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Current Treatment of Obstetric Brachial Plexus Injury: A Review Article

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Abstract

An injury of the obstetric brachial plexus (OBPI) is a disorder of the peripheral nervous system. The incidence of OBPI decreased by 47.1% over the sixteen-year study period, from 1.7 to 0.9 cases per 1000 live births. In Indonesia, the incidence of OBPI is 0.141%. Although most babies recover spontaneously in the first 3 months of life, 20-30% suffer from permanent functional deficits, which significantly impairs their quality of life, meaning a small number remain with poor recovery that requires exploration of the surgical brachial plexus. This study aims to examine the latest developments in OBPI management and rehabilitation to provide a more comprehensive understanding of the best approach in improving patient recovery. The research uses a literature review method with a descriptive-analytical approach. Data were collected from a variety of relevant scientific literature, using purposive sampling techniques to ensure the validity of the sources. Data analysis was carried out by the content analysis method to identify the latest patterns and trends in OBPI treatment. The results showed that conservative treatments, such as physical therapy, electrotherapy, and kinesiotaping, were effective in preventing contractures and improving upper limb function. On the other hand, operative interventions, such as microscopic reconstruction, provide significant results in patients with severe injuries. A multidisciplinary approach involving physiotherapists, neurosurgeons, and pediatricians is highly recommended to achieve the best results. The conclusion of this study is that a comprehensive approach, starting from early diagnosis to coordinated treatment, is the key to the success of OBPI management. The implications of this research include improving clinical understanding, developing practical guidelines, and educating medical personnel and patients' families. This review will explain the latest updates on OBPI management and rehabilitation.

Keywords: *Obstetric brachial plexus injury, treatment, nerve injury, contracture, neonatal nerve injury.*

Introduction

Obstetric Brachial Plexus Injury (OBPI) or Obstetrical Brachial Plexus Palsy (OBPP), similar to Perinatal Brachial Plexus Palsy (PBPP) or Neonatal Brachial Plexus Palsy (NBPP), is a peripheral nervous system disorder and occurs in as many as 0.4% of baby born. It is considered a rare, unpredictable, and unavoidable upper limb injury (Al-Mohrej et al., 2018). Because there is no universally accepted name for this condition, the term Obstetrical Brachial Plexus Palsy (OBPP) is commonly used worldwide (Phua et al., 2012).

Before the 2000s, the incidence of OBPI was 4.6 per 1000 live births (Hoeksma et al., 2000).Recently, the incidence of OBPI fell dramatically, paralleled by a significant increase in the cesarean delivery rate. Systemic changes in obstetric practice would have contributed to these trends. It dropped 47.1% over the 16-year study period, "The rate of cases per 1000 live births has decreased from 1.7 to 0.9 (DeFrancesco et al., 2019). In Indonesia, the incidence of OBPI was 0.141%. All were Erb palsy and single pregnancy, were 12.5% shoulder dystocia, and 6.25% clavicle fracture (Handoyo & Ismiarto, 2010). Among newborns with shoulder dystocia, clavicle fracture is not associated with a significant change in the risk of OBPI (Gandhi et al., 2019).

The OBPI is associated with macrosomia, shoulder dystocia, and mechanical extraction. It occurs more often in newborns by vaginal delivery (Endres et al., 2015). A prenatal ultrasound finding of a difference in fetal abdominal (AC) to head circumference (HC) ≥ 50 mm associated with shoulder dystocia, female, black, and Hispanic subgroups, and it had moderately increased risks of OBPP and also various factors like foot presentation, transverse fetal position, vacuum, forceps, breech/foot extraction, birth weight ≥3,500 g, asphyxia, and severe asphyxia. Sectio cesarea tends to have a protective effect (Handoyo & Ismiarto, 2010).

When a majority of affected infants recover spontaneously by 3 months, 20-30% of them suffer permanent functional deficits that significantly impair their quality of life (Polcaro et al., 2023).

Currently, there is no official consensus on the management and rehabilitation of OBPI. Therefore, this review will explain the latest update on the management and rehabilitation of OBPI.

Anatomy

The brachial plexus is a network of nerves that provides both motor and sensory innervation to the upper extremity. It is formed by the anterior primary rami of spinal nerves C5 through T1, and is divided into rami/roots, trunks, divisions, cords, and terminal branches, from proximal to distal. The trunks of the brachial plexus are located within the posterior triangle of the neck, between the middle and anterior scalene muscles. Together with the axillary artery, the brachial plexus forms a large neurovascular bundle that travels through the axilla to supply the upper extremity (Polcaro et al., 2023).

Table 1. Functional impairment by level of injury (O'Berry et al., 2017).

