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Cross-sectional Study

# Clinical and functional outcome after different surgical approaches for brachial plexus injuries: Cohort study

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ABSTRACT

*Introduction:* Brachial plexus injury (BPI) can result in complete loss of neurological function and reduces the quality of life. Nerve transfer, nerve grafting, external neurolysis, and free functional muscle transfer are several management options that determine the eventual outcomes. Despite various methods of treatment, hardly any literature compares directly the result of these treatment options. This study aimed to analyze differences in clinical and functional outcomes after a reconstructive surgery.

*Methods:* A cohort retrospective study was conducted on traumatic brachial plexus injured patients aged from 17 to 65 years at one hospital in Surabaya, Indonesia, from January 2009 to December 2019. All patients were divided into 4 groups depending on the types of surgery. The clinical outcomes were measured using elbow and shoulder muscle strength, elbow and shoulder range of motion (ROM), and pain level (measured using Visual Analog Scale/VAS); the functional outcomes were measured using the overall quality of life using the DASH (disabilities of the arms, shoulder, and hand) score.

*Results:* This study included 316 patients comprising of 256 males with an average age of 27.53 ± 11.37, an average time from injury to surgery of 17.74 ± 35.82 months, and average follow-up duration of 59.89 ± 37.68 months. Most cases were caused by road traffic accidents (77.22%) and most were total arm type of BPI injury (70.7%). There was no significant difference in the mean values of study parameters except in VAS ($p = 0.042$) as nerve grafting resulted in less pain than external neurolysis (2.27 ± 1.03 vs. 3.68 ± 1.93, respectively; $p = 0.017$). Besides, nerve transfer procedure also resulted in less pain compared to external neurolysis (2.99 ± 1.84 vs. 3.68 ± 1.93, respectively; $p = 0.036$).

*Conclusion:* We found no significant difference between types of surgery and the postsurgical outcome. A wider multicenter study was required to define the clinical and functional outcomes clearly.

## 1. Introduction

Brachial plexus injury (BPI) is a severe injury that greatly limits patients' daily activity and reduces the quality of life [1]. The initial three to six months of injury is the golden period that a physician can manage, but it is possible for BPI patients to not show any signs of spontaneous recovery response after three months. Complete loss of neurological function is expected by 20–24 months afterwards. The outcomes of the procedures depend on the severity of the injury and the remaining function in the first place [2].

Previous epidemiological studies in Soetomo General Academic Hospital Surabaya showed as much as 90% of BPI patients required a surgery because of getting motorcycle accidents [3]. Four methods of surgical armamentarium have been found to be result in best outcome: Nerve transfer, nerve grafting, external neurolysis, and free functional muscle transfer [4].

Available studies comparing surgical techniques only includes small amount of samples. In a systematic review done by Yang LJS et al. included 33 studies analyzing nerve transfer compared to nerve repair summarized 33 studies [5]. Amongst the studies included, the highest amount of sample was 54 which was done by Samii et al.[6]. Within the author's knowledge, up to date, highest amount of sample in a single study comparing surgical technique for BPI was done by Terzis et al. with 263 patients but was published at 1999 and most others are less

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than 100 patients [7]. Despite various treatment options for BPI, hardly any recent studies compared the result of these treatment and most are only reviews. If any, the study included only handful amount of samples [8]. Aside from the small samples, most only compares two surgical methods which make the study less comprehensive.

This study aimed to comprehensively analyze the outcome of four surgical method for treating BPI. Clinical and functional outcomes in terms of shoulder and elbow motoric capabilities, where it is important to know the best surgical approach for the patient's optimal post-operative function, were compared, which are: Manual Muscle Testing (MMT), range of motion (ROM), visual analogue score (VAS) and the disabilities of the arm, shoulder and hand (DASH) score in patients with traumatic BPI after a reconstructive surgery at Soetomo General Academic Hospital in Surabaya.

## 2. Methods and materials

### 2.1. Patients

This study was a cohort retrospective study involving patients aged 17–65 years who suffered from traumatic BPI at Soetomo General Academic Hospital in Surabaya, Indonesia. Data were collected from medical record database of this hospital within period of January 2009 to December 2019. By applying a consecutive sampling method, this study garnered 316 patients who were further divided into 4 groups depending on the types of surgery, which were nerve transfer, nerve grafting, external neurolysis, and free functional muscle transfer (FFMT). Traumatic brachial plexus lesion patients with comorbid that can cause polyneuropathy (e.g. Diabetes Mellitus) were excluded in addition to patients with traumatic brachial plexus injury with organic brain injury.

