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A comparative study of train-of-four (TOF) count at corrugator supercilii and at adductor pollicis reflecting abdominal muscles relaxation

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***Abstract*---**Introduction: Diaphragm and lateral abdominal muscles frequently show sparing effects to muscle relaxants. This study compared visual estimation of neuromuscular transmission of corrugator supercilii and adductor pollicis (AP) with electromyographic measurements of lateral abdominal wall muscles during recovery from vecuronium-induced intense neuromuscular block. Methods: 60 patients undergoing elective surgeries under general anesthesia were included. Following loss of consciousness, supramaximal stimulations were applied using electrical nerve stimlators to left 10th intercostal, ulnar and facial nerves. Electromyographic activity (EMG) of abdominal wall muscles were measured. After Inj. Vecuronium 0.1 mg/kg, Electromyographic activity measurements counted the visually detectable train-of-four (TOF) responses at corrugator supercilii and adductor pollicis. The onset time, the duration of action and quantitative measurements of neuromuscular block were done. Observations: Clinical duration of action of vecuronium almost coincided with train-of-four response at corrugators supercilii where

as train-of-four recovery at adductor policis occurred late during recovery stage. Corrugators supercilii had a stronger positive correlation with abdominal muscles relaxation as compared to the adductor policies. Corrugators supercilii had a stronger correlation coefficient (0.910 vs 0.417) than adductor policis with respect to abdominal muscle. It indicated that corrugator supercilii is a better predictor than AP to measure abdominal muscle relaxation.

***Keywords*---**neuromuscular monitor, TOF, corrugator supercilii, vecuronium.

Introduction

Neuromuscular monitoring is done to access the onset of neuromuscular blockade, determine the level of muscular relaxation during surgery and to access the recovery to minimize the risk of residual paralysis. The train-of-four (TOF) provides a clinical tool to assess neuromuscular block in the anesthetized patient. Usually the ulnar, facial or common peroneal nerve is used to assess the muscle response by giving a supramaximal stimuli. Sparring effect had been demonstrated by the diaphragm and lateral abdominal wall muscles and considered resistant to neuromuscular blocking agents. Neuromuscular transmission monitoring of these muscles was important to detect early recovery when profound block was requested for surgical purpose. More recently, a recovery profile resembling that of resistant to neuromuscular blocking agents muscles had been demonstrated by the corrugator supercilii muscle. The corrugator supercilii was easy to stimulate and its evoked contraction could be simply observed.

Plaud B et al[1] had shown the response of the superciliary arch (corrugator supercilii) reflected blockade of laryngeal adductor muscles not the orbicularis oculi (OO). H. J. Lee, K. S. Kim et al[2] had shown corrugator supercilii(CSC) was a better predictor of optimal intubating conditions than adductor pollicis or orbicularis oculli after administration of rocuronium. Yamamoto s et al[3] had shown the comparison of corrugators supercilli and adductor pollicis for reversal of neuromuscular block by sugamadex. As compared with adductor pollicis, neuromuscular transmission monitoring of the corrugator supercilii might reveal information on lateral abdominal wall muscles relaxation. This study compared visual estimation of neuromuscular transmission of corrugator supercilii and adductor pollicis (AP) with electromyographic measurements of lateral abdominal wall muscles during recovery from vecuronium-induced intense neuromuscular block.

Materials and Methods

This cross sectional study included 60 patients of either sex between 18 to 60 years, ASA I&II, undergoing elective surgeries under general anesthesia with endotracheal intubation. A thorough preanesthetic evaluation was done before surgery and kept nil per oral eight hours before surgery. Patients were premedicated with injection Glycopyrolate 0.2mg, midazolam 0.05mg/kg and

