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Original Article

Driving Pressure during Mechanical Ventilation of Acute Respiratory Distress Syndrome

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ABSTRACT

Background: Driving pressure has been identified as a more accurate indicator of mortality risk than low tidal volume (VT) and pulmonary compliance (Ppl). It was also noted that when this pressure surpasses the 18 cm H_2O mark, there is a significant elevation in the relative risk of death. This study aimed to evaluate the effect of driving pressure guided ventilation in acute respiratory distress syndrome (ARDS).

Patients and Methods: The study included 64 subjects selected from the respiratory intensive care unit (RICU) of Al-Azhar University Hospital (Damietta). All participants received management through a protective lung strategy that was informed by driving Pressure. The study outcomes included 1). Determination of weaning categories; 2). Adverse events; 3). Length of ICU stay and duration of mechanical ventilation; 4). Mechanical Ventilation-free days, and 5). Organ/s dysfunction.

Results: The commonest cause of admission was pneumonia (36%), and least percentage was septic shock (1.6%). The median ICU stay was 7 days (4 to 25 days) and weaning success rate was 76.6% with mortality rate of 23.4%. The severity was mainly severe (40.6%) and moderate (31.2%). Driving pressure at day 1 of ≤ 21 had sensitivity of 97.96%, specificity of 80.0% and area under curve (AUC) of 0.952. The driving pressure was significantly increased in cases with failure weaning than the success weaning (24.67 ± 1.05 vs 16.86 ± 1.24, respectively). In addition, it was significantly increased in died than alive patients. There was progressive significant increase of driving pressure from mild to moderate to severe cases. Pneumothorax was recorded among 9.4% and pleural effusion was recorded for 7.8% of patients.

Conclusion: Use of driving pressure guided ventilation in patients with ARDS improves lung compliance, decreases the duration of mechanical ventilation and the length of ICU stay. Driving pressure < 21 can predict mortality.

Keywords: ARDS; Driving Pressure; Mechanical Ventilation.

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INTRODUCTION

Acute respiratory distress syndrome (ARDS) is a frequent disease that affects up to 23% of mechanically ventilated patients over the course of the intensive care unit (ICU) stay [1, 2].

Mechanical ventilation plays a crucial role in managing patients with ARDS, with numerous randomized controlled clinical trials assessing the effectiveness and safety of different mechanical ventilation strategies for ARDS treatment [3].

In the realm of ARDS patient care, the metric of Driving Pressure (DP), delineated as the discrepancy between the end-inspiratory airway pressure (specifically, the plateau pressure (Pplat)) and Positive End-Expiratory Pressure (PEEP), has been elucidated as a more potent prognosticator of mortality relative to the metrics of low Tidal Volume (VT) and Pulmonary Compliance (Ppl),Notably, the mortality risk's relative increment was pronouncedly significant upon surpassing a DP threshold of 18 cm H_2O. It warrants specific mention that the establishment of a DP range from 14 to 18 cmH_2O as a predictive benchmark for outcomes or as a calibration standard for VT adjustment lacks empirical validation and confirmation [4-7].

This study aimed to evaluate the effect of driving pressure guided ventilation in acute respiratory distress syndrome (ARDS).

PATIENTS AND METHODS

This study, designed as a prospective, observational investigation. It is conducted at the respiratory intensive care unit (RICU) of Al-Azhar University Hospital (Damietta) over a span of 24 months, commencing March 2022 and finished in February 2024. It was started after the receipt of approval from the institutional ethics committee. Written informed consent was secured from the patients' relatives prior to participation. They provided with a detailed explanation regarding the objectives of the study, and each patient assigned a unique secret code number to ensure confidentiality.

Inclusion criteria: Throughout the duration of the study, patients admitted to the respiratory ICU and undergoing mechanical ventilation through an endotracheal tube, who met the criteria for ARDS as per the New Global definition, were included. The selection criteria further narrowed down to patients aged 18 years or older exhibiting an ARDS diagnosis.

Exclusion Criteria: The study design specifically excluded pregnant individuals and barotrauma at time of presentation. The presence of organ dysfunction was assessed utilizing the SOFA score.

