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Surgical Approach to Brachial Plexus Root Repair: A Case Study with Literature Review

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Abstract **Original Research Article**

This article presents a clinical case study of a 32-year-old patient with brachial plexus trauma following a motorcycle accident, as well as a review of the relevant literature on surgical approaches to brachial plexus root repair. The case study highlights the patient's symptoms, initial assessments, further investigations, surgical management, and post-operative results. The literature review synthesizes the main surgical approaches used in the repair of brachial plexus injuries, highlighting direct root repair techniques, nerve grafts, nerve transfers, as well as their results and complications. This study contributes to the body of knowledge on surgical options for brachial plexus injuries, highlighting the importance of post-operative rehabilitation and long-term follow-up in improving patients' functional recovery.

Keywords: Brachial Plexus, Trauma, Nerve Repair, Nerve Grafts, Nerve Transfers.

1. INTRODUCTION

a. Background and importance of the brachial plexus in the innervation of the upper limb.

The brachial plexus is a complex network of nerves located in the cervical and axillary region of the body. It plays a crucial role in the innervation of the upper limb, providing the nerve pathways that enable movement and sensation in this part of the body.

The brachial plexus is made up of nerve roots from the C5 to T1 cervical segments of the spinal cord, and is divided into nerve trunks, divisions and cords. These structures branch to form the major peripheral nerves, such as the musculocutaneous nerve, radial nerve, ulnar nerve and median nerve, which innervate the muscles and skin of the upper limb.

The importance of the brachial plexus in the motor and sensory function of the arm and hand makes it a major subject of study and concern for orthopaedic surgeons. Injuries to the roots of the brachial plexus can result from traumatic accidents, surgical complications, tumors or neurological disorders, and can significantly impair patients' quality of life.

In this article, we will present a clinical case study of brachial plexus root transection, while thoroughly reviewing the existing literature on the subject. Our aim is to highlight recent diagnostic and therapeutic advances in the management of this condition, with an emphasis on the challenges encountered and future prospects.

Brachial plexus root lesions are traumatic injuries that can have devastating consequences on the motor and sensory function of the upper limb. These injuries often occur during serious accidents such as birth trauma, road accidents or falls, as well as during complex surgical procedures [1].

b. Significance of brachial plexus root lesions and their impact on motor and sensory function.

The importance of these lesions lies in the vital role played by the brachial plexus in the innervation of the upper limb. The roots of the brachial plexus supply the essential nerve fibers that enable electrical signals to be transmitted between the central nervous system and the muscles, joints and skin of the arm and hand. Thus, any damage to the brachial plexus roots can result in significant impairment of motor and sensory function in this region.

The consequences of brachial plexus root lesions can be profound, affecting the daily lives of affected individuals. Patients may experience partial or

total paralysis of the upper limb, reduced muscle strength, impaired coordination of movements and sensitivity disorders.

These deficits can have a considerable impact on the ability to perform simple tasks such as feeding, dressing, washing and working.

Rehabilitation of patients with brachial plexus root injuries is a complex challenge for healthcare professionals. Early, multidisciplinary management is essential to maximize the chances of functional recovery. This often involves surgical interventions, specialized rehabilitation techniques and long-term follow-up.

In this article, we will look at a clinical case study of brachial plexus root transection, together with a review of the existing literature. The aim is to gain a better understanding of the mechanisms of these lesions, evaluate current diagnostic and therapeutic approaches, and identify recent advances that could improve the management and prognosis of patients with brachial plexus root lesions [2].

c. Objectives of the article: presentation of a case study and review of the literature on brachial plexus root transection.

- Present a clinical case study: We will describe in detail a specific case of brachial plexus root transection, highlighting the patient's medical history, mechanism of injury, associated symptoms, initial assessment and additional investigations carried out. We will also discuss the surgical management of the case, the techniques used, the results obtained and the post-operative follow-up. This case study will provide a concrete insight into the clinical challenges faced by patients with brachial plexus root lesions.
- Reviewing the literature: We will take an in-depth look at recent studies and publications on brachial plexus root transection. We will highlight advances in diagnostic approaches such as medical imaging and electrophysiological techniques, as well as advances in therapeutic approaches such as nerve repair, nerve grafts, nerve transfers, functional electrical stimulation and rehabilitation. We will also analyze the clinical results of different approaches and discuss future prospects in this field.

By combining a clinical case study with a review of the literature, this article aims to provide a comprehensive view of brachial plexus root transection, presenting both an actual case and current knowledge in the field. We hope that this approach will enable healthcare professionals to improve their understanding of this complex condition and optimize the management of patients with brachial plexus root lesions [3, 4].

2. METHODS

a. Anatomy and Physiology of the Brachial Plexus

The brachial plexus is an essential nerve structure for the innervation of the upper limb. It is formed by the convergence of nerve roots from cervical segments C5 to T1 of the spinal cord. Here's a detailed description of the anatomy of the brachial plexus, highlighting its various components:

a. Brachial Plexus Roots :

- The roots of the brachial plexus correspond to the anterior branches of the cervical spinal nerves C5 to T1.
- They emerge from the spinal cord in the cervical region and group together to form the nerve trunks.

b. Nerve Trunks :

- The C5 and C6 roots fuse to form the upper trunk.
- The C7 root continues as a middle trunk.
- The C8 and T1 roots fuse to form the lower trunk.
- The nerve trunks are located in the lateral neck region, between the anterior and middle scalene muscles.

c. Divisions of the Brachial Plexus :

- Each nerve trunk is divided into two divisions: an anterior and a posterior one.
- Anterior divisions are located on the anterior side of the corresponding trunk, while posterior divisions are located on the posterior side.
- These divisions provide the nerve pathways to the various regions of the upper limb.

d. Nerve Cords :

- The anterior divisions of the upper and middle trunks come together to form the lateral cord.
- The anterior division of the lower trunk continues as the medial cord.
- The posterior divisions of the three trunks come together to form the posterior cord.
- Nerve cords are named according to their position relative to the axillary artery [5].

b. Detailed Description of Brachial Plexus Anatomy: Roots, Trunks, Divisions, Cords.

The organization of the brachial plexus into roots, trunks, divisions and cords enables efficient distribution of the major peripheral nerves that emerge from it. These include the musculocutaneous nerve,

radial nerve, ulnar nerve, median nerve, axillary nerve and other important nerve branches.

This anatomical organization of the brachial plexus enables complete, coordinated innervat ion of the muscles, joints and skin of the upper limb, contributing to its motor and sensory function. A precise understanding of this anatomy is crucial to the optimal diagnosis and treatment of brachial plexus injuries [6].

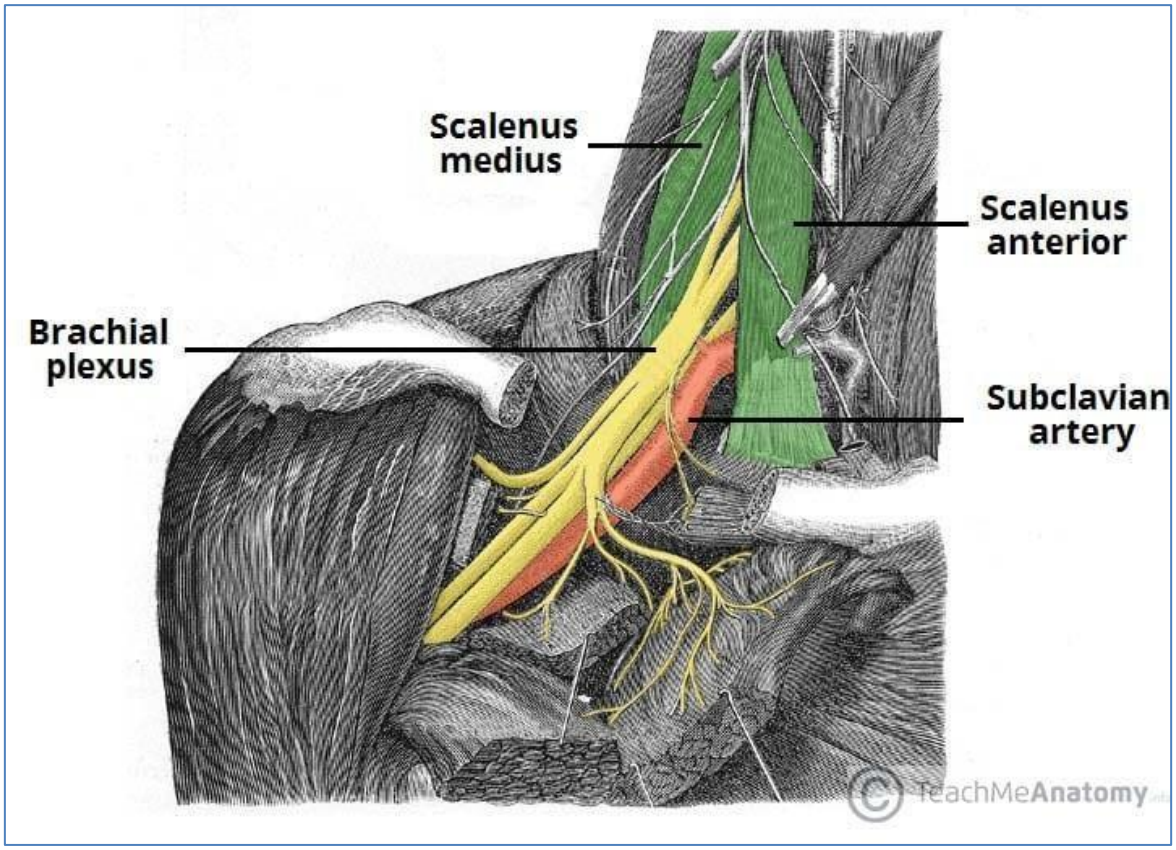

Fig. 1: Proximal portion of the brachial plexus, in the neck.