Diagnosis of traumatic brachial plexus injury was performed according to clinical manifestation and radiographic findings. This study has passed the ethics clearance by the Institutional Board Review of the Faculty of Medicine, Universitas Airlangga/Soetomo General Academic Hospital, Surabaya, Indonesia (Ethics number: 0094/KEPK/XI/2020). Written informed consent had been acquired from all participants. This cohort retrospective study is fully compliant with STROCSS 2021 criteria (the checklist is stated as an attachment) [9]. This research is registered under researchregister.com with the research unique identifying number of researchregistry7643.

### 2.2. Surgical procedures

There were four surgeries procedures presented: nerve graft, nerve transfer, external neurolysis and free functional muscle transfer. Nerve transfer was conducted through exploration of the supraclavicular brachial plexus from transverse supraclavicular incision and of the infraclavicular plexus through a deltopectoral incision [10]. Nerve graft commonly uses the sural nerve or the medial cutaneous nerve of the forearm where the donor site still will be in situ until nerve transfer and nerve grafts were attached to the root stumps proximally [11]. External neurolysis procedures consisted of lysis of adhesions and release of encapsulating scar. In free functional muscle transfer procedures, gracilis muscle was being used after extensive strength and excursion testing [12]. BPI injury was further classified into total arm type, upper arm type and lower arm type [13].

### 2.3. Functional outcomes

Several criteria were applied to measure the functional and clinical outcomes. The clinical outcomes were measured using elbow and shoulder muscle strength, elbow and shoulder range of motion (ROM), and pain level (measured using Visual Analog Scale/VAS); the functional outcomes were measured using the overall quality of life using the DASH (disabilities of the arms, shoulder, and hand) score. The Medical Research Council (MRC) scale was used to quantify the strength level of the elbow and shoulder muscle with 0 meaning no visible/palpable contraction and 5 meaning normal strength. The elbow and shoulder range of motion was measured by the maximum number of movements that a joint could make on one of the three planes which are sagittal, frontal, or transversal [14]. To further investigate the functional outcomes in our traumatic brachial plexus lesion patients, the DASH score was utilized. DASH score contained 30 items that the participants filled out. It comprised of several daily activities in various grades of difficulties and several symptoms such as pain or tingling sensation [15].

### 2.4. Statistical analysis

Comparison between the mean DASH score, shoulder muscle power, shoulder range of movement assessment, elbow muscle power, elbow range of movement, and VAS score from each surgical procedure groups were initially analyzed using the Kolmogorov Smirnov to know the data's normality. If the data distribution was normal with a significance level of more than 0.05, the ANOVA test will be used, while the Kruskal Wallis was the alternative test. For detailed analysis comparing each treatment methods one by one uses Mann-Whitney, Mann Whitney were used. Data having p-values lower than 0.05 were considered as statistically significant.

The calculations were performed using a statistical package program (SPSS v26, SPSS Inc, Chicago, IL).

## 3. Results

A total of 316 patients were sampled. Their average age was 27.53 ± 11.37; the average time from injury to surgery was 17.74 ± 35.82 days; and the average follow up duration was 59.89 ± 37.68 days. Of all the patients, 256 patients were male. As many as 77.25% patients got road traffic accidents. Most BPI types were total arm type (70.7%), followed by upper arm type (25.5%) and lower arm type (3.8%)

Patients' shoulder MMT, shoulder ROM, elbow MMT, elbow ROM, VAS and DASH score were presented. No significant difference in shoulder muscle strength ($p = 0.591$), shoulder ROM ($p = 0.330$), elbow muscle strength ($p = 0.23$), elbow ROM ($p = 0.50$), and DASH scores (0.29) was found after either nerve transfer, nerve grafting, external neurolysis, or FFMT procedures. On the contrary, significant difference was found in VAS when comparing the four surgical methods ($p = 0.04$). All of the study result of each parameter and surgical method is layed out on Table 1.

Detailed comparison for VAS over each surgical method are detailed on Table 2. Significant difference was found when comparing between nerve transfer with external neurolysis ($p = 0.036$) and nerve grafting with external neurolysis ($p = 0.017$).

## 4. Discussion

Other factors that influence outcomes after brachial plexus surgery may be associated with the patient, the lesion, or the surgical technique. In several studies, age likely affects motor outcomes which poorer outcomes are associated with older age. A study by Coulet et al. compared clinical result of 23 upper BPI patients who underwent partial ulnar transfer with intercostal nerve transfer. His study found that there are no observable difference in outcome in patients older than 30 years compared to younger patients[16]. Terzis JK et al. analyzed the result of musculocutaneous nerve reconstruction in traumatic plexopathy patients. This study found that patients older than 40 years have worse outcomes than younger patients (<20 years). Higher cortical plasticity in younger patients might contribute to this better recovery [17]. An interesting study was done by Suroto H et al. which created a scoring system for BPI patients. In its scoring system, age was not even included as it is deemed not to affect the outcome of postsurgical BPI [18].