Level of Injury	**Muscle Involvement**	**Weakness/Functional Impairment**
C5	Deltoid, biceps brachialis	Shoulder abduction Shoulder external rotation Elbow flexion
C6	Biceps, brachialis, brachioradialis	Elbow flexion Wrist ectension Forearm suppination
C7	Triceps, wrist extensors, wrist flexors, finger extensors	Elbow extension Wrist extension/flexion Finger flexion
C8	Thenar muscles, wrist flexors	Wrist flexion Finger flexion
T1	Lumbricals	Thumb/finger abduction
	Interossei	Thum/finger adduction

The brachial plexus is a network of nerves that provides both sensory and motor functions to the upper limb, including the scapular region. The plexus is made up of various named areas based on how it is formed, As it travels through the posterior triangle of the neck, it enters the axilla and then extends into the arm, forearm, and hand. The brachial plexus roots, which are the ventral rami from spinal nerves C5 through T1, come together and allow their fibers to intermingle, forming superior, inferior, and middle trunks (Polcaro et al., 2023).

Epidemiology

The study investigated the occurrence of obstetric brachial plexus injury (OBPI), described its natural course, and reported on the frequency of shoulder contracture. Between 1988 and 1997, 13,366 children aged 30 weeks or more were born at the Academic Medical Center, Amsterdam. Out of the total cases, 62 patients had an OBPI, which accounts for 4.6 per 1000 cases. Among these cases, complete neurological recovery was observed in 72.6% of patients. However, half of them experienced delayed recovery, which took more than three weeks, with an average recovery time of 6.2 +/- 3.1 months. In at least one-third of the children who experienced delayed recovery and at least two-thirds of those with incomplete recovery and shoulder

There was a significant decrease in the incidence of birth trauma in the United States which coincided with a notable increase in the rate of cesarean deliveries. These trends may have been influenced by systemic changes in obstetric practices. The database yielded a total of 5,564,628 sample births extrapolated to 23,385,597 population births. The population incidence of OBPI dropped 47.1% over the 16-year study period, from 1.7 to 0.9 cases per 1000 live births (DeFrancesco et al., 2019). Obstetric brachial plexus injury occurs in 0.3% of births. The current recovery rate stands at 84%, which means that out of 1,000 births, there are only 0.5 permanent injuries (Backe et al., 2008). In

Canada, OBPI incidence was 1.24 per 1000 live births, consistent from 2004 to 2012. The factors that strongly increase the risk of Obstetric Brachial Plexus Injury (OBPI) are humerus fracture, shoulder dystocia, and clavicle fracture. However, Most infants with OBPI (55%–60%) were not referred at birth. Among those referred, 28% had good timing of assessment, and 66% had satisfactory (Coroneos et al., 2016).

In a large study, 9% of infants with NBPP also had a clavicle fracture at birth. However, the severity of brachial plexus injury did not correlate with the presence of a clavicle fracture (Leshikar et al., 2018). .Another study suggests that clavicle fracture is not associated with a significant change in the risk of OBPI among newborns with shoulder dystocia (Gandhi et al., 2019).

In Indonesia, a retrospective study of the characteristics and risk factors of OBPP was conducted in Hasan Sadikin Hospital, Bandung, from January 2002 to April 2007. The incidence of Obstetric Brachial Plexus Palsy (OBPP) was found to be 0.141%. All cases were related to Erb's palsy and occurred in a single pregnancy. Among the cases, 68.75% involved head-occiput posterior presentation, 50% resulted from spontaneous birth, 18.75% had meconium staining, 62.5% had a birth weight ≥3,500 g, 56.25% were male, 68.75% experienced asphyxia, 12.5% had shoulder dystocia, and 6.25% had clavicle fracture (Handoyo & Ismiarto, 2010).

Research Methods

This study is a literature review that discusses obstetric brachial plexus injury (OBPI). This study uses a descriptive-analytical approach to review the scientific literature related to events, risk factors, mechanisms of injury, diagnosis, classification, and conservative and operative treatment methods. The population used in this study is all scientific literature relevant to the topic of OBPI, both in the form of international journals, research reports, and other medical publications. Samples were taken using purposive sampling techniques, which is to select studies that meet certain criteria, such as discussing OBPI treatment, injury classification, and rehabilitation.

Data Collection Technique

Data is collected in the following ways:

1. Searching scientific databases such as PubMed, ScienceDirect, and Google Scholar used relevant keywords, such as "Obstetric Brachial Plexus Injury," "treatment," "nerve injury," and "neonatal brachial plexus palsy."
2. Download relevant articles and select based on specified criteria.
3. Organize the data obtained into a thematic format according to the topics discussed in the research.

Data Analysis Technique

The data was analyzed using the content analysis method with the following steps:

1. Read the entire selected literature to understand the context and the main results.
2. Identify emerging themes or patterns related to OBPI treatment.
3. Compare the results of the study to find generalizable conclusions.
4. Arrange tables or graphs to present quantitative data (such as treatment success rates or incidence percentages).
5. Interpreting data by referring to theories and previous research results.

