Original Article

Dynamometer based hand grip strength as a clinical tool for objective assessment of post-operative residual muscle weakness

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ABSTRACT

Background and Aims: Residual neuromuscular block continues to be a significant postoperative complication despite neuromuscular monitoring. This study aims to determine the applicability of a hand-held forced dynamometer for hand grip strength assessment as an objective measure of residual muscle weakness. **Methods:** The study included patients undergoing surgery under general anaesthesia. A demonstration was given to the patient on the usage of a dynamometer for handgrip strength and a peak expiratory flow meter for peak expiratory flow rate (PEFR) and baseline values were recorded. The parameters were monitored at 15 minutes post-extubation and again at intervals of 15 minutes until one hour, half-hourly until four hours, and hourly until six hours post-operatively. Paired t-test was used for comparison of baseline muscle strength and PEFR with the parameters at different time points. Association between muscle strength and PEFR was tested with the Pearson-correlation test. **Results:** Muscle strength was 50 to 60%, 75% and 100% of baseline at 15, 45 and 210 minutes after extubation, respectively. PEFR was 50 to 60%, 75% and 100% of baseline at 15, 60 and 180 minutes after extubation. The Pearson-correlation test established a positive correlation between handgrip strength and PEFR (correlation-coefficient 0.86). **Conclusion:** A significant reduction in the postoperative muscle strength can be detected using an objective forced dynamometer to measure handgrip strength even when train of four count has returned to unity and even when there are no clinical signs of muscle weakness. The residual muscle weakness is significant enough to affect the PEFR in the postoperative period.

Key words: Hand grip strength, neuromuscular monitoring, peak expiratory flow rate, residual muscle weakness, residual neuromuscular block

INTRODUCTION

Residual neuromuscular block continues to be a significant postoperative complication with an incidence of 10–40%.[1] Recovery of train-of-four (TOF) ratio greater than 0.9 is recommended to restore airway protection.[2,3] However, there is a possibility of post-operative respiratory dysfunction even after adequate recovery of the TOF ratio.[4] Some researchers have observed that partial neuromuscular block, even to a degree that does not evoke stridor or oxygen desaturation, can cause partial inspiratory airway collapse.[5] Therefore, an objective assessment of motor power recovery in the post-operative period is important.

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The present study aimed to evaluate the role of objective assessment of hand grip strength in residual muscle weakness. The primary objective was to determine the residual muscle weakness using a forced dynamometer by comparing the immediate post-operative muscle strength to the pre-operative baseline value. The secondary objectives were to determine the time to recover to baseline muscle strength and to correlate the changes in the muscle strength with respiratory function using peak expiratory flow rate (PEFR).