Patients who satisfied the aforementioned criteria were assigned to a single group, in accordance with the designated ventilator management protocol for ARDS. Sixty-seven patient (67) submitted to driving pressure-guided ventilation in respiratory intensive care unit were included. However, three patients were excluded due to insufficient data. Thus, the actual number of patients were 64.

Baseline ventilations: All participants enrolled in the study received management through a protective lung strategy that was informed by driving Pressure, in alignment with guidelines from the ARDS network. This approach was implemented using the Newport e360 Respiratory Ventilator set to volume assist-control mode. The tidal volume (TV) was maintained between 4 to 8 mL/kg of predicted body weight (PBW). PBW was calculated for males as 50 + (0.91(Height - 152.4)) and for females as 45 + (0.91(Height - 152.4)).

The choice of PEEP was based upon the driving pressure (DP) to keep DP (Pplat- PEEP) range from 14 to 18 cmH_2O. We started with VT 8 ml/kg (IBW) then decreased to keep DP range from 14 to 18 cmH_2O and if this target DP not met until VT 4 ml/kg we increased PEEP gradually by 2 cmH_2O increments to achieve target DP.

The study outcomes included 1). Determination of weaning categories (simple, difficult and prolonged); 2). Adverse events as barotrauma (by CXR and/or lung ultrasound) if suspected clinically, hemodynamic instability or number of patients with Organ/s dysfunction using (SOFA) score; 3). Length of ICU stay and duration of mechanical ventilation; 4). Mechanical Ventilation-free days (days of unassisted breathing on the 28th day) and organ dysfunction-free days (days alive and free of organ dysfunction at 28th day); 5). Organ/s dysfunction using (SOFA) score. The study parameters were recorded at the beginning of the study, 12 hours post-inclusion, then daily on day 1, 2, 3, and 4.

Statistical Analysis: Data was meticulously gathered, scrutinized, encoded, and then inputted into the Statistical Package for Social Sciences SPSS for windows, version 27 (IBM®), Armonk, NY, USA). For data adhering to parametric criteria, quantitative metrics were delineated through means, standard deviations, and ranges. Conversely, for datasets identified as non-parametric, median values alongside inter-quartile ranges (IQR) were utilized for presentation. Furthermore, qualitative data were depicted in terms of numerical counts and corresponding percentages. Repeated analysis of variance (ANOVA) was used to test values over the first 4 days, and receiver operation characteristic (ROC) curve was used to estimate the accuracy of driving pressure in prediction of the outcome of MV and mortality. P value < 0.05 was considered significant.

RESULTS

In the current study shows that diabetes mellitus and hypertension were found the commonest comorbidities among the studied patients (67.2% and 64.1%; respectively) followed by CNS and hypothyroidism (18.8% and 14.1%; respectively). Also, the commonest cause of admission was pneumonia (36%), and least percentage was found in septic shock (1.6%) (Data not tabulated). The ICU stay duration ranged between 4 to 25 days (median 7 days). The MV days ranged between 3 and 20 days (median 5 days). Weaning success was registered for 76.6%, and mortality was 23.4%. The severity was mainly severe (40.6%) and moderate (31.2%) (Table 1).

The ROC curve showed that the best cut off point for driving pressure at day 1 to predict weaning success was found ≤ 21 with sensitivity of 97.96%, specificity of 80.0% and area under curve (AUC) of 0.952. However, the best cut off point for driving pressure at day 1 to predict mortality was found > 21 with sensitivity of 80.0%, specificity of 97.96% and AUC of 0.952 (Table 2, Figure 1).

