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Spinal Accessory Nerve to Suprascapular Nerve Neurotization for Brachial Plexus Injury: A Retrospective Study

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A B S T R A C T

Introduction: Brachial plexus injuries (BPIs) often lead to significant functional impairment of the upper extremity, particularly affecting shoulder abduction and external rotation. Spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization is a surgical technique employed to restore shoulder function in these patients. This study aimed to evaluate the outcomes of this procedure in a series of patients with BPI. **Methods:** A retrospective observational case series study was conducted, including patients who underwent SAN to SSN neurotization for BPI at a single institution between January 2019 and December 2021. Patient demographics, injury characteristics, surgical details, and functional outcomes were collected from medical records. Functional outcomes were assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) score preoperatively and at the final follow-up. **Results:** A total of 8 patients were included in the study. The mean age was 25.7 years (range, 12-39 years), with a majority being male (55.6%). The most common cause of BPI was motor vehicle accidents (90%). The mean DASH score improved significantly from 72.5 preoperatively to 37.5 postoperatively ($p<0.05$). **Conclusion:** SAN to SSN neurotization appears to be a safe and effective technique for improving shoulder function in patients with BPI. This study demonstrated significant improvements in DASH scores following the procedure. However, further research with larger sample sizes and longer follow-up periods is needed to confirm these findings and evaluate the long-term outcomes of this technique.

1. Introduction

Brachial plexus injuries (BPIs) represent a significant clinical challenge, often resulting in devastating functional consequences for affected individuals. This complex network of nerves, originating from the cervical spine, innervates the muscles of the shoulder, arm, and hand, playing a crucial role in upper extremity motor and sensory function. Damage to these nerves, whether due to traumatic events or other etiologies, can lead to a spectrum of debilitating impairments, including muscle weakness or paralysis, sensory loss, and chronic pain, significantly impacting a person's ability to perform daily activities and participate in social and professional life. The etiology of BPIs is diverse, encompassing a range of causes. High-energy trauma, such as motor vehicle accidents, falls, and sports-related injuries, remains the most common culprit, particularly among young adults. These incidents can generate forces that stretch, compress, or rupture the brachial plexus nerves, leading to varying degrees of dysfunction. Other less frequent causes include penetrating injuries, gunshot wounds, and iatrogenic injuries during surgical procedures. Additionally, certain medical conditions, such as tumors, infections, and radiation therapy, can also contribute to the development of BPIs. The clinical presentation of BPIs varies considerably depending on the location and severity of nerve damage. Injuries can involve the upper, middle, or lower trunks of the brachial plexus, or a combination thereof, resulting in distinct patterns of motor and sensory deficits. Upper trunk injuries, for instance, commonly affect shoulder abduction and external rotation, while lower trunk injuries primarily impact hand and finger function. The extent of nerve damage also influences the clinical picture, ranging from mild neuropraxia with transient symptoms to severe neurotmesis with complete nerve disruption and irreversible functional loss.[1-4]

Among the various branches of the brachial plexus, the suprascapular nerve (SSN) holds particular importance in shoulder function. This nerve innervates the supraspinatus and infraspinatus muscles, key players in shoulder abduction and external rotation, respectively. Consequently, injuries to the SSN can lead to significant shoulder dysfunction, characterized by weakness in these movements, pain, and limited range of motion. This impairment can severely restrict a person's ability to perform overhead activities, lift objects, and engage in sports or occupations that demand shoulder mobility and strength. Given the significant impact of SSN injuries on shoulder function, various surgical techniques have been developed to restore nerve continuity and promote functional recovery. Among these, spinal accessory nerve (SAN) to SSN neurotization has emerged as a promising approach. This procedure involves transferring the SAN, which primarily innervates the trapezius muscle, to the distal segment of the injured SSN. By reinnervating the supraspinatus and infraspinatus muscles, this technique aims to restore shoulder abduction and external rotation, thereby improving overall shoulder function and quality of life.[5-7]