METHODS

This was a prospective observational study conducted from November 2021 to March 2022 after approval from the institutional ethics committee (EC/NIMS/2860/2021) and registration in the Clinical Trial Registry of India (CTRI/2021/11/038127). Informed written consent was obtained from all the patients. Patients of age 18 to 60 years undergoing surgery under general anaesthesia and belonging to American Society of Anesthesiologists (ASA) classes I and II were included in the study. Patients undergoing surgery involving the upper limb or having a deformity or fracture of the upper limb and those with a pre-existing neuromuscular disease or pulmonary diseases were excluded from the study. They were kept nil per oral for six hours for solids and two hours for clear fluids before the surgery. Standard ASA monitoring was used for all the patients during the intraoperative period. An intravenous cannula was placed in the non-dominant hand. A demonstration was given on the method of using a dynamometer (Camry Electronic hand dynamometer model: EH101) for handgrip strength and peak expiratory flow meter (Cipla Breath O Meter) for PEFR. Handgrip was assessed by instructing patients to exert maximum grip three times at intervals of one minute and the highest value of the three readings was noted. PEFR was measured by asking the patient to take a deep inspiration followed by breathing out into the mouthpiece of the peak expiratory flow meter as quickly and as forcibly as possible. The highest value of three readings taken one minute apart was noted. Just before anaesthesia induction, baseline values for handgrip strength from the dominant hand and PEFR were acquired. Standard anaesthesia practice for general anaesthesia was followed. Neuromuscular function was monitored by assessing the contraction of the adductor pollicis muscle using acceleromyography (Train of four (TOF)-Watch Sx). Intravenous anaesthesia was administered with fentanyl (2 μg/kg), and propofol (2.0 mg/kg). Atracurium (0.5 mg/kg) was administered for muscle relaxation after the loss of verbal response and tracheal intubation was performed after 3 minutes. Depth of anaesthesia was maintained using sevoflurane to a minimum alveolar concentration (MAC) of 0.8 to 1.2, fentanyl 1 μg/kg/hour. Repeat doses of atracurium (0.1 mg/kg) were administered when TOF count increased to two. Ventilation was assisted to maintain end-tidal CO_2 levels between 35 and 45 mmHg. Body temperature was monitored using a nasopharyngeal probe. Forced air warmer was used in all patients and temperature was maintained at 35°C or higher. At the end of the surgery, patients were given neostigmine (0.05 mg/kg) with glycopyrrolate (5 μg/kg) for reversal of neuromuscular block when TOF count was four and were extubated when the TOF ratio was greater than 0.9 and clinical criteria for motor power recovery such as sustained head lift for 5 seconds, hand grip and tidal volume of 5 ml/kg were satisfied. After tracheal extubation, the patients were admitted to the post-anaesthesia care unit (PACU) and the modified Aldrete score was used to exclude anaesthetic drugs induced residual sedation before taking the study measurements. Patients with altered sensorium and high pain scores despite multimodal analgesia (intravenous paracetamol, opioids and epidural local anaesthetics) were excluded under the post-inclusion-exclusion criteria. Hand grip strength and PEFR were monitored at 15 minutes post-extubation and again at intervals of 15 minutes until one hour, intervals of 30 minutes until four hours, and hourly until six hours post-operatively. Monitoring was terminated earlier if the baseline value was achieved. Each value at any particular time was the highest of three readings taken at intervals of one minute. At every point of time, patients were also assessed for subjective signs of muscle weakness which included eye opening, sustained head lift, ability to cough, ability to swallow and tongue protrusion. After complete recovery of hand grip strength to baseline, patients were discharged from the PACU. All the patients were monitored for postoperative respiratory problems such as hypoxia or aspiration during the study period.

Statistical Package for the Social Sciences (SPSS) version 21 (SPSS Inc., Chicago) was used for Statistical analysis. Data were expressed as mean and standard deviation (SD) for continuous variables (muscle strength and PEFR). Paired t-test was used for comparison of baseline muscle strength and PEFR with the parameters at different time points. Pearson correlation test was applied to assess an association between muscle strength and PEFR. Skewness and kurtosis of data were evaluated for accepting the normality of distribution. Applying the SD of 17 from a pilot study with 95% confidence interval, alpha error of 5%, 5% precision, and dropout percentage of 10%, the sample size was taken as 50.

RESULTS

We screened 58 patients who fulfilled our study criteria, out of which eight were excluded due to high pain scores, to finally include 50 patients. The mean age of our study population was 25.9 years and the male-to-female ratio was 31:19 [Table 1]. All baseline parameters were normally distributed. Muscle strength remained 50 to 60% of baseline at 15 minutes, 75% at 45 minutes, and reached 100% of baseline at 210 minutes after extubation [Table 2]. None of the patients had a return to baseline muscle strength until 60 minutes. Only 2% of the study population returned to baseline muscle strength at 60 minutes [Figure 1]. PEFR remained around 50 to 60 percent of baseline at 15 minutes, 75% of baseline at 60 minutes, and reached 100% of baseline at 180 minutes after extubation [Table 3]. None of the patients had a return to baseline PEFR until 120 minutes. Only 6% of patients gained baseline PEFR at 120 minutes [Figure 1]. None of our study population experienced respiratory complications such as hypoxia. Pearson correlation test established a positive correlation between muscle strength using a handheld dynamometer and PEFR with a correlation coefficient of 0.86, the scatter diagram showing a linear pattern [Figure 2].

DISCUSSION

The muscle strength and PEFR in our study remained lower than the baseline values for a significant duration of 210 and 180 minutes, respectively, in the postoperative period after complete recovery of TOF, with a strong positive correlation though there was no subjective detection of any signs of weakness. The superiority of objective measures of residual muscle weakness over subjective assessment has been established in the literature.[6] Our study has emphasised the importance of a dynamometer as an objective measurement for residual muscular weakness. Hooda *et al*. have concluded the superiority of objective measurements of muscle strength over subjective assessment in predicting postoperative residual paralysis.[7]

In a study by Wardhana *et al*., quantitative TOF monitoring based reversal was found to be superior to reversal without monitoring with respect to residual