With this method, the study aims to provide a comprehensive overview of the latest developments in OBPI treatment and rehabilitation.

Results and Discussion

Mechanism of Injury and Risk Factor

During delivery, the brachial plexus complex may become unilaterally injured when lateral traction is applied to the head for shoulder clearance. In some cases, the affected arm of an infant may exhibit reduced movements and asymmetrical primitive reflex responses due to nerve involvement that can range from a stretch injury to a complete avulsion (O'Berry et al., 2017).

There are some risk factors that can lead to plexus injuries during childbirth. These include shoulder dystocia, macrosomia, diabetes, vacuum extraction, and forceps delivery. However, it is difficult to accurately predict the likelihood of these injuries based on these factors alone. In fact, almost half of all plexus injuries occur during spontaneous vaginal deliveries that last for 30 minutes or less during the second stage of labor. When it comes to determining the likelihood of permanent injury, there are some additional risk factors to consider. These include a high maternal body mass index, shoulder dystocia, fractured humerus, and fetal asphyxia. Interestingly, clavicle fractures were more common in cases where the injury was transient, which may suggest a protective effect. But, plexus injury is not well predicted by known risk factors. A multicenter study of prenatal ultrasound found a difference in fetal abdominal (AC) to head circumference (HC) $\geq$ 50 mm, while uncommon is associated with shoulder dystocia (Endres et al., 2015).Female, black, and Hispanic subgroups had moderately increased risks of OBPI (DeFrancesco et al., 2019).

Classification

The brachial plexus is a complex network of nerves that can be injured at multiple levels, causing various pathological changes. OBPI has further been classified into four categories, referred to as the Narakas classification. The four Narakas classification categories are (1) upper plexus palsy (i.e., Erb's palsy, C5-C6 spinal

Table 2. Narakas classification of neonatal brachial plexus palsy (Al-Qattan et al., 2009).

Narakas Classification	Anatomical Location	Functional Deficit
Group I	C5-C6	Shoulder abduction, external rotation, elbow flexion, forearm suppination
Group II	C5-C7	As above, plus wrist and digital extension
Group III	C5-T1	Flail ectremity
Groupp IV	C5-T1	Flail Extremity with Horner's Syndrome

Nerve roots and extended upper plexus palsy (i.e., C5-C7 spinal nerve roots), (2) intermediate plexus palsy (C7 and sometimes C8-Th1 spinal nerve roots), (3) lower plexus palsy (i.e., Klumpke's palsy, C8-Th1 spinal nerve roots), and (4) total plexus palsy (C5-C8 and sometimes Th1 spinal nerve roots) (Al-Qattan et al., 2009).

Summarizes OBPI according to the Narakas classification and shows representative images of the clinical presentation of NBPP (Lindell-Iwan et al., 1996).

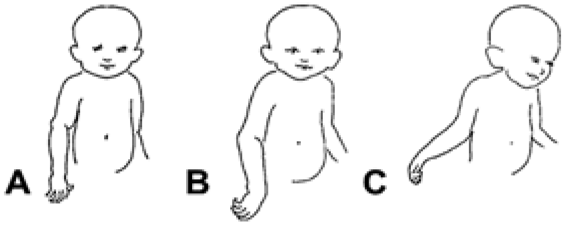

Figure 2 Representative images of the clinical appearance of neonatal brachial plexus palsy: A) mild, C5-C6 spinal nerve roots; B) intermediate, C5-C7 spinal nerve roots; C) severe, C5-Th1 spinal nerve roots (image adapted from16).

The pathological classification of brachial plexus injury was classified using MR imaging into five types: (I) nerve root injury in continuity (including Sunderland grade I-IV injury); (II) postganglionic spinal nerve rupture with or without proximal stump; (III) preganglionic root injury (visible); (IV) preganglionic nerve root injury and postganglionic spinal nerves injury; (V) preganglionic root injury (invisible) (J. Yang et al., 2014).

Brachial Plexus (BP) injuries can be further classified by pathological outcomes, such as neuropraxia, axonotmesis, and neurotmesis, which describe axonal loss lesions, demyelinating lesions, or a combination respectively. Neuropraxia lesions follow intact nerve fibers and damage to the myelin sheath. Axonotmesis observes axonal loss with the preservation of supporting connective tissue structures. Neurotmesis, the most severe outcome, is characterized by a complete transection of the axons and supporting connective tissue structures (Orozco et al., 2020).

