Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age

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AIM The aim of this investigation was to study the incidence of obstetric brachial plexus palsy (OBPP), to prospectively follow the recovery process, to assess the functional outcome at 18 months of age, and to find early prognostic indicators.

METHOD Of the 38 749 children born between 1999 and 2001 in western Sweden, 114 (70 males, 44 females) had an OBPP. Ninety-eight children were examined on six occasions at up to 18 months of age. Muscle strength, range of motion, hand preference, and functional abilities were noted, and the severity of the OBPP was classified.

RESULTS The incidence of OBPP was 2.9 per 1000 live births, and the incidence of persisting OBPP was 0.46 per 1000. At 3 months of age, the predictive value of regained elbow flexion for complete recovery was 100%, 99% of shoulder external rotation, and 96% of forearm supination. Most of the 18 children with persisting OBPP could perform functional activities but asymmetries were noted. Five children had a mild, 11 had a moderate, and two had a severe impairment. Three had undergone nerve surgery, one with a mild and two with a severe persisting impairment.

INTERPRETATION Most children with an OBPP recover completely. Muscle strength at 3 months of age can be used to predict outcome.

Obstetric brachial plexus palsy (OBPP) is the consequence of a complicated delivery and is caused by injury to the nerves from the cervical roots C5 to C8 and the first thoracic root (T1). The incidence of OBPP has been reported to be 1.6 to 5.1 per 1000 live births in population-based studies.1,2 In western Sweden the incidence of OBPP increased from 1.7 to 2.7 per 1000 live births over the period 1987 to 1997.3

The natural course of OBPP has been described.2,4–8 However, no previous study has met the ideal design for the natural course of OBPP, which should be a prospective analysis of a demographic population with sufficient follow-up and clear end-stage assessment.9 At birth, it is often not possible to determine whether a newborn infant with OBPP will recover completely,2 or whether subsequent functional impairments will result.10 According to Hoeksma et al.,2 the muscle groups responsible for external rotation of the shoulder and forearm supination are the last to recover, and a high correlation has been found between the function of these muscle groups at 3 months of age and subsequent outcome.

The outcome is usually favourable,11 and the majority of patients with OBPP have been reported to recover completely.1,2 Moreover, children with a persisting OBPP manage daily activities fairly well,7 but often in an asymmetrical and sometimes awkward way.2

In children with a persisting functional impairment, it is important to assess the function of the affected limb repeatedly, as some may develop significant late impairments. Muscular imbalance in the injured arm and shoulder may lead to glenohumeral joint deformity,7 which may progress with age12 and cause permanent changes.13 Partridge and Edwards14 reported pain, impaired sensation, arthritis, and functional limitations, which may interfere with daily activities in adults with OBPP.

With the aim of finding obstetric risk factors for OBPP and of studying the outcome of this perinatal complication, a prospective multicentre study was performed in western Sweden. The obstetric part has been reported previously by Mollberg et al.3,15–17 This paediatric part had the objective of studying the incidence, the recovery process, and the outcome of OBPP and of finding early indicators of recovery.

METHOD The study had a prospective design in a well-defined catchment area. Over a period of 2 years, from November 1999 to
November 2001, all deliveries (n=38 749) were recorded at the seven obstetric units in the health care region of western Sweden and the County of Halland, with a total population of 1 million. For the obstetric part of the study, a protocol was constructed to record the details of the final stage of delivery, with the main focus on manual assistance. These data were reported by Mollberg et al.

In this paediatric part, all newborn infants were seen by a neonatologist, and those with an OBPP were referred to a physiotherapist, who examined the child on six occasions: during the first week and at 2 weeks, 3 months, 6 months, 12 months, and 18 months of age. All the children were examined on the first three occasions and at the last check-up. Examinations at 6 and 12 months were performed only if the infant still had symptoms of an OBPP at the examination at 3 months of age.

A protocol for recording muscle strength, range of motion, and hand preference was used at all examinations. At the last examination at 18 months, functional skills, presence of oedema in the injured arm/hand, occurrence of the trumpet sign (Fig. S1, published online) or a scapula alata (Fig. S2, published online), protective reflexes, and sensibility were assessed. The healthy arm/hand was used as a control. Complete neurological recovery was defined as full muscle strength in the injured arm and hand and no anatomical or functional differences between the affected and non-affected side.

