Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2023 Feb 21; 11(B):367-375.
https://doi.org/10.3889/oamjms.2023.11474
eISSN: 1857-9655
Category: *B - Clinical Sciences*
Section: *Pediatrics*

Mechanical Ventilation Trigger Tool Identify Errors Associated with Mechanical Ventilation in Newborn Infant

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Edited by: Ksenija Bogoeva-Kostovska
Citation: ELHamid ELMeneza SA, Abd ELSamee Koriem M, Abd Elwakeel Ibrahim A. Mechanical Ventilation Trigger Tool Identify Errors Associated with Mechanical Ventilation in Newborn Infant. Open Access Maced J Med Sci. 2023 Feb 21; 11(B):367-375. https://doi.org/10.3889/oamjms.2023.11474
Keywords: Adverse event; Mechanical ventilation; Medical errors; Newborn infants; Patient safety; Ventilator trigger tools
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Received: 11-Jan-2023
Revised: 26-Jan-2023
Accepted: 11-Feb-2023

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Patient safety is the core of quality of health care. Newborn infants who are admitted to NICU are liable to adverse events. Medical errors represent a serious public health problem and pose a threat to patient safety. Mechanical ventilation is a complex procedure that exposes newborn infants to adverse events and complications.

AIM: The objective of this study was to identify medical errors related to mechanical ventilation (MV) in newborn infants using the newly design MV trigger tool.

METHODS: Observational cohort study was conducted for 6-month duration to determine the medical errors related to mechanical ventilation. It was carried out on newborn infants who needed mechanical ventilation and admitted to the NICU. Furthermore, we used the mechanical ventilation trigger tool to estimate number, types, and risk factors for the related errors.

RESULTS: There were 142 errors related to mechanical ventilation. Nearly 21.13% of the errors were related to ventilator settings, 38.39% were related to endotracheal intubation, and 40.14% of the errors were due to manipulation of the ventilators. The adverse events were diagnosed in 73.24% of the detected errors. Error of commission was seen in 53.5% of cases, and omission errors were reported in 46.5% of the cases. Mechanical ventilation trigger tool has 95.87% sensitivity and 95.24% specificity with 95.77% accuracy to detect errors.

CONCLUSION: The mechanical ventilation trigger tool may be efficient and effective in identifying errors and adverse events related to mechanical ventilation; it has high sensitivity and specificity. It might increase awareness to improve MV-related care.

Introduction

Patient safety is the core of quality of health care. Newborn infants who are admitted to NICU are liable to medical errors spectrum form near miss to sentinel events. Mechanical ventilation (MV) is a complicated procedure that increases the risk for errors as adverse events. There are variable grades of harm that may affect the quality of life of the ventilated newborn infants. Consistent and meticulous detection of dangerous incidents in neonatal intensive care unit (NICU) continues to be a challenge for majority of NICUs. Voluntary reports disclosed barely 2–8% of reported harms [1].

A trigger is a medical record trace that search medical record to determine whether an adverse event (AEs) might have occurred [2]. The use of triggers is one of the current techniques for assessing the global level of harm in a health-care organization. Trigger tool includes a list of potential AEs causes and instructions for collecting the data needed to measure the rate of AEs [3]. Recently, ventilator trigger tool was established to focus on respiratory support-related errors [4].

Research question

Can mechanical ventilation trigger tool assist health-care organizations to measure and analyze the medical errors related to use of MV in NICU?

Objective

This study aims to identify medical errors related to MV in newborn infants using the MV trigger tool.

Methods

Observational cohort study was conducted for 6 months to determine the number, type, and risk factors for medical errors related to MV using the MV trigger tools [4]. The study was done in NICU of Alzahraa University hospital and included newborn infants admitted to NICU and needed MV. The medical records were checked for the triggers, level of injury, and preventability of incidents.

Interventions

1. The researchers observed the health-care workers during the process of intubation, preparation, and application of MV. They observed the endotracheal intubation (ETT) technique, preparation of ventilator circuit, monitored ventilator pulmonary function and graphics, proper application of ventilatory strategies to underlying diseases, response to changes in the patient condition, and weaning process. The medical records were reviewed for possibility of errors using MV trigger collection forms. The trigger manual of definition was available to ensure proper understanding of each trigger [4].
2. When triggers were discovered, complete description of the events that lead to the errors were recorded, then errors were classified into commissions or omissions, latent, active, or mixed, additionally errors were categorized to AEs or sentinel or near miss.
3. The triggers detected were registered as in the used template (Supplement Tables 1 and 2).
4. Each recognized trigger was added in the patient record and verified that AEs or near miss or sentinel event had ensued.
5. The events were described and appraised for severity, then the grade of harm was determined and judged for preventability [5], [6].
6. All triggers that were concomitant with each error were determined.
7. Monthly record for all errors was calculated as in Supplementary Table 3.

