Nerve Transfers in Birth Related Brachial Plexus Injuries: Where Do We Stand?

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KEYWORDS

• Obstetrical brachial plexus palsy • Erb's palsy • Nerve graft • Nerve transfer • Neurotization

KEY POINTS

- Birth-related or obstetrical brachial plexus palsy (OBPP) differs from adult brachial plexus palsy in important ways.
- Interpositional nerve grafting remains the mainstay of operative treatment for OBPP.
- Unlike in adults, outcomes after nerve grafting in infants are very good.
- Good indications for distal nerve transfers in OBPP include late presentation (>12 months of age), isolated nerve deficits, and absence of proximal roots for grafting.
- The role of distal nerve transfers as a primary reconstructive strategy for Erb's palsy (C5-C6 injuries) remains unknown.

INTRODUCTION

Birth-related, or obstetrical, brachial plexus palsies (OBPP) occur in approximately 1 in 1000 live births.[1] Risk factors associated with OBPP include greater fetal weight, maternal diabetes, shoulder dystocia, and difficult delivery requiring forceps or vacuum suction.[2–5] The most common mechanism involves a traction injury to the brachial plexus during the last stage of a vaginal vertex delivery, when the infant's head is laterally displaced away from the shoulder.[2–5] Less commonly, OBPP is seen after breech delivery and cesarean section.[6,7] Patterns of birth-related brachial plexus injury include the upper (Erb's) palsy (C5, C6 ± C7), total palsy (C5, C6, C7, C8 ± T1), and intermediate palsy (C7, ±C8, T1).[8] Isolated injury to the lower plexus roots (C8-T1), traditionally known as Klumpke's paralysis, is exceedingly rare.[9]

There is a wide spectrum of severity in OBPP, and many infants with a birth-related brachial plexus injury recover satisfactory function spontaneously without need for operative intervention.[7,10–12] However, only those children with the mildest neurologic injury, who demonstrate complete neurologic recovery before 1 month of age, go on to develop a truly normal limb.[13] When visible differences in the movement between the upper limbs persist beyond this time frame, long-term differences in appearance and function of the affected limb are expected. Such differences can include limb length discrepancy, joint contractures, glenohumeral dysplasia, and subtle differences in upper limb coordination, even when functional recovery is otherwise excellent.[14–16]

Approximately 10% to 30% of infants with OBPP require surgical intervention owing to unsatisfactory motor recovery.[13,17–19] However,

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indications for surgical intervention and specific reconstructive approaches in OBPP remain controversial and vary widely by institution. Furthermore, the assessment and management of OBPP differs fundamentally from brachial plexus injuries in adults and older children owing to several factors, such as greater neuroregenerative capacity and cortical plasticity, shorter limb length, and differing therapy approaches in infants.[20] The traditional approach to brachial plexus reconstruction in OBPP entails neuroma resection and interpositional nerve grafting, which may be combined with extraplexal nerve transfers depending on the severity of the lesion and availability of proximal cervical roots for grafting.[13,18,21–26] Intraplexal distal nerve transfers, now widely used as a primary surgical approach for adult brachial plexus injuries, have only recently been applied as a primary approach to reconstruction in OBPP. The purpose of this article is to review the available evidence for use of distal nerve transfers in infants with birth-related brachial plexus injuries in the broader context of OBPP management.

PRIMARY SURGICAL MANAGEMENT USING INTERPOSITIONAL NERVE GRAFTING ± NERVE TRANSFERS (CONVENTIONAL APPROACH)

Surgical Indications and Timing

Total plexus palsy

Most surgeons agree that infants with T1 involvement who fail to show rapid recovery, and/or presence of Horner's syndrome, are indications for early surgical intervention at 3 months of age or younger.[4,13,27–29] Unlike in adults, recovery of T1 function can reliably occur after early interpositional nerve grafting and/or extraplexal transfers, and is the first priority in the surgical reconstruction of OBPP.

Upper plexus palsy

More debate exists as to the timing and indications for surgical intervention in infants where T1 is intact. Absence of elbow flexion at defined time points, such as 3 months[30] or 5 months,[13] and the Hospital for Sick Children algorithm[29,31] (**Fig. 1**), are commonly used indications. The Hospital for Sick Children algorithm was developed to identify those children who are likely to develop poor functional recovery, while minimizing the false-positive and false-negative predictions. In this approach, children who fail the "test score" at 3 months of age, who fail to progress in their motor recovery between 3 and 6 months of age, who fail the "cookie test" at 9 months of age, or demonstrate poor shoulder recovery by 9 months of age are offered a primary nerve operation.[7,29,31] The "test score" is calculated at 3 months of age based on 5 movements (elbow flexion, and elbow, wrist, finger, and thumb extension) that together were found to statistically limit the false prediction rate for poor recovery to 5.3%.[7] The "cookie test" evaluates the ability of the infant to bring their hand to their mouth against gravity, with the shoulder held in adduction and with less than 45° of neck flexion.[29,31]

Preoperative Evaluation

Once the decision to proceed with a primary nerve operation has been made, preoperative computed tomography or magnetic resonance myelography is performed to screen for cervical root avulsion.[1,32–35] In the setting of OBPP after a vaginal vertex delivery, ruptures (postganglionic injuries) are frequently seen in the upper plexus, whereas root avulsions (preganglionic injuries) are more common in the lower plexus.[4,36,37] The presence or absence of root avulsion has implications for reconstruction, because avulsed roots have no capacity for spontaneous regeneration and cannot serve as donors for interpositional nerve grafting.[37] Root avulsions in the upper plexus are more frequently seen in the setting of OBPP after a breech delivery.[38,39]

A preoperative diaphragmatic ultrasound examination may also be obtained to evaluate the integrity and function of the phrenic nerve.[18] We routinely obtain this study in our center.

Surgical Techniques

The mainstay of brachial plexus reconstruction in OBPP is neuroma excision and interpositional nerve grafting.[13,18,21–26] Extraplexal nerve transfers may also be performed if there are insufficient cervical roots to act as donors for nerve grafting or if there is insufficient graft material available to accomplish the desired reconstruction. Specific reconstructive algorithms vary between surgeons and institutions, but there is overall consensus that the primary target for reinnervation in a total plexus injury is the lower trunk, and that the reconstruction should be anatomic when possible.[18,27,40,41] Detailed descriptions of the surgical approaches for interpositional nerve grafting and extraplexal transfers in OBPP have been published elsewhere,[18,27,40–44] and are not the focus of this article. A brief overview is provided here to set the broader context of OBPP management for later discussion of nerve transfers.

Interpositional nerve grafting

Sural nerve harvest The sural nerves are the primary source for nerve graft, and can be