Original Article

Predictors of Co-activation in Erb's Palsy: A Retrospective Study

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Abstract

Context: Three per thousand births have Erb's palsy. Spontaneous recovery is 50%. Co-activation yields poor outcomes. There are no objective indicators of its emergence. **Aims:** Analyze if 1 month Axon Viability Index (AVI) of the axillary nerve and which active movement score (AMS) measures can predict co-activation. **Settings and Design:** Tertiary level rehabilitation center, retrospective design. **Methods and Material:** The electronic medical record (EMR) was reviewed for patients with Erb's palsy with Narakas grade 2 lesions, as having co-activation or not. The one-month Axillary AVI was used with monthly AMS scores. The inclusion criteria were an AVI greater than ten percent. Exclusion criteria were bi-brachial palsy, congenital anomalies, concomitant or subsequent neurological injuries, and orthopedic injuries. **Statistical Analysis Used:** Descriptive statistics were used to calculate the median and interquartile values for AMS scores at each respective time point. Statistical significance for each time point was determined using a student's *t*-test. **Results:** Regarding the *t*-test on the AVI data, a significant *P* value of 0.001 was found favoring the co-activation group. AVI of the Axillary nerve between 0.1 and 0.5 at 1 month is a reliable indicator of future development of co-activation. The following were strong indicators of the emergence of co-activation respectively: month three Wrist Extension in sitting, Shoulder Abduction in supine, Shoulder Abduction in sitting, Elbow Flexion in sitting, month six Elbow Flexion in sitting, month seven Elbow Flexion in sitting. **Conclusions:** The axillary AVI at one month is a good predictor of future development of co-activation. The mentioned AMS items are the earliest indicators of co-activation.

Keywords: Birth brachial plexus injury, co-activation, disuse apraxia, Erb's palsy

Introduction

Erb's palsy has an incidence of 0.9 to 2.6 per 1000.[1] Half show full spontaneous recovery; 20%–30% residual deficits, and 10%–15% considerable alteration of function.[2-4] Until recently shoulder dystocia was taken for granted as the cause.[5] Co-activation complicates outcomes in Erb's palsy. Indicators of its emergence are not known. This review compares Axon Viability Index (AVI) and active movement score (AMS) in infants with and without coactivation. Upon co-activation being found botulinum became an adjuvant.[6] Criteria for when to inject followed.[7] Palpation, motor recovery, and EMG have limitations. Specific measures predicting emergence are needed. The AVI predicts the need for surgery. The AMS reports change. If they predict co-activation is unknown.

Objectives

1. Analyze 1-month AVI of the Axillary nerve to predict the emergence
2. Analyze which AMS measures predict co-activation

Subjects and Methods

The Narakas Classification[8] is the standard nomenclature to express lesion severity in Birth Brachial Plexus Injury (BBPI) and is documented at 1 month of age.[9] The hospital's electronic medical record (EMR) was reviewed for patients with Erb's palsy. Inclusion criteria were Narakas grade 2 lesions seen monthly from 1 to 7 months with or without co-activation and an AVI greater than ten percent. Exclusion criteria were bi-brachial palsy, congenital anomalies, concomitant or subsequent neurological injuries, and or orthopedic injuries. They were further categorized as having or not having co-activation. Nerve conduction studies were reviewed and the 1-month axillary AVI was recorded. Monthly records were reviewed, and AMS scores were noted. The following baseline details were noted: age, gender, and side. Ethics committee is obtained by 9.11.2020.

Co-activation was defined as palpable activity of Pectoralis Major or Lattisumus Dorsi with active shoulder abduction by deltoid, and/or the same prior muscles with Infraspinatus during external rotation, and/or activation of Pronator Teres during forearm supination.

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Surface EMG has been used to identify co-activation in other conditions.[10] The AMS is validated for use in BBPI. It is an objective, discrete variable that is rated on a scale of 1 to 7, with higher values indicating better function. Values were taken at one to seven months for the supine movements and from three to seven months for the sitting movements. The authors state all measures can be used at any time frame. We had difficulty making infants one- and 2-months-old sit or consistently do all the movements in the mother's arms. From three months on they were made to sit as mentioned.