nalbufine 0.2mg/kg. Anaesthesia was induced with Inj. Propofol and endotracheal intubation was performed by direct laryngoscopy after giving inj succinyl choline 1.5mg/kg. Anaesthesia was maintained with nitrous oxide oxygen in 2:1 ratio with Isoflurane and controlled ventilation. Following loss of consciousness, supramaximal stimulations were applied using electrical nerve stimlators to three nerves: left 10th intercostal, ulnar and facial. Electromyographic activity (EMG) of abdominal wall muscles were measured. After bolus dose of Inj. Vecuronium 0.1 mg/kg, an independent observer blinded to the Electromyographic activity measurements, counted the visually detectable train-of-four (TOF) responses at corrugator supercilii and adductor pollicis. TOF was elicited every 10 seconds .The time from the end of injection of the relaxant to the time when all four responses of TOF were abolished was taken as onset time. The interval between the administration of the bolus dose of the relaxant and the reappearance of the two responses to TOF was taken as the duration of action. Quantitative measurements of neuromuscular block were done during the surgery. Patients were reversed with Inj. Neostigmine 50 mcg/kg along with Inj. Glycopyrolate 10 mcg/kg at the end of surgery and endotracheal tube was removed.

Quantitative measurements of neuromuscular block

Single twitches (0.2 ms at 0.1 Hz) were applied to the 10th left intercostal nerve during end expiratory pauses using percutaneous insulated needle electrodes inserted on the posterior axillary line to cause intense reproducible lateral abdominal wall muscle motions. The resulting evoked electromyographic (EMG) activity of abdominal wall muscle was measured using Ag–AgCl surface electrodes placed on the left anterior axillary line of the thoracoabdominal wall 2 cm apart from the umbilical line. EMG of abdominal muscle was amplified and recorded with a gated-EMG amplifier using a latency of 2 mili seconds and a window of 20 mili seconds. Peak-to-peak amplitude of compound action potential activity of anterolateral abdominal wall muscles (ABEMG) was calculated.

For stimulation of the ulnar nerve, the electrodes were applied at the volar side of the wrist. The distal electrode was placed 1cm proximal where the proximal flexion crease crosses the radial side of the flexor carpi ulnaris muscle. The proximal electrode was placed 2-5 cm proximal to the distal electrode. Two recording electrodes were attached over the adductor pollicis muscle. The forearm to be investigated and the four fingers were immobilized with vinyl belts on the arm board of the operating bed but the thumb was allowed to move freely. This placement of electrodes allowed electrical stimulation to elicit only finger flexion and thumb adduction. Similarly The electrode was placed on the corrugator supercilii after the skin was prepared with alcohol wipes to reduce skin impedance and removed dead cells. Single twitches (0.2 ms at 0.1 Hz) were applied at the upper branch of the facial nerve and to the ulnar nerve at the wrist to determine supramaximal current intensity. After supramaximal stimulation intensities had been defined (8 min stability in responses amplitude) for the three muscles, recording and measurement devices at adductor pollicis and corrugator suercilii were removed, the stimulation pattern of both ulnar and facial nerves were switched to train-of-four (TOF) supramaximal stimulation applied every minute.

Electromyographic Measurements

The time course of action of vecuronium on anterolateral abdominal wall muscles was evaluated using the following parameters: (1) onset time, (2) maximum effect, and (3) time to recovery of 25, 50,
75, and 90% of control twitch height.

Visual estimate of NMT

Estimation of neuromuscular function performed by an independent observer blinded to EMG measurements consisted of a simple count of visually detectable TOF responses at corrugator supercilii (CSC) and adductor pollicis (AP).

Statistical Evaluation and Data Analysis

Data entry, cleaning and analysis were done through SPSS 21.0 software. Quantitative variables were described as Mean ± SD. Qualitative variables were described in terms of percentage. Pearsons correlation was established between the dependent and independent variables where ever applicable. For any significant association the confidence interval was set at 95% ie p value < 0.05(α error=5%). The observations were presented in the form of tables and graphs.

Observation and Results

Table 1
Demographic variables in terms of mean ± SD

Variable	Age(years)	Weight(kg)	Height(cm)	BMI
Mean	39.4	63.7	161.3	24.7
SD	13.4	13.7	9.15	5.7

Variables were in terms of mean ± SD. The mean age was found to be 9.5±13.8, weight 63.7±13.7, height 161.3±9.15, the BMI to be 24.7±5.7.

