicate that improvement is still proceeding.

This seems a hopeful line of treatment but one can hope for improvement only, as muscular power and balance are always abnormal and the capitellum is still deformed.

APPENDIX IV.

A Case of Anterior Dislocation of the Radial Head in a Child aged two weeks.

The infant first reported for treatment after this thesis had been completed and therefore is not included in the series of 106 cases of Erb's paralysis. The case, however, was considered worthy of inclusion as an Appendix as it is the youngest case of anterior dislocation yet encountered.

The baby was a forceps delivery but did not need resuscitation despite a long and difficult labour. The mother did not know whether the arms had been pulled upon or not.

Clinical Findings: M. Rt. Erb's paralysis.

Shoulder: Paresis of the usually affected muscles only.
Full passive movements.

Arm: Paresis of biceps and brachialis.

Elbow: Passive extension full.
Flexion ? slightly limited in terminal degrees.

Forearm:/

<u>Forearm</u>: Supinators paralysed.

Radial and ulnar extensors of wrist paralysed.

Long extensors of fingers paralysed.

Passive supination full.

No spasm of unparalysed muscles.

Radial head palpable anterior to its normal position and does not apparently alter this position on movements of the elbow or forearm. Dislocation irreducible.

<u>X-ray findings</u>: Anterior dislocation of the radial head.

Metaphysis of normal shape.

Wide space between radial head and ulna.

Absence of normal posterior curvature of upper third of ulna.

CASE OF ANTERIOR DISLOCATION
AGED TWO WEEKS.