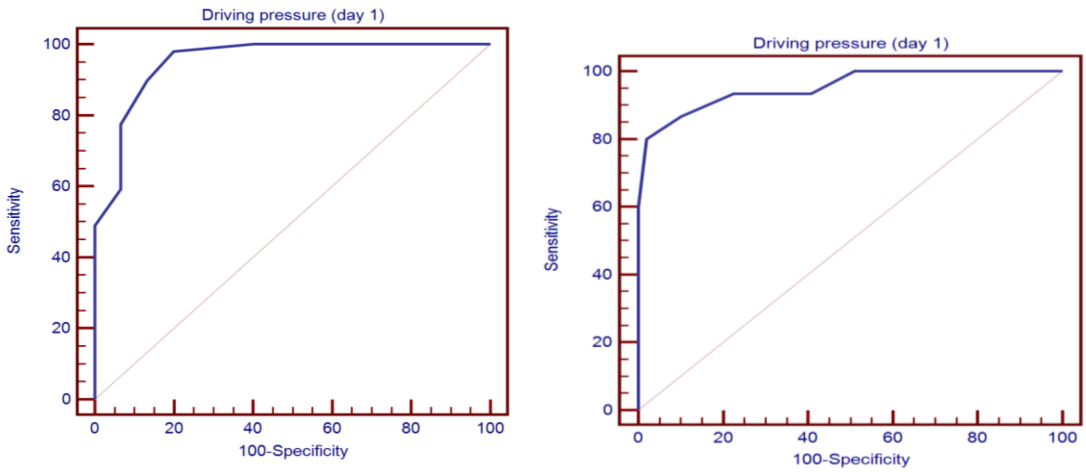
Table (3) showed significant progressive increase of TV from the day one to the day 4 (it was 456.41 ± 49.61, 480.89 ± 68.03, 486.2 ± 70.14 and 498.13 ± 33.75 at days 1, 2, 3 and 4 respectively). Similar situation was recorded for Pf ratio, while there was progressive significant reduction of FiO2 from the day 1 to the day 4. PEEP was increased in the second day, then decreased in the third and fourth days, with significant variances. On the other hand, no significant changes were registered overtime for compliance, plateau pressure and driving pressure.

The driving pressure was significantly increased in cases with failure weaning than the success weaning (24.67 ± 1.05 vs 16.86 ± 1.24, respectively). In addition, it was significantly increased in died than alive patients. Finally, there was progressive significant increase of driving pressure from mild to moderate to severe cases (Table 4).

Regarding compilations, pneumothorax was recorded among 9.4% and pleural effusion was recorded for 7.8% of patients (Table 5).

Table (1): Outcome of the studied patients:

		Total no.=64
ICU stay (days)	Median	7
	Range	4 – 25
Ventilation (days)	Median	5
	Range	3 – 20
Weaning success	Failure	15 (23.4%)
	Success	49 (76.6%)
ICU Mortality	Alive	49 (76.6%)
	Died	15 (23.4%)
Severity	Mild	18 (28.1%)
	Moderate	20 (31.2%)
	Sever	26 (40.6%)
SOFA score 1	Median	16
	Range	5 – 32
SOFA score 2	Median	9
	Range	4 – 35



a) Weaning success b) Death

Figure (1): Receiver operating characteristic curve (ROC) for driving pressure at day 1 to predict weaning success and mortality among the studied patients

Table (2): Predictive power of driving pressure for weaning success and mortality

Day 1	Cut off point	AUC	Sensitivity	Specificity	PPV	NPV
Weaning success	≤21	0.952	97.96	80.0	94.1	92.3
Dead	>21	0.952	80	97.96	92.3	94.1

AUC: Area under curve; PPV: Positive predictive value; NPV: Negative predictive value

Table (3): Comparison of Ventilator parameters after day 1, day 2, day 3 and day 4

		Day 1	Day 2	Day 3	Day 4	Test-value	P-value
TV	Mean±SD	456.41 ± 49.61	480.89 ± 68.03	486.2 ± 70.14	498.13 ± 33.75	6.23	0.001
	Range	360 – 600	220 – 650	220 – 650	450 – 560		
Pf ratio	Mean±SD	162.58 ± 73.68	279.44 ± 69.51	316.16 ± 76.14	343.22 ± 91.02	***79.25***	***<0.001****
	Range	50 – 290	160 – 390	175 – 401	180 – 450		
FiO_2	Median (IQR)	0.72 (0.51-1)	0.35 (0.35-0.45)	0.35 (0.35-0.45)	0.35 (0.35-0.44)	***103.44***	***<0.001****
	Range	0.32 – 1	0.28 – 1	0.28 – 0.5	0.28 – 0.5		
Compliance	Mean±SD	35.81 ± 6.37	36.06 ± 4.89	36.55 ± 5.12	34.13 ± 4.11	2.82	0.061
	Range	22 – 52	24 – 44	21 – 45	25 – 40		
Plat	Mean±SD	29.14 ± 5.74	30.81 ± 3.66	29.42 ± 4.26	29.23 ± 4.58	2.96	0.062
	Range	19 – 39	24 – 39	22 – 38	22 – 38		
PEEP	Mean±SD	10.67 ± 3.04	11.88 ± 1.56	10.78 ± 1.70	7.52 ± 1.86	***48.30***	***<0.001****
	Range	5 – 16	8 – 14	7 – 14	4 – 11		
Driving pressure	Mean±SD	18.69 ± 3.62	18.94 ± 3.38	18.70 ± 3.56	18.69 ± 3.54	0.29	0.787
	Range	12 – 27	14 – 26	14 – 26	14 – 27		

