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Author: Anguelova, G.V.
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Chapter 2

A cross-sectional study of hand sensation in adults with conservatively treated obstetric brachial plexus lesion

G.V. Anguelova, M.J.A. Malessy, J.G. van Dijk

Abstract

**Aim** Sensory function is assumed to recover almost completely in obstetric brachial plexus lesion (OBPL), and is stated to recover much better than motor function. However, there is no obvious physiological reason why this should be so. Any persistent problems with sensory innervation might contribute to disability. For these reasons, we aimed to assess sensory dysfunction resulting from obstetric brachial plexus lesions (OBPL).

**Method** Adults with conservatively treated OBPL ($n=17$; median age 38y; five males; lesion levels: C5–C6, $n=7$; C5–C7, $n=7$; C5–C8, $n=2$; C5–Th1, $n=1$) and healthy control persons ($n=19$; median age 23y; nine males) were investigated. Sensory function was measured using Semmes-Weinstein monofilaments, two-point discrimination, object recognition, and a locognosia test.

**Results** Scores of the Semmes-Weinstein monofilaments and two-point discrimination, but not object recognition or locognosia, were significantly worse in those with OBPL than in control persons.

**Interpretation** There may be systematic abnormalities in sensory function in adults with conservatively treated OBPL. The existence of these impairments and their contribution to functional impairment needs to be acknowledged.

Introduction

An obstetric brachial plexus lesion (OBPL) is a closed traction injury of the brachial plexus acquired during labour, with an incidence of 0.5 to 2.6 per 1000 live births. Although the prognosis of OBPL was generally considered to be good in over 90% of cases, a systematic literature search showed functional deficits in 20 to 30% of cases, taking study design, population, duration of follow-up, and end-stage assessment into account. Severe OBPL can cause skeletal malformations, cosmetic deformities, behavioural problems (assessed with the Pre-School Behaviour Checklist), and socioeconomic limitations.

Most of these studies focused on motor functions, and few provided details of sensory function. This lack of attention may be due to the perception that sensory function recovers almost completely in OBPL in contrast to motor function. By itself, this discrepancy is surprising, as there are no reasons to assume that sensory and motor axons respond fundamentally different to injury in infants. As a result, widespread sensory dysfunction, as occurs in adults after nerve injury, would therefore be expected. Our first aim was to assess sensory function in OBPL anew and to explore the reasons for the discrepancy between reported and expected results. Secondly, knowledge of the potential for sensory recovery after conservative treatment is relevant with an eye on nerve surgery: after all, should spontaneous recovery of sensation be limited, this might serve as an argument to support surgical intervention. We therefore studied sensory functions in a group of patients with OBPL who had not undergone nerve surgery.

Method

**Participants** Seventeen adults with OBPL participated as well as 19 control persons. Adults were investigated instead of children for ethical reasons and because detailed sensory investigation is hardly feasible in children. Six patients had participated in earlier research projects of the Leiden University Medical Centre Rehabilitation Department and others were recruited through the Dutch Erb’s Palsy Association.
Exclusion criteria for patients and controls were, firstly, the presence of any relevant disorder affecting movement or sensation other than OBPL and, secondly, when nerve repair of the brachial plexus had been performed at any age. Figure 1 shows the number of potentially eligible participants, those examined for eligibility, confirmed eligible, and included in the study. The protocol was approved by the Medical Ethics Committee of the Leiden University Medical Centre. All participants provided informed consent.

Sensory assessment
Sensory function was assessed in both hands with four tests: two-point discrimination (North Coast Medical, Inc., Morgan Hill, California USA), pressure sensation with Semmes-Weinstein monofilaments, locognosia (i.e. the ability to locate sites of touch), and object recognition, all detailed below. A screen prevented participants from seeing their own hand during sensory testing, while investigators could see the hand. Blinding of the observer for which hand was affected was not possible in this study owing to motor deficits in the affected arm (limited supination for example). Sensory stimuli were given to the thumb (C6 dermatome), the index and middle finger (largely C7), and the ring and little finger (C8/T1). Results are expressed quantitatively, and, as results in previous reports were categorized as normal and abnormal, current results are dichotomized as normal or abnormal.