Table 1: Demographic data

Parameter	Value (mean±Standard deviation)
Age (years)	25.9±7.9
Gender (male/female)	31/19
BMI (kg/m^2)	23.6±4.6
Duration of anaesthesia (min)	240±55

BMI=Body mass index

Table 2: Comparison of muscle strength

Time	Muscle strength (kg) (mean±Standard deviation	Percentage of baseline	*P*
Baseline	23.46±13.43	100	
15 min	13.43±5.6	57.2	0.00
30 min	16.23±6.4	69.2	0.00
45 min	17.53±6.3	74.7	0.00
60 min	19.1±6.4	81.4	0.00
90 min	19.76±5.8	84.2	0.00
120 min	21.27±6.2	90.6	0.001
150 min	22.45±6.7	95.6	0.037
180 min	22.9±5.65	97.6	0.397
210 min	23.8±6.5	101.4	0.926
240 min	24.2±6.5	103.1	0.9
300 min	24±6.6	102.3	0.91

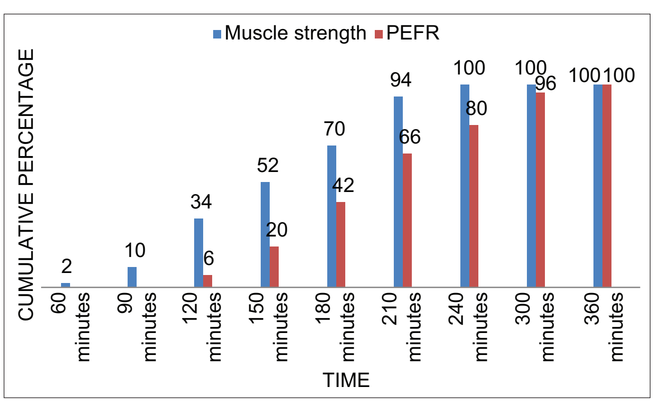

Figure 1: Comparison of Percentage of Patients Who Attained Baseline Muscle Strength And Peak expiratory flow rate (PEFR) With Time

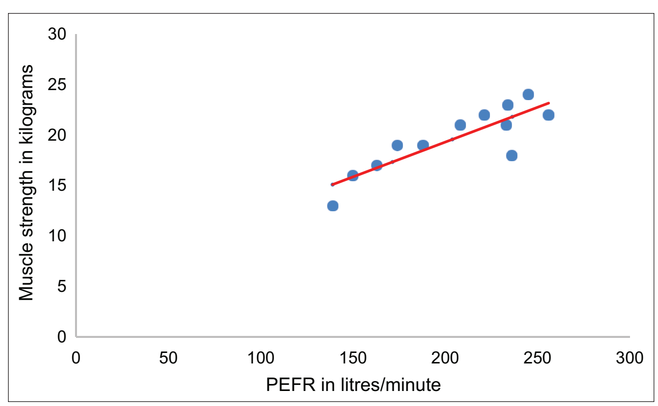

Figure 2: Scatter Diagram For Correlation Of Muscle Strength With PEFR

Table 3: Comparison of Peak expiratory flow rate (PEFR) with time

Time	PEFR (l/min) (mean±standard deviation)	Percentage of baseline	*P*
Baseline	336.73±60.532	100	
15 min	199.68±40.988	59.3	0.00
30 min	216.18±44.600	64.2	0.00
45 min	234.02±46.428	69.5	0.00
60 min	250.86±49.849	74.5	0.00
90 min	270.05±53.111	80.2	0.00
120 min	299±52.944	88.8	0.00
150 min	318.2±63.194	94.5	0.00
180 min	334.37±58.360	99.3	0.003
210 min	353.56±55.610	105	0.043
240 min	340±49.646	101	0.07
300 min	367.03±91	109	0.4

weakness; however, there was residual weakness in one of the cases where TOF was used for monitoring.[8] Debaene *et al*., found that neither clinical tests such as head lift or tongue depressor test nor visual estimation of TOF or double burst stimulation could detect residual paralysis accurately.[9]