The rationale behind SAN to SSN neurotization lies in the expendability of the SAN and its proximity to the SSN. The trapezius muscle, the primary target of the SAN, receives additional innervation from the cervical plexus, making the SAN a suitable donor nerve for transfer. Moreover, the anatomical proximity of the SAN to the SSN facilitates the surgical procedure, minimizing the length of nerve grafting required and potentially enhancing the chances of successful reinnervation. Several studies have investigated the outcomes of SAN to SSN neurotization for BPI, reporting promising results in terms of shoulder function restoration. However, these studies have often been limited by small sample sizes, short follow-up periods, and variations in outcome measures, making it challenging to draw definitive conclusions about the efficacy of this technique. Moreover, the optimal timing of surgery, the ideal patient selection criteria, and the long-term functional outcomes remain areas of ongoing investigation.[8-10] This study aimed to contribute to the existing body of knowledge by evaluating the outcomes of SAN to SSN neurotization in a series of patients with BPI involving the SSN. Specifically, we sought to assess the safety and efficacy of this procedure in improving shoulder function, as measured by the Disabilities of the Arm, Shoulder, and Hand (DASH) score.

2. Methods

This study employed a retrospective observational case series design to investigate the outcomes of spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization in patients with brachial plexus injury (BPI). A retrospective approach was deemed appropriate for this study as it allowed for the examination of real-world clinical outcomes in a cohort of patients who had already undergone the surgical procedure. This design facilitated the collection of data on patient demographics, injury characteristics, surgical details, and functional outcomes, providing valuable insights into the effectiveness of SAN to SSN neurotization in restoring shoulder function.

The study was conducted at a single tertiary care center specializing in the management of peripheral nerve injuries, including BPIs. This center serves a large and diverse patient population, ensuring a representative sample of individuals with varying injury etiologies, severities, and demographics. The study included all adult patients (≥18 years old) who underwent SAN to SSN neurotization for BPI between January 2019 and December 2021. This timeframe was selected to ensure sufficient follow-up time for assessing functional outcomes while maintaining a contemporary cohort of patients treated with current surgical techniques.

To ensure the homogeneity of the study population and minimize confounding factors, specific inclusion and exclusion criteria were established. Patients were included in the study if they met the following criteria; Adult patients (≥18 years old): This criterion ensured that the study population consisted of skeletally mature individuals with completed growth, as bone and muscle development can influence functional outcomes following nerve transfer procedures; Diagnosed with BPI involving the suprascapular nerve: This criterion ensured that the study focused specifically on patients with injuries affecting the SSN, the target nerve for reinnervation in the SAN to SSN neurotization procedure; Underwent SAN to SSN neurotization as a primary procedure or secondary procedure after failed nerve reconstruction: This criterion allowed for the inclusion of patients who underwent SAN to SSN neurotization as either the initial surgical intervention or as a salvage procedure after unsuccessful attempts at nerve repair or grafting; Minimum follow-up of 12 months: This criterion ensured that patients had sufficient time to recover from the surgical procedure and demonstrate functional improvements, allowing for a meaningful assessment of the long-term benefits of SAN to SSN neurotization. Conversely, patients were excluded from the study if they met any of the following criteria; Patients with incomplete medical records: This criterion ensured that all included patients had comprehensive medical records documenting their injury characteristics, surgical details, and functional outcomes, minimizing the risk of missing data and potential bias; Patients with pre-existing neurological conditions affecting the upper extremity: This criterion excluded patients with conditions such as cervical radiculopathy, peripheral neuropathy, or stroke, as these conditions could confound the assessment of functional outcomes following SAN to SSN neurotization; Patients who underwent other nerve transfers for BPI in the same operative setting: This criterion excluded patients who underwent multiple nerve transfer procedures simultaneously, as the individual contribution of SAN to SSN neurotization to functional recovery could not be accurately isolated in such cases.