Patients’ arms were categorized as affected and healthy. Hand dominance was based on the participants’ opinion on the matter and corroborated by observing with which hand they wrote. In a previous study on children with OBPL, hand preference was based on the hand using for drawing; we chose writing as more suitable for adults and because drawing and writing preference are highly correlated.

Object recognition
We chose six common objects (a key, a paper clip, a teaspoon, a short pencil, a button, and a coin) for this test. Participants had to name them after manipulating them while deprived of visual feedback. The objects were placed one at a time on the fingertips of the affected side for patients. Hand dominance might affect the results, which raised the question of which hand was to be used for the control persons group. As the affected side is often the non-dominant one in OBPL, the test was performed on the non-dominant side in control persons. One point was awarded for any object recognized correctly. A count lower than six was considered abnormal.

Locognosia
Participants were seated at a table with their supinated forearm resting on the table surface. As stated, a screen occluded the hand being tested from the participant’s vision. A drawing of a hand was placed in front of the participants, on which fingertips were divided in numbered quadrants (Fig. 2a). Separate left- and right-hand versions were used to prevent confusion. A 6.65 Semmes-Weinstein monofilament was used to touch a quadrant for about 2 seconds, and the participant was requested to state the number of the touched quadrant referring to the drawing. When uncertain, participants could request the stimulus to be repeated. No feedback about correctness of the answers was given. Each of the 20 quadrants was examined twice, in a random sequence.

Each correctly identified quadrant was awarded two points; one point was given when the touch was localized either in the correct quadrant of an adjacent finger or in the wrong quadrant of the correct finger. Any other response merited zero points. Scores were then calculated in two ways. The first involved adding points per finger for both repetitions (see Fig. 2a for quadrant numbers): thumb, quadrants 1 to 4; index finger, quadrants 5 to 8; middle finger, quadrants 9 to 12; ring finger, quadrants 13 to 16; small finger, quadrants 17 to 20. There was a maximum of 16 points per finger (four quadrants, two repetitions, two points per correctly identified quadrant). Secondly, points were added per dermatome for both repetitions: dermatome C6, quadrants 1 to 6; dermatome C7, quadrants 7 to 14; dermatome C8, quadrants 15 to 20. The number of quadrants differed per dermatome and thus the maximum score was 24 points for dermatome C6, 32 for C7, and 24 for C8. To account for these differences, percentages were calculated as follows. In patients with OBPL the affected hand score was divided by the uninjured hand score, whereas in control persons the non-dominant side score was divided by the dominant side score. Thus, if the affected hand score for dermatome C7 in a patient with OBPL was 21 points and the unaffected hand score for the same area was 27, the final percentage corresponding to dermatome C7 would be (21/27)×100=77.78%. In uninjured hands, localization ability using this test is not always perfect and
therefore the maximum score may not always be achieved. The locognosia score was considered abnormal when lower than 100%.

**Two-point discrimination**

An NC12776 North Coast Touch-Test® Two-Point Discriminator was used. This is a plastic circular frame with two blunt pins in pairs at variable distances from each other and one unpaired pin. This frame was used to assess both static and dynamic two-point discrimination. We used a test protocol as described by Van Nes and colleagues with several adaptations. According to the protocol, the two-point discriminator was rested gently on the skin without application of any pressure, only the instrument weight. Static examination was performed by applying the ends of the discriminator arms to one point at the distal phalanx. For dynamic examination, the ends of the arms were gently moved from the proximal to the distal end of the distal phalanx, over a distance of approximately 1cm. The distance between the two ends was varied to obtain a threshold value. For this purpose, a participant had to differentiate correctly between the two points at a given distance seven out of 10 times, where catch trials were randomly applied. The adaptations we made to the protocol are as follows. Various distances between the blunt pins were tested in a descending order (from 15mm to 2mm). One data-collecting series was performed for both static and dynamic assessments. On each hand the index finger (C6–C7) and the small finger (C8) were tested, resulting in eight values per participant (two fingers, two hands, static and dynamic testing). The two-point discrimination score was the smallest distance identified for the following sites: static index finger (C6–C7), dynamic index finger (C6–C7), static small finger (C8). The best possible score for each site was the smallest distance between the pins, namely 2.0mm. The scores for these sites were reported separately for the 17 affected hands of the patients with OBPL, the 17 healthy hands of the patients, and the 38 (two times 19 participants) hands of the control persons group. Abnormal sensibility was defined according to Sundholm et al., as a two-point discrimination score higher than 3mm.

