Preoperative versus Intraoperative Nerve Root Injury Concordance in Brachial Plexus Birth Injury

Clark Jia-Long Chen[1], Christopher Stephen Crowe[2], Eugene Park, Scott H Kozin[3], Dan Ariel Zlotolow
[1]Orthopaedic Surgery, Albert Einstein Healthcare Network, [2]Plastic Surgery, [3]Shriners Hosp for Children

INTRODUCTION:

Brachial plexus birth injuries (BPBI) pose complex clinical challenges, in which optimal outcomes are dependent on variable diagnostic and therapeutic strategies. The ideal timing for surgery and observation of potential spontaneous recovery in severe injury for cervical and thoracic nerve roots that make up the brachial plexus is subject to continued discussion[1,2]. Neve injuries range from the C5 and C6 nerve roots which contribute to the upper trunk; C7 nerve root which contributes to the middle trunk; and C8 and T1 nerve roots which contribute to the lower trunk[3]. Though careful decision-making is required with respect to BPBI cases, advances in diagnostic tools such as, neurophysiological studies and MRI can aid in such decision-making[4]. Intraoperatively, motor evoked potentials can be elicited with a nerve stimulator to test downstream function. However, physical examination with the active movement scale (AMS) remains the primary mainstay of diagnostic workup in the management of BPBI for the objective of assessing infant functional status[5]. The purpose of this study is to examine the accuracy of predicting intraoperative brachial plexus nerve root findings based on preoperative examinations. This study is a largely descriptive study based on our findings from a single institution.

METHODS:

Out of the infants that presented with BPBI, a total of 164 patients underwent brachial plexus exploration with sural nerve autograft between 2004 to 2023. Data was available for all 162 patients. Two patients with prefixed plexus also underwent surgery but were excluded from this study to allow for uniformity of nerve root injuries. The AMS scores are a collection of infant motor function on 15 distinct areas that are summed to create a composite score representing the function of the affected limb. The AMS scores were collected independently by a trained brachial plexopathy occupational therapist to reduce scoring bias. Preoperative nerve root injuries were tabulated according to physician medical record documentation referring to the corresponding AMS scores for involved nerve roots. Injuries followed 4 distinct patterns derived from the nerve roots involved, which were progressively more severe as more nerve roots were involved. During preoperative evaluation it was only noted whether or not a nerve root was injured and not the specific type of injury, such as rupture, avulsion, and partial avulsion. Horner's syndrome was not considered as part of this study due to its lack of power in predictive postoperative outcomes. Intraoperative nerve assessment data was then collected from operative reports regarding the actual injury. Data was collected and placed into a matrix, and analysis was conducted using statistical methods.

RESULTS:

Nerve root injuries were categorized as Injury A (C5, C6), Injury B (C5, C6, C7), Injury C (C5, C6, C7, C8), and Injury D (C5, C6, C7, C8, T1). Precision, sensitivity (recall), and the F1 score focused on positive class performance. High precision indicated that when a positive result is predicted, it is usually correct. The F1 score provided a balanced metric of precision and recall. Accuracy measures overall performance, including both true positives and true negatives. Among the 162 cases analyzed, the overall accuracy was 83.33%, with 135 cases correctly identified and 27 cases not in concordance. For Injury A, precision was 0.47, recall was 0.70, F1 score was 0.56, and specificity was 0.95. Injury B showed better performance with a precision of 0.70, recall of 0.79, F1 score of 0.74, and specificity of 0.88. Injury C had a precision of 1.00 but low recall of 0.07, resulting in an F1 score of 0.13 and specificity of 1.00. The concept of the Injury C classification only emerged after 2016, resulting in a smaller cohort in this study. Injury D exhibited high precision of 0.95, high recall of 0.98, high F1 score of 0.96, and high specificity of 0.92. Injury D represented the largest injury type treated. The Cohen's Kappa value of 0.70 indicated substantial agreement between preoperative predictions and intraoperative findings beyond chance. Differential analysis using the 2012 as an arbitrary midpoint cut off had an accuracy of 86.68% and Cohen's Kappa of 0.77 prior to 2012. Data after the cut off had an accuracy of 81.19% and a Cohen's Kappa of 0.65. There was no statistical difference between data sets using the 2012 cut off using the McNemar's test value of 3.27 with a p-value of 0.07.

DISCUSSION AND CONCLUSION:

The complexity of accurately diagnosing BPBI in infants plays a crucial role in treatment. Our findings reveal a significant agreement between preoperative assessments and intraoperative findings, with an accuracy of 83%. This underscores the importance of physical examination in BPBI diagnosis. However, there is considerable room for improvement. Our understanding of nuances concerning C8 nerve root injuries has expanded beyond the traditional Narakas classification. Only recently have we begun to recognize and search for Injury C (C5, C6, C7, C8), reflecting a paradigm shift in our understanding of C8 and T1 nerve root functions distinct from the lower trunk. Nevertheless, we cannot see what we cannot understand. Observer bias remains a factor, potentially affecting the accuracy of intraoperative findings versus the true extent BPBI. Enhancements to this study could include examining the impact of intraoperative neurodiagnostic tools,

such as nerve stimulators, on diagnostic accuracy. Future research should aim to refine these diagnostic tools and methodologies to further improve the precision and outcomes of surgical interventions for obstetric BPBI.

Table 1: Concordance of Preoperative Brachial Plexus Injury Prediction

	Intraoperative Findings				
Preoperative Prediction	A	B	C	D	Total
A (C5 & C6)	7	7	1	0	15
B (C5, C6, & C7)	3	33	9	2	47
C (C5, C6, C7, & C8)	0	0	1	0	1
D (C5, C6, C7, C8, & T1)	0	2	3	94	99
Total	10	42	14	96	162

Green boxes indicate concordance of preoperative injury and intraoperative injury. The overall accuracy was 83.33%, with 135 cases correctly identified out of a total of 162 cases. On the other hand, 27 cases were not concordant.

Table 2: Performance Metrics for Brachial Plexus Injury Patterns

	Injury A	Injury B	Injury C	Injury D
True Positive	7	33	1	94
False Positive	8	14	0	5
False Negative	3	9	13	2
True Negative	141	106	148	61
Accuracy	0.93	0.86	0.92	0.96
Precision (Recall)	0.47	0.70	1.00	0.95
Sensitivity	0.70	0.79	0.07	0.98
Specificity	0.95	0.88	1.00	0.92
F1 Score	0.56	0.74	0.13	0.96
Cohen's Kappa	0.70			

Nerve root injury was divided into the following patterns: Injury A (C5, C6), Injury B (C5, C6, C7), Injury C (C5, C6, C7, C8), Injury D (C5, C6, C7, C8, T1). Cohen's kappa error was 0.70, indicating preoperative exam predicted intraoperative nerve root injury with substantial accuracy. Injury D was the largest group with 96 patients, and had the largest positive class performance with precision of 0.95.