The 1-month axillary AVI is validated for use in BBPI.[11] It was designed to be a more accurate prognosticator compared to the then-gold standard of no antigravity elbow flexion at 3 months. The best cut-off point from this study was for the axillary nerve (AVI, sensitivity, and specificity) and were <10%, 88%, and 89%, respectively. The measure simply requires one to divide the CMAP of the involved side by that of the unaffected side. In concordance with the study, those with an AVI <10% were excluded as they were more likely to have a poor prognosis and in need of surgery. As the other proximal upper extremity nerves were not tested in this paper or had lower accuracy, we chose the Axillary AVI at one month as our sole NCS variable.[11]

Statistical analysis

Descriptive statistics were used to calculate median and interquartile values for AMS scores at each respective time point. Statistical significance for each timepoint was determined using a Student's *t*-test, with *P* values under 0.05 considered significant. Fisher exact test was used to determine the significance between coactivation and sidedness and Wilcoxon rank sum test with continuity correction for co-activation and each muscle group at their respective time points. Those were: Shoulder Adduction, Shoulder Abduction, Shoulder Internal Rotation, Shoulder External Rotation, Elbow Flexion, Elbow Extension, Forearm Pronation, Forearm Supination, Wrist Flexion, Wrist Extension, Finger Flexion, Finger Extension, Thumb Flexion, Thumb Extension from the first to the seventh months of life. All analysis was done in R Studio release 2022.07.1.

Results

The following AMS measures were not used in the statistical analysis as they did not show major changes: Shoulder Adduction, Shoulder Internal Rotation, Elbow Extension, Forearm Pronation, Wrist Flexion, Finger Flexion, Thumb Flexion, Thumb Extension.

There was a non-significant difference between the groups at baseline Fisher's exact test for count data ($P = 0.8238$).

Regarding the *t*-test on the AVI data, a significant *P* value of 0.001 was found favoring the co-activation group. AVI of the axillary nerve between 0.1 and 0.5 at 1 month is a reliable indicator of future development of co-activation [see Figure 1].

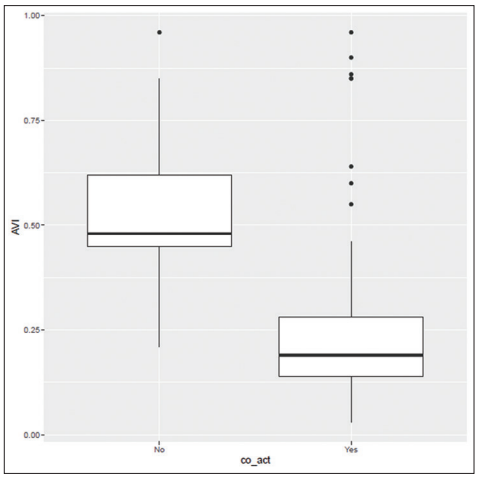

Figure 1: Axillary Axon Viability Index to predict coactivation

With regards to interquartile mapping, the following were statistically significant favoring the co-activation group serving as a strong indicator of the emergence of co-activation respectively: month three Wrist Extension in sitting ($P = 0.03021$), month three Shoulder Abduction in supine ($P = 0.04867$), month three Shoulder Abduction in sitting ($P = 0.06488$), month three Elbow Flexion in sitting ($P = 0.03021$), month six Elbow Flexion in sitting ($P = 0.0221$), month seven Elbow Flexion in sitting ($P = 0.0001836$). With the effects of chance eliminated the overall strength of agreement of the AMS was 0.51 with a 95% confidence interval of 0.46–0.56 a score considered in the moderate range of agreement**.** The overall quadratic weighted kappa coefficient of the AMS was 0.89 with a 95% confidence interval of 0.87 to 0.91 [see Figure 2].

Discussion

In this cohort of 116 patients, 29 did not develop coactivation and 87 did develop it (75%). AVI of less than 0.5 at 1 month is a good predictor for the future development of co-activation. Exam findings that indicate emerging coactivation at 3 months are: Wrist Extension in sitting, Shoulder Abduction in supine, Shoulder Abduction in sitting, Elbow Flexion in sitting, from six months Elbow Flexion in sitting, and from seven months Elbow Flexion in sitting. Beyond these points, the AMS began to plateau or regress in those who later developed full-blown co-activation.