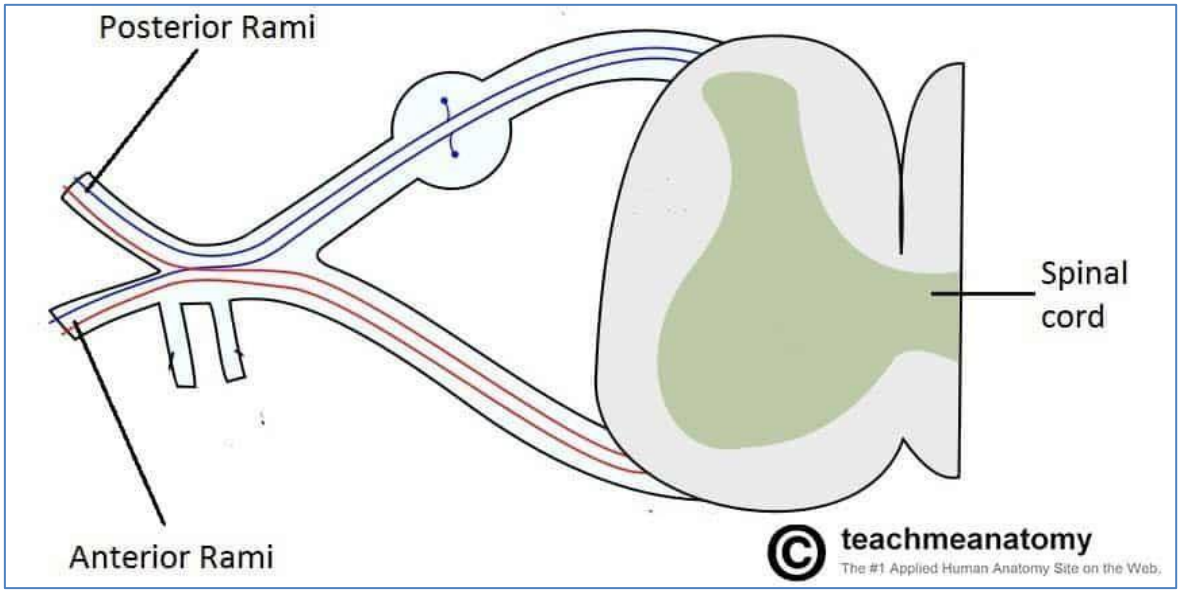

Fig. 2: The spinal cord outflow at each vertebral level. The anterior rami of vertebral levels C5-C8 and T1 make up the roots of the brachial plexus.

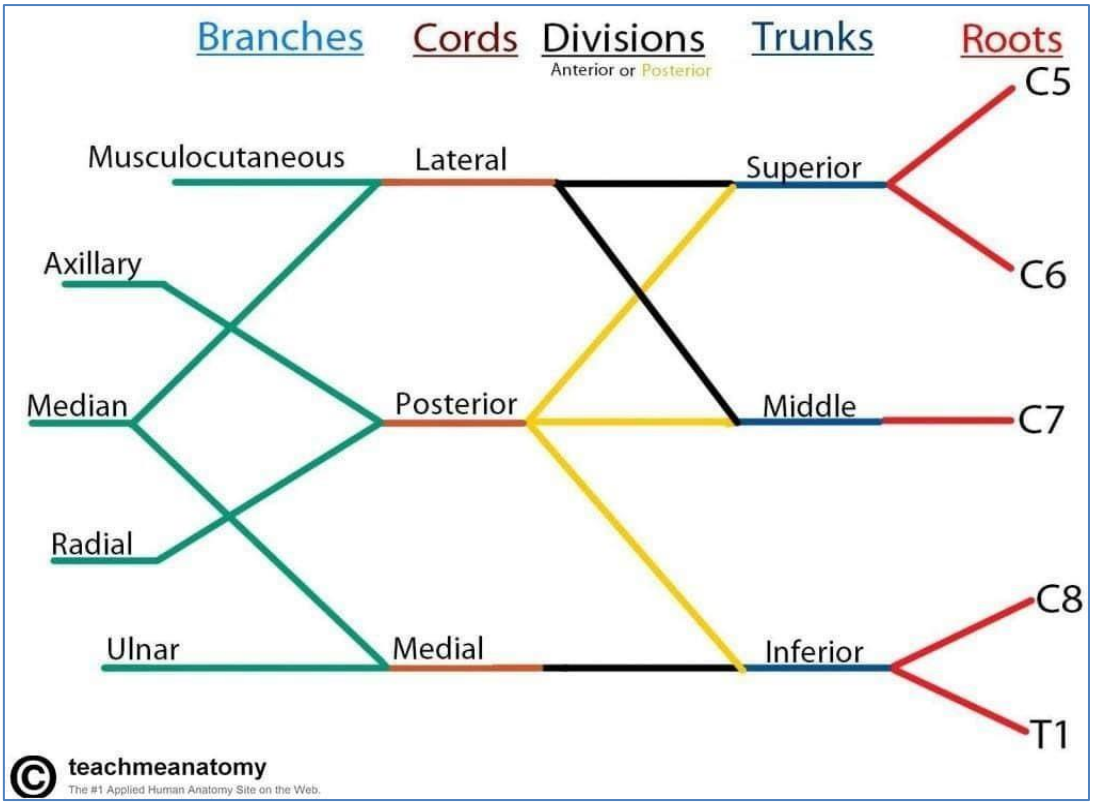

Fig. 3: Diagrammatic representation of the brachial plexus. For simplicity, the smaller branches of the brachial plexus are not shown. The posterior divisions are shown in yellow, and anterior divisions in black.

c. Functional Role of the Brachial Plexus in Upper Limb Innervation.

The brachial plexus plays an essential role in the innervation of the upper limbs. As a complex nervous network, it provides the nerve pathways needed to transmit motor and sensory signals between the central nervous system and the muscles, joints and skin of the arm and hand. The main roles of the brachial plexus in the innervation of the upper limbs are as follows:

1. **Motor innervation**: The brachial plexus sends motor nerve fibers to the muscles of the arm, forearm and hand. These nerve fibers enable muscle movement and coordination, enabling a wide variety of actions, such as flexing, extending, pronating, supinating, grasping and manipulating objects.
2. **Sensory innervation**: The brachial plexus is also responsible for the sensory innervation of the upper limb. Sensory nerve fibers of the brachial plexus transmit sensory information, such as touch, temperature and pain, from the skin of the arm, forearm, hand and fingers to the central nervous system. This enables sensory perception and sensitivity to touch and environmental stimuli.
3. **Reflexes**: The brachial plexus is involved in some important reflexes of the upper limb. For example, the withdrawal reflex (or flexion reflex) is triggered when the skin of the upper limb is painfully stimulated, resulting in a reflex response to withdraw the limb.

- The brachial plexus gives rise to several major peripheral nerves that play a crucial role in the innervation of the upper limb. Here's an overview of the main nerves arising from the brachial plexus and their function:

Musculocutaneous Nerve:

- Origin: Nerve originating from the lateral cord of the brachial plexus (C5-C7 roots).
- Function: Motor innervation of the brachial, brachialis and coraco-brachial muscles, as well as the skin of the anterior arm.

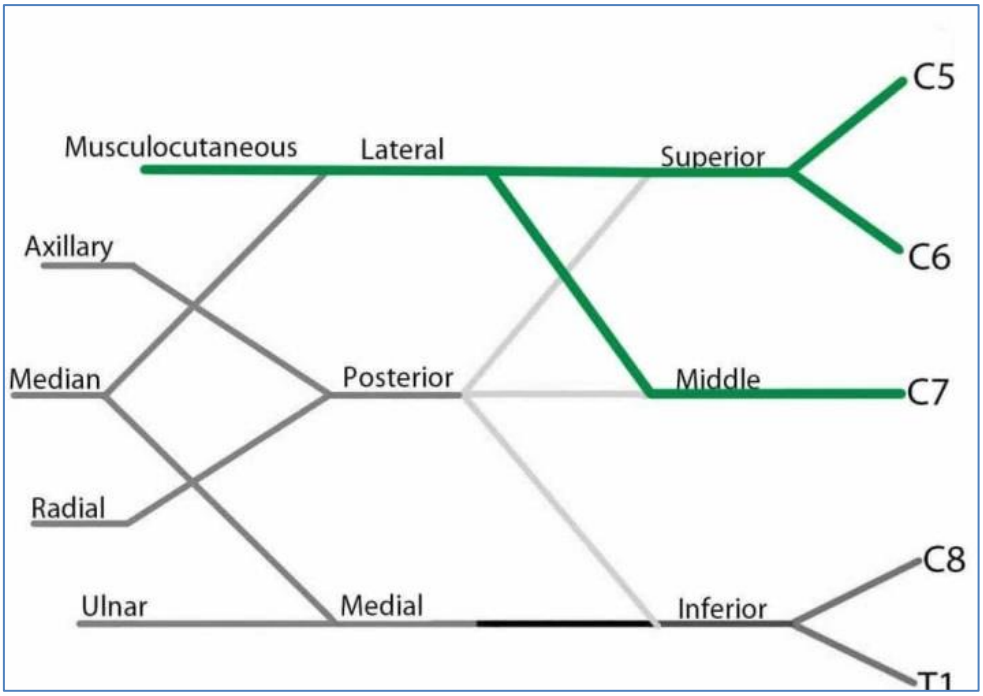

Fig. 4: Origin, course and termination of the musculocutaneous nerve

Radial Nerve:

- **Origin**: Nerve originating from the posterior cord of the brachial plexus (C5- T1 roots).
- **Function**: Motor innervation of the extensor muscles of the forearm, wrist and hand. It also supplies sensory innervation to the dorsal surface of the arm, forearm, hand and posterior fingers.