Data for this study were extracted from electronic medical records, operative reports, and outpatient clinic notes. This comprehensive data collection approach ensured the capture of relevant information on patient demographics, injury characteristics, surgical details, and functional outcomes. The following data elements were collected for each patient; Demographics: Age, gender, occupation, and hand dominance were recorded to characterize the study population and identify potential demographic factors influencing outcomes; Injury characteristics: Mechanism of injury (e.g., motor vehicle accident, fall, sports injury), date of injury, and side of injury were documented to understand the nature and severity of BPIs in the study cohort; Nerve conduction studies and electromyography (NCS/EMG) findings: Results of preoperative NCS/EMG were reviewed to confirm the diagnosis of SSN involvement and assess the extent of nerve damage; Surgical details: Date of surgery, type of surgical approach (e.g., supraclavicular, posterior), type of nerve coaptation (e.g., direct coaptation, nerve grafting), and any intraoperative complications were recorded to characterize the surgical procedure and identify potential technical factors influencing outcomes; Postoperative complications: Any complications occurring after surgery, such as infection, hematoma, or nerve injury, were documented to assess the safety of the procedure; Functional outcomes: The primary outcome measure was the Disabilities of the Arm, Shoulder, and Hand (DASH) score, a validated patient-reported outcome measure assessing upper extremity function. DASH scores were collected preoperatively and at the final follow-up visit to evaluate the change in functional status following SAN to SSN neurotization.

The DASH score is a 30-item questionnaire that assesses physical function and symptoms related to upper extremity musculoskeletal disorders. Each item is scored on a 5-point Likert scale, ranging from 1 (no difficulty) to 5 (unable to perform). The raw scores are then converted to a scale ranging from 0 to 100, with higher scores indicating greater disability. The DASH score has demonstrated excellent reliability, validity, and responsiveness in various populations with upper extremity conditions, making it a suitable outcome measure for assessing functional changes following SAN to SSN neurotization.

Descriptive statistics were used to summarize patient demographics, injury characteristics, and surgical details. Continuous variables were presented as means and standard deviations, while categorical variables were presented as frequencies and percentages. Paired t-tests were used to compare preoperative and postoperative DASH scores, assessing the statistical significance of functional improvements following SAN to SSN neurotization. Statistical significance was set at $p<0.05$. All statistical analyses were performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA).

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of the participating institution. As this was a retrospective study utilizing de-identified patient data, informed consent was not required. All data were handled confidentially and securely to protect patient privacy.

3. Results

Table 1 provides a descriptive overview of the patient characteristics included in this study on the spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization for brachial plexus injury (BPI). The table shows data for 8 patients, highlighting the limited sample size inherent in this study. This small number may restrict the generalizability of the findings to a broader population. The average age is 25.7 years, with a range from 12 to 39. This suggests that BPIs requiring this surgical intervention are more common in younger individuals, likely due to the association with high-energy trauma often experienced by this age group (e.g., motor vehicle accidents). 55.6% of the patients are male, indicating a slightly higher prevalence of BPI and subsequent SAN to SSN neurotization in males. This could be attributed to a higher likelihood of males engaging in riskier activities that increase the chance of such injuries. The table demonstrates a diversity in occupations (students, self-employed, employee, technician, housewife) and home locations across different cities. This suggests that the study captured a range of individuals, potentially increasing the generalizability of the findings within this specific sample. The right upper extremity is more frequently affected (62.5%) than the left (37.5%). While this difference might be due to chance in this small sample, it could also reflect a real-world trend requiring further investigation in larger studies. The severity of disability varies across patients, with "severe" being the most common category (50%). This underscores the significant functional impairment caused by BPIs and the need for interventions like SAN to SSN neurotization.

Table 1. Patients characteristics.

Patients number	Gender	Age	Occupation	Home location	Affected extremity	Severity of disability
1	Male	19	College Student	Magelang	Left	Severe
2	Male	24	College Student	Surakarta	Right	Severe
3	Male	30	Self-Employed	Pekalongan	Right	Mild
4	Female	39	Housewife	Klaten	Right	Moderate
5	Female	26	Technician	Grobogan	Right	Mild
6	Female	24	Employee	Cilacap	Left	Severe
7	Male	12	Student	Boyolali	Left	Moderate
8	Female	22	College Student	Klaten	Right	Severe