Data analysis

Data were analyzed using Statistical Program for the Social Science (SPSS) version 17 (International Business Machines Corporation USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as number and percentage and Chi-square test was used to detect differences between the studied variables. Pearson correlation test was applied for correlations between the studied variables. Sensitivity and specificity were used for the evaluation of the triggers.

Results

The results are displayed from Tables 1-6 and Supplementary Tables 1-3.

327 cases were admitted to the NICU during the study period. Forty-six (12.88 %) cases required respiratory support in form of MV. Patient characteristics are shown in Table 1.

Table 1: Demographic data of the studied neonates

Parameters	Cases	n = 46	Percentage related to total number cases	χ^2	p
Gender	Male	31	67.4	5.56	0.018
	Female	15	32.6		
Gestational age (weeks)	Preterm	15	32.6	12.78	0.0051
	Late preterm	15	32.6		
	Full term	15	32.6		
	Postdate	1	2.2		
	Range	24 – 43			
	Mean ± SD	34.23 ± 4.62			
BW (kg)	BW < 1	6	13	29.87	< 0.001
	BW 1–1.5	5	11		
	BW 1.501–2.5	14	30		
	BW 2.501–4	21	46		
	Range (g)	500 – 3800			
	Mean ± SD (g)	2275 ± 1015.149			

SD: Standard deviation, BW: Birth weight.

Errors related to MV in the studied neonates

A total of 142 medical errors were detected by the ventilator trigger tool and direct observations. There were 55 errors (38.73%) due to endotracheal intubation, 30 errors (21.13%) associated with ventilator settings, and 57 errors (40.14%) caused by manipulation of the ventilators. There were no significant differences between these categories as $p < 0.271$. The errors due to commission were noticed in 53.5% of the total errors (Table 2).

Table 2 shows that 73.24% of MV errors were classified as adverse events; it is significantly higher than near miss (25.4%) and sentinel events (1.4%), $P < 0.039$. These errors caused no harm in 25.4% and low-grade harm in 70.4% of all recorded errors.

Active causes triggered 54.7% of the reported errors (Table 4). The rate of errors associated to MV was 0.43 errors/patient during the 6 months (Supplementary Table 3).

Nurses were responsible for 35.21% of the MV errors, errors caused by both physicians and nurses were accountable for 33.81% of errors, whereas 30.98% of errors were caused by physicians.

Table 5 shows that ventilator trigger errors detected 82.39% of the reported errors.

Table 2: Errors related to mechanical ventilation in the studied neonates

Errors related to MV	Number of errors	Percentage to total number of errors (142)	Commission (76; 53.5), n (%)	Omission (66; 46.5), n (%)
Errors related to endotracheal intubation	55	38.73	34 (23.94)	21 (14.78)
Inappropriate ventilator setting	30	21.13	15 (10.56)	15 (10.56)
Errors related to manipulation of MV	57	40.14	27 (19.01)	30 (21.13)
Total errors related to MV	142	100	76 (53.5)	66 (46.5)
χ^2	6.379		2.539	
p	0.271		0.281	
Preventable errors	100 (70.4)			
Nonpreventable	42 (29.6)			

χ^2: Chi square test. MV: Mechanical ventilation.

Table 3: Type of medical errors events

Errors related to mechanical ventilation	Adverse events, n (%)	Near misses, n (%)	Sentinel events, n (%)
Errors related to endotracheal intubation	45 (31.69)	10 (7.04)	0
Inappropriate ventilator setting	16 (11.27)	14 (9.85)	0
Errors related to use of MV	43 (30.28)	12 (8.45)	2 (1.4)
Total 284	104 (73.2)	36 (25.4)	2 (1.4)
χ^2	10.04		
p	< 0.039		
Grade of harm			
No harm	36 (25.4)		
Low	100 (70.4)		
Moderate	4 (2.8)		
Severe	2 (1.4)		
χ^2	150.2		
p	0.001		

χ^2: Chi square test. MV: Mechanical ventilation.

The first trigger (T1-Ventilator associated pneumonia) could detect ventilator-associated pneumonia (VAP) in 83.33% of cases. There are three causes for trigger to appear; poor handling of ventilator circuit, inappropriate ETT insertion and aspiration. Poor handling of ventilator circuit was the most common item in this trigger. It was found in 83.33 of errors detected by trigger 1.

