Review Article

Evaluation and Diagnostic-Treatment Approaches of Brachial Plexus Injuries in Adults

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ABSTRACT

Background: Brachial plexus injury (BPI), as one of the most devastating injuries in adults, has various negative consequences such as profound functional impairment, debilitating pain, significant mental health consequences, and economic impacts. We aimed to review the evaluation and diagnostic-treatment Approaches of BPI in adults through a review study.

Methods: An electronic literature search was completed in Google Scholar, Springer, PubMed, and Science Direct databases from 1980 to 2023. Various keywords related to the purpose such as Brachial plexus, surgical strategy, adult were used.

Results: 1.2% of people with multiple traumas had BPIs. BPI is more common in young adult males. For brachial plexus palsy, preoperative evaluation of nerve root avulsion is helpful in surgical planning. . EMG is useful in confirming a diagnosis, localizing the lesion level, estimating the extent of axon loss, and determining whether the lesion is complete. There are different options available for BPI, such as coordinating care, rehabilitation and psychosocial support. In recent times, significant advancements have been made in surgical techniques for nerve repairs.

Conclusion: Although it is often not possible to prevent damage to the brachial plexus, it is possible to reduce the risk of further problems after the injury by taking some measures.

KEYWORDS
Brachial plexus; Surgical strategy; Adult

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INTRODUCTION

Brachial plexus injuries (BPI) are among the most severe injuries from the patient's point of view [1], resulting in a partial or whole loss of motor and sensory function [2]. Traumatic BPI in adults are destructive injuries that occur mostly in men aged 15 to 25 years [3]. This injury may make it difficult to carry out every day and work-related duties and responsibilities. It can also result in mental health issues like depression, which can occasionally lead to suicide, unemployment, and a detrimental effect on the economy [1]. The last fifty years have seen a

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notable rise in the frequency of this injury as a result of advancements in transportation technology, particularly with regard to motor vehicles [4].
The most frequent source of injury to the brachial network is traffic accidents. BPI are not limited to sports-related trauma; they can also result from gunshot wounds, cuts, carrying a large backpack, and incorrect posture. It should be mentioned men between the ages of 15 and 25 yr make up the majority of those who have BPI [5]. Non-traumatic causes of this damage include tumors, radiation, and congenital abnormalities.
In order to develop prevention strategies and treatment programs, epidemiological studies of BPI are essential for assessing the scope of the issue and identifying the traits of those who are impacted. BPIs are uncommon; the estimated yearly incidence of BPIs in the general population falls between 0.17 and 1.6 per 100,000 people annually [6]. The majority of patients with brachial plexus trauma are young males, and the majority of closed lesions are brought on by motorbike accidents that affect the supraclavicular plexus [6, 7]. Every patient with a BPI needs to be referred as soon as possible to a specialist in treating it. No patient should be left without receiving therapy and rehabilitation [6, 8]. For a better prognosis, a customized treatment is therefore necessary for these complex injuries.
Reviewing the treatment and diagnostic methods for this damage was the aim of this study.

METHODS

The present research is a review study about assess and diagnostic-treatment Approaches of BPI in adults. The results of this study were obtained based on published articles. In this research, all the articles published from 1980 until 2023 were selected through a search in databases such as Google Scholar, Springer, PubMed, and Science Direct. Keywords Brachial plexus, surgical strategy, and adult were used to search for articles.

Epidemiology of BPI in adults

Differentiating between adults and children is critical when it comes to the epidemiology of BPI. By the end of the 1990s, Midha reported that 1.2% of people with multiple traumas had BPIs [9]. Although precise data are few, BPI is more common in young adult males; patients typically range in age from 16 to 63, with an average age of 19 to 25 years [9]. The majority of BPI in this population are brought on by traumatic events like motorbike accidents, sporting events, or workplace mishaps. Furthermore, iatrogenic lesions are a significant factor in adult BPI [9].