Table 2
Time course of action of vecuronium 0.1 mg/kg on abdominal muscle activity measured with EMG

Variable	Onset Time	RTH 25 (Min)	RTH 50 (Min)	RTH 75 (Min)	RTH 90 (Min)
Mean	148.1	43.5	53.7	60.8	65.30
SD	21.846	6.41	6.29	7.77	4.36

The mean OT (onset time) was found to be 148.1±21.846.During recovery, the meanRTH25 (recovery of 25% of control twitch height) was 43.5±6.41, the RTH50 was 53.7±6.29, the RTH75 was 60.8±7.77, the RTH90 was 65.30±4.36 .

Table 3
Time to recovery of 1, 2, 3, and 4 visually detectable TOF responses at the abdominal muscle, CSC and AP muscles (T1, T2, T3, T4, respectively) after a bolus dose of vecuronium 0.1 mg/kg

TOF	AB	CSC	AP
T1	42.1±6.9	39.2±7.6	50.6±8.9
T2	44.5±4.7	40.8±5.1	55.7±9.1
T3	56.2±6.5	54.7±7.5	60.7±9.2
T4	61.9±6.3	60.6±7.8	65.7±9.2

Table 4
Linear regression model for TOF response of CSC and AP compared to AB(abdominal muscle)

TOF	mean±SD		r(pearson"s correlation coefficient)		P-value
	CSC	AP	CSC	AP	
T1	39.2±7.6	50.6±8.9	0.954	0.646	<0.01
T2	40.8±5.1	55.7±9.1	0.874	0.579	
T3	54.7±7.4	60.7±9.1	0.940	0.547	
T4	60.6±7.8	65.7±9.1	0.933	0.385	

It showed that CSC has strong positive correlation with abdominal muscle relaxation as compared to the adductor policis.

Table 5
Linear regression model for TOF response between CSC and AP

TOF	CSC(Mean ±SD)	AP(Mean ±SD)	r	r^2	B	P
T1	39.2±7.6	50.6±8.9	0.388	0.15	0.329	0.002
T2	40.8±5.1	55.7±9.2	0.11	0.012	0.061	0.404
T3	54.7±7.5	60.7±9.2	0.227	0.052	0.185	0.081
T4	60.6±7.8	65.7±9.2	0.026	0.001	0.022	0.844

It described correlation between CSC and AP for TOF response after applying a linear regression model. The Pearson's correlation coefficient (r) for all the TOF stages were either weak (T2-0.11 and T4-0.026) or mild (T1-0.388, T3-0.227). The r^2 showed the percentage of change in one variable attributable to change in another variable. A maximum of 15% change in T1 of AP could be attributable to change in T1 of CSC. Similarly 5% change in T2 of AP could be attributable to change in T2 of CSC. However in case of T2 and T4 the change in AP couldn't be attributable to change in CSC (1% and 0.1%). The unstandardized coefficient (B) showed change in one unit of one variable resulting in change of units in the other. Change of 1 minute of T1 of AP resulted in change of 0.329 minutes of T1 of CSC. Change of 1 minute of T4 of AP resulted in change of 0.022 minutes of T1 of CSC. In this case only the correlation between T1 of CSC and T1 of AP were

significant. Overall, one of the variable either CSC or AP would be a better predictor for predicting TOF of AB.

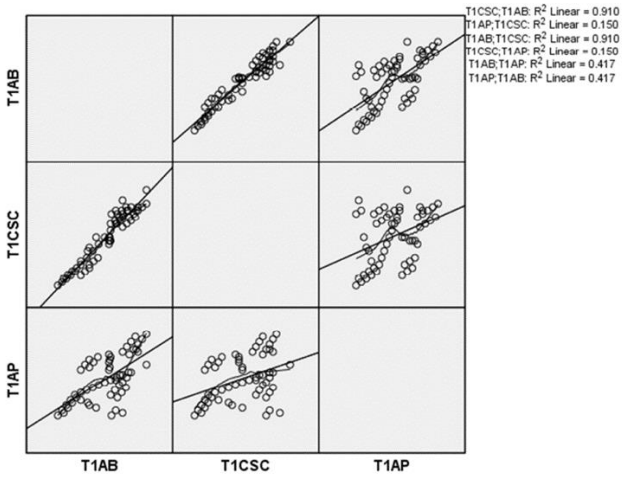

Figure 1. Complex scatter plot for correlation between 3 muscles for TOF1

CSC had a stronger correlation (0.910 vs 0.417) than AP with respect to Abdominal muscle.