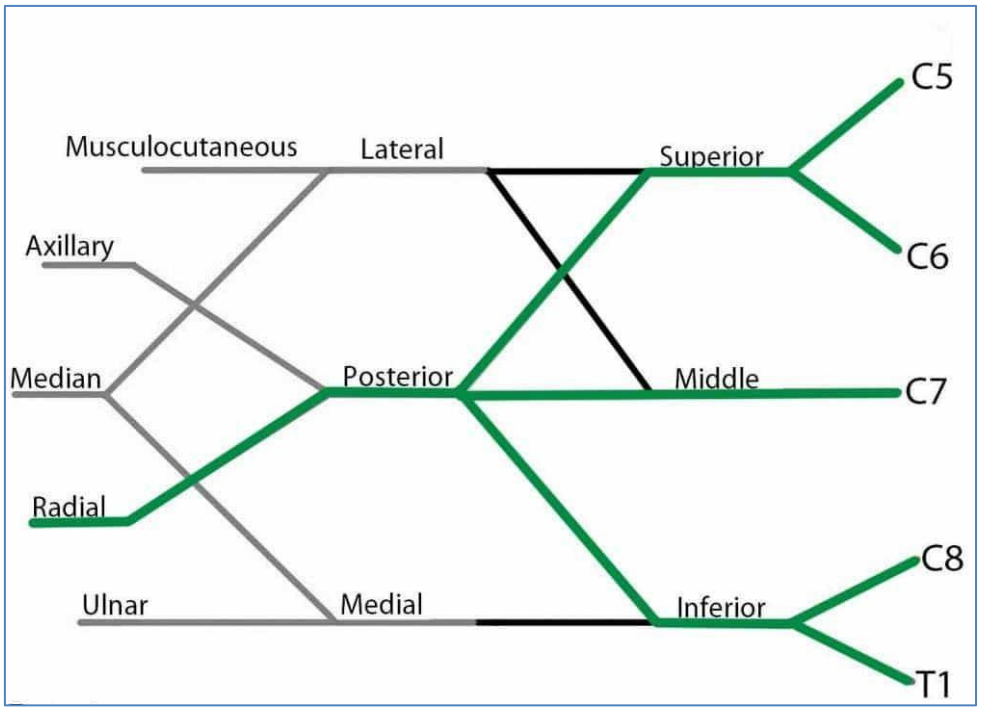

Fig. 5: Origin, course and termination of the radial nerve

Ulnar Nerve:

- **Origin**: Nerve originating from the medial cord of the brachial plexus (C8-T1 roots).
- **Function**: Motor innervation of the deep flexor muscles of the fingers, the short flexor muscles of the thumb, and certain muscles of the hand. It also supplies sensory innervation to the medial side of the hand and fingers.

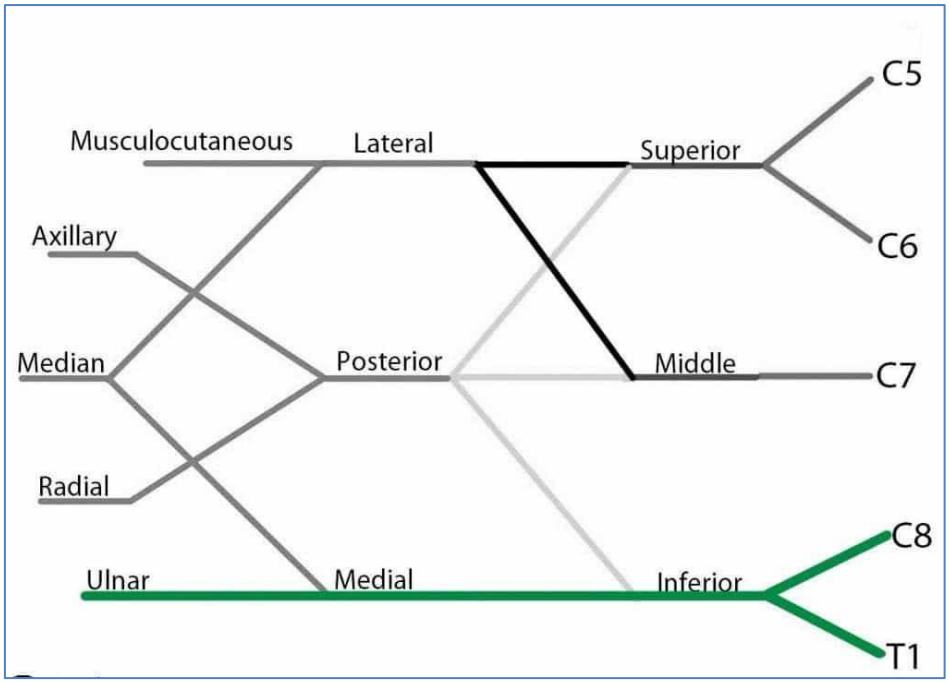

Fig. 6: Origin, course and termination of the nerve

Median Nerve:

- **Origin**: Nerve originating from the C5-T1 roots of the brachial plexus (C6-C8 roots).
- **Function**: Motor innervation of the superficial flexor muscles of the fingers, thumb muscles and certain forearm muscles. It also supplies sensory innervation to the palmar surface of the fingers, with the exception of the little finger.

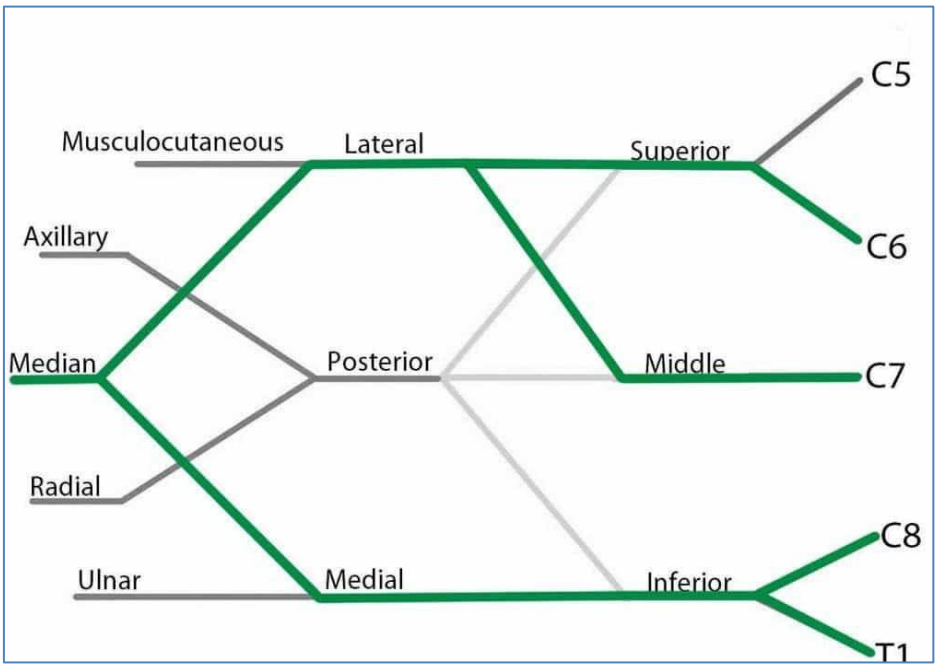

Fig. 7: Origin, course and termination of the nerve

Axillary Nerve:

- **Origin**: Nerve originating from the posterior cord of the brachial plexus (C5- C6 roots).
- **Function**: Motor innervation of the deltoid and rotator cuff muscles of the shoulder. It also supplies sensitive innervation to the skin of the shoulder region.

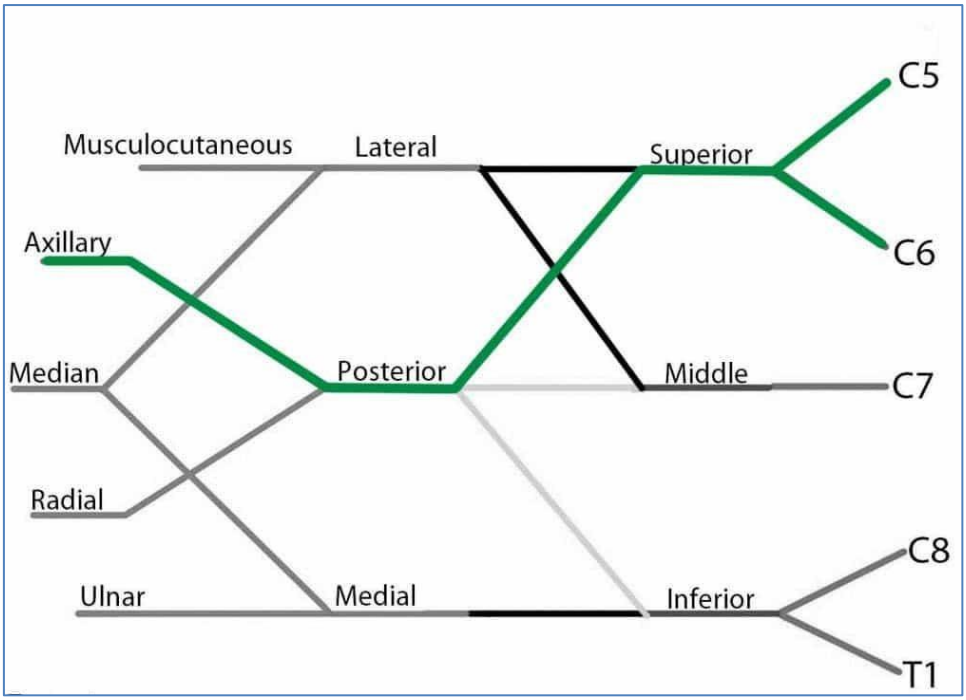

Fig. 8: Origin, course and termination of the nerve

These major peripheral nerves originating from the brachial plexus have specific functions in motor control and sensitivity of the upper limb. They work in synergy to provide a full range of movement and sensitivity in the arm, forearm, hand and finger regions [7- 10].

