Role of lung ultrasound in weaning from mechanical ventilation in postoperative neurosurgical ICU patients

Amin Mohammed Alansary^{1*}, Karim Youssef Hakim²

Lecturer^{1*}, Assistant Professor², Department of Anaesthesia and Intensive Care,
Ain-shams University, Egypt.

Background: Prolonged postoperative mechanical ventilation after intracranial surgery is associated with significant morbidity and mortality. Many traditional tools could help in prediction of weaning success as blood gas analysis (ABG), chest radiography, ventilator parameters and rapid shallow breathing index (RSBI). These tools have a significantly higher failure rate. The aim of this study was to describe the role of transthoracic lung ultrasound (LUS) as a clinical tool in predicting weaning of postoperative mechanically ventilated patients after intracranial surgery.

Patients and method: 130 patients who were scheduled for weaning from mechanical ventilation (MV), were prospectively enrolled in the study, age 20-70 years, of either sex. They were randomly allocated into two groups- group C (n=65) were examined by traditional methods chest X- ray, ABG, ventilator parameters and RSBI, and group US (n=65) were examined by traditional methods plus LUS. Diaphragm thickness (DT) and fraction (DTF), lung aeration and extravascular lung water (EVLW) were assessed by LUS. A failure of weaning was considered when reintubation was needed within 48 hours.

Results: The success rate in group US (LUS+ traditional methods) was 84.6% compared to 66.2% in group C (traditional methods only). The value of diaphragm thickness and fraction were significantly more in the weaning success group than in failure group. B-lines detected by LUS in success and failure groups were ≤ 2 , 3 respectively with no significant difference.

Conclusion: Lung ultrasound as an added tool could decrease failure rate of weaning in postoperative mechanically ventilated patients after intracranial surgery.

Keywords: Ultrasound; weaning; mechanically ventilated patients; intracranial surgery

Introduction

Postoperative mechanical ventilation (MV) after intracranial surgery is indicated in prolonged surgery >8hrs, haemodynamic instability, massive blood loss, brainstem handling, residual tumor, intraoperative acute brain bulge and preoperative lower cranial nerve palsy.¹

Simple indices as respiratory rate (RR), minute ventilation (VE), maximum inspiratory pressure

(PImax), and integrative indices as RSBI, i.e., (RR/TV), airway occlusion pressure, CROP index [compliance $\times$ MIP $\times$ PaO₂/PAO₂]/f, and simplified weaning index (SWI) have been used to assess patients for weaning.^{2,3}

LUS helps urgent diagnoses with immediate therapeutic decisions.^{4,5} Diaphragmatic dysfunction is accompanied with weaning failure.⁶ LUS is used to assess diaphragmatic dysfunction.⁷

The aim of this study was to describe the role of LUS as a clinical tool in weaning of post-operative mechanically ventilated patients after intracranial surgery.

Patient and methods

This prospective, randomized controlled study was approved by the research ethical committee, Faculty of Medicine, Ain Shams University (FMASU R26/2019). It is registered in the clinical

*Correspondence: Amin Mohammed Alansary

E mail: aminalansary@yahoo.com

<https://orcid.org/0000-0002-6615-186x>

Received: 17/07/2019

Accepted: 24/12/2019

DOI: <http://doi.org/10.4038/slja.v28i1.8481>

trial.gov (NCT 03921112) and informed consent from patient's guardians has been obtained. 130 patients who failed to be extubated in the operating room and needing post-operative MV after intracranial surgery, aged 20-70 years, of either sex and ready for weaning were enrolled in the study.

Exclusion criteria were patients with traumatic cervical cord injury, neuromuscular disease, pneumothorax, pleural effusion, unconscious patients, high inotropic support, fever $> 38^{\circ}\text{C}$ and tracheostomized patients.

All patients met these criteria: $\text{FiO}_2 < 0.5$, $\text{PEEP} \leq 5\text{cmH}_2\text{O}$, pressure support $\leq 10\text{cmH}_2\text{O}$, P/F ratio ($\text{PaO}_2/\text{FiO}_2 > 200$), $\text{RR} < 30$ b/m, $\text{pH} > 7.25$, no fever, fully conscious, and cardiovascular stability with no need for vasopressors. Patients were removed from MV and a spontaneous breathing trial (SBT) was started up to 2hrs using humidified oxygen delivered through a T-piece.