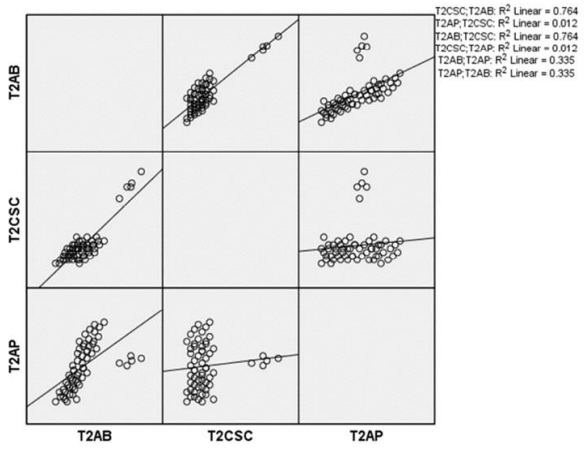

Figure 2. Complex scatter plot for correlation between 3 muscles for TOF2

Corrugators supercilii (T2CSC)had a strong positive correlation with abdominal muscle (T2AB) ie 0.764 vs 0.335 that of adductor policis(T2AP).

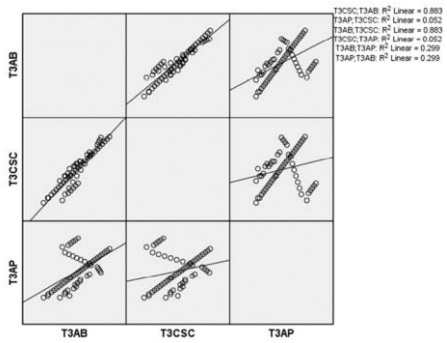

Figure 3. Complex scatter plot for correlation between 3 muscles for TOF3

Corrugator supercilii (T3CSC)had a strong positive correlation with abdominal muscle (T3AB) i.e. 0.883 vs 0.299 than adductor policis (T3AP). There was weak positive correlation between T3CSC and T3AP i.e. 0.052.

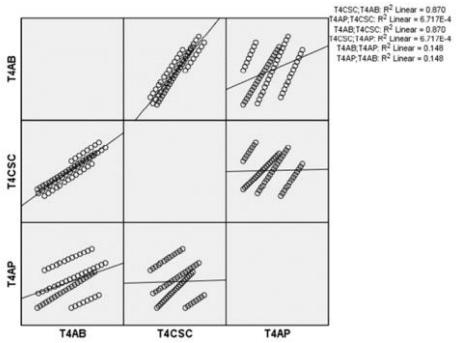

Figure 4. Complex scatter plot for correlation between 3 muscles for TOF4

Corrugators supercilii (T4CSC)had a strong positive correlation with abdominal muscle (T4AB) i.e. 0.870 vs 0.148 that of adductor policis(T4AP).

Discussion

The administration of neuromuscular blocking agents titrated upon visually detectable train-of-four responses at corrugator supercilii could be an interesting strategy to maintain relaxation. The neuromuscular responses to vecuronium was recorded at the eyelid (corrugator supercilii), the thumb (adductor pollicis) and the abdominal muscles. The two muscles (corrugators supercilii and adductor pollicis) are described as sensitive with greater maximum blockade and longer duration of action. Electromyographic activity (EMG) was used to measure neuromuscular block of abdominal muscles as there was no system available to simply monitor abdominal muscles relaxation. In a study Dhonneur G, Slavov V, Merle JC, et al[4] have used electromyography to compare onset and recovery at the diaphragm and geniohyoid muscles after an intubating dose of mivacurium (0.2mg/kg) to determine if the geniohyoid muscles were particularly sensitive to neuromuscular blocking agents.

