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Original Article

Comparative Study on the Effect of Long-term Mechanical Ventilation on Diaphragmatic Function in Polytrauma Patients

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Abstract

Objective: Ventilatory support is an essential lifesaving therapy but prolonged mechanical ventilation promotes diaphragmatic dysfunction both structurally and functionally. This adverse effect of prolonged mechanical ventilation on diaphragm is termed as ventilator-induced diaphragmatic dysfunction. Hence, ventilator-induced diaphragmatic dysfunction increases weaning time and also has impact on weaning outcomes, that is, hospital mortality and long-term associated morbidity. This study aims to study the effect of long-term mechanical ventilation on diaphragm function, to study the advantage of early weaning off decision resulting in improved patient's outcome, and to conclude the difficulty in assessing left hemidiaphragm when compared to the right hemidiaphragm.

Methods: Polytrauma in-patients in the Department of Surgery, MGMMC, Indore, on mechanical ventilation. These patients were assessed for diaphragmatic thickness and excursion through ultrasonography.

Results: A total of 100 patients were included with the study period of 1 year. Out of these, 36 patients were discharged and 64 died due to mechanical ventilation for longer duration.

Conclusion: Though ventilator support is lifesaving, it should be used precautionarily and intermittent ventilator support is much prognostically better in terms of outcome when compared to controlled ventilation.

Key words: Diaphragmatic thickness, Polytrauma, Thickness fraction, Ultrasonography, Ventilator-induced diaphragmatic dysfunction

INTRODUCTION

Diaphragm is a dome-shaped fibromuscular sheet. It acts as the main muscle involved in respiration. Ventilatory support is an essential lifesaving therapy used clinically to sustain gaseous exchange and reduce respiratory distress in patients who are incapable of maintaining sufficient alveolar ventilation due to various reasons such as neuromuscular disorders or polytrauma. Prolonged mechanical ventilation promotes diaphragmatic dysfunction both structurally and functionally. This adverse effect of prolonged mechanical ventilation on diaphragm is termed as ventilator-induced diaphragmatic dysfunction. Hence, decision of weaning from ventilation is important in the care of ventilator-dependent patients. Ventilator-induced diaphragmatic dysfunction increases weaning time and also has impact on weaning outcomes, that is, hospital mortality and long-term associated morbidity.

Assessment of this ventilator-induced diaphragmatic dysfunction is quite difficult. Fluoroscopy, ultrasonography, magnetic resonance imaging, and phrenic nerve stimulation are some of the various modalities used for assessment. Ultrasonography being the safest, easy to perform, and with least radiation exposure is the easiest modality that can be used for assessing dysfunction both morphologically and functionally. Two parameters mainly used to assess diaphragmatic function are diaphragmatic excursion and thickness fraction (TF) of diaphragmatic muscle TF.

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Here, in this study, we try to assess the diaphragmatic dysfunction in polytrauma patients who needed prolonged mechanical ventilation. This dysfunction is assessed ultrasonographically on the basis of TF of the diaphragmatic muscle in polytrauma patients.

MATERIALS AND METHODS

One hundred cases with polytrauma enrolled in the Department of Surgery, Mahatma Gandhi Memorial Medical College, Indore. The ages of the patients were decided to be 18–60 years. Polytrauma patients with requirement of mechanical ventilation at the time of admission were selected. Patients were randomly divided into experimental and control groups using a randomized number table. All patients' attendants gave written informed consent to participate in the study. This prospective clinical study was approved by the MPMSU Review Board and the attendants of all the patients were provided informed consent. The management protocol was designed for the clinical trial.

Inclusion Criteria

The following criteria were included in the study:

- Patients of age between 18 and 60years
- Relatives who give written informed consent
- Polytrauma patients requiring mechanical ventilation at the time of admission.

Exclusion Criteria

The following criteria were excluded from the study:

- Relatives not willing to give written consent
- Patients with known respiratory or other neuromuscular causes leading to diaphragmatic dysfunction
- Age <18 years and >60 years.