Sensory evaluation

It's critical to pay attention to the patient's sensation, including any changes in or lack of sensation. However, the aforementioned areas do not feel in the sensory tests. Dry skin is lost in injured dermatomes as a result of the loss of pseudomotor function [1].

Radiographic evaluation

A radiographic examination of the cervical spine, implicated shoulder and extremity, and chest should be done in order to rule out coexisting fractures of the spine, ribs, clavicle, scapula, or bones inside the affected extremity [5]. Investigators can use routine chest AP X-rays to determine whether there are first and second rib fractures [5]. Cervical radiographs can be used to diagnose transverse process fractures of the cervical vertebrae. Given that the phrenic nerve receives contributions from C3 to C5, respiratory-expiratory chest films, diaphragm ultrasonography, or fluoroscopy can all provide information about the function of the phrenic nerve and possible damage to the C5 nerve root [5]. Patients with BPI represent 10% to 25% incidence of accompanying arterial injury [10]. Vascular imaging such as magnetic resonance angiography or arteriography is recommended if a physical examination reveals aberrant radial or ulnar pulses [5].

Myelography

Visualizing nerve root injury is made possible by the combination of CT and myelography [11, 12]. The presence of a pseudomeningocele or asymmetric or missing nerve rootlets on a CT myelogram are strongly suggestive of a nerve root avulsion. The benefit of MRI is that it is noninvasive and also useful [12]. Nerve rootlet anatomy can be easily shown using specialized MRI sequences [11]. The sensitivity of root avulsion was shown to be equal in a retrospective assessment comparing CT myelography with

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MRI in the evaluation of brachial plexus injuries. Nonetheless, an MRI may show abnormalities due to prior orthopedic surgeries related to the neck or shoulder in a large number of individuals. The gold standard of radiologic examination for nerve root avulsion in our practice is CT myelography [11].

CT Myelography

For brachial plexus palsy, preoperative evaluation of nerve root avulsion is helpful in surgical planning [13]. While CT myelography is the accepted way for both adults and infants, find an alternative is crucial because of the risk of infection and seizures associated with intrathecal contrast administration and evidence that early radiation exposure may raise the risk of cancer later on. Computed tomographic myelography (CTM) is a valuable tool for assessing the degree of nerve injury [13].

MRI

The use of MRI in the diagnosis of traumatic brain injuries has been studied by some authors [14, 15]. As a consequence, diagnosis is essential to distinguish low-grade lesions not requiring surgical treatment from high-grade lesions and to identify their location [16, 17]. Given that magnetic resonance imaging (MRI) is a multi-planar, non-invasive, non-radiative imaging technique. It is a fundamental form of diagnostic imaging [18].

Magnetic Resonance Neurography (MRN)

Peripheral nerve visualization is the goal of MRN, a type of MRI [19]. The fundamental idea behind MRN is to use a mixture of targeted suppression techniques to suppress surrounding fat, muscles, and arteries, allowing nerves to be distinguished from surrounding tissue [20, 21]. However, earlier clinical usage is prevented by limitations in spatial resolution and signal-to-noise ratio (SNR) [19]. It took, therefore, more than ten years to prove that MRN was a clinically useful approach. In particular, by including isotropic three-dimensional (3D) pictures and functional imaging, like diffusion-weighted or diffusion-tensor imaging, into the MRN technique, the widespread usage of 3T scanners has accelerated technical maturation [19]. MRN is now developing toward robustness in quantitative imaging and optimization in morphological imaging [19].

Ultrasonography (USG)

The radiological technique that is most accessible is ultrasound. Advancements in high-frequency ultrasonography have made it possible to visualize the nerve roots of the brachial plexus. However, there is little evidence available in the literature about the precise ultrasound diagnosis of BP root injury, particularly with the diagnostic accuracy for each nerve root from C5 to T1 at various times after the injury [22].