1) RESULTS

a) Case study: Brachial plexus root transection

In this part of the article, we will present a specific clinical case of brachial plexus root transection. This case study will illustrate the clinical challenges and management approaches associated with this complex condition.

- A 32-year-old man
- No significant medical history.

Mechanism of Injury:

- The patient was involved in a motorcycle accident, resulting in direct open trauma to the left shoulder and arm.

Symptoms:

Absence of distal left upper limb pulses.

- Complete paralysis of the left arm, with inability to move fingers, wrist, elbow and shoulder.
- Loss of sensation throughout the right upper limb. Initial assessment :
- Physical examination: Absence of voluntary movement, muscular atrophy, reduced or absent reflexes, impaired sensitivity in the left upper limb.
- Medical imaging: X-rays, emergency angioscan, bodyscan and/or magnetic resonance imaging (MRI) of the shoulder and brachial plexus to assess damage and extent of injury.
- Electromyography (EMG) and nerve conduction studies to assess brachial plexus nerve integrity. Surgical management:
- Surgical procedure to repair severed brachial plexus roots.
- Techniques used: Direct root repair
- Results and post-operative follow-up:
- Results vary according to the extent of the injury, the surgery performed and post-operative rehabilitation.
- Intensive rehabilitation to optimize functional recovery.

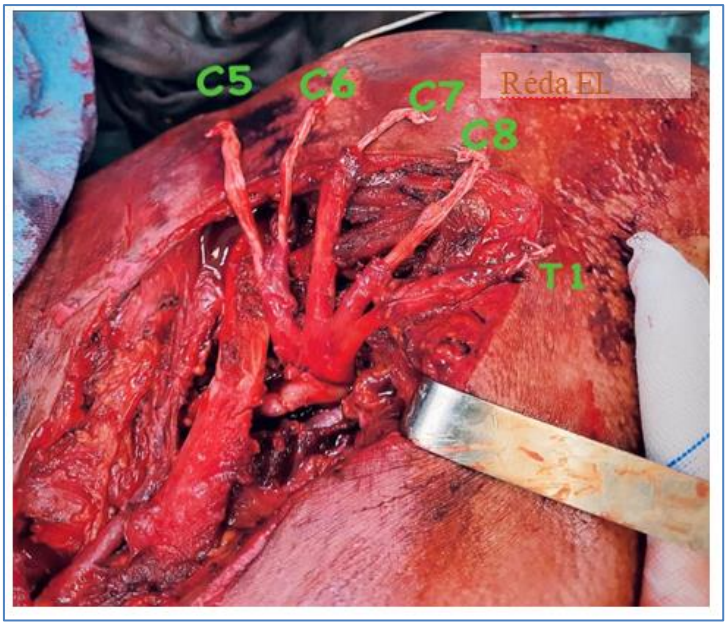

Figure 10: Clinical image of brachial plexus root transection

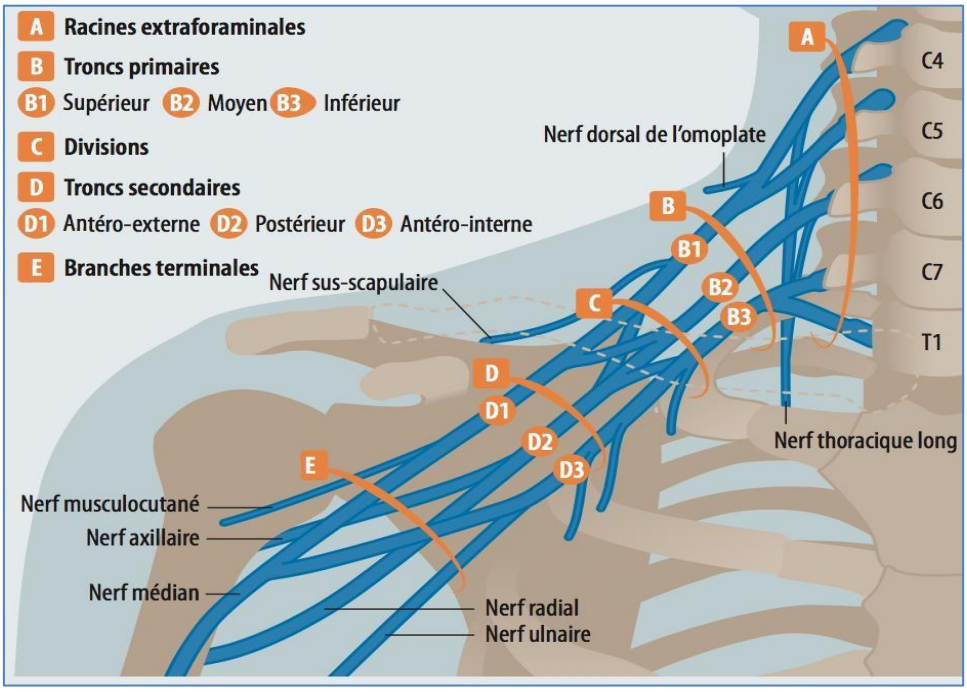

Figure 11: Illustration of the roots of the brachial plexus

b) Initial Assessment and Further Investigations.

In view of the vascular lesion, with the subclavian artery torn off, the vascular surgeons admitted the patient to the OR. For an autograft through the great saphenous vein.

Injuries to the roots of the brachial plexus, such as transection, are serious traumas that can lead to partial or total paralysis of the upper limb.

Surgical treatment is often required to repair severed roots and restore nerve function.

Post-operative rehabilitation plays a crucial role in the functional recovery of the upper limb.

Surgical approaches, such as direct repair, nerve grafts and nerve transfers, are tailored to each specific case.

Intensive rehabilitation and long-term follow-up are essential to optimize functional results.

c) Surgical Approach: Techniques Used, Post-Operative Results and Follow-Up.

This clinical case study illustrates the challenges faced by patients with brachial plexus root

transection and highlights the importance of multidisciplinary management, including surgery, rehabilitation and long-term follow-up. Understanding this condition and appropriate treatment approaches helps to improve functional outcomes and quality of life for patients with brachial plexus root lesions. Significant complications during management. In this specific clinical case, the following challenges and complications were encountered:

1. Severity of injury and trauma: Complete severance of the brachial plexus roots resulted in total paralysis and loss of sensation in the upper limb. Pulse absent in the entire upper limb. Such an injury requires complex, intensive management to maximize the chances of functional recovery.
2. Surgical complications: Brachial plexus root repair surgery carries the risk of complications, including infection, excessive bleeding, healing problems, further nerve damage or unsatisfactory results. Specialized surgical expertise is essential to minimize these risks.
3. Intensive rehabilitation: Post-operative rehabilitation is a major challenge in the management of brachial plexus root transection. Rehabilitation must be intensive, personalized and prolonged to promote optimal functional recovery. This may involve specific exercises, nerve stimulation techniques and close collaboration between patient, therapists and physicians.
4. Unpredictable results: Functional results following brachial plexus root transection may vary from patient to patient. Despite intensive therapeutic efforts, some patients may experience partial recovery or permanent functional limitations. Managing patient expectations and providing psychological support are essential for successful overall management [11, 12].

3. DISCUSSION

A) Review of the Literature: Diagnostic and Therapeutic Approaches

Root transection of the brachial plexus is a serious injury that can lead to partial or total paralysis of the upper limb. Therapeutic management of this condition aims to restore motor and sensory function to the arm and hand. In this literature review, we look in detail at recent therapeutic approaches to brachial plexus root transection.

Diagnostic Approach

1. **Medical Imaging**
   - Advances in medical imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI), have improved the visualization and assessment of brachial plexus root lesions. These modalities provide detailed information on the extent of the lesion, adjacent anatomical structures and possible nerve compression.
2. **Electrophysiology**
   - Nerve conduction studies and electromyography (EMG) are important tools for assessing brachial plexus nerve integrity and diagnosing root lesions. These tests measure nerve conduction velocity, amplitude of muscle responses and identify areas of nerve dysfunction [13, 14].