Patients were in-patients receiving invasive controlled mechanical ventilation. Before including the patients for the study, brief history was taken to rule out respiratory disease or any other neuromuscular disease leading to diaphragmatic dysfunction. The experimental group (50 patients with 7 males and 13 females) was evaluated sonographically for diaphragmatic thickness at inspiration and expiration and weaning off was delayed, whereas the control group (50 patients with 5 males and 15 females) was evaluated for inspiratory and expiratory diaphragm thickness and early weaning off was planned.

All the patients on controlled mechanical ventilation were evaluated sonographically for the right and left hemidiaphragmatic thickness at inspiration and expiration at the time of admission, after 2 days, 7 days, and 15 days of mechanical ventilation. The hemidiaphragmatic thickness at inspiration and expiration was measured using a 6–13 MHz ultrasound transducer in the zone of apposition.

The right and left hemidiaphragmatic TF was calculated as a percentage using the formula:

TF = thickness at end inspiration – thickness at end expiration

Thickness at end expiration

Gradual diaphragmatic TF was noted for all the patients of both the right and left hemidiaphragms at the time of admission, after 2 days, 7 days, and after 15 days of admission. Day of successful weaning was noted. Outcome of the patients on the basis of death or discharge was noted from the hospital records.

The diaphragmatic TF was compared to prolonged weaning time and outcome. An independent radiologist blind to the patients assessed the diaphragmatic thickness at end of inspiration and expiration at all four durations under study. Continuous variables, such as TF, were described as mean and SD. Comparisons were made. Chi-square or Fisher's exact test and the Student's test were used for categorical and quantitative variables. All analyses were performed with the SPSS software version 17 (SPSS Inc., Chicago, IL). $P < 0.05$ was considered statistically significant.

RESULTS

Table 1 shows the comparison of mean TF of the right hemidiaphragm at the time of admission of two groups of polytrauma patients. For this variable, the difference between the mean values of two groups was found to be statistically significant ($P < 0.05$), mean of Group 1 = 57.0722 ± 1.30364 mm and Group 2 = 55.0372 ± 5.20697 mm.

Table 2 shows the comparison of mean TF of the left hemidiaphragm at the time of admission of two groups of polytrauma patients. For this variable, the difference between the mean values of two groups was found to be statistically not significant ($P > 0.05$), mean of Group 1

Table 1: Comparison of TF of the right hemidiaphragm of two groups at the time of admission

Group	*n*	Mean	SD	*P*-value	Result
TF of the right hemidiaphragm at admission					
1	50	57.0722	1.30364	0.02865	SIG
2	50	55.0372	5.20697		

TF: Thickness fraction

= 56.251 ± 1.14148 mm and Group 2 = 57.0722 ± 1.30364 mm.

Table 3 shows the comparison of mean TF of the right hemidiaphragm after 15 days of admission of two groups of polytrauma patients. For this variable, the difference between the mean values of two groups was found to be statistically insignificant ($P < 0.05$), mean of Group 1 = 20.5362 ± 1.2008 mm and Group 2 = 35.593 ± 1.75221 mm.

Table 4 shows the comparison of mean TF of the left hemidiaphragm after 15 days of admission of two groups of polytrauma patients. For this variable, the difference between the mean values of two groups was found to be statistically not significant ($P > 0.05$), mean of Group 1 = 19.9642 ± 1.25181 mm and Group 2 = 34.8592 ± 1.76513 mm

Table 5 shows the comparison of outcome of two groups. For the variable, that is, outcome decided on the basis of death or discharge, in Group 1 (patients on prolonged controlled mechanical ventilation), out of 50, 46 deaths, 92%, were reported and 4 discharges, 8%, were reported. In Group 2, out of 50, 18 deaths were reported and 32 patients were discharged.