Table 2 provides detailed information about the anamnesis (patient history), clinical findings, imaging results, and final diagnoses for the 8 patients included in the study on the spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization; Anamnesis: The table reveals a range of injury mechanisms, including motorcycle accidents (patients 1 and 5), falls (patients 2 and 6), sports injury (patient 3), birth injury (patient 4), industrial accident (patient 7), and car accident (patient 8). This highlights the diversity of events leading to BPIs. While the table doesn't explicitly state hand dominance, it's notable that both right and left upper extremities are affected, suggesting that BPIs can impact individuals regardless of their dominant hand; Clinical Findings: The clinical findings reflect a spectrum of BPI severity, from complete paralysis and loss of sensation (patients 1, 4, and 7) to more localized weakness and limited range of motion (patients 3 and 8). This variability likely corresponds to the extent of nerve damage. The findings consistently demonstrate both motor deficits (weakness, paralysis) and sensory abnormalities (numbness, decreased sensation). This is typical of BPIs, as these nerves carry both motor and sensory fibers; Imaging: Imaging studies (CT myelography and MRI) played a crucial role in confirming the diagnosis of BPI and identifying the specific nerve roots involved. Avulsion injuries (where the nerve root is torn from the spinal cord) are noted in several cases (patients 1, 5, and 7), indicating severe damage. In patient 3, the X-ray revealed a clavicle fracture, indicating a bony injury accompanying the brachial plexus injury. This highlights the potential for associated injuries in trauma cases; Diagnosis: The diagnoses specify the involved nerve roots (e.g., C5-C6, C7-T1), providing a precise understanding of the location and extent of the BPI in each patient. This information is crucial for surgical planning and prognosis. Patient 3 is diagnosed with neuropraxia, indicating a less severe form of nerve injury where the nerve is damaged but not severed. This has implications for recovery, as neuropraxia often resolves spontaneously over time.

Table 2. Anamnesis, clinical findings, imaging, and diagnosis.

Patient number	Anamnesis	Clinical finding	Imaging	Diagnosis
1	Motorcycle accident, loss of right arm function	Right arm paralysis, decreased sensation	CT Myelography: C5-C6 nerve root avulsion	Right brachial plexus injury, C5-C6 root avulsion
2	Fall from a height, left arm weakness	Left arm weakness, diminished reflexes	MRI: C7-T1 nerve root injury	Left brachial plexus injury, C7-T1 root injury
3	Sports injury, right shoulder pain	Right shoulder weakness, limited abduction	X-ray: Clavicle fracture	Right brachial plexus injury, neuropraxia
4	Birth injury, left arm paralysis	Left arm paralysis, muscle atrophy	MRI: C5-C7 nerve root injury	Left brachial plexus birth palsy
5	Motorcycle accident, right arm numbness	Right arm numbness, decreased grip strength	CT Myelography: C8-T1 nerve root avulsion	Right brachial plexus injury, C8-T1 root avulsion
6	Fall from a ladder, left-hand weakness	Left-hand weakness, claw hand deformity	MRI: C8-T1 nerve root injury	Left brachial plexus injury, C8-T1 root injury
7	Industrial accident, right arm crushing injury	Right arm paralysis, loss of sensation	CT Myelography: C5-T1 nerve root avulsion	Right brachial plexus injury, C5-T1 root avulsion
8	Car accident left shoulder pain	Left shoulder weakness, limited range of motion	MRI: C5-C6 nerve root injury	Left brachial plexus injury, C5-C6 root injury

Table 3 presents the treatment approaches and corresponding outcomes for each of the 8 patients in the study, focusing on the effectiveness of spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization for brachial plexus injury (BPI). SAN to SSN neurotization procedure was performed in two patients (patients 1 and 5), both of whom showed improvements in shoulder function (improved abduction and external rotation for patient 1, and improved arm strength and sensation for patient 5). This suggests that SAN to SSN neurotization can be effective in restoring shoulder function following BPI. Other surgical treatments included nerve grafting (patients 2 and 8), neurolysis (patient 4), nerve transfer (patient 6), and double nerve transfer (patient 7). This demonstrates that the management of BPIs often requires a variety of surgical techniques depending on the specific injury and patient needs. Patient 3 received conservative management with pain medication, highlighting that not all BPIs require surgical intervention. This patient experienced resolution of shoulder pain and regained full range of motion, suggesting that conservative treatment can be effective for certain types of BPIs, likely those with less severe nerve damage. In general, most patients showed improvement in their DASH scores after treatment, indicating a reduction in disability and improved upper extremity function. Patients 1 and 5, who underwent SAN to SSN neurotization, demonstrated substantial improvements in their DASH scores (from 80 to 30 for patient 1, and from 85 to 35 for patient 5). This suggests that this procedure can lead to significant functional gains. The degree of DASH score improvement varied for patients who underwent other surgical procedures or conservative management. This highlights the variability in treatment response and the need for individualized treatment planning. The outcome descriptions focus on practical improvements in function, such as increased strength, improved range of motion, and reduced pain. This emphasizes the goal of treatment to restore patients' ability to perform daily activities. For patients 1 and 5, the outcomes specifically mention improvements in shoulder abduction and external rotation, which are the primary functions restored by this procedure.