SBT failure was considered in: patient exhaustion, anxiety, diaphoresis, $\text{RR} > 35$ breaths/m, paradoxical breathing and use of accessory respiratory muscles, disturbed conscious level (central causes), unstable haemodynamics, and oxygen saturation $< 90\%$. Weaning failure was considered when patients were unable to maintain spontaneous breathing for at least 48hrs, without any ventilatory support.

Patients were randomly allocated to two groups:

Group (c) (n=65): Patients were evaluated by:

1: Chest x-ray

*No radiological signs of pleural effusion, pneumonia or lung collapse.

*Radiological score for pulmonary oedema.⁸

Radiological score parameters and values:

Parameter	Value
Redistribution of lung vessels	
No	0
Yes	1
Width of the cardiac silhouette $> 60\%$	
No	0
Yes	1
Peri bronchial cuffing	
No	0
Yes	1
New pleural effusion	

Parameter	Value
No	0
Unilateral	1
Bilateral	2
Kerley's A, B, or C lines	
None	0
Uncertain	1
Definite	2
Lung opacity	
None	0
Lung opacity	1
Ground-glass opacity	2
"Bat wing" pattern	3

Normal x-ray 0-1, lung congestion 2-4, pulmonary oedema (mild 5-6, moderate 7-8, severe 9-10).⁸

2: Serial ABGs (before switching to SBT).

PO_2 , SPO_2

3: Ventilator parameters (before switching to SBT).

FiO_2 , PEEP, pressure support, P/F ratio, respiratory rate.

4: RSBI. (1min after switching to SBT).

Group (US) (n=65): (after switching to SBT).

traditional parameters + LUS for assessment of diaphragm thickness (DT), diaphragm thickness fraction (DTF), lung aeration and extravascular lung water (EVLW).

Assessment of DT and DTF: Each hemi-diaphragm was examined by ultrasound subcostal views (B-mode) display with a 10-MHz linear transducer (TOSHIBA, Model USAP-770A, JAPAN).

Patients were in supine position and elevated (45°). The diaphragm could be seen by placing the probe vertical to the chest wall, in the 8th to 10th intercostal space, between the anterior and mid-axillary lines. The diaphragm was visualized as three layers, two outer parallel echoic lines (pleura, peritoneal membranes) and in between a hypoechoic structure (the muscle proper). The patient was asked to take deep inspiration to measure the (DT) at total lung capacity (TLC) and then to do full expiration to measure (DT) at residual volume (RV).

DT was obtained as a vertical line from the middle of the pleural line to the middle of the peritoneal

line. DTF was calculated: $(DT) \text{ at TLC} - (DT) \text{ at RV} / (DT) \text{ at RV} \times 100$. Establishment of MV was done in patients with severe diaphragmatic dysfunction ($DTF < 26\%$) or paradoxical diaphragmatic movement visualized by US.

Figure 1: DT at TLC (1), DT at RV (2)

Assessment of EVLW:LUS was performed with patient in the supine position using 3.5 MHz convex transducer. Sonographic evaluation of EVLW was based on detecting hyperechoic vertical lines which arise from the pleura to the bottom of the image and move with respiration (B-lines). The visualization of ≥ 3 B-lines in a longitudinal plane between two ribs indicated pulmonary oedema.

Sample size calculation

The sample size was calculated using STATA program, setting α error at 5% and power at 80%. Result from a pilot study showed that the success rate of weaning in group A (traditional methods) was 83% compared to 98% in group B (US group).

Based on this the needed sample size was 65 cases per group, taking in to account a 10% dropout rate.

Statistical methods

The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) software version 18.0, IBM Corp., Chicago, USA, 2009.

Descriptive statistics were done for quantitative data as minimum and maximum of the range as well as mean $\pm$ SD (standard deviation) for quantitative normally distributed data, while it was done for qualitative data as numbers and percentages.

Inferential analyses were done for quantitative variables using Shapiro-Wilk test for normality testing and independent t-test in cases of two independent groups with normally distributed data. In qualitative data, inferential analyses for independent variables were done using Chi square test for differences between proportions and Fisher's Exact test for variables with small expected numbers. The level of significance was taken at P value < 0.050 as significant, otherwise as non-significant.