**Semmes-Weinstein monofilaments**

The A835-2 Sammons Preston monofilament kit 5PC was used to determine sensibility in six points on each hand (Fig. 2b) using five differently sized monofilaments (marking number 2.83, 3.61, 4.31, 4.56, and 6.65). The filaments were of equal length (38mm) but differed in diameter. Each filament was pushed against the skin, forcing it to bend. The thickness determines its stiffness and hence the applied pressure, being higher for thicker filaments. Participants indicated whether they perceived any touch. The filaments were tested starting from the thickest towards the thinnest. The marking number of the finest filament felt was noted for each site. These results were condensed into three Semmes-Weinstein subscores according to the corresponding dermatome: dermatome C6, the noted Semmes-Weinstein marking number of the point on the thumb in Fig. 2b); dermatomes C6–C7, the noted Semmes-Weinstein marking numbers mean of the two points on the index finger; and dermatome C8, the noted Semmes-Weinstein marking numbers mean of the two points on the small finger. The best score to be achieved for each site is the smallest possible Semmes-Weinstein marking number: 2.83. The scores for these sites were reported separately for the 17 affected hands of the patients with OBPL, the 17 healthy hands of the patients, and the 38 (two times 19 participants) hands of the control persons group. The score was considered abnormal when higher than 2.83, which is equivalent to 0.05g.

**Extent of OBPL**

Arm motor function of all patients was examined by one of the authors (MJAM), an experienced brachial plexus surgeon. Individual muscles were graded according to the Medical Research Council scale; active and passive range of motion was documented; the Mallet scale for shoulder function and the Raimondi scale for hand function were assessed. Subsequently motor function was used to determine the extent of OBPL, classified in three groups: group 1, C5 and C6 damage, with impaired shoulder abduction, exorotation, and elbow flexion; group 2, C5, C6, and C7, with paresis as in the first group but with additional weakness of elbow, wrist and finger extension; group 3, C5 to C8, and C5 to Th1 lesions, with additional wrist and finger weakness. This classification aids the comparison with previous reports.

**Statistical analysis**

Statistics were analysed with SPSS 16.0 (SPSS, Inc. Chicago, IL, USA.). Differences between groups were tested with the Mann–Whitney U test for continuous variables or the χ² test for dichotomous variables. Comparisons were not performed between lesion extent groups owing to the small number.
of participants in each group. We considered a 0.05 significance level too conservative as some of the tests might overlap in the sensory modalities they represent. Thus two-tailed $p$ values of no more than 0.01 were considered statistically significant.

Results

Adults with conservatively treated OBPL and control persons did not differ in demographic characteristics (Table I). The unaffected hand was the dominant one in 14 of 17 adults with conservatively treated OBPL. Two of the three participants in whom the affected hand was the dominant one had a partial C5 to C6 injury; the remaining participant had a total C5 to C6 and partial C7 injury. Of adults with conservatively treated OBPL, 35% were left-handed, whereas only 10% of the control persons group were left-handed. Sensory functional scores were not normally distributed in either the OBPL or the control persons group.