Electrophysiology Studies (EPS)

Subclinical injuries and subclinical healing are identified by electrodiagnostic studies. An electrodiagnostic method for assessing the amount of electrical activity produced by skeletal muscle is electromyography (EMG) [5]. EMG is useful in confirming a diagnosis, localizing the lesion level, estimating the extent of axon loss, and determining whether the lesion is complete. In differentiating between preganglionic and postganglionic lesions is also helpful [5]. In particular, identifying the lesion as pre- or postganglionic depends on sensory nerve action potentials (SNAPs) [5]. The sensory neuron's cell body is located in the dorsal root ganglion; consequently, continuous postganglionic electrical activity preserves SNAPs in lesions close to the dorsal root ganglions. The extremity may be insensate in that nerve distribution, yet the patient with a preganglionic lesion will exhibit signs of SNAPs. Postganglionic or mixed pre-and postganglionic lesions lack the SNAPs. It is typically advised to perform an EMG on closed traction injuries 4–6 weeks following the injury in order to search for a spontaneous recover [5]. In order to track the course of healing and anticipate the possibility of surgically exploring the BPI lesion, serial EPS along with recurrent physical exams is required [11, 23]. Recovery and a favorable prognosis are indicated by the presence of active motor units, the emergence of early potentials, and a decrease in the quantity of fibrillation potentials.

Treatment Strategy

There are different options available for BPI, such as coordinating care, rehabilitation and psychosocial support.

Coordinating Care

A multidisciplinary team's cooperation is necessary to provide patients with BPI with comprehensive treatment. This team, which ideally includes colleagues from the fields of hand therapy, electrodiagnostics, pain management, mental health, and social work, is led by a peripheral nerve surgeon[24]. When there are concurrent injuries, it could be important to involve doctors from different subspecialties. Early evaluation reduces treatment delays, optimizes patient experience, and enhances patient education at tertiary facilities with a focus on BPIs [25].

Rehabilitation

The kind, location, and seriousness of the injury all affect how BPI is managed. Usually, computed tomography myelography or magnetic resonance imaging are used to determine it. The optimal time for surgery, according to surgeons nowadays, is three to six months after the injury; traction injuries typically heal on their own during this time, and surgical exploration may result in further damage. If nerve function has not returned by the end of this spontaneous recovery period, surgery is advised [26]. Complete rips, ruptures, and cuts usually do not heal in this amount of time; hence, early surgery is recommended in lieu of this. No wonder, the optimum course of action prior to surgery is rehabilitation, including neurotrophic therapy [27]. Rehabilitation therapy can support the restoration of neurological function after surgery [27, 28]. Early rehabilitation intervention is required because brachial plexus damage, whether treated surgically or not, can result in a degree of upper extremity muscle loss and rapid muscular atrophy [27]. The major goal of BPI rehabilitation is to support nerve regeneration and functional recovery while protecting and recovering function in joints and undamaged muscles. On the basis of this assumption, the probability of developing later anomalies including muscular atrophy, tight joints, and restricted range of motion is greatly reduced [27].

Psychosocial support

Patients with BPI commonly experience depression, anxiety, PTSD, and suicide thoughts [29]. The patient experiences a psychologic load that affects every part of their life due to persistent pain, abrupt changes in their functional status, residual stress from the event, and altered physical appearance. This is a major factor in patient-reported outcomes and impedes both adaptation and recovery [29]. Growing proof indicates that resiliency training, psychologic counseling, and mental health support are essential for sustaining patient engagement and maximizing patient satisfaction during the protracted recovery period following a surgical reconstruction, even though these services are outside the scope of many hand surgeons [30]. These extremely significant fields can be addressed by the integration of mental health specialists and social workers [21].