Table 4: Active and latent errors

Errors related to mechanical ventilation 142	Active errors, n (%)	Latent errors, n (%)	Mixed errors, n (%)
Errors related to endotracheal intubation	44 (30.9)	4 (2.7)	8 (5.5)
Inappropriate ventilator setting	15 (10.5)	15 (10.5)	1 (0.7
Errors related to manipulation of MV	19 (13.3)	12 (8.4)	25 (17.5)
Total	78 (54.7)	31 (21.6)	33 (23.7)
χ^2	40.165		
P	< 0.001		
Active errors related to mechanical ventilation in relation to medical staff			
Errors related to (MV) due to personal	Physician, n (%)	Nurse, n (%)	Both, n (%)
Errors related to endotracheal intubation	21 (38.2)	23 (41.8	11 (20)
Inappropriate ventilator setting	18 (60)	7 (23.3)	5 (16.7)
Errors related to manipulation of MV	5 (8.8)	20 (35.1)	32 (56.1)
Total 222	44 (30.98)	50 (35.21	48 (33.81)
χ^2	34.15		
p	0.001		

Post hoc test between nurses and mixed = 0.05. MV: Mechanical ventilation.

The second triggers (T2 – Antibiotic use) consisted of three items; poor handling of intravenous lines and ventilatory circuit as well as inappropriate insertion techniques. This trigger detects 89.28% of cases of healthcare-acquired infection. Poor handling of IV line was most common item in this trigger as found in 83.33 of errors detected by trigger 2.

The third trigger (T3 - Unplanned Extubation) distinguished all cases of the unplanned extubation (100%). Unplanned extubation occurred in 32.6% of the ventilated cases. There are four causes for trigger to appear; reintubation, inappropriate sedation, poor taping of ETT, and prolonged duration of intubation. Reintubation was the most frequent item in this trigger, as found in 100% of errors detected by trigger 3.

The fourth trigger (T4 - Development of air leak syndrome) identified 100% of related errors. There are ten items to detect this trigger. Malposition of ETT was the most frequent item in this study as found in 100% of errors detected by trigger 4.

The fifth trigger (T5 - Development of CLD) identified all cases of chronic lung disease (CLD). CLD was diagnosed among 4.34% of the studied cases.

The six triggers (T6 - Obstructed ETT) were able to detect 100% of the related errors. Obstructed ETT was diagnosed in 30.43% of cases. Turbulence in the flow-time wave was the most frequent finding; it was detected in 100% of errors.

The seventh trigger (T7 - High FIO_2) detected 60% of related errors.

The eights trigger (T8 - Pulmonary hemorrhage) identified 100% of associated errors. Pulmonary hemorrhage was diagnosed in 10.8% of studied cases.

The ninth trigger (T9 - Hypocarbia; $PaCO_2$ < 40) detected 75% of the related errors. Prolonged expiratory time was seen in 50% of the trigger items.

The tenth trigger (T10 – Hypercarbia, $PaCO_2$ > 55–60) revealed 75% of the associated errors. Inadequate expiratory time was noticed in 100% of the trigger components.

The eleventh trigger (T11 - Endotracheal intubations trauma) detected 76.9% of interrelated errors. Difficult reintubation was found in 100% of the errors.

The trigger tool had sensitivity of 95.87%, specificity of 95.24%, positive predictive value (PPV) of

Table 5: Ventilator trigger tools in studied neonates

Triggers	Total number of errors	Number of errors detected by the ventilator trigger	Percentage of errors detected by trigger	Number of errors not detected by the ventilator trigger	Percentage 0f errors not detected by trigger	Percentage of events to studied cases (46)
T1 - Ventilator associated pneumonia	6	5	83.3	1	16.7	13.04
T2 - Antibiotic use	28	25	89.3	3	10.7	60.06
T3 - Unplanned extubation	15	15	100	0	0	32.6
T4 - Development of air leak syndrome	5	5	100	0	0	10.86
T5 - Development of CLD	2	2	100	0	0	4.35
T6 - Obstructed ETT	14	14	100	0	0	30.43
T7 - High FIO_2	20	12	60	8	40	43.47
T8 - Pulmonary hemorrhage	5	5	100	0	0	10.8
T9 - Hypocarbia	16	12	75	4	25	34.78
T10 - Hypercarbia	18	12	75	6	25	39.13
T11 - Endotracheal intubations trauma	13	10	76.9	3	23.1	28.26
Total	142	117	82.4	25	17.6	100
χ^2	20.54					
p	0.025					
Accuracy	All triggers (%)				Pulmonary graphics (%)	
Sensitivity	95.87				85.25	
Specificity	95.24				98.77	
PPV	99.15				98.11	
NPV	80.00				89.89	
Accuracy	95.77				92.96	

χ^2: Chi square test, NPP: Negative predictive value, PPV: Positive predictive value, T: Trigger, CLD: Chronic lung disease .