Table II shows results of adults with conservatively treated OBPL and control persons for object recognition and locognosia. Scores for object recognition and locognosia did not differ significantly between the two groups. Table III shows results for two-point discrimination and Semmes-Weinstein monofilaments tests. The two-point discrimination and Semmes-Weinstein tests of the affected hand of adults with conservatively treated OBPL yielded significantly different scores than the hands of the control persons group, concerning worse function. For comparability with previous literature,6–8,10 we additionally present our findings as the number and percentage of adults with conservatively treated OBPL with abnormal results for each of the four modalities.

Discussion

Our main finding is that sensory hand function is abnormal in adults with conservatively treated OBPL, according to the Semmes-Weinstein monofilaments and two-point discrimination test. We therefore conclude that the widely held perception that sensory recovery is generally good in these patients should be revised. First, we will discuss a possible explanation for the apparent discrepancy between this perception and our conclusions. Second, as sensation is of paramount importance in daily tasks performance, our findings support the view that treatment should also be focused on sensation improvement. Finally, no clearly absent sensation areas were found such as may be encountered in adults with severe nerve injuries. We also present a possible explanation for this absence of major sensation ‘gaps’ in OBPL.

How well does sensation recover in OBPL?

Sensory function in OBPL has been reported to be excellent.6–13 Of these reports, five presented original data.6–10 The comparison might be affected by the inclusion of some surgically treated cases, but in four papers operated cases concerned only a small fraction of the total number of cases6–9 and in the fifth paper cases without surgery could be identified.10 We suggest that the apparent discrepancy originates not so much in different results as in a difference in interpretation. For instance, the paper by Anand and Birch10 allowed non-operated cases to be identified. These authors investigated a group of patients of whom 20 had undergone surgery and four had not. Their conclusion was that sensory function restoration was excellent, described as normal limits being found ‘in all dermatomes for at least one modality in 16 out of 20 operated cases’.

Unfortunately, this nuanced definition of excellent sensibility and the definition of the operated group seems to have been lost in later citations of this paper. Six sensory modalities were tested (monofilaments, cotton wool, pinprick, warm sensation, cool sensation, joint position sense and vibration). Healthy participants should, however, have normal results for all six modalities in all dermatomes. The results may be rephrased to read that only three out of 20 participants (15%) had normal sensation for all six modalities. Note that these 20 cases were the operated ones; the four non-operated cases did not recover any sensory function at all.10

Apart from treatment options, the number of affected roots can additionally influence the results: more extensively damaged cases will most likely have worse sensory recovery. In the Anand and Birch study, all four non-operated cases had lesions of all five nerve roots.10 Except for the paper by Sundholm and colleagues,6 who described functional groups, all the other articles expressed the extent of the lesion through the roots which were involved. The proportion
of patients with a C5 to C6 lesion was higher in these three studies, though the proportion of patients with a C5 to C8 and C5 to Th1 lesion was higher as well. The study populations in these articles are thus more or less comparable to ours, though the conclusion was mostly drawn that sensory function had recovered excellently. Of note, Sundholm and colleagues expressed caution about the purported excellent recovery of sensibility, and acknowledged the impaired tactile sensibility, especially in participants with complete plexus lesions.

The nature of nerve lesions in OBPL
As mentioned, the present study did not show evident skin areas of severely abnormal sensation, and neither did previous studies. For example, the locognosia test in our study showed that localizing touch is not significantly different from the control persons group. Our findings agree with Colon and colleagues; there is reasonably good sensation in skin areas in which profound deficits might be expected. The absence of such major ‘gaps’ in sensation in OBPL may be explained partly by the fact that in most infants with OBPL there is not an anatomical gap between two torn nerve stumps. Such a true rupture occurs frequently in traumatic brachial plexus lesions in adults. Instead, the stretched and damaged nerve in infants forms a neuroma-in-continuity, which is a tangled mass of connective scar tissue and outgrowing, branching axons. Even in the most severe OBPL, at least some axons are likely to pass through the neuroma-in-continuity and reach the nerve distal to the lesion site. This ability to cross the neuroma might be attributable to the superior ability of the peripheral nervous system in infants to regenerate, compared with that in adults.