Patient recovery is often non-linear. Defying expectations, some patients have an abnormal early NCS and near normal function, or the reverse. Others with an abnormal early NCS can have a sudden appearance of near-normal function in key muscles. The reason for all this lies in the neurological basis for this condition. Muscle imbalance may cause movement restriction by three principal mechanisms. First, sustained weakness of one muscle group in relation to the other may perpetuate power imbalance.[12] Second, in the process of neuromuscular healing, agonist and antagonist muscle groups may develop aberrant co-contraction activity, resulting in minimal effective movement.[13] Third, imbalance may lead to residual structural joint deformities, including contractures,

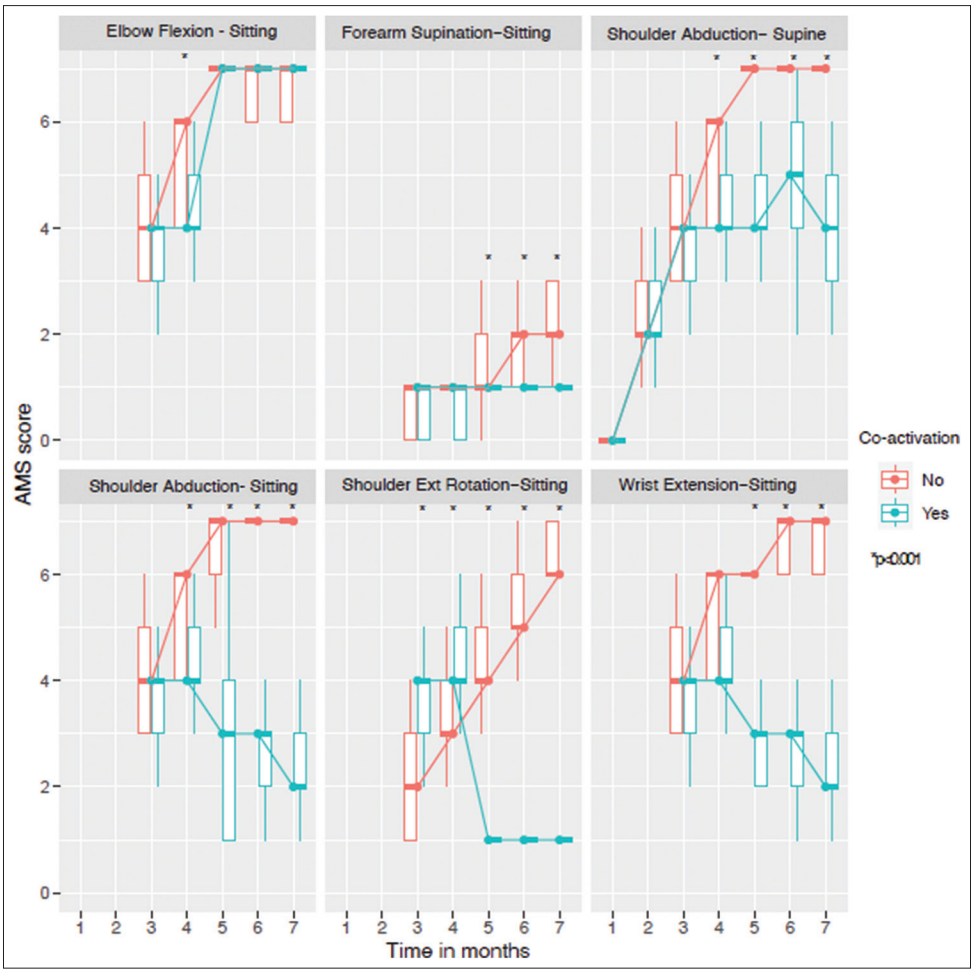

Figure 2: Interquartile differences between those with and without co-activation at each time frame

subluxations, and dislocations.[14] Abnormal motor learning patterns are related to either central apraxia[6] or peripheral nerve synkinesis.[15] Both result from abnormal axonal outgrowth during regeneration at the level of the peripheral nervous system,[13] and manifest as co-activation.

The indexed literature doesn't state when co-activation likely starts. In this cohort, we found onset from three to seven months. There are many options to detect the presence of co-activation. As useful as these are, most are binary and vary between clinicians. Inconsistent Yes/No results leave open a wide window to speculate whether the noted change warrants further action. Clinical exams reveal visible and palpable contraction in the antagonist muscles, and needle EMG findings are the main methods.[16] Having detected it, the treatment plan needs to be revised. The indications for Onabotulinum injection are; co-contraction resulting in little to no joint motion; plateau/drop in the Active Movement Scale for target joint movements while the total AMS score continues to improve,[16] and lastly inadequate quality and speed of recuperation.[2] The problem with these measures is one of exam compliance and limited range to demonstrate change. Many babies are ambivalent about clinical exams or needle EMG.