99.15%, and negative predictive value (NPP) of 80.00% at accuracy of 95.77% to detect errors related to MV.

Pearson correlation test showed a positive correlation between length of stay in NICU and total number of errors (Table 6).

Table 6: Correlation between total numbers of errors related to mechanical ventilation and length of stay in neonatal intensive care unit

Items	Errors related to mechanical ventilation	
	R	p
Length of stay in NICU		
All MV errors	0.586	<0.001
Errors related to endotracheal intubation	0.410	0.005
Inappropriate ventilator setting	0.317	0.032
Errors related to manipulation of MV	0.649	< 0.001

Person correlation test. NICU: Neonatal intensive care unit, MV: Mechanical ventilation.

Discussion

Medical errors are potentially harmful eight times more in the neonatal intensive care unit when compared to adult settings in the hospital [7], [8]. Newborn infants are more vulnerable and even minor errors lead to devastating short- and long-term consequences [9].

The objective of this study was to identify medical errors related to MV in newborn infants using the mechanical ventilation trigger tool. Identification of nature of errors and risk factors for incidents may support training and implementation of procedures that prevent MV-related errors.

There were 327 cases admitted to the NICU during the study period. Only 12.88% of these cases needed respiratory support in the form of MV. A total of 142 errors associated to MV were identified in the ventilated cases. This finding agrees with others [10], [11]. In agreement with our finding, Valentin and Bion found that the highly sophisticated treatments, technologies, and diagnostic tools are associated with high risk of medical errors and adverse events [12].

In this study, the errors related to MV occurred due to three causes; abnormal ventilator settings (21.13%), endotracheal intubation (38.73%), and manipulation of the ventilators (40.14%). There was an insignificant increase in errors related to the manipulation of ventilators than other causes. In earlier study, we showed that respiratory equipment is responsible for 26.97% of the errors related to the use of instrument in NICU [13].

In the current study, 70.4% of errors could have been prevented. Kugelman *et al.* found that 83% of iatrogenic events were considered preventable [14]. Furthermore, Sharek *et al*. found that the majority of AEs were classified as preventable [3]. These errors could have been prevented if the health-care system could add more protective layers as procedures for effective monitoring of the ventilated cases and increase the number of the nurses per ventilated cases.

Errors of commission triggered 53.52% of the total errors and omission errors were found in 46.48% of all errors related to MV. Commission errors were considered when doing something wrong, while omission errors when fail to do the intended plan of care. Both errors of commission and omission can be related to individual or system causes [5]. System causes include all the health organization errors as arranging daily work, emergency planning, equipment availability or accessibility, lack of communication systems, inadequate supervision, stressful environment, or poor welfare for workers [15].

MV is the most invasive procedure in NICU; subsequently more errors are expected to appear among mechanically ventilated neonates. The current study showed a significant increase in adverse events than near miss and sentinel event, $P < 0.039$, this finding was in relative agreement with others [9], [11], [13]. Similarly, Pham *et al*. reported higher adverse events than near miss or events that cause death [16]. Lower incidences were reported by other authors [17].

These events lead to low grade of harm in 70.5% of total errors. Up to our knowledge, no studies looked at subsequent grade of harm resulted from adverse events related to MV. The study revealed a positive correlation of the errors and increased length of hospital stay. This was expected as even low grade of harm needs more observations and monitorings to the affected cases, whereas moderate harm might need additional procedures.

In this study, active errors were significantly higher than latent and mixed errors, $p < 0.001$. This result relatively consistent with other studies [18], [19], [20]. Human factor-related errors could be knowledge based, rule-based, or skill-based. In addition, human factors include noncompliance with the protocols and instructions, insufficient direction for the use of equipment, inappropriate clinical situations, unfitting circuit setup, inefficient staff training, faulty alarm settings, health-care worker incapable to interpret and react to alarm(s), and unavailable or inadequate backing supporting system.

The actuality that active errors and errors of commission were more than latent errors and errors of omissions denote the demand for regular training of the NICU staff and necessity to improve the clinical setting including procedures and policies for monitoring ventilated cases.