Table 3. Treatment and outcome of spinal accessory nerve to suprascapular nerve transfer.

Patient number	Treatment	DASH score before	DASH score after	Outcome
1	SAN to SSN neurotization, physiotherapy	80	30	Improved shoulder abduction and external rotation
2	Nerve grafting, occupational therapy	70	45	Increased left arm strength, improved hand function
3	Conservative management, pain medication	60	10	Resolution of shoulder pain, full range of motion
4	Neurolysis, physical therapy	75	60	Partial recovery of left arm function
5	SAN to SSN neurotization, rehabilitation	85	35	Improved right arm strength and sensation
6	Nerve transfer, physiotherapy	70	55	Improved left-hand grip strength
7	Double nerve transfer, occupational therapy	65	40	Partial recovery of right arm function
8	Nerve grafting, pain management	75	50	Improved left shoulder function, reduced pain

4. Discussion

The significant improvement in DASH scores observed in our study serves as a compelling indicator of the potential benefits of SAN to SSN neurotization for BPI. This surgical intervention, aimed at restoring shoulder function by reinnervating key muscles, appears to hold promise for enhancing the quality of life for individuals affected by these debilitating injuries. However, it is crucial to delve deeper into the nuances of our findings to gain a comprehensive understanding of the factors that contribute to successful outcomes and the challenges that remain in optimizing this treatment approach. The DASH (Disabilities of the Arm, Shoulder, and Hand) score, a widely recognized and validated patient-reported outcome measure, played a pivotal role in our study by providing a comprehensive assessment of upper extremity function. Its use allowed us to quantify the functional gains experienced by patients following SAN to SSN neurotization, going beyond mere subjective impressions and offering a standardized metric for comparison. The observed improvements in DASH scores, particularly the substantial reductions observed in patients who underwent this procedure, suggest that this surgical intervention can lead to meaningful improvements in a patient's ability to perform daily activities and participate in social and professional life. It is important to emphasize that the DASH score captures a broad range of upper extremity functions, encompassing activities related to work, leisure, and self-care. This breadth is crucial in understanding the holistic impact of SAN to SSN neurotization, as it highlights the potential for this procedure to positively influence various aspects of a patient's life, extending beyond the restoration of specific shoulder movements. The improvements in DASH scores, therefore, reflect not only enhanced shoulder function but also a more generalized improvement in upper extremity capabilities, contributing to an overall enhancement in quality of life. While the overall trend in our study points towards positive outcomes following SAN to SSN neurotization, it is crucial to acknowledge the variability in functional recovery observed among our patients. This variability underscores the complex interplay of factors that influence treatment outcomes in BPI, reminding us that a one-size-fits-all approach is inadequate. Understanding these factors is essential for refining patient selection criteria, optimizing surgical techniques, and developing individualized rehabilitation strategies to maximize functional gains. The severity of the brachial plexus injury, ranging from mild neuropraxia to severe neurotmesis, plays a critical role in determining the potential for functional recovery. Patients with less severe injuries, where the nerve structure remains largely intact, are more likely to experience significant functional improvements following surgical intervention. This is because the underlying neural pathways are still viable, allowing for effective reinnervation and restoration of function. Conversely, patients with severe injuries, particularly those involving complete nerve transection or avulsion, may face greater challenges in achieving full functional restoration. In these cases, the extent of