The VAS value showed a significant difference between nerve

**Table 1**
Characteristics and statistical analysis of study parameters.

| Parameters | Nerve Grafting | | Nerve Transfer | | External Neurolysis | | Free Functional Muscle Transfer | | P-Values |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity N (%) | Mean ± SD | Quantity N (%) | Mean ± SD | Quantity N (%) | Mean ± SD | Quantity N (%) | Mean ± SD | |
| DASH Score | 15 (4.8%) | 34.18 ± 25.93 | 109 (34.5%) | 36.07 ± 23.38 | 38 (12%) | 43.63 ± 24.77 | 154 (48.7%) | 36.73 ± 22.81 | 0.291 |
| Shoulder's MMT | 15 (4.8%) | 2.53 ± 1.19 | 109 (34.5%) | 2.91 ± 1.27 | 38 (12%) | 2.8 ± 1.14 | 154 (48.7%) | 2.88 ± 1.12 | 0.591 |
| Shoulder's ROM | 15 (4.8%) | 52 ± 43.09 | 109 (34.5%) | 69.63 ± 48.15 | 38 (12%) | 57.63 ± 44.12 | 154 (48.7%) | 66.98 ± 45.96 | 0.330 |
| Elbow's MMT | 15 (4.8%) | 3.13 ± 0.99 | 109 (34.5%) | 3.33 ± 1.16 | 38 (12%) | 3.11 ± 1.18 | 154 (48.7%) | 3.08 ± 1.18 | 0.231 |
| Elbow's ROM | 15 (4.8%) | 90 ± 41.4 | 109 (34.5%) | 95.78 ± 54.26 | 38 (12%) | 79.47 ± 48.78 | 154 (48.7% | 87.92 ± 46.88 | 0.503 |
| VAS | 15 (4.8%) | 2.27 ± 1.03 | 109 (34.5%) | 2.99 ± 1.84 | 38 (12%) | 3.68 ± 1.93 | 154 (48.7% | 3.26 ± 1.90 | 0.042* |

*P < 0.05 considered statistically significant.

**Table 2**
Mann Whitney for analysis of difference between procedures compared with VAS.

| Compared Procedures | VAS of Related Surgical Interventions (p value) |
|---|---|
| Nerve transfer vs nerve grafting | 0.225 |
| Nerve transfer vs external neurolysis | 0.036 |
| Nerve transfer vs free functional muscle transfer | 0.169 |
| Nerve grafting vs external neurolysis | 0.017 |
| Nerve grafting vs free functional muscle transfer | 0.056 |
| External neurolysis vs free functional muscle transfer | 0.186 |

transfer, nerve grafting, external neurolysis, and free functional muscle transfer procedures (p = 0.042). VAS is a subjective measure of pain level experienced by a patient. The VAS has 10 scores ranging from 0 (no pain) to 10 (most painful) [2]. Despite this interesting result, timing of BPI surgery might influence this outcome. In a systematic review conducted by Martin E et al., the study summarized the result of 569 patients from 43 studies, they found that surgical outcome in terms of VAS is best if the operation is done within 1 month after injury or, the more lenient time limit which is significantly better, less than 6 months. The implication of lower scores are not only on the patient's quality of life but also better rehabilitation and better the quality of life. Other factors which might influence VAS outcome, the systematic review found, are good presurgical motor skills and early rehabilitation [2]. In a prospective study by Terzis JK et al. which studies the treatment outcome of 312 BPI patients found that location of the lesion also affects motor outcomes. Upper brachial plexus lesions involving C5-7 had the best outcome; whereas C8 and T1 lesions had poor results. Worse outcomes were noted when complete lesions occurred [7].

With VAS as the only significant parameter, the types of surgeries were compared with VAS as the dependent factor. Nerve grafting had a significant difference in VAS with an external neurolysis and free functional muscle transfer. In fact, there have been numerous studies trying to explore which types of surgery are more superior. Systematic review done by Yang LJS et al. compares nerve transfer, nerve reconstruction or both. Over the 33 papers it included, the study found that nerve transfer is better in achieving elbow flexion recovery but none is better in achieving shoulder motor recovery [19]. Another systematic review by Donnelly MR et al. compares double fascicular transfer and single fascicular transfer in treating traumatic BPI. The study found that double fascicular transfer arguably shows better outputs than single nerve transfer [20]. Additionally, extending the idea further, prospective cohort by O'Grady KM et al. found that upper trunk obstetric BPI patients who underwent triple nerve transfer has significantly better outcome compared to single nerve transfer in terms of shoulder external rotation, forearm supination, operative time, and length of hospital stay [21]. Functioning free-muscle transfers is now commonly used for managing delayed presentation of BPI patients [12]. FFMT often uses gracilis muscle when a salvage procedure in BPI is performed due to functional similarities with arm and forearm muscles as well as microvascular supplies, low morbidity in donor site, as well as a reliable and relatively long motor nerve [22]. Retrospective study conducted in Surabaya by Suroto H et al. which covers 491 BPI patients found that FFMT resulted in a significantly more desirable outcome in the DASH and VAS scores than nerve transfer for incomplete BPI [22]. A neurolysis surgery technique has a tendency for its clinical outcomes to be difficult to evaluate functionally because many factors outside the success of the operation affect it. It is commonly used to maintain the continuity of nerve lesions and improve nerve structure, but this technique is not recommended if there is vascular disturbance in the lesion area. The use of nerve stimulation before and after neurolysis can be increased by nerve conduction [23]. Not only motor and sensory deficits, but also pain and functional limitations may have a significant impact on the quality of life.