The range of passive joint motion and muscle strength in the affected arm were assessed according to an ordinal scale, modified from the British Medical Research Council’s muscle grading system, and classified from 0 to 5. Zero indicates no muscle activity and 5 indicates normal muscle strength (Appendix SI, published online). Muscle groups performing six different movements in the shoulder (flexion, extension, abduction, adduction, and internal and external rotation), four movements in the elbow (flexion, extension, pronation, and supination), two movements in the wrist (dorsal extension and volar flexion), and two movements in the fingers (flexion and extension) were examined. An evaluation of strength in the abduction and adduction of the thumb in the affected hand was added at 18 months of age.

Muscle function at the first examination was used to localize the anatomical lesion. Muscle strength less than 3 in the shoulder and/or in elbow flexion indicated a nerve injury at the level of C5 to C6, a corresponding weakness in elbow, wrist, and/or finger extension indicated a lesion at C7, and weakness in finger flexion indicated an injury at C8 to T1. A mild impairment was defined as strength more than 2 but less than 5 in at least one muscle group, a moderate impairment was 2 in at least one muscle group, and a severe impairment was defined as less than 2 in at least one muscle group (Appendix SI).

Functional skills were evaluated at 18 months of age by observing how the child performed eight different activities reflecting the function of the shoulder, elbow, hand, and fingers. The tasks were taken from the Callier–Azusa scale and Denver II, and the results were related to what a healthy child is able to perform at 18 months of age. A 5-point scale was used to classify the involvement of the affected arm and hand in the tasks. A score of 1 indicated that the arm and hand were not used at all and a score of 5 meant that they were used in a normal way without any side difference. Scores of 2 to 4 were specially defined for each of the eight exercises (Appendix SII, published online). The child’s hand preference was documented at all examinations by observing spontaneous activities. At the age of 18 months, the grading of persisting impairment was based on a 4-point ordinal scale according to muscle strength (Appendix SI).

The study was approved by the local medical ethics committee of the University of Gothenburg, Sweden. Informed consent was given by the parents.

**Statistical analysis**

The $\chi^2$ test was used to analyse the rate of recovery in different muscle groups. The Mann–Whitney U test was used to compare the strength in different muscle groups in the children who recovered completely and in the children with a persistent impairment. A probability value of less than 0.05 was considered significant.

**RESULTS**

**Incidence**

During the 2-year period, 114 infants (70 males and 44 females), with an OBPP were identified among the 38 749 live-born children in the region, giving an incidence of 2.9 per 1000. When calculated using vaginal deliveries only, the incidence was 3.6 per 1000. The parents of six infants did not wish to participate, and nine children did not complete all the examinations. One girl was excluded because of a fracture of the humerus. This means that the follow-up results from 98 children (86%) can be reported. At 3 months of age, some data were missing for a further five children. The recovery of muscle strength and the predictive value calculations were, therefore, based on 93 patients. The prevalence of persisting OBPP at 18 months of age was 0.46 per 1000 live births.

**Recovery**

The rate of recovery in the 98 children (61 males, 37 females) is shown in Figure 1. At 3 months of age, 49 infants (50%) had regained full function, and at 18 months 80 children (82%) had regained full function. Eighteen children (18%) still had symptoms at the last examination. There were 51 males (64%) and 29 females among the 80 children who recovered, compared with eight (44%) males and 10 females among the 18 children with a persisting OBPP.

The recovery of muscle strength followed a specific pattern, with forearm pronation recovering before forearm supination. This pattern of recovery was the same for the children who recovered completely as for those who still had symptoms of OBPP at 18 months.

The median strength in shoulder external rotation, elbow flexion, and forearm supination at 3 months of age differed significantly between the children who recovered completely and those with a permanent impairment (Table I). Of the 16 children with strength in shoulder external rotation of less than 3 at 3 months of age, 15 still had functional deficits at
18 months, and, of the 20 children with strength in forearm supination of less than 3 at 3 months of age, 17 had functional deficits at 18 months. One child with persistent OBPP did not participate in the functional tests.

**Prediction of recovery at 3 months of age**

At 3 months of age, the positive predictive value of regained elbow flexion, that is the chance that the child would recover completely if the muscle strength in elbow flexion was at least 3, was 100% (confidence interval [CI]=0.94–1.0). When shoulder external rotation and forearm supination were used, the positive predictive values were 99% (CI=0.92–1.0) and 96% (CI=0.88–0.99), respectively. The corresponding sensitivity values were 89%, 96%, and 99%, and the specificity values were 100%, 94%, and 85% respectively.