Table (4): Relation between driving pressure at the fourth day and weaning success, mortality and severity

After 4 Days		Driving pressure		Test-value•	P-value
		Mean±SD	**Range**		
Weaning success	Failure	24.67 ± 1.05	23 – 27	***22.048***	***<0.001****
	Success	16.86 ± 1.24	14 – 20		
Death	Alive	16.86 ± 1.24	14 – 20	***-22.048***	***<0.001****
	Died	24.67 ± 1.05	23 – 27		
Severity	Mild	16.56 ± 1.25	14 – 18	***5.228***	***0.008****
	Moderate	19.30 ± 3.5	16 – 26		
	Sever	19.69 ± 4.08	15 – 27		

Table (5): Percentage of complications during the study among the studied patients:

		Total no.=64
Pneumothorax	No	58 (90.6%)
	Yes	6 (9.4%)
Pleural effusion	No	59 (92.2%)
	Yes	5 (7.8%)

DISCUSSION

The pivotal therapeutic intervention for ARDS is mechanical ventilation, which serves as a temporizing measure to sustain adequate gas exchange while addressing the underlying pathology responsible for ARDS. Thus, the primary objective of mechanical ventilation is to ensure the maintenance of effective gas exchange [(8-13).]

The use of protective ventilation strategies and introduction of PEEP as standard of treatment of ARDS have decreased mortality rates of patients with ARDS, However, percentages are still high with estimated mortality rates ranging from 26% to 58%, being the highest among patients with severe disease. The disease is, also, associated with long term cognitive, psychological and physical sequel that interferes with the quality of life [(14-16)]

It is essential to articulate with precision that the demarcation line signifying a driving pressure of 14 or 15 cmH2O as a predictive indicator for outcomes or as a criterion for the titration of VT lacks empirical validation and confirmation [(4)]

The incidence of weaning failure was 23.4%. This was the same rate of mortality. The disease was mild, moderate and severe among 28.1%, 31.2% and 40.6%, respectively. There were significant differences in DP between weaning success and weaning failure and between alive and dead. This is in line with **Hamama *et al*.** who reported that, the reduced rate of mortality may be attributed to the use of DP guided ventilation for patients with ARDS [(17)].

The retrospective analysis of several studies in patients with ARDS comparing different PEEP levels at the same VT or different VT levels at the same PEEP, or a combination of both, suggested that DP (the difference between Pplat and PEEP) was a strong predictor of mortality as compared with low VT and Ppl. In addition, the relative risk of mortality significantly increased above a threshold of 15 cm H_2O [(3)]. These results agree with the present study.

The DP was progressively and significantly increased over days from the day 1 to the day 4, and the DP was significantly associated with weaning success and mortality, with a good predictive power. These results agree with a multilevel mediation analysis of data from 3562 patients with ARDS enrolled in previous trial that conducted by **Amato *et al.* [(4)].** They examined DP as an independent variable associated with survival in patients with ARDS and found that DP was the ventilation variable that best stratified the risk of mortality and decreases in DP (below 15 cmH_2O) owing to changes in ventilator settings were strongly associated with increased survival. Furthermore, an augmentation of one SD in DP, quantified approximately as 7 cm of water, was correlated with a heightened mortality risk (relative risk, 1.41; 95% CI 1.31 to 1.51; P<0.001). Modifications in TV or PEEP subsequent to randomization did not exhibit an independent correlation with survival outcomes. Their association was significant solely if they contributed to a reduction in DP.