Agreements in BPI management, such as surgical options (nerve transfer, nerve grafting, neurolysis, and functional muscle transfer) should be generally performed within six months of injury [24]. In postganglionic BPI, nerve surgery procedure may be performed as early as possible to obtain optimal outcomes [25]. Surgery indicated in severe BPI is generally performed three to four months after the injury. If a complete return to function is considered not possible, the surgical intervention should focus on restoring the function of elbow flexion, followed by wrist extension and finger flexion. Although the universal approach to BPI management has not been clearly defined to achieve the best outcome, it is mutually agreed that the methods of surgery depend on the surgeon's preference and experience. For further read, review by Maldonado AA published five operations which they believed always result in good outcome in their center albeit with not very big amount of sample or evidence[26]. Another interesting review for further read is done by Chuang DC which mentions that proximal nerve grafts or nerve transfers remained the first option for reconstructive strategy, and distal nerve transfers should be an addition due to its value in some specific situations (long nerve grafts (>10 cm) required in the proximal nerve grafting and for unhealthy proximal nerve root) but this paper is also more of an expert opinion [27].

The treatment of traumatic BPI is very challenging. From the protein expression, Apoptosis is inhibited by the activities of Bcl-2 the early stage and a significant decrease of Bcl-2 coupled with a substantial increase of Bax and p53 in the late stage [28]. Clinical practice has shown that individuals with BPI tend to experience emotional and psychological changes due to pain, disruptions in daily activities, dependence on others, inability to work with jobs prior to the injury, uncertainty about the future, and appearance at work injured extremity. All of the consequences may lead to depression and more and more pain levels than without depression([29,30]).

Apart from the critical analysis, this study posits several limitations. The data were collected from a single hospital and thus may not be representative for all hospitals in Indonesia. Biases of different selection criteria, protocols, and treatment were common in observation studies. The lack of heterogeneity of this study only allowed us to suggest the

effect of delay in surgery but not to properly assess the surgery outcomes; whereas other factors such as the patient, the lesion, or the surgical technique may take part.

## 5. Conclusion

Types of surgery and the study parameters mostly have non-significant results; there is no clear deal of conclusion yet on which procedures serve better. For now, the best methods of surgery depend on the surgeon's preference and experience. Multicenter studies with a wider scope of patients in larger sample groups and more objective parameters are needed to generate a proper and acceptable guideline.

## Ethical approval

This study passed ethical clearance by the Institutional Board Review of the Faculty of Medicine, Universitas Airlangga/dr. Soetomo General District Hospital, Surabaya, Indonesia (Ethics number: 0094/KEPK/XI/2020; Retrospectively Registered).

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## Author contribution

HS devised the project, the main conceptual ideas and proof outline. HS, JK, and FD conceived the study, researched literature and developed the study protocol. JK was involved in gaining ethical approval. JK and FD was involved in data analysis and wrote the first draft of manuscript. All authors discussed, reviewed and edited the manuscript and approved the final version of the manuscript.

## Registration of research studies

1. Name of the registry: Research Registry
2. Unique Identifying number or registration ID: researchregistry7643
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/registrationdetails/620b878091cd290020ce686f/

## Guarantor

Heri Suroto, M.D, Ph.D acts as guarantor of this study.

## Consent

Written informed consent had been acquired from all participants.

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The following information is required for submission. Please note that failure to respond to these questions/statements will mean your submission will be returned. If you have nothing to declare in any of these categories then this should be stated.

## Provenance and peer review

Not commissioned, externally peer-reviewed.

## Consent

Written informed consent had been acquired from all participants.

## Contributorship

This research may not be performed if there is no support of the hospital medical personnel, nurses, and all associated hospital management staffs.

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The following information is required for submission. Please note that failure to respond to these questions/statements will mean your submission will be returned. If you have nothing to declare in any of these categories then this should be stated.

## Declaration of competing interest

The authors declare no potential conflict of interest with respect to the research, authorship and/or publication of this article.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103714.

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