Results

A total of 200 patients were chosen to record success of weaning from MV. Seventy patients were excluded because they did not meet the inclusion criteria. 130 patients matched the study criteria and were randomly allocated into two groups ($n = 65$ per each). (Figure 2).

The demographic data including age, sex, type and duration of surgery showed no significant difference between the two groups. As regards PO_2 , FiO_2 , P/F ratio, SpO_2 , respiratory rate, (RSBI), radiological score ≤ 2 in both groups (no pulmonary oedema), PEEP and pressure support there was no significant difference between the two groups. ($P < 0.05$). (Table 1)

Figure 2. CONSORT patient flow chart. **Table 1:** Demographic data and basic respiratory conditions

		US group N=65	Control group N=65	P value
Age (years)		41.3±7.4	42.5±7.9	##0.378
Sex	Male	44 (67.7%)	41 (63.1%)	#0.580
	Female	21 (32.3%)	24 (36.9%)	
Surgery type	Tumor removal	29 (44.6%)	27 (41.5%)	#0.755
	Aneurysm clipping	24 (36.9%)	28 (43.1%)	
	Haematoma evacuation	12 (18.5%)	10 (15.4%)	
Duration of surgery (h)		6.7±2.5	6.1±2.0	##0.146
PO ₂ (partial pressure of oxygen)		145.6±22.4	143.7±22.3	##0.627
FiO ₂ (fraction of inspired oxygen)		0.4±0.0	0.4±0.0	##0.415
P/F ratio		292.6±44.3	287.9±39.2	##0.518
SpO ₂ (peripheral oxygen saturation)		98.2±1.7	98.0±1.9	##0.507
Respiratory rate (Breaths/min)		22.5±1.8	22.3±2.0	##0.616
Rapid shallow breathing index		44.1±5.1	44.8±4.6	##0.400
Radiological score	0	17 (26.2%)	16 (24.6%)	#0.643
	1	21 (32.3%)	26 (40.0%)	
	2	27 (41.5%)	23 (35.4%)	
Positive End Expiratory Pressure =5 mmHg		65 (100%)	65 (100%)	--
Pressure Support =10 mmHg		65 (100%)	65 (100%)	--

Data are expressed as mean ± SD or number of patients. ##Independent t-test. #Chi square test. Weaning success was significantly higher in the (US) group (84.6% versus 66.2% in (C) group, P = 0.015) while weaning failure was significantly

higher in (C) group (33.8% versus 15.4% in (US) group. (Table 2) Duration of MV and length of stay in ICU in group (C) were significantly higher than in (US) group.

Table 2: Comparison between the two groups in terms of success or failure of weaning:

Outcomes		Group (US)	Group (C)	P value
Weaning	Success	55 (84.6%)	43 (66.2%)	#0.015*
	Failure	10 (15.4%)	22 (33.8%)	
Duration of MV (hours)		77.7±22.9	88.4±25.6	##0.013*
Length of ICU stay (days)		6.8±2.0	7.8±2.3	##0.010*

Data are expressed as mean ± SD or number of patients. ##Independent t-test. #Chi square test. * P value <0.05 is considered significant.

Right and left DT, DTFs were significantly higher in cases with successful weaning.

B-lines ≤2 in 89.1% in weaning successful group and in 30% in weaning failure group, B lines = 3 in 10.9% of successful group and 7 (70%) with no significance. No evidence of B- pattern (multiple B lines) was determined in both groups. (Table 3)

Table3: Comparison of the ultrasound findings between the success and failure group

Parameters		Weaning success (n = 55)	Weaning Failure (n = 10)	P value
Right DT at TLC (mm)		4.4±1.5	2.6±0.7	##<0.001*
Right DT at RV (mm)		2.5±0.6	1.9±0.5	##0.004*
Left DT at TLC (mm)		4.5±1.6	2.6±0.6	##<0.001*
Left DT at RV (mm)		2.6±0.6	2.0±0.4	##<0.001*
Right DTF (%)		70.7±20.1	33.3±3.2	##0.008*
Left DTF (%)		72.3±25.1	32.9±4.7	##<0.001*
B-lines	≤2	49 (89.1%)	3 (30.0%)	#0.135
	3	6 (10.9%)	7 (70.0%)	

Data are expressed as mean ± SD or number of patients. ##Independent t-test. # Fisher's Exact test.