Most patients with OBPL have a degree of functional motor recovery, and it is well known that some motor axons form functional connections in almost all muscles in OBPL. This is even evident at the age of 3 to 6 months, when the biceps muscle shows reinnervation even in the face of severe paresis. In short, the motor findings in OBPL exhibit a degree of continuity to all muscles, in contrast to upper plexus lesions in adults, in whom some muscles may remain paralytic for life.

In summary, spontaneous motor repair and sensory repair in OBPL show a striking similarity, in that there are no myotomes or dermatomes that remain completely denervated. The latter pattern is what most physicians would expect in adult cases of severe nerve injury. We hypothesize that the nature of the nerve lesion in OBPL and adults, namely a neuroma-in-continuity versus partial or complete nerve rupture, gives rise to a major difference in clinical expression. In OBPL, reinnervation usually occurs to some degree. Thus, rather than concluding that motor and sensory findings differ significantly in OBPL, we contend that they share a similar clinical pattern.

Limitations and consequences
The unaffected hand was dominant in all 17 adults with conservatively treated OBPL except for three, two of them having a partial C5 to C6 injury and one having a total C5 to C6 and partial C7 injury, which confirms previous reports in the literature. Prevalence of left-handedness is considered to be approximately 10% in a normal population, which corresponds with our findings in the control persons group.

Possible drawbacks of this study are the small sample size. Therefore a comparison was not performed between the lesion extent groups. The high non-participation rate was probably due to patients being asked to take part in a separate study involving electrical stimuli. Also, no criterion standard exists for the assessment of the severity of the nerve lesion in OBPL. A minor issue may be that sensory tests require participants to supinate their hand, and that these participants supinated the OBPL hand with their healthy hand. Future research may be directed at OBPL pathophysiology: in which dermatomes do axons passing the neuroma-in-continuity end up? Through which nerves and roots do the regenerated fibres run? Is there sensory misrouting, and can this be demonstrated and quantified? Another avenue for future research is the consequences of sensory dysfunction for the quality of life in patients with OBPL.

Acknowledgements
We thank colleagues from the Clinical Neurophysiology and Rehabilitation Department, C Jerosch-Herold for offering us her locognosia test protocol, and R Post for his Semmes-Weinstein monofilaments test protocol.
References


Figure 1: Flow chart indicating the number of potentially eligible participants, those examined for eligibility, confirmed eligible, and included in the study. Potentially eligible patients were asked to participate in the current study and an associated study involving electrical stimuli as part of the same visit. This led to several participation refusals. *Competing study involving electrical stimuli.

Potentially eligible patients (n = 48)

Assessed for eligibility (n = 20)

Confirmed eligible (n = 17)

Included in the study (n = 17)

Refused to participate (n = 28) *

Excluded (n = 3)
  • Nerve repair brachial plexus (n = 2)
  • Age under 18 (n = 1)

Figure 2: (a) The areas where a Semmes-Weinstein monofilament was applied to determine locognosia in each participant. The different dermatomes are separated by dotted lines. (b) The six locations where the monofilaments of the Semmes-Weinstein test for sensory function were applied. The different spinal root areas are separated by dotted lines. We analyzed differences between the median for the three clusters of points: the thumb (C6), the index finger (C6–C7), and the small finger (C8).
Table 1: Demographic details of adults with conservatively treated obstetric brachial plexus lesion (OBPL) participants and control persons.