DISCUSSION

In the recent past, many studies have been done regarding the prolonged controlle d mechanical ventilator-induced diaphragmatic dysfunction, its diagnostic assessment using ultrasonography, its effect on prolonged weaning time, and few management strategies. These studies are reportedly conducted on both animal and human models. Diaphragmatic dysfunction is often underdiagnosed and is among the risk factors for failed weaning. The studies conducted are determined to study the prevalence of diaphragmatic dysfunction diagnosed by B-mode ultrasonography and to determine whether prolonged weaning subjects with diaphragmatic dysfunction have increased duration of mechanical ventilation compared with those without diaphragmatic dysfunction.

In our institutional study, we found out that the incidence of polytrauma patients reporting in Indore region is 30%. There were 17,542 patients in 1 year of period of study out of 40,593 patients visiting surgery emergency room. This decreased number patients could be due to distribution of patients to various health-care centers in this region of Central India and the impact of coronavirus disease 2019 pandemic and its lockdown status.

In this study, there were 50 patients each in the group of (1) polytrauma patients with late weaning time and (2) polytrauma patients with early weaning time.

We found significant differences in the sex ratio of polytrauma patients. Overall, male patients are more prone to polytrauma when compared to females. Polytrauma is more common in 25–40 years of age group followed by 18–25 years and 40–60 years. The male-to-female ratio was 6.14:1.

This is consistent with the study conducted by Shahram Bolandparvaz *et al.* where a total of 47,295 trauma patients were studied, out of the total 75% of the trauma patients were of the 15–44 years of age group and male-to-female ratio was 2.7:1.0.

Table 2: Comparison of TF of the left hemidiaphragm of two groups at the time of admission

Group	*n*	Mean	SD	*P*-value	Result
TF of the left hemidiaphragm at admission					
1	50	56.251	1.14148	0.37663	Non SIG
2	50	57.0722	1.30364		

TF: Thickness fraction

Table 3: Comparison of TF of the right hemidiaphragm of two groups after 15 days

Group	*n*	Mean	SD	*P*-value	Result
TF of the right hemidiaphragm after 2 days of admission					
1	50	20.5362	1.2008	0.05492	IN SIG
2	50	35.593	1.75221		

TF: Thickness fraction

Table 4: Comparison of TF of the left hemidiaphragm of two groups after 15 days

Group	*n*	Mean	SD	*P*-value	Result
TF of the right hemidiaphragm after 2 days of admission					
1	50	19.9642	1.25181	0.06177	Non SIG
2	50	34.8592	1.76513		

TF: Thickness fraction

Table 5: Comparison of outcome (death/discharge) in two study groups

Variable	Group	Number	Death	Discharge	Total
Outcome	1	50	46	4	
			92%	8%	100%
	2	50	18	32	
			36%	64%	100%
Total		100	64	36	

Further, in our study, the comparison of diaphragmatic TF of the right hemidiaphragm of both study groups at the time of admission is statistically significant, that is, $P < 0.05$. This suggests that TF at the time of admission for both the groups is almost comparable at the time of admission.

Next, the comparison of diaphragmatic TF of the left hemidiaphragam of both study groups at the time of admission is statistically significant, that is, $P < 0.05$. This suggests that the TF at the time of admission for both the groups is almost comparable at the time of admission.

The comparison of diaphragmatic TF of the right hemidiaphragm of both study groups after 2 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 2 days of ventilator support has decreased significantly.

The comparison of diaphragmatic TF of the left hemidiaphragm of both study groups after 2 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 2 days of ventilator support has decreased significantly.

The comparison of diaphragmatic TF of the right hemidiaphragm of both study groups after 7 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 7 days of ventilator support has decreased significantly, but more for Group 1, that is, patients on >5 days of controlled mechanical ventilation than Group 2, that is, patients in whom weaning off was successful around day 2.