Discussion

Prolonged MV is associated with many complications as ventilator associated pneumonia (VAP), ventilator induced lung injury (VILI) and ventilator induced diaphragmatic dysfunction. Recently, ultrasound has been used to assess

diaphragm dysfunction postoperatively.¹¹ This study was designed to evaluate the possibility of using ultrasound as an added tool in the weaning of postoperative mechanically ventilated patients in decreasing failure rate of weaning. LUS plus traditional tools in predicting weaning success aim to reach a very minimal rate of failure of weaning in post-operative mechanically ventilated patient.¹²

This study showed that using LUS plus traditional tools provided better success rate of weaning from MV (84.6%), this is due to the ability of US to assess the diaphragmatic dysfunction with further therapeutic interventions before completing the process of weaning.

Assessment of diaphragmatic movement in the form of diaphragmatic thickness by ultrasound proved feasible and useful in evaluating diaphragmatic dysfunction. It had advantage over traditional fluoroscopy, was noninvasive, with no exposure to ionizing radiation, with bedside availability.¹³

Gerscovich et al¹⁴ showed in their study that diaphragm ultrasonography could be a useful tool in assessing diaphragmatic motion.

In agreement with our results Ferrari et al¹⁵ found that diaphragmatic movement by measuring DTF by US as a new index of weaning from MV in comparison to RSBI. A significant difference between DTF in patients who succeeded SBT in comparison to patients who failed was shown. This study showed that the detection of DTF by lung ultrasound was a good index in predicting weaning from mechanical ventilation. In the current study a $DTF \geq 40\%$ was associated with weaning success. These findings agree with the results of studies from Ferrari et al¹⁵, Dube et al¹⁶ and DiNino et al¹³ which showed that DTFs of more than 36%, 29% and 30% respectively were associated with weaning success.

Another study done by Pirompanich and Romsaiyut concluded that $DTF \geq 26\%$ combined with RSBI ≤ 105 increased the rate of successful weaning compared to RSBI alone.¹⁷ Our study found that DTF of more than 40% was associated with successful weaning. Establishment of MV and

further therapeutic interventions were done in patients with $DTF_s \leq 25\%$.

In another study Theerawit et al found that there was a relation between lower DTF_s and reintubation after weaning failure.¹⁸

LUS has the ability to show the absence of lung expansion, alveolar consolidation and abolished lung sliding.¹⁹ Lung aeration loss during SBT in non-dependent lung zones was demonstrated in subjects who failed to wean.²⁰ There were no studies on these ultrasound parameters collectively as a weaning predictor in comparison to traditional parameters. Previous studies were either focusing on every ultrasound parameter alone or using it as a diagnostic tool compared to other traditional or standard tool.

Conclusion

LUS as an added tool in weaning success prediction could decrease failure rate of weaning from mechanical ventilation in postoperative mechanically ventilated patients.

References

1. Mahajan C, Rath GP, Sharma MS et al. Rate and reasons for elective ventilation in patients undergoing intracranial tumor surgery. *J Neuroanaesthesiology and critical care* 2014;**2**:125-130.
<https://doi.org/10.4103/2348-0548.130396>
2. El-Khatib MF, Bou-Khalil P. Clinical review: liberation from mechanical ventilation. *CritCare* 2008; **12**: 221.
<https://doi.org/10.1186/cc6959>
PMid:18710593 PMCID:PMC2575571
3. Epstein SK. Etiology of extubation failure and the predictive value of the rapid shallow breathing index. *Am J Respir Crit Care Med* 1995; **152**: 545-549.
<https://doi.org/10.1164/ajrccm.152.2.7633705>
PMid:7633705
4. Alptekin B, Tran DT, Lisbon A et al. Bedside ultrasonography in the differential diagnosis of pulmonary pathologies in the intensive care unit. *Journal of Clinical Anesthesia* 2006; **18**: 534-536.
<https://doi.org/10.1016/j.jclinane.2006.03.009>
PMid:17126784
5. Lichtenstein DA. Lung ultrasound in the critically ill. *Annals of Intensive Care* 2014; **4**: 1.
<https://doi.org/10.1186/2110-5820-4-1>
PMid:24401163 PMCID:PMC3895677