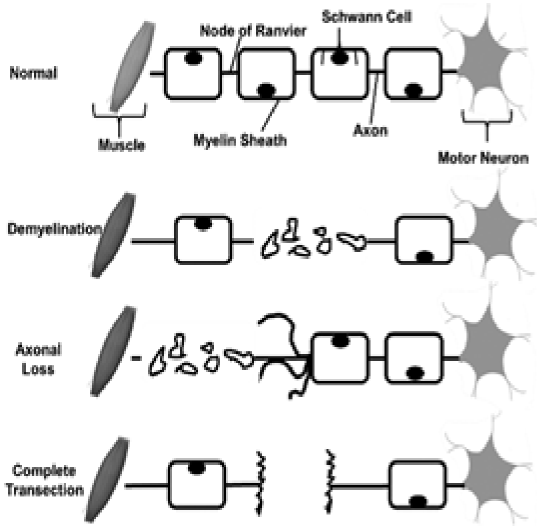

Figure 3. Classification of brachial plexus injury based on pathological outcomes.

Diagnose

The diagnosis of NBPP is clinically apparent, and no ancillary exam is necessary. Plain X-rays can be helpful for the detection of concurrent lesions, such as clavicular fractures or phrenic paralysis (Terzis & Kokkalis, 2009). The clinical presentation can be classified according to the anatomic structures compromised. In around two-thirds of cases, the right side is impacted due to the most common fetal presentation. Although bilateral cases are rare, they can still occur in up to 5% of cases but are typically asymmetric (van Dijk et al., 2001).

An isolated lesion of the upper trunk (C5-C6), also known as Erb's palsy or Narakas grade I injury, is common. This injury results in a typical limb posture called "waiter's tip." The arm is in a position where it is adducted, internally rotated, and the elbow is extended while the wrist is flexed. On the affected side, the Moro reflex is absent, while the grasp reflex is normal. The motor deficit includes an inability to perform shoulder abduction, external rotation, and elbow flexion. The biceps tendon reflex is lost, but pain sensibility is usually preserved (Al-Qattan et al., 1995).

Figure 4 Patient with an upper brachial plexus lesion on the right side exhibits the characteristic "waiter's tip" posture, wherein the arm is adducted and internally rotated, the elbow is extended, and the wrist is flexed.21

Upper and middle trunk (C5-C7) lesions, or Narakas grade II injury, account for one-third of the cases. In Erb's palsy, motor deficits are commonly observed along with compromised elbow and wrist extensions. Finger flexion is still present but weaker than on the healthy side. Additionally, all tendon reflexes are absent in the affected limb. If pain sensibility is lost in the thumb or middle finger, it may indicate a poor prognosis (Al-Qattan & Al-Khawashki, 2002).

Figure 5. Patient with a total brachial plexus lesion on the right side showing a flailing arm and Horner sign, characterized by miosis, partial ptosis, and enophthalmos.

Total plexus lesions (C5-T1) are seen in 17% of the cases. Some patients can still show minor finger movements and are classified as Narakas grade III injury. Narakas grade IV is a type of brachial plexus injury that affects the arm, causing abnormal sensitivity and a condition called Claude-Bernard-Horner syndrome, which involves the eyes. This injury may also result in Klumpke's palsy, which affects the lower plexus and is less common. Most reported cases of Narakas grade IV involve total plexus lesions, but upper plexus function may eventually recover. Patients with this injury may develop a late posture of elbow flexion, wrist extension, and supination, which is known as "beggar's hand".

Imaging

Magnetic resonance imaging is the best method to visualize the anatomy and problems of the brachial plexus. It helps to locate nerve damage, which is crucial for planning appropriate treatment. MRI also shows nerve continuity, with or without neuroma formation, and can even reveal a completely disrupted/avulsed nerve. This helps determine the severity of nerve injury and is useful for preoperative planning.

Computed tomography myelography has a higher spatial resolution for nerve root visualization than MR myelography. However, it is an invasive procedure and may have difficulties in showing some pseudo meningocele that have little or no communication with the dural sac (Caranci et al., 2013). Interpretation - Root avulsion(s) on MRI and flail upper extremity at birth are excellent indicators for nerve surgery in brachial plexus birth injury. Shoulder pathology develops very early in permanent BPBI (Grahn et al., 2019).

Medical professionals currently rely on electrodiagnostic techniques, such as nerve conduction and electromyography studies to diagnose patients. In identifying preganglionic injuries, electrodiagnostic testing is more accurate and specific than imaging. This finding is particularly important in lower nerve roots, as preganglionic lesions in the lower plexus are a recognized indication for early intervention (Smith, Chang, et al., 2018). Diffusion tensor magnetic resonance imaging (DTI) is a technique that can help characterize the microstructure of tissues and provide measures of myelination, axon diameter, fiber density, and organization. This can be particularly useful in assessing the health and condition of the roots of the brachial plexus (Wade, Whittam, et al., 2020).

Treatment

Two main treatments/therapies for OBPI rehabilitation were identified: conservative treatment and surgical treatment. The successful treatment of patients with OBPI requires a thorough understanding of the anatomy of the brachial plexus and the pathophysiology of nerve injury. Nerve injury during the perinatal period can cause a weak or paralyzed upper extremity in newborns. To develop a treatment plan, a series of physical examinations, along with a detailed maternal and perinatal history, are essential. The plan may involve occupational/physical therapy, rehabilitation management, nerve reconstruction, and secondary musculoskeletal surgeries (Wade, Bligh, et al., 2020).