Multimodal pain management

Pain is experienced by patients at every stage of BPI, including acute neuromuscular injury pain, postoperative pain in the surgical site, and chronic neuropathic pain. Pain has a substantial negative impact on patients' quality of life, mental health, and compliance with therapy [5]. It has to be handled as soon as it is identified. Outcomes of Tom's study and colleagues suggests the use of the Patient Reported Outcome Measure (PROM), preferably for those patients who can report pain autonomously, in addition to the commonly used Visual Analog Scale (VAS) and Numeric Rating Scale (NRS) for the functional assessment of BPI [31]. For BPI, there is not, however, an efficacy analysis of several pain evaluation measures. Both surgical and non-surgical patients can employ the several kinds of medicines indicated in the overview of pain management after complex nerve injury [32], including narcotics, hormones, psychiatric medications, and central analgesics. Injectable administered orally and locally are only two examples of delivery modalities. Because pain is subjective and sometimes associated with psychological disorders, psychotherapy and psychotropic drugs may occasionally offer additional benefits that have long-lasting effects [33]. Continuous interscalene brachial plexus block (CISB) is superior to single interscalene brachial plexus block (SISB) in terms of effective analgesia, improved sleep quality, and decreased opioid-related problems [34].

Few studies have compared the effectiveness of different medications and ways of administering them. One of the non-pharmacological techniques

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that, when paired with pharmacotherapy, provide a comprehensive pain treatment is psychotherapy, along with physiotherapy, exercise therapy, invasive surgery, and other treatments [27]. It is imperative to realize that non-pharmacological methods cannot be replaced by medicine. Moreover, even though chronic neuropathologic pain is frequently difficult to control with medication, it can still be utilized to temporarily relieve acute nerve injury pain or pain following surgery. In addition to surgical procedures like nerve transplant and neuroma excision, neurostimulation has shown increased efficacy in the management of persistent neuropathic pain in recent years [27]. For those with severe and medically intractable pain, thalamic DBS, for instance, has shown to be a successful therapy choice [35]. However, because there are so many variations in stimulation parameters, research on this type of brain stimulation usually includes few examples, and there is no generally recognized standard stimulation paradigm. It is recommended that further research be conducted in more detail.

Surgical Treatment

The type of BPI will be confirmed based on the results of the preoperative investigation and the functional deficit that was clinically discovered. This will help identify which surgical treatments, out of a range of options, are best for treating the patient. Because there aren't always enough nerve units accessible, decisions about whether to restore the stability of the shoulder or bend the elbow must be made [36].

In recent times, significant advancements have been made in surgical techniques for nerve repairs. A thorough comprehension of nerve topography is crucial for the surgeon to accurately align the motor and/or sensory fascicles [37]. The glued anastomosis can be performed with accurate apposition and minimal trauma to the nerve. By making a fibrin semi-clot, the anastomosis can be insulated. This provides some of the benefits of sheathed anastomosis. In this way, the insertion of the scar tissue from surrounding tissue into the anastomotic site would be minimal [38]. In addition to maximizing functional recovery, this will guarantee healthy nerve regeneration. The results of nerve repair with fibrin glue with PRP were promising [39]. The longitudinal extent of the injury must be taken into account during nerve healing. It is necessary to sufficiently resect the nerve endings in order to expose the typical fascicular arrangement. Neurolysis, end-to-end suturing, nerve grafting, and nerve transfer are the four primary surgical therapeutic modalities now available for peripheral nerve injury [37].