Therapeutic Approach

1. **Direct nerve repair:**
   - Direct nerve repair involves suturing the ends of severed nerve roots to restore nerve continuity.
   - This approach is generally used for partial root sections and when the nerve endings are in good condition.
   - Precise surgical techniques and delicate manipulation of nerve tissue are required to ensure successful repair.
2. **Nerve grafts:**
   - Nerve grafts are a common option for extensive sections of brachial plexus roots.
   - Autologous nerve segments, such as the sural nerve, the intercostal nerve or the nerve of the extensor digitorum brevis muscle of the wrist, can be used as grafts to restore nerve continuity.
   - This approach enables axonal regeneration through the nerve graft, facilitating functional recovery.
3. **Nerve transfers:**
   - Nerve transfers are an innovative approach to restoring motor function after brachial plexus root transection.
   - Non-essential functional nerves, such as the thoracodorsal nerve or ulnar nerve, are diverted to the affected muscles or areas to restore motor function.
   - Nerve transfers enable faster nerve reconnection and improved functional recovery.
4. **Functional Electrical Stimulation (FES):**
   - Functional electrical stimulation is used as a complement to surgery and rehabilitation to facilitate the recovery of motor function.
   - Electrodes are placed on paralyzed muscles, and electrical stimulation is applied to induce muscle contractions.
   - This approach helps maintain muscle strength, prevent atrophy and promote muscle coordination.

5. **Specialized Rehabilitation:**
   - Post-operative rehabilitation is essential to optimize functional results after brachial plexus root transection.
   - Specialized rehabilitation programs, including muscle strengthening exercises, joint mobilization techniques, sensory stimulation and functional activities, are used to promote recovery and adaptation of the upper limb [15-20].

Comparative Analysis of Different Approaches and Their Clinical Results.

1. **Surgical Approaches To Brachial Plexus Root Repair:**
   a. Oberlin C, *et al.,* (1994). Nerve transfers in brachial plexus palsies [21].
   b. Terzis JK, *et al.,* (2004). Reconstruction of brachial plexus injuries in adults [22].
   c. Bertelli JA, *et al.,* (2016). Combined nerve transfers for C5 and C6 brachial plexus avulsion injury [23].

2. ***Nerve Grafts in Brachial Plexus Root Repair:***
   a. Leechavengvongs S, *et al.,* (1997). Nerve transfer to biceps muscle using a part of ulnar nerve for C5-C6 avulsion of the brachial plexus: anatomical study and report of four cases [24].
   b. Ray WZ, *et al.,* (2008). Nerve transfers and nerve grafting for upper plexus injuries [25].
   c. Bertelli JA, *et al.,* (2010). Sensory recovery after peripheral nerve repair in brachial plexus avulsion injuries [26].

3. ***Nerve Transfers in Brachial Plexus Root Repair:***
   a. Gu YD, *et al.,* (1988). Long-term functional results of contralateral C7 transfer [26].
   b. Chuang DC, *et al.,* (1998). Double free-muscle transfer for the treatment of brachial plexus root avulsions [27].
   c. Doi K, *et al.,* (2007). Surgical techniques for total avulsion of the brachial plexus [28].

4. ***Functional Electrical Stimulation (FES) In Brachial Plexus Root Repair:***
   a. Cheesborough JE, *et al.,* (2017). Electrical stimulation for the treatment of upper limb dysfunction in persons with brachial plexus injury: a systematic review [29].
   b. Rosén B, *et al.,* (2020). Upper limb functional electrical stimulation for brachial plexus injuries: a systematic review [30].

Oberlin C, *et al.,* (1994). Nerve Transfers in Brachial Plexus Palsies.

The study entitled "Nerve transfers in brachial plexus palsies" was conducted by Oberlin C and colleagues in 1994. The aim of this study was to evaluate the use of nerve transfers in the treatment of brachial plexus palsies.

Brachial plexus paralysis usually occurs as a result of trauma or nerve damage in the brachial plexus region, leading to loss of motor and sensory function in the upper limb. Treatment of these paralyses represents a clinical challenge, and various surgical approaches have been proposed to restore motor function.

In this study, researchers examined the use of nerve transfers as a method of nerve repair for brachial plexus paralysis. Nerve transfers involve rerouting existing non-essential nerves to paralyzed muscles to restore motor function.

The authors analyzed a group of patients with brachial plexus paralysis who were treated with nerve transfers. They assessed patients' functional outcomes in terms of recovery of muscle strength, range of motion and ability to perform specific upper limb tasks.

In the study by Oberlin C *et al.,* (1994) entitled "Nerve transfers in brachial plexus palsies", different nerve transfer techniques were used for the repair of brachial plexus injuries. Details of the technique used in this study are as follows:

1. Transferring the ulnar nerve to the musculocutaneous nerve: In some cases of brachial plexus injury, the musculocutaneous nerve, responsible for innervation of the forearm flexor muscles, may be affected. In this study, the ulnar nerve, which primarily controls the hand muscles, was transferred to the musculocutaneous nerve to restore function to the forearm flexors.
2. Transfer of the accessory spinal nerve to the suprascapular nerve: The suprascapular nerve is responsible for innervation of the shoulder muscles, and can be injured in some brachial plexus lesions. In this study, the accessory spinal nerve, which controls the trapezius and sternocleidomastoid muscles, was transferred to the suprascapular nerve to restore shoulder function.
3. Transferring the intercostal nerve to the axillary nerve: The axillary nerve, which originally innervated the shoulder and arm muscles, can be affected in brachial plexus lesions. In this study, an intercostal nerve from the intercostal space was used to restore innervation of the axillary nerve and restore function to the shoulder and arm.

These nerve transfer techniques bypass brachial plexus lesions by using healthy nerves to restore innervation to the affected muscles. The aim is to restore motor function to the upper limb and improve quality of life for patients with brachial plexus injuries.

The results of the study showed that nerve transfers were a promising approach in the treatment of brachial plexus paralysis. Patients showed significant improvements in motor function, with recovery of muscle strength and improved ability to perform specific movements of the upper limb.

This study helped demonstrate the effectiveness of nerve transfers in the treatment of brachial plexus paralysis. Since then, this surgical approach has become a commonly used therapeutic option in the management of these conditions [21].

Terzis JK, *et al.*, (2004). Reconstruction of Brachial Plexus Injuries in Adults.

The study entitled "Reconstruction of brachial plexus injuries in adults" was carried out by Terzis JK and colleagues in 2004. The aim of this study was to examine the different reconstructive techniques used in brachial plexus injuries in adults.

Brachial plexus lesions in adults can result from trauma, tumors, infections or congenital conditions. These injuries can result in loss of motor and sensory function of the upper limb, requiring surgical reconstruction to restore function and improve patients' quality of life.

In this study, researchers reviewed the reconstructive techniques used in adult brachial plexus injuries. They examined patients' functional outcomes after surgery, focusing on restoration of motor and sensory function in the upper limb.

The authors analyzed different surgical approaches, such as nerve transfers, nerve grafts, muscle transfers and direct nerve repair techniques. They evaluated the results in terms of recovery of muscle strength, joint mobility and sensitivity of the upper limb.

Indeed, different surgical techniques have been used for the reconstruction of brachial plexus lesions in adults. Here are details of some of the techniques used in this study:

1. Nerve transfer: In cases of brachial plexus injury, where nerve roots are torn or damaged, nerve transfer techniques can be used. This involves harvesting healthy nerves from other parts of the body, such as the nerves of the lower limb or opposite side, and transplanting them to the affected muscles or nerves of the upper limb. These nerve transfers restore muscle innervation and motor function.
2. Nerve grafts: In cases where damage to the brachial plexus is more extensive and nerve roots are completely destroyed, nerve grafts can be used. This involves taking a healthy nerve segment from another part of the body, usually the sural nerve of the lower limb, and grafting it to replace the missing or damaged sections of the brachial plexus. Nerve grafts restore nerve continuity and promote axonal regeneration.
3. Tendon transfer: In addition to nerve repair techniques, tendon transfers can be used to restore muscle function in the upper limb. This involves detaching a tendon from a functional muscle and repositioning it to provide a new attachment for a paralyzed or weakened muscle. Tendon transfers restore the movement and muscle strength needed for daily activities.

The results of the study showed that surgical reconstruction of the brachial plexus in adults can lead to a significant improvement in motor and sensory function. Nerve transfers and nerve grafts proved to be effective techniques for restoring motor function, while muscle transfers were used to improve grip and hand functionality.

This study has helped to highlight the importance of surgical reconstruction in the management of brachial plexus injuries in adults. Different reconstructive techniques can be used in a complementary manner to optimize functional results [22].

Bertelli JA, *et al.*, (2016). Combined Nerve Transfers For C5 and C6 Brachial Plexus Avulsion Injury.

The study entitled "Combined nerve transfers for C5 and C6 brachial plexus avulsion injury" was conducted by Bertelli JA and colleagues in 2016. This study aimed to evaluate the efficacy of combined nerve transfers for C5 and C6 brachial plexus root avulsion injury.

Brachial plexus root avulsion is a serious injury in which the nerve roots are completely torn from the spinal cord. This condition results in loss of motor and sensory function in the upper limb. The surgical management of such injuries is complex, requiring advanced nerve repair techniques.

In this study, researchers proposed a combined nerve transfer approach for C5 and C6 root avulsion lesions. This approach involved using existing non-essential nerves to restore motor function in the affected brachial plexus region.

Here are the details of the surgical technique used in this study:

1. Transfer of the accessory spinal nerve to the musculocutaneous nerve: The musculocutaneous nerve, responsible for innervation of the forearm flexor muscles, can be affected in C5 and C6 root avulsion lesions. In this study, the accessory spinal nerve, which controls the trapezius and sternocleidomastoid

muscles, was transferred to the musculocutaneous nerve to restore forearm flexor function.
2. Transferring the median nerve to the axillary nerve: The axillary nerve, which originally innervated the shoulder and upper arm muscles, can also be affected in C5 and C6 root avulsion lesions. In this study, the median nerve, which primarily controls the flexor muscles of the wrist and fingers, was transferred to the axillary nerve to restore innervation of the shoulder and arm muscles.
3. Additional nerve grafts: In addition to nerve transfers, nerve grafts can be used to restore nerve continuity and promote axonal regeneration. In this study, additional nerve grafts from healthy nerves were used as needed to repair missing or damaged sections of the brachial plexus.