In a supplementary analysis scrutinized the influence of driving pressure on mortality among ARDS patients subjected to lung protective MV across, 787 individuals participating in two distinct randomized controlled trials concerning ARDS patients orchestrated by **Guérin *et al.* [(18)]** and **Papazian *et al.* [(19)] .** It was discerned that driving pressure emerged as a prognostic indicator for mortality, in conjunction with plateau pressure and static compliance. It was observed that subjects exhibiting lower metrics of DP demonstrated enhanced survival rates (manifested through reduced 90-day mortality), accompanied by an augmentation in static lung compliance and a marked diminution in the SOFA score amongst the survivors, in stark contrast to their counterparts with elevated DP metrics. This correlation mirrors, the findings of our investigation, albeit with a notable discrepancy in the parameters of oxygenation between the two cohorts, diverging from our observations.

In the current study, pneumothorax was occurred in 6 patients (9.4%) while pleural effusion was occurred in 5 patients (7.8%). Other studies such as the study of **Hamama *et al.* [(17)]**. **Cavalcanti *et al.* [(20)]** explained complication by alveolar overdistention and pneumothorax produced by unnecessary higher PEEP. **Villar *et al.* [(21)]** provided evidence that driving pressure was associated with an increase in mortality despite optimized protective ventilation. In addition, **Urner *et al.* [(22)]** evaluated the dose-effect relationship between driving pressure and survival. A hazard ratio of 1.064 was seen with a daily increment of driving pressure. A higher mortality was recorded with driving pressure levels of $\geq$ 15 cm H_2O, even if present for a short period.

Conclusion: We concluded that in patients with ARDS, use of driving pressure guided ventilation that decreases 28[th] day of mortality, improves lung compliance, decreases the incidence of organ dysfunction, decreases the duration of mechanical ventilation and the length of ICU stay.

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None

REFERENCES

1. Bellani G, Laffey JG, Pham T, Fan E, Brochard L, Esteban A, et al.; LUNG SAFE Investigators; ESICM Trials Group. Epidemiology, Patterns of Care, and Mortality for Patients with Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries. JAMA. 2016 Feb 23; 315(8):788-800. doi: 10.1001/jama.2016.0291.

2. Huang X, Zhang R, Fan G, Wu D, Lu H, Wang D, et al.; CHARDSnet group. Incidence and outcomes of acute respiratory distress syndrome in intensive care units of mainland China: a multicentre prospective longitudinal study. Crit Care. 2020 Aug 20; 24(1):515. doi: 10.1186/s13054-020-03112-0.

3. Diaz JV, Brower R, Calfee CS, Matthay MA. Therapeutic strategies for severe acute lung injury. Crit Care Med. 2010 Aug; 38(8):1644-50. doi: 10.1097/CCM.0b013e3181e795ee.

4. Amato MB, Meade MO, Slutsky AS, Brochard L, Costa EL, Schoenfeld DA, Stewart TE, Briel M, Talmor D, Mercat A, Richard JC, Carvalho CR, Brower RG. Driving pressure and survival in the acute respiratory distress syndrome. N Engl J Med. 2015 Feb 19;372(8):747-55. doi: 10.1056/NEJMsa1410639.

5. Bellani G, Grassi A, Sosio S, Gatti S, Kavanagh BP, Pesenti A, Foti G. Driving Pressure Is Associated with Outcome during Assisted Ventilation in Acute Respiratory Distress Syndrome. Anesthesiology. 2019 Sep; 131(3):594-604. doi: 10.1097/ALN. 0000000000002846.

6. Zaidi SF, Shaikh A, Khan DA, Surani S, Ratnani I. Driving pressure in mechanical ventilation: A review. World J Crit Care Med. 2024 Mar 9;13(1):88385. doi: 10.5492/wjccm.v13.i1.88385.

7. Das A, Camporota L, Hardman JG, Bates DG. What links ventilator driving pressure with survival in the acute respiratory distress syndrome? A computational study. Respir Res. 2019 Feb 11;20 (1):29. doi: 10.1186/s12931-019-0990-5.

8. Slutsky AS, Ranieri VM. Ventilator-induced lung injury. N Engl J Med. 2013 Nov 28; 369(22):2126-36. doi: 10.1056/NEJMra1208707.

9. Katira BH. Ventilator-Induced Lung Injury: Classic and Novel Concepts. Respir Care. 2019 Jun; 64(6):629-637. doi: 10.4187/respcare.07055.