Being able to predict when co-contraction emerges allows treatment to be modified pre-emptively. As electrophysiology and clinical exam don't always agree, we used both to predict the emergence of co-activation. Compared to EMG, NCS is relatively easier on the infant and parents. To improve prognostic accuracy Heise *et al.*[11] proposed the AVI. This study was done to predict which patients would need surgery. The best measure their study produced was the Axillary AVI. Any infant with an AVI <10% was deemed to have a poor prognosis and needed surgery. Further applications were not considered. The first month of NCS provides the clearest depiction of the nerve damage extent. Taking the same approach we wanted to see if this measure could be used to detect co-activation. The AVI has been used in other studies of BPP and has proven useful.[17] The premise we have based the use on is that a more severe injury (with Axillary AVI greater than 10%, but less than 50%) should pre-dispose to co-activation versus those who don't develop it. The longer time the brain spends without input from the reinnervated muscles, the less they will be mapped into motor functions. Simply put the worse the injury, the worse the central apraxia. The results support this.

Taken alone active movements are not a reliable prognosticator. Three- and six-month sitting elbow flexion is the standard

in whether to operate according to some schools of thought. We found elbow flexion in sitting only became relevant as an indicator at 7 months. Parents often report good progress, not realizing that is true for the uninvolved muscles, not the ones treatment is targeting. The AMS was designed to track BPP recovery objectively and has sixteen measures. For the current objectives, it is superfluous. Curtis *et al*.[18] state all measures can be tested at any time. They also mention testing in supine, side lying, and sitting. Consistently making one- and two-month-old infants sit to test some movements were difficult (Shoulder abduction and external rotation as examples). As their validation was done on 10 five-month-old babies this may be the reason. They mention testing while the baby is upright in the mother's arms as equal to sitting. As some cooperated and others didn't, we didn't use the full scale until 3 months of age. There is no way to record 'not applicable' in this scale. As infants with BPP mature, rechecking muscles with preserved innervation and normal function is redundant. In this study, the following measures showed no differences between the groups: Shoulder Adduction, Shoulder Internal Rotation, Elbow Extension, Forearm Pronation, Wrist Flexion, Finger Flexion, Thumb Flexion, Thumb Extension. This is not a surprise. These muscles have complete innervation and freedom to act. Simply put they are of little value to detect co-activation. Interestingly the AMS validation study also shows these measures have the highest inter-rater consistency. The relevant movements sadly had less agreement. The use of forearm supination as a clinical measure has a different problem. As it is only useful for fine ADLs it has been shown as an unreliable as a predictor of outcomes.[19] Functional supination in children only emerges at twelve months. Our outcomes support the same. From our results, it appears that tracking Wrist Extension in sitting, Shoulder Abduction in supine, Shoulder Abduction in sitting, Elbow Flexion in sitting from three months, and Elbow Flexion in sitting from six months, Elbow Flexion in sitting from seven months are sensitive enough to detect co-contraction. No other studies have looked this deeply into this measure.

For the AMS DeMatteo and Bain[16] mentions a plateau in target joint movements. What is not detailed is, which movements specifically, in what time frame, and how much is significant enough to warrant changing the treatment plan. The plateau is not enough to diagnose this though. Due to co-activation patients might not be able to demonstrate more than a score of 6 at 7 months of age. That may improve as their activity options widen. Our study shows an AMS plateau at the above-mentioned timeframes indicates this.

Co-activation also occurs in post-operative patients. This isn't considered in standard treatment algorithms which are mostly centered around deciding if, and when surgery should be done. Three decades ago, the indication for surgery was set as no antigravity bicep function at 3 months.[20] More recently others suggest waiting for the sixth month before deciding the same.[21,22] Our results suggest 3- and 6-month sitting elbow flexion only became significant at seven months between the two groups. Upon waiting until the sixth month it is revealed that 85% of biceps improve.[21] Early nerve surgery, however, results in recovery of biceps strength in 80%–100% of cases.[23] Regardless both groups will always have an incomplete function.[24] This is due to co-activation from central apraxia. The newly innervated muscle is not mapped to motor functions. Finally, addressing co-activation early can prevent, delay, or reduce the extent of future surgery.[25] The present study was hospital-based with a small sample size. These results should be compared with similar large hospital-based studies for further validation and correlation.

Conclusion

The Axillary AVI at 1 month of more than 0.1 but less than 0.5 is a good predictor of future development of co-activation. Wrist Extension in sitting, Shoulder Abduction in supine, Shoulder Abduction in sitting, Elbow Flexion in sitting from three months, and Elbow Flexion in sitting from six months, Elbow Flexion in sitting from seven months are the earliest indicators of co-activation. Knowing these indicators will allow one to modify the treatment plan earlier using agents like botulinum toxin.

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Conflicts of interest

There are no conflicts of interest.

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