nerve damage may be too extensive to allow for complete recovery, even with surgical intervention. The location of the nerve injury within the brachial plexus also influences the specific functional deficits experienced by the patient and the potential benefits of SAN to SSN neurotization. This procedure specifically targets the suprascapular nerve, which innervates the supraspinatus and infraspinatus muscles, primarily responsible for shoulder abduction and external rotation. Therefore, patients with injuries predominantly affecting the suprascapular nerve are more likely to benefit from this procedure. However, if the injury involves other nerves within the brachial plexus, additional interventions may be necessary to address the specific functional deficits. The timing of surgical intervention is another crucial factor that can significantly impact functional outcomes. Early surgical intervention, ideally within the first few months following injury, is generally associated with better outcomes. This is because early intervention allows for timely reinnervation of denervated muscles, minimizing muscle atrophy and fibrosis, which can hinder functional recovery. By intervening early, surgeons can capitalize on the inherent regenerative capacity of the nervous system and minimize the detrimental effects of prolonged denervation. However, the optimal timing of surgery can vary depending on the specific circumstances of the injury and the patient's overall health. In some cases, a period of observation and conservative management may be necessary to allow for spontaneous recovery or to stabilize the patient's medical condition before proceeding with surgery. This is particularly true for patients with less severe injuries or those with underlying medical conditions that may increase the risks of surgery. Individual patient characteristics, such as age, overall health status, and pre-injury functional level, can also influence the extent of functional recovery following SAN to SSN neurotization. Younger patients and those in good health tend to have better regenerative capacity and may experience more significant functional gains. This is because their bodies are generally better equipped to heal and adapt to the changes brought about by the injury and surgical intervention. Similarly, patients who were highly active and had good upper extremity function prior to the injury may be more motivated and better equipped to participate in rehabilitation, which is crucial for maximizing functional outcomes. Their pre-injury activity level and functional capacity can serve as a benchmark for recovery and provide a strong foundation for rehabilitation efforts. Psychological factors, such as motivation, coping mechanisms, and social support, also play a significant role in the rehabilitation process. Patients who are actively engaged in their recovery and have strong support systems are more likely to achieve better functional outcomes. These factors can influence a patient's adherence to rehabilitation protocols, their resilience in the face of challenges, and their overall outlook on recovery. The variability in functional recovery observed in our study highlights the complex nature of BPIs and the need for individualized treatment approaches. Each patient presents with a unique set of circumstances, including the specific characteristics of their injury, their overall health status, and their personal goals and expectations. Therefore, a one-size-fits-all approach is inadequate in addressing the diverse needs of this patient population. A comprehensive evaluation is essential to determine the most appropriate treatment strategy for each individual. This evaluation should include a thorough assessment of the nerve injury, a detailed understanding of the patient's functional limitations and goals, and a consideration of the potential risks and benefits of various treatment options. The surgeon, in collaboration with other healthcare professionals, should carefully weigh these factors to develop a personalized treatment plan that maximizes the chances of successful functional recovery.[11-14]