The combined use of nerve transfers and nerve grafts restores innervation to the muscles and nerves of the upper limb in patients with avulsion lesions of the C5 and C6 roots. This surgical approach aims to restore motor and sensory function to the upper limb and improve patients' quality of life.

The authors examined a group of patients with avulsion lesions of the C5 and C6 roots of the brachial plexus who were treated with this combined nerve transfer approach. They assessed patients' functional outcomes in terms of recovery of muscle strength, range of motion and ability to perform specific upper limb tasks.

The results of the study showed that combined nerve transfers for avulsion lesions of the C5 and C6 roots of the brachial plexus led to significant improvements in motor function in patients. Patients showed increased muscle strength and improved ability to perform specific movements of the upper limb.

This study suggests that combined nerve transfers may be an effective approach to restoring motor function in patients with avulsion lesions of the C5 and C6 roots of the brachial plexus. However, it should be noted that each case is unique, and results may vary depending on the severity of the lesion, individual patient characteristics and other factors. It is therefore essential to consult a specialized healthcare professional to determine the best treatment approach for each specific case [23].

Nerve Grafts in Brachial Plexus Root Repair: Leechavengvongs S, *et al.*, (1997). Nerve Transfer to Biceps Muscle Using a Part of Ulnar Nerve for C5-C6 Avulsion of the Brachial Plexus: Anatomical Study and Report of Four Cases.

The study entitled "Nerve transfer to biceps muscle using a part of ulnar nerve for C5- C6 avulsion of the brachial plexus: anatomical study and report of four cases" was carried out by Leechavengvongs S and colleagues in 1997. The aim of this study was to evaluate the use of nerve transfer from the ulnar nerve to the biceps muscle to treat avulsions of the C5-C6 roots of the brachial plexus.

Avulsions of the C5-C6 roots of the brachial plexus are serious lesions that result in loss of motor function in the upper limb. Treatment of these lesions is challenging, and various surgical approaches have been proposed to restore motor function.

In this study, researchers investigated the use of nerve transfer from the ulnar nerve to the biceps muscle as a repair method in avulsions of the C5-C6 roots of the brachial plexus. They conducted an anatomical study to assess the feasibility of this technique, and also reported four clinical cases where this approach was used.

The authors performed anatomical dissections to demonstrate the possibility of transferring part of the ulnar nerve to the biceps muscle. They studied the feasibility of this technique by assessing the available length of the ulnar nerve and its ability to reach the biceps muscle.

Here are the details of the surgical technique used in this study:
1. Transfer of ulnar nerve to biceps muscle nerve: In C5 and C6 root avulsion lesions, the biceps muscle nerve is often affected, resulting in loss of biceps muscle function. In this study, a portion of the ulnar nerve, which primarily controls hand muscles, was used as a nerve graft to restore innervation of the biceps muscle nerve. A section of the ulnar nerve was harvested and connected to the biceps muscle nerve to restore biceps muscle function.
2. Repair of innervation of other forearm flexor muscles: In addition to transferring the ulnar nerve to the biceps nerve, other repair techniques have been used to restore innervation of other forearm flexor muscles. Additional nerve grafts from healthy nerves were used to repair missing or damaged sections of the brachial plexus and restore muscle innervation.

In the four clinical cases reported, the patients presented with avulsion of the C5-C6 roots of the brachial plexus. The authors performed nerve transfer from the ulnar nerve to the biceps muscle to restore motor function to the biceps muscle.

The results of the study showed that nerve transfer from the ulnar nerve to the biceps muscle was feasible and could lead to recovery of biceps muscle

motor function in patients with avulsion of the C5-C6 roots of the brachial plexus.

This study has helped to broaden the surgical options for repairing avulsions of the C5-C6 roots of the brachial plexus. Nerve transfer from the ulnar nerve to the biceps muscle can be used when other donor nerves are unavailable or unsuitable.

It is important to note that each case of brachial plexus injury is unique, and the choice of repair technique will depend on various factors such as the severity of the injury, individual patient characteristics and functional goals. A full assessment by a specialist surgeon is essential to determine the best treatment approach for each patient [24].

Ray WZ, *et al.*, (2008). Nerve Transfers and Nerve Grafting for Upper Plexus Injuries.

The study entitled "Nerve transfers and nerve grafting for upper plexus injuries" was conducted by Ray WZ and colleagues in 2008. The aim of this study was to evaluate the use of nerve transfers and nerve grafts in the treatment of upper brachial plexus injuries.

Lesions of the upper brachial plexus, usually affecting the C5 and C6 roots, lead to loss of motor and sensory function in the upper limb. Choosing the right surgical technique to restore function is crucial in these cases.

In this study, researchers examined the use of nerve transfers and nerve grafts as repair methods for upper brachial plexus injuries. They assessed patients' functional outcomes after surgery, focusing on the recovery of motor function in the upper limb.

The authors reviewed the records of patients with upper brachial plexus injuries who had undergone nerve transfers or nerve grafts. They assessed outcomes in terms of recovery of muscle strength, range of motion and ability to perform functional activities.

Here are the details of the surgical technique used in this study:

1. Nerve transfer: Nerve transfers are surgical techniques in which functional nerves from other parts of the body are used to restore innervation to paralyzed or weakened muscles. In this study, nerve transfers were performed to repair damage to the upper roots of the brachial plexus. For example, the median nerve can be transferred to the musculocutaneous nerve to restore function to the forearm flexor muscles.
2. Nerve grafts: Nerve grafts are used when nerve roots are completely destroyed or non-functional. In these cases, a healthy nerve segment taken from another part of the body, usually the sural nerve of the lower limb, is used as a graft to restore nerve continuity and promote axonal regeneration. Nerve grafts can be used to repair missing or damaged sections of the brachial plexus.
3. Muscle resuscitation techniques: In addition to nerve transfers and nerve grafts, muscle resuscitation techniques can be used to restore muscle function. These can include tendon transfers, where a functional tendon is detached and repositioned to provide a new attachment for a paralyzed muscle. These techniques restore the movement and muscle strength needed for everyday activities.

The results of the study showed that nerve transfers and nerve grafts were effective approaches to restoring motor function in patients with upper brachial plexus injuries. Patients showed significant improvements in muscle strength, range of motion and ability to perform specific upper limb tasks.

This study has helped to highlight the importance of nerve transfers and nerve grafts in the repair of upper brachial plexus injuries. These surgical techniques offer patients opportunities for functional recovery, using nerves or nerve segments to restore nerve continuity and promote axonal regrowth [25].

Bertelli JA, *et al.*, (2010). Sensory Recovery after Peripheral Nerve Repair in Brachial Plexus Avulsion Injuries.

The study entitled "Sensory recovery after peripheral nerve repair in brachial plexus avulsion injuries" was conducted by Bertelli JA and colleagues in 2010. This study aimed to evaluate sensory recovery after peripheral nerve repair in brachial plexus avulsion injuries.

Brachial plexus avulsion lesions lead not only to loss of motor function, but also to impaired sensitivity of the upper limb. Restoration of sensation is an important aspect of functional recovery and quality of life for patients.

In this study, researchers examined sensory recovery in patients with brachial plexus avulsion lesions who were treated with peripheral nerve repair. They assessed outcomes in terms of skin sensitivity recovery in different regions of the upper limb.

The authors analyzed the records of patients who had undergone peripheral nerve repair to treat their brachial plexus avulsion injuries. They assessed sensory recovery using clinical tests to measure sensitivity to pain, light touch and tactile discrimination in areas innervated by the repaired nerves.

Here are some details of the surgical technique used in this study:

1. Nerve grafts: Nerve grafts were used to restore nerve continuity and promote axonal regeneration. Healthy nerve segments, harvested from other parts of the patient's body, were used as grafts to repair missing or damaged sections of the brachial plexus. Nerve grafts help guide axon growth and restore innervation to affected sensory areas.
2. Sensory nerve transfer: In some cases, sensory nerve transfers have been performed to restore sensitivity in affected areas. Sensory nerves from other parts of the body have been transferred to the brachial plexus nerves to restore tactile sensation and proprioception. The aim of these nerve transfers is to reconnect sensory pathways and restore normal sensory perception.
3. Sensory rehabilitation: In addition to surgical techniques, intensive sensory rehabilitation has been implemented to facilitate sensory recovery following nerve repair. This includes specific exercises to stimulate and retrain sensory pathways, as well as sensory therapies based on tactile, vibratory and proprioceptive stimuli.

The aim of these surgical techniques and sensory rehabilitation was to restore sensation in the affected areas and improve quality of life in patients with brachial plexus avulsion lesions.

The results of the study evaluated the effectiveness of these approaches in post-operative sensory recovery.

The results of the study showed that peripheral nerve repair in brachial plexus avulsion lesions enabled significant recovery of cutaneous sensitivity. Patients showed improvements in sensitivity to pain, light touch and tactile discrimination in areas innervated by the repaired nerves.

This study has helped to highlight the importance of peripheral nerve repair in the recovery of sensation in patients with brachial plexus avulsion lesions. Nerve repair restores nerve continuity and promotes axonal regrowth, leading to improved sensory recovery.