It is essential to refer patients to interdisciplinary specialty clinics as early as possible for the latest advancements in clinical care. It is also essential to raise awareness of the psychosocial and patient-reported quality-of-life issues associated with chronic disablement of OBPI (L. J.-S. Yang, 2014).

OBPI can result in persistent deficits for those who develop it. Recent advancements in surgical techniques have led to the development of safe and reliable treatment options for neonatal brachial plexus palsy (NBPP). Mounting evidence supports the safety and effectiveness of surgery for patients with persistent NBPP. Despite this, primary nerve surgery for NBPP is still underused. Surgery is just one aspect of the multidisciplinary care required for NBPP. Early referral and implementation of interdisciplinary strategies provide the best chance of functional recovery for these children. Primary care physicians, nerve surgeons, physiatrists, and occupational and physical therapists must work together to modify current treatment paradigms and deliver improved quality care to neonates and children affected by NBPP (Smith, Daunter, et al., 2018).

The modified Mallet Classification, Toronto Test Score, and Active Movement Scale are reliable instruments for assessing upper extremity function in patients with Perinatal brachial plexus palsy (PBPP). A widely used assessment tool is the Active Movement Scale by The Hospital for Sick Children. Fifteen different movements in the affected arms are assessed and scored on an eight-point scale. The infant is enticed to move using a variety of play stimuli. The eight gradations allow for discrimination of movements. This tool also allows for comparing children who have surgery with those who are treated conservatively, and it allows for comparing pre- and postoperative results. Using the Active Movement Scale, elbow flexion and extension, wrist extension, and finger and thumb extension are scored. If children do not reach a preset score by three months of age, surgery is recommended. Children who pass at three months and are followed conservatively are retested at nine months for improvement of elbow flexion using the 'cookie test'. With the child sitting, a cookie is given. If the child can get the cookie to his or her mouth with the elbow held at the side and less than 45° of neck flexion, the elbow flexion is deemed adequate, and surgery is not indicated. If the children fail to get the cookie to their mouth, the primary exploration and repair of the brachial plexus will be performed (Andersen et al., 2006).

Canada's National Clinical Practice Guideline for Obstetrical Brachial Plexus Injury (OBPI) provides seven recommendations to address clinical gaps and guide the identification, referral, treatment, and outcome assessment of this condition. The recommendations are as follows:

1. Newborns with arm asymmetry or risk factors should be physically examined for OBPI.
2. Newborns diagnosed with OBPI should be referred to a multidisciplinary center within one month of birth.
3. A comprehensive pregnancy and birth history, along with physical examination findings at birth, should be provided
4. Multidisciplinary centers should include a therapist and a peripheral nerve surgeon with experience in treating OBPI.
5. Physical therapy should be advised and coordinated by a multidisciplinary team.
6. Microsurgical nerve repair is recommended for cases of root avulsion and other OBPI that meet the center's operative criteria.

7. A common data set should be used to assess outcomes, which includes the Narakas classification, limb length, Active Movement Scale (AMS), and Brachial Plexus Outcome Measure (BPOM) at 2 years after birth or surgery (Coroneos et al., 2017).

Conservative

Conservative treatment for injuries involves a collaborative effort between physiatrists, physiotherapists, and occupational therapists. These skilled professionals use complementary rehabilitation techniques and resources such as electrostimulation, botulinum toxin injections, immobilizing splints, and constraint-induced movement therapy of the non-injured limb. The treatment plan is developed with the input of professionals and family members, who work together to achieve the best possible outcome (Frade et al., 2019).

During the first two weeks of life, parents should hold the affected hand close to their infant's face, encouraging them to see and experience the hand. After two weeks of age, therapy may be initiated

This waiting period allows for the tenderness from the injury to subside and will decrease discomfort for the infant. Parents can promote sensory awareness by touching their child's arm and playing with their fingers. For joint protection, the family should be instructed not to allow the arm to lag behind when picking up the child. Splinting can prevent progressive contractures by promoting proper positioning of the affected extremity. Kinesiotaping can also encourage proper positioning, especially of the shoulder. Typically, a pediatric occupational therapist or an orthopedist is responsible for creating splints. Serial casting to gradually improve the range of motion may be indicated if flexion contractures develop.[7]

Few studies have investigated the outcomes of using BTX-A injections in the internal rotator muscles of the shoulder during closed reduction and spica cast immobilization for children with brachial plexus birth palsy (Greenhill et al., 2018).

Figure 6. Rehabilitation treatment for OBPP: (A) Kinesiotaping and (B) Bracing.