**Localization of the anatomical lesion**

The lesion was right-sided in 46 (47%) infants and left-sided in 52 (53%). The localization of the anatomical lesion could not be determined in eight of the 80 children who recovered completely, as they had already normalized at the first evaluation by the physiotherapist. Of the remaining 72 children, 61 (85%) had a lesion involving C5 to C6, seven (10%) a lesion involving C5 to C7, three (4/100) a lesion involving C5 to T1, and one child had a lesion involving C8 to T1. Among the 18 children who still had symptoms at 18 months of age, three (17%) had a lesion involving C5 to C6, one with a mild and two with a moderate impairment, four (22%) a lesion involving C5 to C7, one with a mild and three with a moderate impairment, and 11 (61%) a lesion involving C5 to T1, three with a mild, six with a moderate, and two with a severe impairment.

**Outcome at 18 months of age**

Of the 18 children with persisting symptoms at 18 months of age, three underwent nerve reconstruction surgery between the age of 6 and 10 months. The results for these children are presented separately. No other treatments were used except for instructions to the parents to help the child to move the arm and to stimulate the child to actively use it.

**Muscle strength**

Strength in the arm and hand in the 15 non-surgically treated children is shown in Table SIa (published online). Median strength in forearm supination was 3, that is the movement could generally be performed against gravity (range 2–5), and median strength in shoulder external rotation was 4 (range 2–5).

**Range of passive motion**

Four children had reduced shoulder external rotation, six reduced elbow extension, two reduced forearm supination, and one reduced forearm pronation (Table II).

**Sensibility, trumpet sign, and scapula alata**

The parents of the 15 children had not noticed any differences in sensibility between the children's arms. The trumpet sign was present in 12 children and scapula alata in nine.

**Motor development and protective reactions**

One child had not been able to turn over to the side of the injured arm and two children did not crawl before they started to walk. It was not possible to elicit protective reactions forwards or towards the impaired side in one child.

**Functional skills and hand preference**

The assessment of function at 18 months of age is presented in Table SII (published online). One child did not participate in any of these tests, whereas the other 14 used the injured arm and hand quite well but mostly in an asymmetrical way.

**Severity of the injury**

Five children were classified as having a mild, 10 a moderate, and none a severe impairment (Table II).
Outcome in the three surgically treated children

Two children were unable to supinate the forearm and two were able to perform an external rotation in the shoulder only if gravity was eliminated (Table SIb, published online). One child had reduced shoulder external rotation and flexion (Table II). The parents of one child had noted decreased sensitivity to pain and another child had an impaired reaction to cold. The trunpet sign and scapula alata were present in two children. Oedema was present in the hand and fingers in one child and in the forearm and hand in another. One child had not been able to turn over to the OBPP side and two children did not crawl before they started to walk. It was not possible to elicit protective reactions forwards and towards the impaired side in these three children.

All had a reduced capacity to use their injured arm and hand. One child did not use the arm/hand spontaneously but was able to use it as a support when encouraged to do so. None was able to turn over a page in a book with the injured hand. Two were unable to hold a pencil whereas the third child was able to hold a pencil if it was placed in its hand but was not able to scribble. One child was not able to clap his hands at all and the other two used the injured hand only to clap against. Two children were able to hold a raisin if it was placed in their hand and the third child used the pinch grasp to pick up a raisin. None was able to lift the injured hand to the mouth (Table SII). All preferred the healthy hand. One child was classified as having a moderate and two a severe impairment (Table II).

DISCUSSION

The strength of this study was that it is one of few prospective, population-based analyses of children with an OBPP with regular follow-ups with a detailed description of the neurological end stage at 18 months of age. The surgically treated children were reported separately. The incidence of OBPP was 2.9 per 1000 live births. Reported incidences of OBPP vary in the literature.1,2,9 This could be explained by differing inclusion criteria and differences in the obstetric management of deliveries.15

The reported rates of recovery differ between studies. Most children in this study recovered completely, and only 18% had persisting symptoms of the OBPP at 18 months of age. Noetzel et al.6 and Hoeksma et al.2 reported complete recovery in 66% and Michelow et al.4 in 92%. We defined complete recovery as full muscle strength in the arm and no anatomical or functional asymmetry. According to Hoeksma et al.,2 recovery is often poorly or not defined in the literature, which may be one reason for the varying recovery rates reported.