<table>
<thead>
<tr>
<th></th>
<th>OBPL total number</th>
<th>Control total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBPL gender</td>
<td>17 (9M/8F)</td>
<td>19 (9M/10F)</td>
</tr>
<tr>
<td>Median age years</td>
<td>38 (20–58)</td>
<td>23 (20–55)</td>
</tr>
<tr>
<td>Median body mass index (kg/m²)</td>
<td>25 (18–35)</td>
<td>21 (18–25)</td>
</tr>
<tr>
<td>Dominant hand</td>
<td>11/6</td>
<td>17/2</td>
</tr>
<tr>
<td>Affected hand</td>
<td>9/8</td>
<td>—</td>
</tr>
<tr>
<td>OBPL lesion level</td>
<td>7 (C5–C6)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>7 (C5–C7)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>2 (C5–C8)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>1 (C5–Th1)</td>
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</table>

Table 2: Medians (10th and 90th centiles) from the object recognition and the locognosia tests for adults with conservatively treated obstetric brachial plexus lesion (OBPL) participants and control persons. Object recognition is presented as the number of a maximum of six objects recognized correctly. Locognosia is presented as the score of the affected hand as a percentage of that of the healthy hand. For control persons results are presented similarly, but now the score of the non-dominant hand is expressed as a percentage of that of the dominant one.

<table>
<thead>
<tr>
<th></th>
<th>Observe persons</th>
<th>OBPL, healthy side (n=17)</th>
<th>OBPL, OBPL side (n=17)</th>
<th>p (OBPL side vs control persons)</th>
<th>p (OBPL side vs healthy side)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object recognition</td>
<td>6.0 (3.2–6.0)</td>
<td>6.0 (6.0–6.0)</td>
<td>6.0 (0.7–10.0)</td>
<td>0.036</td>
<td>0.036</td>
</tr>
<tr>
<td>Control persons</td>
<td>6.0 (3.2–6.0)</td>
<td>6.0 (6.0–6.0)</td>
<td>6.0 (0.7–10.0)</td>
<td>0.036</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Table 3: Medians (10th and 90th centiles) from the two-point discrimination and Semmes-Weinstein tests for control persons and obstetric brachial plexus lesion (OBPL) participants’ healthy and OBPL sides. Two-point discrimination is presented as subscores with a minimum and best score of 2.0mm. Semmes-Weinstein is presented as subscores with a minimum and best score of 2.83.

<table>
<thead>
<tr>
<th></th>
<th>Control persons, both hands (n=38)</th>
<th>OBPL, healthy side (n=17)</th>
<th>OBPL, OBPL side (abnormal number)</th>
<th>p (OBPL side vs control persons)</th>
<th>p (OBPL side vs healthy side)</th>
</tr>
</thead>
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<tr>
<td>Two-point discrimination</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Static index finger (C6–C7)</td>
<td>3.0 (2.0–4.0)</td>
<td>4.0 (2.0–12.0)</td>
<td>13</td>
<td>0.001*</td>
<td>0.104</td>
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<td>Dynamic index finger (C6–C7)</td>
<td>2.0 (2.0–3.0)</td>
<td>3.0 (2.0–5.2)</td>
<td>8</td>
<td>0.001*</td>
<td>0.267</td>
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<td>Static little finger (C8)</td>
<td>4.0 (2.0–6.4)</td>
<td>4.0 (2.0–20.0)</td>
<td>14</td>
<td>0.001*</td>
<td>0.025</td>
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<tr>
<td>Dynamic little finger (C8)</td>
<td>4.0 (2.0–3.2)</td>
<td>3.0 (2.0–8.8)</td>
<td>6</td>
<td>0.001*</td>
<td>0.284</td>
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<tr>
<td>Semmes-Weinstein</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root C6</td>
<td>2.83 (2.83–3.61)</td>
<td>2.83 (2.83–4.31)</td>
<td>13</td>
<td>0.001*</td>
<td>0.028</td>
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<td>Roots C6–C7</td>
<td>2.83 (2.83–3.22)</td>
<td>3.61 (2.83–4.60)</td>
<td>15</td>
<td>0.001*</td>
<td>0.020</td>
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<tr>
<td>Root C8</td>
<td>2.83 (2.83–3.12)</td>
<td>3.35 (2.83–4.09)</td>
<td>12</td>
<td>0.001*</td>
<td>0.023</td>
</tr>
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*p<0.01.