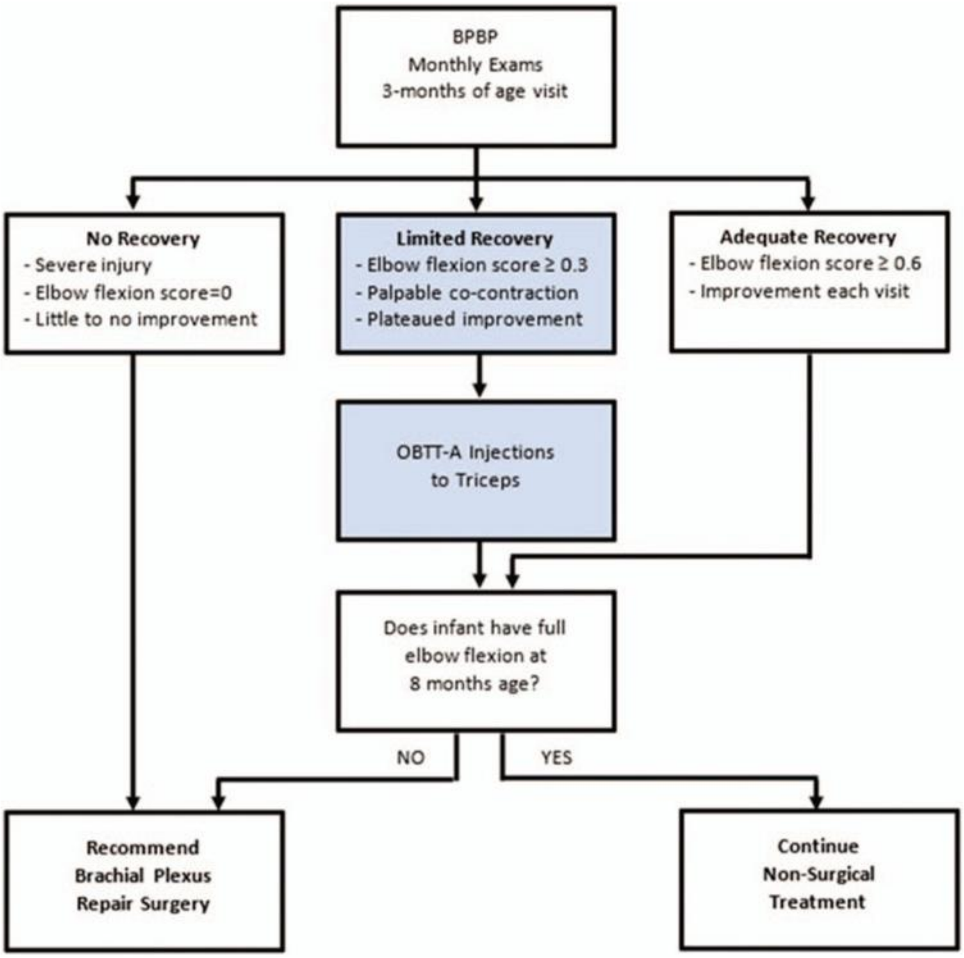

Figure 7 Morscher et al. described the treatment algorithm indications for OBTT-A injection to the triceps. OBTT-A = onabotulinum toxin type A.

A systematic review found the overall beneficial effect of BTX-A in treating co-contractures seen in patients with BPBI. Specifically, BTX-A is shown to reduce internal rotation/adduction contractures of the shoulder, elbow flexion/extension contractures, and forearm pronation contractures. These beneficial effects are blunted when used in older patients. Nevertheless, BTX-A is a valuable treatment for BPBIs with a relatively low-risk profile.[34] A retrospective observational cohort study showed onabotulinum toxin type A (OBTT-A) injection to the triceps in infants with BPBP before six months of age therapeutically improved elbow flexion and diagnostically guided surgical decisions when full elbow flexion was not achieved by eight months of age with no known complications (Morscher et al., 2020).

Operative

Surgical treatment for Neonatal Brachial Plexus Palsy (NBPP) involves two types of surgeries. Primary surgeries are recommended for infants who do not show any signs of spontaneous recovery in the first three months of life. Secondary surgeries, on the other hand, are suggested for children who have undergone primary surgery but still have functional limitations in the injured limb or have significant functional deficits.

The choice of treatment for NBPP is determined by the clinical evaluation and the type of injury. However, regardless of the type of injury, it is widely agreed that conservative treatment should begin as soon as possible. Surgical management can be divided into two phases: primary and secondary. Primary surgery refers to the surgical exploration and reconstruction of the brachial plexus. Secondary procedures are orthopedic and aim to minimize any residual deficits. The goal of surgical management is to improve function in the affected limb (Socolovsky et al., 2016).