10. Marini JJ, Rocco PRM, Gattinoni L. Static and Dynamic Contributors to Ventilator-induced Lung Injury in Clinical Practice. Pressure, Energy, and Power. Am J Respir Crit Care Med. 2020 Apr 1; 201(7):767-774. doi: 10.1164/rccm.201908-1545CI.

11. Wilcox ME, Maas MB. Beating the Clock in Ventilator-induced Lung Injury. Am J Respir Crit Care Med. 2023 Jun 1; 207(11):1415-1416. doi: 10.1164/rccm.202212-2268ED.

2. Sklar MC, Munshi L. Advances in Ventilator Management for Patients with Acute Respiratory Distress Syndrome. Clin Chest Med. 2022 Sep; 43(3):499-509. doi: 10.1016/j.ccm.2022.05.002.

13. Kallet RH. Mechanical Ventilation in ARDS: Quo Vadis? Respir Care. 2022 Jun; 67(6):730-749. doi: 10.4187/respcare.09832.

14. Bienvenu OJ, Colantuoni E, Mendez-Tellez PA, Dinglas VD, Shanholtz C, Husain N, et al. Depressive symptoms and impaired physical function after acute lung injury: a 2-year longitudinal study. Am J Respir Crit Care Med. 2012 Mar 1; 185(5):517-24. doi: 10.1164/rccm.201103-0503OC.

15. Ziaka M, Exadaktylos A. ARDS associated acute brain injury: from the lung to the brain. Eur J Med Res. 2022 Aug 13;27(1):150. doi: 10.1186/s40001-022-00780-2.

16. Saeidi M, Safaei A, Sadat Z, Abbasi P, Sarcheshmeh MSM, Dehghani F, Tahrekhani M, Abdi M. Prevalence of Depression, Anxiety and Stress Among Patients Discharged from Critical Care Units. J Crit Care Med (Targu Mures). 2021 May 12;7(2):113-122. doi: 10.2478/jccm-2021-0012.

17. Hamama KM, Fathy SM, Abdelrahman RS, Alsharif SE, Ahmed SA. Driving pressure-guided ventilation versus protective lung ventilation in ARDS patients: A prospective randomized controlled study. Egy J Anesthesia 2021; 37(1): 261–267. doi: 0.1080/11101849.2021.1930401.

18. Guérin C, Papazian L, Reignier J, Ayzac L, Loundou A, Forel JM; investigators of the Acurasys and Proseva trials. Effect of driving pressure on mortality in ARDS patients during lung protective mechanical ventilation in two randomized controlled trials. Crit Care. 2016 Nov 29; 20(1):384. doi: 10.1186/s13054-016-1556-2.

19. Papazian L, Forel JM, Gacouin A, Penot-Ragon C, Perrin G, Loundou A, et al.; ACURASYS Study Investigators. Neuromuscular blockers in early acute respiratory distress syndrome. N Engl J Med. 2010 Sep 16;363(12):1107-16. doi: 10.1056/ NEJMoa1005372.

20. Cavalcanti AB, Suzumura ÉA, Laranjeira LN, Paisani DM, Damiani LP, Guimarães HP, et al. Effect of Lung Recruitment and Titrated Positive End-Expiratory Pressure (PEEP) vs Low PEEP on Mortality in Patients With Acute Respiratory Distress Syndrome: A Randomized Clinical Trial. JAMA. 2017 Oct 10; 318(14):1335-1345. doi: 10.1001/ jama.2017.14171.

21. Villar J, Blanco J, Añón JM, Santos-Bouza A, Blanch L, Ambrós A, et al. The ALIEN study: incidence and outcome of acute respiratory distress syndrome in the era of lung protective ventilation. Intensive Care Med. 2011 Dec; 37(12):1932-41. doi: 10.1007/ s00134-011-2380-4.

22. Urner M, Jüni P, Rojas-Saunero LP, Hansen B, Brochard LJ, Ferguson ND, Fan E. Limiting Dynamic Driving Pressure in Patients Requiring Mechanical Ventilation. Crit Care Med. 2023; 51 (7): 861-871. doi: 10.1097/CCM.0000000000005844.

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