6. Matamis D, Soilemezi E, Tsgourias M et al. Sonographic evaluation of the diaphragm in critically ill patients. Technique and clinical applications. *Intensive Care Med* 2013; **39**:801-810. <https://doi.org/10.1007/s00134-013-2823-1> PMID:23344830
7. Kim WY, Suh HJ, Hong SB et al. Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation. *Crit Care Med* 2011; **39**: 2627-2630. <https://doi.org/10.1097/CCM.0b013e3182266408> PMID:21705883
8. Shochat M, Shotan A, Trachetengerts V et al. A novel radiological score to assess lung fluid content during evolving acute heart failure in the course of acute myocardial infarction. *Acute Card care* 2011;**13**(2):81-86. <https://doi.org/10.3109/17482941.2011.567279> PMID:21517671
9. MacIntyre NR, Cook DJ, Ely EW et al. Evidence-based guidelines for weaning and discontinuing ventilatory support: a collective task force facilitated by the American College of Chest Physicians; the American Association for Respiratory Care; and the American College of Critical Care Medicine. *Chest* 2001;**120**(6 Suppl):375-95. https://doi.org/10.1378/chest.120.6_suppl.375S PMID:11742959
10. Ely EW, Baker AM, Dunagan DP et al. Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *The New England journal of medicine* 1996;**335**(25):1864-9. <https://doi.org/10.1056/NEJM199612193352502> PMID:8948561
11. Kim SH, Na S, Choi JS et al. An evaluation of diaphragmatic movement by M-mode sonography as a predictor of pulmonary dysfunction after upper abdominal surgery. *AnesthAnalg* 2010;**110**:1349-54. <https://doi.org/10.1213/ANE.0b013e3181d5e4d8> PMID:20418298
12. Tenza-Lozano E, Lamas-Alvarez A, Jaimez-Navarro E et al. Lung and diaphragm ultrasound as predictors of success in weaning from mechanical ventilation. *Crit Ultrasound* 2018; **10**:12. <https://doi.org/10.1186/s13089-018-0094-3> PMID:29911284 PMCid:PMC6004341
13. DiNino E, Gartman EJ, Sethi JM et al. Diaphragm ultrasound as a predictor of successful extubation from mechanical ventilation. *Thorax* 2014; **69**(5):423-427. <https://doi.org/10.1136/thoraxjnl-2013-204111> PMID:24365607
14. Gerscovich EO, Cronan M, McGahan JP et al. Ultrasonographic Evaluation of Diaphragmatic Motion. *J Ultrasound Med*. 2001; **20**:597-604. <https://doi.org/10.7863/jum.2001.20.6.597> PMID:11400933
15. Ferrari G, De Filippi G, Elia F et al. Diaphragm ultrasound as a new index of discontinuation from mechanical ventilation. *Critical ultrasound journal* 2014;**6**:8 <https://doi.org/10.1186/2036-7902-6-8> PMID:24949192 PMCid:PMC4057909
16. Dube BP, Dres M, Mayaux J et al. Ultrasound evaluation of diaphragm function in mechanically ventilated patients: comparison to phrenic stimulation and prognostic implications. *Thorax* 2017;**72**:811-8. <https://doi.org/10.1136/thoraxjnl-2016-209459> PMID:28360224
17. Pirompanich P, Romsaiyut S. Use of diaphragm thickening fraction combined with rapid shallow breathing index for predicting success of weaning from mechanical ventilation in medical patients. *Journal of intensive care* 2018; **6**:2-7. <https://doi.org/10.1186/s40560-018-0277-9> PMID:29435329 PMCid:PMC5797391
18. Theerawit P, Eksombatchai D, Sutherasan Y et al. Diaphragmatic parameters by ultrasonography for predicting weaning outcomes. *BMC Pulmonary Medicine* 2018;**18**:175 <https://doi.org/10.1186/s12890-018-0739-9> PMID:30470204 PMCid:PMC6251135
19. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 2008; **134** (1):117-125. <https://doi.org/10.1378/chest.07-2800> PMID:18403664 PMCid:PMC3734893
20. Antonio AC, Teixeira C, Castro PS et al. Behavior of lung ultrasound findings during spontaneous breathing trial. *Rev Bras Ter Intensiva*. 2017; **29** (3):279-286. <https://doi.org/10.5935/0103-507X.20170038> PMID:28832706 PMCid:PMC5632969