It should be noted that each case of brachial plexus injury is unique, and sensory recovery may vary depending on the severity of the injury, individual patient characteristics and other factors. A full assessment by a specialist surgeon is essential to determine the best treatment approach and provide realistic expectations of sensory recovery for each patient [26].

Nerve Transfers in Brachial Plexus Root Repair:
Gu YD, *et al.*, (1988). Long-Term Functional Results of Contralateral C7 Transfer.

The study entitled "Long-term functional results of contralateral C7 transfer" was conducted by Gu YD and colleagues in 1988. The aim of this study was to evaluate the long-term functional results of contralateral C7 nerve transfer in the treatment of brachial plexus injuries.

Brachial plexus injuries can lead to paralysis of the upper limb, limiting patients' motor function and quality of life. Contralateral C7 nerve transfer is a surgical technique used to restore upper limb motor function in these patients.

In this study, researchers followed a group of patients with brachial plexus injuries who were treated with contralateral C7 nerve transfer. They assessed long-term functional outcomes, focusing on recovery of muscle strength, range of motion and ability to perform specific upper limb tasks.

The authors analyzed patient records and performed clinical and functional assessments at regular intervals after surgery. They assessed recovery of motor function by measuring muscle strength and observing active movements of the upper limb.

Here are the details of the surgical technique used in this study:

1. Contralateral C7 nerve harvesting: In this technique, the C7 nerve from the patient's healthy (contralateral) side is harvested. The C7 nerve is chosen because it is considered the most suitable for transfer due to its length, diameter and ability to provide adequate innervation to the muscles of the upper limb.
2. C7 nerve rerouting: Once the C7 nerve has been harvested, it is rerouted to the affected (ipsilateral) side of the brachial plexus. This involves creating a tunnel through the neck and clavicle to allow passage of the C7 nerve from the healthy side to the affected side.
3. Restoring muscle innervation: Once the C7 nerve has been transferred to the affected side, it is sutured to the nerves of the brachial plexus to restore muscle innervation. Muscles that can benefit from this technique include those responsible for elbow flexion, forearm supination and wrist extension.

This contralateral C7 transfer technique aims to use a healthy nerve on the opposite side to restore muscle innervation to the upper limb affected by brachial plexus root damage. The aim is to restore motor function and enable patients to regain functional use of their upper limb.

The results of the study showed that contralateral C7 nerve transfer enabled long-term functional recovery in patients with brachial plexus injuries. Patients showed significant improvements in muscle strength, range of motion and ability to perform functional activities of the upper limb.

This study demonstrated the efficacy of contralateral C7 nerve transfer in restoring motor function in patients with brachial plexus lesions. Contralateral C7 nerve transfer offers a viable surgical option for improving upper limb function and patients' quality of life [27].

Chuang DC, *et al.*, (1998). Double Free-Muscle Transfer for the Treatment of Brachial Plexus Root Avulsions.

The study entitled "Double free-muscle transfer for the treatment of brachial plexus root avulsions" was conducted by Chuang DC and colleagues in 1998. The aim of this study was to evaluate the efficacy of double free-muscle transfer in the treatment of brachial plexus root avulsions.

Brachial plexus root avulsions are serious injuries that result in loss of motor function in the upper limb. Muscle transplantation is a surgical technique used to restore motor function by transferring functional muscles to paralyzed muscles.

In this study, researchers evaluated the results of double free muscle transplantation in patients with brachial plexus root avulsions. Double free muscle transplantation involves the transfer of two functional muscles, usually the gracilis muscle and the latissimus dorsi muscle, to the paralyzed muscles of the upper limb.

The authors assessed functional outcomes in patients in terms of recovery of muscle strength, range of motion and ability to perform specific upper limb tasks. They also assessed patients' quality of life after surgery.

1. Donor muscle harvesting: In this technique, two healthy muscles from other parts of the patient's body are used as donor muscles. The muscles typically used are the gracilis and latissimus dorsi. These muscles are chosen for their strength, length and ability to provide adequate innervation to the muscles of the upper limb.
2. Preparation of muscle grafts: Donor muscles are harvested with their corresponding blood vessels and nerves. The blood vessels are carefully anastomosed to the blood vessels of the recipient site to ensure adequate vascularization of the muscle grafts.
3. Nerve rerouting: Nerves from donor muscles are transferred and sutured to the corresponding nerves in the affected upper limb. This restores innervation to paralyzed or weakened muscles.
4. Fixation of muscle grafts: Donor muscles are surgically fixed in the affected upper limb using fixation techniques such as bone tunnels or osteosynthesis plates. This restores muscle function and promotes motor recovery in the upper limb.

Double free muscle transfer aims to use healthy muscles from other parts of the body to restore innervation and muscle function in the upper limb affected by avulsed brachial plexus roots. This technique restores strength and movement to the upper limb and improves the patient's overall function.

The results of the study showed that double free muscle transplantation was an effective approach to restoring motor function in patients with brachial plexus root avulsions. Patients showed significant improvement in muscle strength, range of motion and ability to perform functional activities of the upper limb.

This study demonstrated the efficacy of double free muscle transplantation in the rehabilitation of brachial plexus root avulsions. Muscle transplantation offers a viable surgical option for restoring motor function and improving patients' quality of life [28].

Doi K, *et al.*, (2007). Surgical Techniques for Total Avulsion of the Brachial Plexus.

The study entitled "Surgical techniques for total avulsion of the brachial plexus" was conducted by Doi K and colleagues in 2007. The aim of this study was to evaluate the surgical techniques used in the treatment of total avulsion of the brachial plexus.

Total brachial plexus avulsions are severe injuries in which all the nerve roots of the brachial plexus are torn from the spinal cord. These injuries result in complete loss of motor and sensory function of the upper limb, requiring complex surgery to restore function.

In this study, researchers examined different surgical techniques used in the treatment of total brachial plexus avulsions. They assessed functional outcomes in patients in terms of recovery of motor function, sensitivity, range of motion and quality of life after surgery.

The authors analyzed the records of patients who had undergone surgery to treat their total brachial plexus avulsions. They evaluated outcomes according to the different surgical techniques used, such as nerve transfers, nerve grafts, muscle transfers and direct nerve repair techniques.

Here are the details of the surgical technique used in this study:

1. Nerve grafts: Nerve grafts were used to restore nerve continuity and promote axonal regeneration. Healthy nerve segments, harvested from other parts of the patient's body, were used as grafts to repair missing or damaged sections of the brachial plexus. Nerve grafts help guide axon growth and restore innervation to affected muscles and sensory areas.
2. Nerve transfers: Nerve transfers are surgical techniques in which functional nerves from other parts of the body are used to restore innervation to paralyzed or weakened muscles or nerves. In this study, nerve transfers were performed to repair total avulsion lesions of the brachial plexus. For example, the accessory spinal nerve can be transferred to the nerves of the brachial plexus to restore muscle innervation.
3. Muscle transposition: In some cases, when the original nerves are not available for repair, muscle transposition techniques can be used. This involves detaching a functional muscle and repositioning it to provide a new attachment for a paralyzed or weakened muscle. This technique restores the movement and muscle function required for daily activities.
4. Intensive rehabilitation: After surgery, intensive rehabilitation is generally required to promote functional recovery. This may include muscle strengthening exercises, physical and occupational therapies, as well as sensory rehabilitation techniques to improve motor and sensory function of the upper limb.

The results of the study showed that the surgical techniques used in the treatment of total brachial plexus avulsions can achieve significant functional recovery in some patients. Results varied according to the severity of the lesion, the surgical technique used and the patient's individual characteristics.

This study has helped to highlight the importance of an individualized surgical approach in the treatment of total brachial plexus avulsions. The choice of surgical technique will depend on various factors, such as the severity of the lesion, individual patient characteristics and functional goals.

It should be noted that total brachial plexus avulsions represent complex lesions requiring specialized surgical expertise. A thorough evaluation by a specialized surgeon is essential to determine the best treatment approach for each patient and to provide realistic expectations of possible functional outcomes [29].

Functional Electrical Stimulation (FES) In Brachial Plexus Root Repair:

Cheesborough JE, *et al.*, (2017). Electrical Stimulation for the Treatment of Upper Limb Dysfunction in Persons with Brachial Plexus Injury: A Systematic Review.

The study entitled "Electrical stimulation for the treatment of upper limb dysfunction in persons with brachial plexus injury: a systematic review" was conducted by Cheesborough JE and colleagues in 2017. This study aimed to evaluate the efficacy of electrical stimulation in the treatment of upper limb dysfunction in persons with brachial plexus injury.

Brachial plexus lesions can lead to impaired motor and sensory function of the upper limb, limiting individuals' ability to perform daily activities. Electrical stimulation is a non-invasive technique that can be used to improve muscle function and recovery of the upper limb in these patients.

In this study, researchers carried out a systematic review of the existing literature on the use of electrical stimulation in the treatment of upper limb dysfunction in people with brachial plexus injuries. They assessed relevant studies in terms of methodology, results and quality of evidence.

FES uses electrical impulses to stimulate nerves and muscles to restore motor function in the upper limb. Here are some details of the functional electrical stimulation technique:

1. Stimulation electrodes: Electrodes are placed on the skin to deliver electrical impulses. Electrodes can be placed directly on affected muscles or on proximal nerves to stimulate downstream muscles.
2. Programming electrical parameters: Electrical parameters such as pulse intensity, frequency and duration are programmed to suit the patient's individual needs. These parameters can be adjusted to specifically target affected muscles and nerves.
3. Stimulation sessions and rehabilitation: EES is generally used in combination with functional rehabilitation sessions. During stimulation sessions, patients perform assisted active or passive movement exercises, facilitated by electrical stimulation. This helps to strengthen muscles, improve motor coordination and promote functional rehabilitation.