Neurotization is the process of transplanting a healthy motor nerve to an injured nerve. This healthy nerve might originate from the brachial plexus (intraplexus transfer) or from another location [4, 37]. The result is better when the transferred nerve is sutured near to the motor units rather than when nerve grafts are used [36, 40, 41]. Some publications [42, 43] have discussed the impact of primary rebuilt BPI and how they raise the possibility of the antagonist group of muscles reinnervating [36]. For the repair of peripheral nerve injuries, primary end-to-end neurorrhaphy is the best option when the distance between the two ends of the nerve is relatively small [42, 44]. The flexibility of nerve endings causes them to retract after complete transection. It is impossible to do a direct end-to-end suture when this happens. Primary repair should not be attempted in contaminated wounds; however, during initial debridement, nerve endings should be approximated and marked with colored stitches to avoid retraction and facilitate nerve stump dissection during subsequent surgery [36]. Neurorrhaphy will result in excessive stress at the repair site if there are larger defects or longer gaps between the cut ends. This will hinder microvascular flow in the nerve tissue and create excessive scarring at the repair site. Primary neurorrhaphy should not be carried out in these circumstances; instead, an appropriate substitute should be taken into consideration [36].When there is a nerve tissue deficit greater than 2 cm, nerve grafting is often done following all other procedures to approximate the nerve stumps without strain [37, 45].

There are various grafting techniques [37]:

- Cable grafting.
- Interfascicular grafting.
- Fascicular grafting.
- Vascularized grafting.

Better nerve and graft diameter approximation, improved fascicle orientation, a thin graft that receives nutrients via diffusion from its bed, better revascularization of graft, and less scarring are all benefits of interfascicular nerve grafting. Nonetheless, nerve grafting has certain drawbacks as

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well: in longer defects, it can be challenging to identify the right fascicular groups due to the presence of two suture margins, and in longer defects, scarring of the distal suture margin or the graft itself may occur. Development synthetic nerve conduits development for brief nerve gaps that are unsuitable for primary tensionless end-to-end neurorrhaphy has been the subject of extensive investigation. Nerve conduits have the potential to reduce donor-site morbidity, which includes irreversible loss of sensation in the area supplied by the donor nerve, pain, scarring, and neuroma formation [46]. The U.S. Food and Drug Administration has currently approved a number of commercially available synthetic nerve conduits for the repair of peripheral nerves. These conduits include collagen, a biodegradable material derived from the Achilles tendon of cows, and a combination of polyglycolic acid and polylactide caprolactone, which are both biodegradable synthetic aliphatic polyesters. Most published research indicates that the recovery outcome is comparable to autograft use [47-49]. By using a separate proximal nerve as the donor of neurons and their axons to reinnervate the distal targets, nerve transfer, also known as neurotization, includes the healing of a distal denervated nerve element [37]. The concept is to sacrifice a less valuable donor muscle's function in order to restore function to the recipient nerve and muscle during reinnervation. An increasing number of severe BPI cases, in which the proximal spinal nerve roots have been severed from the spinal cord, are being repaired using nerve transfer treatments [37].

The following are the functional priorities in adult BPI nerve transfer, in order of priority:

1. Elbow flexion.
2. Shoulder stabilization.
3. Abduction and external rotation of the shoulder.
4. Sensory function of the thumb and index finger.
5. Hand function.

It is not always possible to achieve full functional recovery after peripheral nerve restoration, even with advances in the precision of microsurgical procedures.

Whenever possible, primary tensionless end-to-end repair ought to be carried out. The current "gold standard" for longer nerve gap is the use of autologous nerve grafts. In recent years, there has been a rise in the usage of commercially available nerve conduits to bridge short nerve gaps. Promising outcomes have been observed in the development of tissue engineering and the application of biodegradable conduits for nerve gap restoration [50, 51].

CONCLUSION

One of the most important upper limb injuries is brachial plexus injury, which can lead to upper limb paralysis, change daily tasks, and have serious social and economic consequences. Methods such as magnetic resonance imaging and CT myelography are very important for diagnosis and evaluation before and after surgery. Therefore, understanding the physiology of nerve damage and progress in brachial plexus reconstruction will lead to improved outcomes [3]. There are two management methods: non-surgical and surgical. Important ideas in caring for patients with brachial plexus injury include understanding the patient's expectations, timing of surgery, importance of functional improvement, and injury history. Considering that peripheral nerve damage has a significant impact on patients' quality of life and functionality, apart from more research on the subject, it is necessary to provide support for patients to improve their quality of life.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

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