It was noted in our study that the handgrip strength remained below the baseline values even after the complete recovery of the TOF ratio. A similar observation was made in a study by Kopman AF *et al*. where the hand grip strength was only 83% of baseline at a TOF ratio of 0.9.[10] In a study by Capron *et al*., a TOF ratio of 0.9 and 1 had a negative predictive value for residual muscle paralysis of only 40% and 77%, respectively, implying that residual muscle paralysis cannot be excluded even after the TOF ratio reaches unity.[11] The results of a study by Goyal *et al*. showed an equal incidence of post operative complications such as the need for supplemental oxygen with or without the use of TOF monitoring for extubation, pointing towards the possibility of residual weakness even with TOF reaching 0.9.[12] Pei *et al*. found a correlation coefficient of 0.88 between the TOF ratio and hand grip strength and concluded that this could be used as an additional measure of postoperative residual weakness.[13] However, this study did not assess hand grip strength after the TOF ratio had returned to one which was the main objective of our study. Our study has proven hand grip strength to be more sensitive compared to TOF in detecting residual muscle weakness. Though minor residual muscle weakness may not have a significant clinical effect in many patients, it does cause some degree of discomfort such as diplopia, generalised weakness, and inability to sit up which can be avoided using a simple measurement with a dynamometer and intervening with an extra dose of neuromuscular block reversal agents. Assessment of muscle strength using a dynamometer may help plan interventions to support respiration and thereby prevent postoperative respiratory complications, especially in the high-risk population.

Dynamometer-based hand grip strength as a measure of muscle strength has certain advantages over TOF monitoring. Nerve stimulation for TOF monitoring is associated with discomfort and is not well suited for awake patients in the postoperative ward. In a study by Nemes *et al*., pain scores were assessed during neuromuscular monitoring in awake volunteers and the scores were five on a scale of zero to ten for currents ranging from 20 mA to 50 mA.[14] Dynamometer use is not associated with any discomfort and can be easily used by patients who are awake. It is less cumbersome and more economical compared with the TOF-Watch. All our study population was able to perform the test after a simple demonstration and none of them complained of any discomfort while using the dynamometer. However, hand grip strength assessment is associated with certain limitations. It requires a completely awake patient who can obey commands. It may be difficult to use the instrument in children and the elderly with poor cognition. The effect of non-modifiable factors such as gender on grip strength has been established in a study by Amin *et al*.;[15] however, this could not have affected our results as all our parameters were compared with baseline parameters of the same patient to avoid confounding.

In our study, PEFR remained below baseline for 180 minutes in the post-operative period though the TOF ratio returned to unity at extubation which correlated with muscle weakness measured using a dynamometer thereby establishing the impact of residual muscle weakness on respiratory function. In a study conducted by Fu *et al*., it was concluded that the pulmonary function measured as forced vital capacity and peak expiratory flow did not return to baseline even after the return of TOF ratio to 0.9.[16] These findings are similar to our study results concerning PEFR. We have chosen PEFR as a measure of respiratory function as it is less cumbersome compared to spirometry.

None of our study population developed respiratory complications or needed respiratory intervention. This can be explained by the fact that patients with pre-existing respiratory compromise were excluded in our study and only ASA grade I and II patients were included. In a study conducted by Eikermann *et al*. on healthy volunteers, it was concluded that residual muscle weakness even to a degree insufficient to evoke respiratory symptoms can markedly increase the risk of susceptible patients to develop severe pulmonary complications such as aspiration.[5] Murphy *et al*. concluded that elderly patients experienced a greater incidence of postoperative residual muscle weakness-related complications compared to the younger population.[17]

The limitation of this study is that high-risk patients with pre-existing respiratory illness or neuromuscular weakness were not included in it. The residual muscle weakness and low PEFR may cause significant clinical impact in such patients unlike our study population which did not show any clinical signs of respiratory compromise.

In the future, studies to evaluate residual muscle weakness measured using an objective forced dynamometer in patients with pre-existing respiratory compromise and correlating with its impact on postoperative respiratory compromise can contribute to decreasing postoperative respiratory complications. Assessment of muscle strength using a dynamometer may help plan interventions to support respiration and thereby prevent postoperative respiratory complications, especially in the high-risk population. In the present era of enhanced recovery after surgery (ERAS), regular application of a dynamometer to assess muscle strength can become an important tool to plan patient discharge.

CONCLUSION

A significant reduction in the postoperative muscle strength can be detected using an objective forced dynamometer to measure hand grip strength even when TOF has returned to unity and even when there are no clinical signs of muscle weakness. Objective assessment of muscle grip strength using a forced dynamometer has the potential to be a new metric to monitor post-operative muscle weakness. The residual muscle weakness is significant enough to affect the PEFR in the postoperative period.

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Conflicts of interest
There are no conflicts of interest.

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