The aim of functional electrical stimulation is to facilitate the recovery of upper limb motor function in patients with brachial plexus root lesions. This may include restoration of muscle strength, coordination, prehension and overall function of the upper limb.

The results of the systematic review showed that electrical stimulation can be beneficial in the

treatment of upper limb dysfunction in people with brachial plexus injuries. Electrical stimulation can improve muscle strength, coordination and functionality of the upper limb, as well as patients' quality of life.

However, the authors pointed out that there are variations in the electrical stimulation protocols used and in the results reported, making direct comparison between studies difficult. In addition, the quality of the evidence was limited in some cases, highlighting the need for more well-designed studies to confirm the results.

This study has highlighted the potential of electrical stimulation as a treatment option for improving upper limb function in people with brachial plexus injuries. However, it is important to note that each case is unique, and the decision to use electrical stimulation must be based on individual assessment and multidisciplinary management [30].

Rosén B, et al., (2020). Upper Limb Functional Electrical Stimulation for Brachial Plexus Injuries: A Systematic Review.

The study entitled "Upper limb functional electrical stimulation for brachial plexus injuries: a systematic review" was conducted by Rosén B and colleagues in 2020. The aim of this study was to evaluate the effectiveness of functional electrical stimulation of the upper limb in the treatment of brachial plexus injuries.

Brachial plexus injuries often result in loss of motor and sensory function in the upper limb, limiting individuals' ability to perform daily activities. Functional electrical stimulation is an approach that uses electrical impulses to selectively activate paralyzed muscles and improve upper limb function.

In this study, researchers conducted a systematic review of the existing literature on the use of functional electrical stimulation in the treatment of brachial plexus injuries. They assessed relevant studies in terms of methodology, results and quality of evidence.

Here are a few details on the functional electrical stimulation technique:

1. Stimulation electrodes: Electrodes are placed on the skin at specific points on the upper limb to deliver electrical impulses. Electrodes can be placed directly on affected muscles or on proximal nerves to stimulate downstream muscles.
2. Programming electrical parameters: Electrical parameters such as intensity, frequency, pulse duration and stimulation pattern are programmed according to the patient's individual needs. These parameters can be adjusted to specifically target affected muscles and nerves.
3. Stimulation sessions and rehabilitation: SEF is generally used in combination with functional rehabilitation sessions. During stimulation sessions, patients perform movements assisted or resisted by electrical impulses. This helps to strengthen muscles, improve motor coordination and promote functional rehabilitation.
4. Adaptive stimulation systems: Some functional electrical stimulation systems use motion sensors or electromyograms (EMGs) to detect the patient's residual muscle activity. This information is used to adapt stimulation parameters in real time, enabling more precise stimulation and better synchronization with the patient's movements.

The aim of functional electrical stimulation is to facilitate the recovery of upper limb motor function in patients with brachial plexus root lesions. This may include restoration of muscle strength, coordination, prehension and overall function of the upper limb.

The results of the systematic review showed that functional electrical stimulation can be beneficial in the treatment of brachial plexus injuries, improving patients' motor function and quality of life. This approach has demonstrated positive effects on muscle strength recovery, range of motion and ability to perform functional activities of the upper limb.

However, the authors pointed out that there are variations in the functional electrical stimulation protocols used, particularly in terms of electrical parameters, session duration and frequency. In addition, the quality of the evidence was variable, highlighting the need for more high-quality studies to confirm the results.

This study highlights the potential of functional electrical stimulation as a therapeutic approach to improving upper limb function in patients with brachial plexus injuries. However, it is important to note that each case is unique, and the decision to use functional electrical stimulation must be based on individual assessment and multidisciplinary management.

It is advisable to consult a specialized healthcare professional to determine whether functional electrical stimulation is appropriate in each specific case and to develop a personalized treatment plan [31].

Presentation of Recent Advances in the Field and Future Prospects.

1. **Advanced Surgical Techniques**: In recent years, new surgical techniques have been developed for brachial plexus root repair. These include approaches such as specific

nerve transfers, improved nerve grafts and the use of biomaterials to promote nerve regeneration. These techniques offer new possibilities for improving functional outcomes in patients.

2. **Regenerative Therapies**: Research has also focused on regenerative therapies for brachial plexus root transection. This includes the use of stem cells, growth factors and bioengineering to promote nerve regeneration and restore motor and sensory function. These advances open up new prospects for nerve recovery in patients with brachial plexus injuries.
3. **Multidisciplinary Approaches**: Multidisciplinary care teams have become increasingly important in the management of brachial plexus injuries. Collaboration between surgeons, neurologists, physiotherapists, occupational therapists and other rehabilitation professionals is essential to develop comprehensive, individualized treatment plans. This enables a holistic approach to maximizing functional outcomes for patients.

Future Prospects:

1. Optimizing functional outcomes: Future research should focus on optimizing functional outcomes after brachial plexus root repair. This includes improving surgical techniques, finding better rehabilitation options and identifying biomarkers predictive of nerve recovery.
2. Personalizing treatment approaches: Personalizing treatment approaches according to individual patient characteristics is a promising area for the future. Further studies are needed to better understand the factors that influence nerve recovery and to develop evidence-based decision-making algorithms to guide the selection of the optimal repair technique for each patient.
3. Emerging technologies: Technological advances, such as the use of artificial intelligence, neural implants and virtual reality, may play an increasing role in the rehabilitation of brachial plexus injuries. These technologies can improve diagnostic accuracy, facilitate rehabilitation and enable more targeted interventions for functional recovery.

In conclusion, recent advances in brachial plexus root transection open up new perspectives for the repair and rehabilitation of these injuries. Advanced surgical techniques, regenerative therapies and multidisciplinary approaches offer opportunities to improve functional outcomes for patients. Future prospects focus on optimizing outcomes, personalizing treatment approaches and exploring emerging technologies for better management of brachial plexus injuries [32- 35].

CONCLUSION

As a general conclusion, it is essential to stress the importance of early, personalized management of brachial plexus root lesions. The key points to remember are as follows:

- Early diagnosis: Early and accurate diagnosis of brachial plexus root lesions is crucial for prompt and appropriate intervention. A comprehensive evaluation, including physical examination, sensitivity testing and imaging studies, is necessary to establish an optimal treatment plan.
- Multidisciplinary approach: The management of brachial plexus root lesions requires a multidisciplinary approach involving orthopaedic surgeons, neurologists, rehabilitation specialists, occupational therapists and other specialized healthcare professionals.
  Coordinated care and collaboration between the various disciplines help optimize functional outcomes and meet individual patient needs.
- Personalized treatment: Every case of brachial plexus root injury is unique, with specific characteristics that need to be taken into account when planning treatment. A personalized approach is needed to select the appropriate surgical technique, determine the optimal timing of surgery and design a rehabilitation program tailored to the patient's individual needs.
- Intensive rehabilitation: Intensive rehabilitation is an essential part of the management of brachial plexus root injuries. Rehabilitation programs must be specifically tailored to each patient, focusing on the recovery of motor and sensory function in the upper limb. A progressive approach guided by rehabilitation professionals will optimize long-term results.
- Long-term follow-up: Brachial plexus root injuries may require long-term follow-up to assess recovery progress, adjust treatments and manage potential complications. Regular follow-up allows functional results to be monitored and any additional interventions required to maximize recovery [36, 37].

Early, personalized management of brachial plexus root lesions is essential to optimize functional outcomes and improve patients' quality of life. A multidisciplinary, evidence-based and patient-centered approach provides comprehensive care tailored to each patient's individual needs.

It is also crucial to highlight gaps in current knowledge and areas requiring further research. Here's a possible presentation:

Highlighting Gaps in Current Knowledge and Areas Requiring Further Research:

Factors predictive of recovery: Despite advances in brachial plexus root repair, there are still gaps in our understanding of factors predictive of functional recovery. Further research is needed to identify biomarkers, clinical features and neurophysiological parameters that can predict functional outcome in patients.

Optimizing surgical techniques: Although various surgical techniques have been developed for brachial plexus root repair, open questions remain about the comparative efficacy of these approaches. Well-designed comparative studies are needed to evaluate and optimize surgical techniques, taking into account lesion severity, individual patient characteristics and long-term functional outcomes.

Personalized rehabilitation: Rehabilitation plays a crucial role in functional recovery after brachial plexus root repair. However, there is a need for further research to develop personalized rehabilitation protocols, tailored to the specific needs of each patient. This includes using emerging technologies, determining optimal electrical stimulation parameters and identifying the most effective rehabilitation strategies to maximize functional results.

Quality of life and social reintegration: In addition to restoring motor function, it is essential to focus on the quality of life and social reintegration of patients with brachial plexus root lesions. Further studies are needed to assess the impact of these lesions on patients' quality of life, their participation in daily activities and their ability to return to a normal life.

Although significant progress has been made in the management of brachial plexus root injuries, gaps in current knowledge persist. Further research is essential to better understand the factors that predict recovery, optimize surgical techniques, develop personalized rehabilitation protocols and assess the overall impact on patients' quality of life. These advances will improve early, personalized management of brachial plexus root lesions and optimize long-term functional outcomes [38- 40].

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