Microsurgical reconstruction was effective in improving function in a small subgroup of patients who did not exhibit any signs of bicep recovery within the first six months of life (Chantaraseno et al., 2014). Although most babies will recover spontaneously within the first three months of life, a small number might have poor recovery and require surgical brachial plexus exploration. The decision for surgery depends on the type of lesion (partial or total palsy) and non-recovery of biceps function by the age of three months. In cases of total palsy, microsurgery is mandatory, and the focus of restoration will be on reinnervating the hand first, followed by providing elbow flexion and shoulder stability. The clinical manifestations at birth are directly correlated with the anatomical lesion. Surgical procedures may include nerve grafting in infants and secondary surgery to increase functional capacity at later ages. However, it is unlikely that normal function will be fully restored, especially in cases of total brachial plexus palsy (Romaña & Rogier, 2013).

A considerable percentage of patients with obstetrical brachial plexus injury (OBPI) who require major reconstructive surgery have birth weights that are considered normal. This percentage ranges from 48% to 82%, depending on the definition of macrosomia. Our study found no significant difference in injury severity or outcome between macrosomic and non macrosomic OBPI patients who underwent the modified Quad surgical procedure.

Recovery of functional elbow flexion is a primary goal in the treatment of neonatal brachial plexus palsy (NBPP). Current neurosurgical options for treatment include nerve grafting and nerve transfer. In a meta-analysis by Tora et al. comparing nerve grafting and nerve transfer for NBPP, there is no statistically significant difference in functional elbow flexion recovery (Tora et al., 2019).

Microsurgical reconstruction is recommended for infants with Brachial Plexus Birth Palsy (BPBP) who do not show significant neurological recovery. Several factors were found to be associated with microsurgery based on univariate analysis, including race, gestational diabetes, neonatal asphyxia, admission to the neonatal intensive care unit, Horner's syndrome, Toronto Test score, and AMS scores for finger/thumb/wrist flexion, finger/thumb extension, wrist extension, elbow flexion, and elbow extension. In multivariate analysis, four factors were found to be independently predictive of microsurgical intervention: Horner's syndrome, mean AMS score for finger/thumb/wrist flexion less than 4.5, AMS score for wrist extension less than 4.5, and AMS score for elbow flexion less than 4.5 (Shah et al., 2019).

A retrospective study on surgical treatment for Brachial Plexus Birth Injury (BPBI) showed that recovery of shoulder external rotation remains unsatisfactory regardless of the technique used. However, transfers of the spinal accessory nerve to the suprascapular nerve resulted in a higher proportion of infants achieving functional shoulder external rotation and fewer secondary shoulder procedures (Manske et al., 2020). Another study found that 76.7% of patients who underwent spinal accessory nerve-to-suprascapular (SAN-SSN) nerve transfer achieved sufficient function to avoid tendon transfers and corrective osteotomies. To assess the success of this procedure, a postoperative time frame of at least 3 years should be used (Segal et al., 2019).

The utilization of 3D models for surgical planning has been linked with a decrease in operating time and a reduction in intra-operative blood loss. Additionally, the use of 3D models in patient education has been shown to improve patient understanding. This technique was found to be helpful by all surveyed surgeons, who agreed to utilize 3D modeling to enhance consent processes and develop novel techniques for complex cases in the future. This low-cost and highly reproducible technique can be adapted to various upper limb reconstructive surgeries. As the resolution of image acquisition and additive manufacturing capabilities improves, the potential applications of this precise 3D-printed surgical adjunct are also expected to increase (Higgins et al., 2020).

A study conducted retrospectively discovered that functional recovery occurred in both specific and nonspecific fascicle transfers. However, the donor fascicle's composition did not impact early outcomes. In young infants, performing ulnar nerve fascicular dissection can put the ulnar nerve at risk for iatrogenic damage. The use of either specific or nonspecific motor fascicles produces similar results in the Oberlin transfer procedure. This method can be carried out with less intrafascicular dissection, shorter surgical exposure time, and lower risk of donor site morbidity. While a retrospective study found that both specific and nonspecific transfers led to functional Mrecovery, it found that the composition of the donor fascicle had no impact on early outcomes. However, ulnar nerve fascicular dissection in young infants can pose a risk of iatrogenic damage. Overall, the use of any motor fascicle, specific or nonspecific, yields comparable results in the Oberlin transfer and is associated with fewer complications (Smith, Chulski, et al., 2018). Another study showed the Oberlin transfer confers an advantageous early recovery of forearm supination over grafting, with equivalent elbow flexion recovery (K. W. C. Chang et al., 2017).

The transfer of the teres major and latissimus dorsi muscles to the posterior rotator cuff is a dependable and secure technique for restoring shoulder abduction and external rotation deficits resulting from birth brachial plexus injury. However, to achieve optimal outcomes, it is crucial to select patients carefully and pay close attention to surgical details (Brogan & Leversedge, 2019).

Rehabilitation

The rehabilitation management goals for infants with brachial plexus palsy are to prevent joint contracture, facilitate active movement, encourage strengthening, and promote sensory awareness.