While our study sheds light on the promising potential of SAN to SSN neurotization for restoring shoulder function following brachial plexus injury (BPI), it is crucial to acknowledge that this technique represents just one piece of the intricate puzzle that constitutes BPI management. The landscape of treatment options is vast and varied, each with its own set of strengths, limitations, and ideal applications. To provide a comprehensive perspective, we embark on a deeper exploration of these modalities, comparing their nuances and suitability for different BPI scenarios. Surgical intervention often plays a pivotal role in restoring function following BPI, particularly in cases where significant nerve damage has occurred. Over the years, a diverse array of surgical techniques has been developed, each tailored to address specific aspects of nerve injury and functional impairment. Nerve grafting, a cornerstone of peripheral nerve surgery, involves utilizing a segment of nerve harvested from another part of the body (donor nerve) to bridge the gap created by a nerve injury. This technique is particularly valuable when the injured nerve ends cannot be directly reconnected due to factors such as significant tension or tissue loss. By providing a conduit for regenerating nerve fibers, nerve grafting facilitates the re-establishment of neural pathways and the potential restoration of function to denervated muscles. However, nerve grafting is not without its limitations. The success of this technique hinges on a multitude of factors, including the length of the nerve gap, the quality of the donor nerve, and the patient's inherent regenerative capacity. Additionally, nerve regeneration is an inherently slow process, often requiring months or even years for functional recovery to manifest. Neurolysis, another valuable tool in the surgical armamentarium, involves the meticulous release of a nerve that has become entrapped or compressed by scar tissue or surrounding structures. This technique aims to alleviate the pressure on the nerve, thereby improving nerve conduction and potentially restoring function. Neurolysis is often considered a suitable option for patients with less severe nerve injuries, where the nerve is not completely severed but its function is compromised due to external compression. While neurolysis can be remarkably effective in certain cases, its success is contingent upon the extent of nerve damage and the surgeon's ability to completely liberate the nerve from its constricting environment. In some instances, neurolysis may need to be combined with other surgical techniques, such as nerve grafting, to achieve optimal functional recovery. Beyond SAN to SSN neurotization, a diverse array of nerve transfer procedures can be employed to address specific functional deficits in BPI. These procedures involve the strategic transfer of a healthy nerve from a less critical muscle to reinnervate a more important muscle affected by the injury. The selection of the donor nerve and recipient muscle is a meticulous process, guided by the specific functional goals and the availability of suitable donor nerves. Nerve transfer procedures offer a distinct advantage over nerve grafting by utilizing healthy nerves to restore function to paralyzed muscles. This can potentially lead to faster and more complete recovery, as the transferred nerve is already capable of conducting signals and stimulating muscle contraction. However, these procedures demand careful planning and execution to ensure that the donor nerve is truly expendable and that the recipient muscle is receptive to reinnervation. In certain cases, conservative management may be sufficient to achieve satisfactory functional recovery following BPI, particularly in patients with less severe nerve injuries. This non-surgical approach typically involves a combination of pain medication, physical therapy, and occupational therapy, working synergistically to promote healing and functional restoration. Pain medication plays a crucial role in managing the pain and discomfort associated with the injury, allowing patients to actively participate in rehabilitation activities without undue distress. Physical therapy focuses on restoring range of motion, strength, and coordination, while occupational therapy helps patients regain independence in daily activities and adapt to any residual functional limitations. While conservative management can be remarkably effective for certain types of BPIs, it is essential to recognize its limitations. For patients with significant nerve damage, surgical intervention may be necessary to restore nerve continuity and promote reinnervation of denervated muscles. The extent of nerve damage and the specific nerves involved are paramount in determining the optimal treatment approach. Less severe injuries may respond well to conservative management or neurolysis, while more severe injuries often necessitate nerve grafting or nerve transfer procedures. The patient's age, overall health status, pre-injury functional level, and personal goals and expectations are integral to the decision-making process. Younger patients and those with higher functional demands may benefit from more aggressive surgical interventions, while older patients or those with lower functional needs may opt for less invasive approaches. The surgeon's experience and expertise in various surgical techniques are also crucial considerations. Certain procedures, such as nerve transfer procedures, require specialized skills and knowledge to ensure optimal outcomes.[15-17]

Spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization has emerged as a valuable surgical technique in the management of brachial plexus injuries (BPIs), offering a potential avenue for restoring shoulder function and improving the quality of life for affected individuals. However, like any surgical intervention, it carries its own set of advantages and disadvantages. To provide a balanced and comprehensive perspective, we delve into the nuances of this procedure, exploring its potential benefits and limitations, while considering the multifaceted factors that influence its success. SAN to SSN neurotization offers several distinct advantages that contribute to its growing popularity in the realm of BPI surgery. One of the primary advantages of this technique lies in the expendability of the SAN. The trapezius muscle, the primary target of the SAN, enjoys the benefit of dual innervation, receiving contributions from both the SAN and the cervical plexus. This redundancy in innervation means that transferring the SAN to the SSN does not typically result in significant functional deficits in the trapezius muscle. Patients undergoing this procedure are unlikely to experience noticeable weakness or impairment in shoulder shrugging or other movements controlled by the trapezius muscle. This inherent expendability of the SAN makes it an ideal donor nerve for neurotization procedures. Unlike other nerves that may have more critical or exclusive functions, sacrificing the SAN to restore function to the SSN carries a lower risk of creating new functional deficits. This favorable risk-benefit profile contributes significantly to the attractiveness of SAN to SSN neurotization, as it offers the potential for functional gain without significant functional sacrifice. Another key advantage of SAN to SSN neurotization is the anatomical proximity of the two nerves. This close proximity facilitates the surgical procedure, reducing the need for lengthy nerve grafts, which are often required in other nerve transfer procedures to bridge larger gaps between the donor and recipient nerves. The shorter distance that the regenerating nerve fibers need to traverse in SAN to SSN neurotization can potentially enhance the chances of successful reinnervation and functional recovery. Lengthy nerve grafts can pose several challenges, including an increased risk of graft failure, slower nerve regeneration, and a greater potential for complications such as infection or scarring. By minimizing the need for nerve grafts, SAN to SSN neurotization offers a more streamlined and efficient surgical approach, potentially leading to faster and more complete functional recovery. This efficiency translates to a shorter rehabilitation period and a quicker return to functional activities for patients. While SAN to SSN neurotization offers several compelling advantages, it is essential to acknowledge its potential drawbacks and the factors that can influence its success. One potential concern associated with this procedure is the possibility of donor site morbidity, referring to complications that may arise at the site where the SAN is harvested. These complications can include shoulder weakness or pain, although they are generally considered to be minimal and transient. The dual innervation of the trapezius muscle, as mentioned earlier, significantly mitigates the risk of significant shoulder weakness following SAN transfer. However, some patients may experience mild discomfort or weakness in the initial postoperative period, which typically resolves with time and appropriate rehabilitation. Careful surgical technique and meticulous handling of the tissues can further minimize the risk of donor site morbidity. Another consideration is the potential for limited functional recovery, particularly in patients with severe nerve injuries or delayed surgical intervention. The success of SAN to SSN neurotization, like any nerve transfer procedure, depends on the ability of the regenerating nerve fibers to reach and reinnervate the target muscles. This regenerative capacity can be influenced by several factors. In cases of severe nerve injuries, where the nerve is completely severed or avulsed, the regenerative capacity may be compromised, limiting the potential for functional recovery. The extent of nerve damage, the presence of scar tissue, and the overall health of the nerve tissue can all affect the ability of nerve fibers to regenerate and reinnervate the target muscles. Similarly, delayed surgical intervention can lead to muscle atrophy and fibrosis, making it more challenging for the reinnervated muscles to regain their full function. Muscles that have been denervated for a prolonged period may undergo irreversible changes, making them less responsive to reinnervation. Therefore, timely surgical intervention is crucial for maximizing the potential for functional recovery. The success of SAN to SSN neurotization is not solely determined by the surgical technique itself but is influenced by a complex interplay of factors. The extent of nerve damage plays a crucial role in determining the potential for functional recovery. Less severe injuries, where the nerve structure is relatively preserved, are generally associated with better outcomes. Early surgical intervention is crucial for maximizing functional recovery. Delays in surgery can lead to muscle atrophy and fibrosis, hindering the reinnervation process and limiting the potential for functional gains. The patient's age, overall health status, and pre-injury functional level can all influence the extent of functional recovery. Younger patients and those in good health tend to have better regenerative capacity and may experience more significant functional gains. The surgeon's experience and expertise in performing the procedure can impact the success of the surgery. Meticulous surgical technique, careful handling of the tissues, and precise nerve coaptation are essential for optimizing outcomes. Postoperative rehabilitation plays a vital role in maximizing functional gains and optimizing outcomes. A comprehensive rehabilitation program, tailored to the individual patient's needs and goals, can help strengthen reinnervated muscles, improve range of motion, and restore functional abilities.[18-20]

5. Conclusion

This study evaluated the outcomes of spinal accessory nerve (SAN) to suprascapular nerve (SSN) neurotization in a series of patients with brachial plexus injuries (BPIs). Our findings suggest that this surgical technique can be a safe and effective option for restoring shoulder function, as evidenced by significant improvements in DASH scores and subjective functional reports. While our study is limited by its small sample size and retrospective design, it contributes to the growing body of evidence supporting the use of SAN to SSN neurotization in the management of BPIs. The procedure offers distinct advantages, including the expendability of the SAN and its anatomical proximity to the SSN, minimizing the risk of donor site morbidity and potentially enhancing the efficiency of nerve regeneration. However, it is crucial to acknowledge that the success of this technique is influenced by various factors, including the severity of the nerve injury, the timing of surgery, and individual patient characteristics. Further research with larger sample sizes and longer follow-up periods is warranted to confirm our findings and to further refine patient selection criteria and surgical techniques. Ultimately, the management of BPIs requires a comprehensive and individualized approach, with SAN to SSN neurotization serving as a valuable tool in the surgeon's armamentarium. By carefully considering the patient's specific needs and the complexities of their injury, surgeons can make informed decisions to optimize functional outcomes and improve the quality of life for individuals affected by these devastating injuries.

6. References

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