It may, however, be too early to assess outcome at the age of 18 months, as further improvement may occur when the child gets older, although, on the other hand, functional problems may increase with age.2 This especially accounts for the surgically treated patients, as neurological end stage is usually not reached until 2.5 years after surgery. Rossi et al.10 stated that normality determined in the first year of life must be confirmed later, when a more exact evaluation can be performed. In this study, 95% of the patients with an injury involving C5 and C6 recovered completely, whereas 79% of the children with an injury involving C5 to T1 still had symptoms of the OBPP at 18 months of age. Among the children who recovered, only three (4%) had an injury at C5 to T1. This agrees with earlier studies in which it was concluded that lesions of the upper part of the brachial plexus are the most common12,21 and they usually result in milder nerve injuries and have a better prognosis than injuries involving C5 to T1.10,22 In this study, there was only one child with an injury involving C8 to T1, a lesion also reported to be rare in other studies.21
Early prediction of outcome of OBPP would be useful for optimal treatment and for information to the parents. In this study, the time for recovery differed between muscle groups, which was also reported by Hoeksma et al. External rotation in the shoulder and supination of the forearm were the most affected movements and those that recovered last. Persisting weakness in these movements at 3 months of age indicated that some degree of impairment would still remain at 18 months. However, the predictive value was highest when elbow flexion was used. Michelow et al. also found that it was possible to predict recovery at 12 months from function at 3 months of age. They stated that infants who remain profoundly weak at 4 to 6 months run the risk of permanent disability. Noetzel et al. analysed the relationship between patterns of recovery and long-term prognosis. They concluded that infants who have antigravity movements in the biceps, triceps, and deltoid by 3 to 4.5 months of age have a good chance of complete recovery by the age of 12 months. They suggested that detailed strength testing to up to 6 months of age can predict complete recovery and identify the children who are destined for long-term severe disability.

At the start of the study we were not aware of any optimal method for assessing muscle strength in infants. Clark and Curtis23 also noted the lack of reliable methods to test muscle power or resistance in infants and stated that it is difficult to evaluate muscle strength in infants as they cannot actively cooperate. It is also difficult to place the arm in positions that completely eliminate the effect of gravity. We tried to solve the problem by constructing a 6-point ordinal scale modified from the British Medical Research Council’s muscle grading system. An alternative could have been the Toronto score, which has been used to predict outcome of OBPP.

It is also difficult to investigate sensibility accurately in a young child. Only two of the children, both of whom underwent nerve reconstruction surgery, were found to have a sensory impairment. This was in line with the finding by Strömbeck et al. and Anand and Birch, who reported that sensibility was considerably less affected than motor function.

In the functional assessments, we used age-relevant tasks from the Callier–Azusa and Denver II scales. As recommended by Clark et al.,23 we used the healthy arm/hand as a control.

An impaired range of motion was most commonly found in the children with a moderate injury and not in those with the most severe lesions. This could be explained by the fact that a severe OBPP results in a severe and general weakness in the arm and hand, without major imbalance between muscle groups, which is probably an important factor for the development of restricted range of joint motions.

CONCLUSION

About three in every 1000 infants in our population suffered an OBPP, and about 0.5 per 1000 still had functional deficits at 18 months of age. Normal or near-normal muscle strength in elbow flexion, shoulder external rotation, and forearm supination at 3 months of age was almost always associated with complete recovery, whereas reduced strength in these muscles indicated that the child would still have functional impairments at 18 months of age. Most children with a persistent OBPP managed activities of daily living but with asymmetric movements.

ONLINE MATERIAL

Additional supporting information may be found in the online version of this article.

Figure S1: A child with a trumpet sign: the arm is abducted and inward rotated, the elbow is flexed, and the forearm is pronated. Published with permission from the parents.

Figure S2: A child with a scapula alata or winging of the scapula. Published with permission from the parents.

Table S1a: Muscle strength in the arm with obstetric brachial plexus palsy (OBPP) in the 15 non-surgically treated children with remaining symptoms of OBPP at 18 months of age

Table S1b: Muscle strength in the arm with obstetric brachial plexus palsy (OBPP) in the three surgically treated children with remaining symptoms of OBPP at 18 months of age

Table SII: Results of the functional tests described in Appendix SII in the 18 children with remaining symptoms of obstetric brachial plexus palsy (OBPP)

Appendix S1: Ordinal scale to classify and score muscle strength in the injured arm/hand

Appendix SII: Assessment of arm/hand function at 18 months of age. Items A to F should be performed sitting at a table

REFERENCES