The comparison of diaphragmatic TF of the left hemidiaphragm of both study groups after 7 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 7 days of ventilator support has decreased significantly. More fall in values of TF is noted in Group 1 in which patients were kept of controlled mechanical ventilation for at least >5 days than in Group 2 where patients were weaned off successfully at around day 2.

The comparison of diaphragmatic TF of the right hemidiaphragm of both study groups after 15 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 15 days of ventilator support has decreased significantly. More fall in TF is noted in Group 1 than Group 2.

The comparison of diaphragmatic TF of the left hemidiaphragm of both study groups after 15 days of controlled mechanical ventilation is statistically insignificant, that is, $P > 0.05$. This suggests that the TF after 15 days of ventilator support has decreased significantly. This suggests that Group 1 patients have a significant decrease in TF when compared to Group 2 patients.

On comparing the final outcome of two study groups, the higher percentage of death, that is, 92% is seen in Group 1 patients those who were kept on ventilator for >5 days. The percentage of patients getting discharged is greater, that is, 64% in Group 2 patients who were kept on ventilator support for almost 2 days.

Various studies conducted with respect to this topic are mentioned as follows:

Ventilator-induced diaphragmatic dysfunction was shown to occur in rats,[1-3] rabbits,[4] piglets,[5] and baboons.[6] In rats, the ventilator-induced diaphragmatic dysfunction is already present within 12 h of controlled mechanical ventilation resulting in reduction of specific force by 20%.[2] This dysfunction increases with increasing time spent on the ventilator. This was further affirmed by larger reductions (25–50%) noted in rabbits after 1 day[4] and piglets after 5 days[5] and baboons after 11 days.[6]

In another study, Zhihualu *et al.* (2016) studied the effect of diaphragmatic dysfunction on prolonging weaning. They included 41 subjects (24 males; 62.2 ± 15.9 years old). Of these, the prevalence of ultrasonographic diaphragmatic dysfunction (defined as diaphragmatic TF <20%) was 34.1%. Subjects with diaphragmatic dysfunction had longer ventilation time after inclusion (293.4 ± 194.8 vs. 101.3 h, $P = 0.02$) and ICU stay (29.2 ± 11.4 vs. 22.4 ± 7.7 d, $P = 0.03$) than subjects without diaphragmatic dysfunction.

Supinski and Callahan (2013) reported that patients with greater levels of diaphragmatic dysfunction have a much poorer prognosis in terms of more prolonged ventilation as well as higher mortality.

A study by Kim *et al.* (2011) in subjects who received mechanical ventilation >48 h reported weaning variable.[7]

Goligher *et al.* (2017) showed that ultrasound assessment of the right hemidiaphragm thickness was feasible and highly reproducible in ventilated patients.[8]

Diaphragmatic thickening and TF are a more accurate index than excursion in reflecting the diaphragm contractility according to the study by Umbrello *et al.* (2015).[9]

Zambon *et al*. (2016) demonstrated diaphragmatic atrophy rate in 40 intubated patients.[10] They found that daily reductions in thickness were 7.5% during controlled mechanical ventilation, 5.3% during high-pressure support ventilation, and 1.5% during low-pressure support ventilation.

CONCLUSION

In our study, we found out that the patients on controlled mechanical ventilation for >2 days are bound to have adverse effect on the diaphragm best assessed by the ultrasonographic measurement of diaphragmatic thickness at inspiration and expiration and TF. Furthermore, this ventilator-induced diaphragmatic dysfunction results in higher mortality and failed weaning off trials, thus prolonging ventilatory time and ICU stay of the patients.

Hence, we conclude by quoting that though ventilator support is lifesaving, it should be used precautionarily and intermittent ventilator support is much prognostically better in terms of outcome when compared to controlled ventilation. These findings should be an eye opener for practicing clinicians. They point to a need for greater awareness of the high prevalence of diaphragmatic dysfunction in patients with prolonged weaning. However, these preliminary results require confirmation in a larger prospective multicenter study.

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