Out of 60 patients 58.3 % were of the age group of 21- 40 and 26.7 % belong to age group 41-60 with mean age being 39.5±13.8.The mean weight was found to be 63.7±13.7kg, height was found to be 161.3±9.15cm and mean body mass index (BMI) was 24.7±5.7. The onset of action of vecuronium was found to be 148.1±21.846 seconds. During recovery, the mean RTH25 was 43.5±6.41, RTH50 was 53.7±6.29, RTH75 was 60.8±7.77, RTH90 was 65.30±4.36. During the time of recovery at corrugator supercilii and adductor pollicis, it was found that the first TOF (39.2 min) and second TOF (40.8 min) at corrugator supercilii while adductor policis was still unresponsive (First TOF at 50.6 min). So the first and second TOF responses of corrugator supercilii appeared earlier and at significantly lower abdominal muscle Electromyographic Activity(ABemg) than the same response at adductor policis.

Appearance of the third TOF response of corrugators supercilii (54.7 min) coincided with second TOF response (50.6 min) of adductor policis . Similarly fourth TOF at corrugators supercilii coincided with 3rd TOF of AP. In comparison of train-of-four stimulation (T1, T2, T3, T4) at the abdominal muscle, corrugators supercilii and adductor policis muscles it was found that clinical duration of action of vecuronium almost coincided with train-of-four response at corrugators supercilii where as train-of-four recovery at adductor policis occurred late during recovery stage. Correlation for train-of-four response showed that corrugators supercilii had a stronger positive correlation with abdominal muscles relaxation as compared to the adductor policis . In a study Rimaniol JM, Dhonneur G, Sperry L, Duvaldestin P et al[5] found both the orbicularis oculi (OO) and the adductor pollicis (AP) muscles had been used to quantify the extent of neuromuscular block of the respiratory muscles.

After applying a linear regression model for correlation between corrugators supercilii and adductor policis for TOF and keeping the correlation with abdominal muscles silent, the pearson's correlation coefficient (r) for all the TOF stages were either weak (T2-0.11 and T4-0.026) or mild (T1-0.388, T3-0.227). Overall, one of the variable either corrugator supercilii or adductor policis would be a better predictor for predicting TOF of abdominal muscles. In this study we found the corrugator supercilii to be a better predictor. From the complex scatter graph their first TOF response showed that corrugators supercilii had a stronger correlation coefficient (0.910 vs 0.417) than adductor policis with respect to Abdominal muscle. It indicated that corrugator supercilii is a better predictor than AP to measure abdominal muscle relaxation. Corrugator supercilii and adductor policis had a very weak positive correlation (0.150). Similar results were also observed in the complex scatter graph of 2nd TOF, 3rd TOF and 4th TOF which indicated corrugator supercilii was a better predictor of abdominal muscle relaxation than adductor policis.

Our study had some limitations. We used a visual method to quantify neuromuscular block at adductor policis and corrugators supercilii. Tactile assessment of train-of-four responses at adductor policis would have been more reliable but we preferred using the same method of train-of-four monitoring at both studied muscles. By using visual TOF count at abdominal muscles, we would have been able to extend our visual method to the three studied muscles. But visual estimation of lateral abdominal muscles neuromuscular block had

never been standardized. In the study of Le Corre F, Plaud B, Benhamou E, Debaene B[6] Visual estimation of the response at the orbicularis oculi correctly predicted good-to-excellent intubating conditions in more than 90% of cases for all the currently available muscle relaxants.

Conclusion

Recovery of the first response to train-of-four at corrugator supercilii warranted low abdominal muscles reactivity, but reappearance of the third response showed significant abdominal muscles recovery. We found that recovery at the eyebrow occurred while intense neuromuscular block still affected sensitive hand muscles. So TOF response of corrugator supercilii and adductor policis with respect to abdominal muscles showed that CSC had strong positive correlation with abdominal muscles relaxation as compared to the adductor policis.

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