There is no current scientific evidence on some rehabilitation means/techniques used in conservative treatments, that is some positioning of the limbs (like the external rotation of the shoulder and forearm to prevent contractures and deformities (glenohumeral dysplasia), the use of kinesiology tapes, weight shift on the injured limb (at critical stages of the child's development), and hydrotherapy from the age of 6 months). The conventional/conservative multidisciplinary treatment includes intensive physiotherapy/occupational therapy sessions using complementary means and techniques such as electrostimulation, immobilizing splints, constraint-induced movement therapy, and joint action with families.

Physical or occupational therapy includes direct treatment sessions as well as the development of a daily home exercise program. These exercises commonly include stretches to address shoulder external rotation, shoulder extension, elbow extension, wrist extension, forearm supination, and finger extension.

Prognosis

Most babies with brachial plexus injuries at birth have an excellent prognosis if recovery begins within three months. The short-term results of latissimus dorsi transfer of patients with obstetric brachial plexus injury and subscapularis release are encouraging. These gains deteriorated over a longitudinal follow-up period. Over the long term, abduction is maintained, but external rotation deteriorates, and there is also a deterioration in internal rotation leading to functional impairment (Werthel et al., 2018).

One of the main reasons for nerve surgery is that sometimes, patients do not recover fully on their own. This is supported by the following observations: 1) In about 30% of infants with OBPP, complete spontaneous recovery does not occur, which can have a long-lasting impact on their daily lives. 2) For infants with a total lesion, which means no functional recovery has taken place within one to two months (often accompanied by Horner's syndrome), the outlook is not good. Both in historical papers and in a more recent paper, it is concluded that spontaneous recovery of proper hand function does not occur. 3) Autopsies and surgical exploration revealed totally ruptured nerves and nerves avulsed from the spinal cord (Pondaag & Malessy, 2014).

Complication

Contractures of the glenohumeral joint and shoulder joint dysplasia are well-known complications of obstetrical brachial plexus palsy (Olofsson et al., 2019). Arthroscopic arthrolysis of the shoulder in children with BPBP sequelae (internal rotation contractures) is a safe and effective procedure that produces clinical improvement in function and mobility (Andrés-Cano et al., 2015). Despite adequate nerve reconstruction, some develop an established deficit with sequelae in the shoulder joint secondary to a muscle imbalance between paralyzed and functional muscles. Shoulder pathology occurs when there is an imbalance of muscles around the shoulder joint. This happens when some muscles are weak or paralyzed, and others are unaffected. As a result, the soft tissues around the shoulder can become tight and cause changes in the structure of the joint. The most common type of tightness is in the muscles that rotate the shoulder inward. This can be disabling for children who experience it (Julka & Vander Have, 2011).

Brachial plexopathy is a condition that causes pain and loss of function in the affected arm. The brachial plexus terminal branches may get trapped in the surrounding connective tissue or medial brachial fascial compartment, leading to debilitating symptoms. To treat these symptoms, open fasciotomy and external neurolysis of the neurovascular bundle in the medial brachial fascial compartment may be performed. This surgical treatment has been found to be effective in reducing pain and restoring arm function, especially when nerve continuity is preserved. Patients with a prolonged duration since injury onset have also experienced these benefits (Morgan et al., 2020).

A study found a high prevalence of language delay among toddlers with neonatal brachial plexus palsy. Although our subject sample is small, these findings warrant further study of this phenomenon. Early identification and timely intervention based on the type of language impairment may be critical for improving communication outcomes in this population (K. W.-C. Chang et al., 2014).

Conclusion

A significant increase in the rate of cesarean delivery and improvement in obstetric practice may have contributed to the dropped incidence of OBPI. It is associated with shoulder dystocia, the use of mechanical extraction, and macrosomia. It occurs more frequently in infants born by vaginal delivery. The significant risk factors of OBPI are foot presentation, breech/foot extraction, and birth weight >3,500 g. Clavicle fracture is not associated with a substantial change in the risk. The anatomical complexity of the brachial plexus results in varying degrees of injury and pathological changes at multiple levels within the plexus. The diagnosis of OBPI is clinically apparent, and no ancillary exam is necessary. Plain X-rays can be helpful for the detection of concurrent lesions, such as clavicular fractures or phrenic paralysis. OBPI has been classified into four categories, referred to as the Narakas classification.

Two main treatments/therapies for OBPI were identified: conservative treatment and surgical treatment. Conservative treatment uses a complementary way, such as electrostimulation, botulinum toxin injection, immobilizing splints, and constraint-induced movement therapy of the non-injured limb. Professionals and family members work jointly. Kinesiotaping can also be used to promote proper positioning, especially of the shoulder. If children do not reach a preset score by three months of age, surgery is recommended. The goal of surgical management is to improve function in the affected limb. The surgical management process can be classified into two phases: primary and secondary. The rehabilitation management goals for infants with brachial plexus palsy are to prevent joint contracture, facilitate active movement, encourage strengthening, and promote sensory awareness.

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