There was a significant increase in errors committed by nurses and mixed errors by nurses and physicians. Nurses are always blamed more than doctors for errors; it was concluded by Hüden and Behice that all nurses in the NICU did not perform all practices necessary for the MV [21]. The high percentage of patient to nurse augment the stress

and workload, especially during the night shift [22]. A report by Pham *et al*. showed that three most commonly reported events to university health system consortium and Pennsylvania patient safety authority were airway/breathing circuit issues, human factor issues, and ventilator malfunction events, whereas the top three event types reported from FDA were ventilator malfunction, power source issue, and alarm failure [19].

The use of triggers, or clues, to identify medical errors is an effective method for measuring the overall level of harm in a health-care organization [23]. In the current study, it was found that MV triggers identified 82.39% of the detected errors related to MV. The ventilator trigger tool had a sensitivity of 95.87%, specificity of 95.24%, PPV 99.15%, NPP 80.00%, and accuracy of 95.77% to identify medical errors related to MV in the neonatal intensive care unit. In relative agreement with this study, Classen *et al*. found that the global trigger tool had a sensitivity to detect patients with at least one adverse event of 94.9% and a specificity to detect patients with no events of 100% [24]. Moreover, Stockwell *et al*. used trigger tool to detect harm in pediatric inpatient found that there were 1093 detected triggers, resulting in identification of 85.0% of the total detected harms [25]. Similarly, Sharek *et al*. found that NICU focused trigger tool appears efficient and effective at identifying adverse event [3].

A unique finding in this study was the use of ventilator graphics monitor data as one of the trigger components, we propose that abnormal graphics can detect errors and can be included in the ventilator trigger tool. Abnormal pulmonary graphics monitoring data can identify incidents that occurred. Close observation to the ventilator monitor or review the recoded data may be useful to predict the adverse events and commence the proper interventions as suction, or decrease the pressure or increase the expiratory time. The graphics abnormalities in the current study were mainly in the form of turbulence (56.5%) that was detected in the flow-time wave and flat-peaked wave (36.95%) as in the flow-time wave. In addition, auto positive end expiratory pressure (PEEP) was found in both flow-time wave and flow-volume loop among 8.7% of errors. The air leak errors were seen in volume-time wave, volume-pressure loop, and flow-volume loop in 6.5% of errors. Similarly, asynchrony of breathing was observed in the flow-time wave and pressure-time wave in 6.5% of errors. The trigger 4 can predict the leak syndrome by reviewing data of volume-time wave or volume-pressure and flow-volume loops. Similarly peaking in pressure volume loop can indicate decrease lung compliance. Consequently, these alert medical staffs to modify the ventilator settings.

Trigger 6 predicted obstruction of ETT as it was associated with turbulence in flow-time wave and excessive vibration in all waves that indicate the presence of secretions. ELMeneza and Gaber found that excessive vibration in all pulmonary waves signify the presence of secretions or need to clear the ventilator connections from the condensed water [26].

The addition of pulmonary graphics as one item of the ventilator trigger tool has a sensitivity of 85.4% and specificity of 97.77%, positive predictive value of 98.11%, and negative predictive value of 89.89% with 92.96% accuracy to detect errors related to MV.

Some triggers as T3; unplanned extubation, T4; development of air-leak syndrome, T5; development of CLD, T6; obstructed ETT, and T8; pulmonary hemorrhage identified 100% of the errors related to the use of ventilator in the NICU, whereas T2 distinguished 89.3% of errors caused healthcare-acquired infection and T1 recognized 83.3% of VAP.

Among the triggers that detected 100% of errors is trigger 3. It is defined by accidental, unplanned extubation that may cause sudden arrest among the ventilated cases. Poor taping of the ET, inappropriate sedation or prolonged ventilation, and reintubation were the triggers to detect these types of errors. In agreement with our findings, Snijders *et al*. found that tube-related incidents accounted for great proportion of harm [18], also Ligi *et al*. observed a significant increase in the rate of unplanned extubations [16].

Triggers T7, T9, T10, and T11 require supplementary elements to expand and augment the detection of the corresponding errors. Trigger T7 (high FIO_2) detected only 60% of the corresponding errors; it was found that staff did not record the temporary orders of increase in FIO_2 when applied for short duration. Similarly, T9 (hypocarbia) and T10 (hypercarbia) perceived 75% of the errors connected to MV. These findings were observed in complicated cases with dependent respiratory support. Trigger 11 (endotracheal intubations trauma) is describing the presence of any vocal cord edema, stenosis, perforation of esophagus, nasal atrophy, stenosis, subglottic stenosis, or palatal grove as well as difficult intubation. Trigger 11 distinguished 76.9% of the associated errors; it could be suspected when medical record showed multiple reintubation or staff reported difficult intubation. It was described earlier that mucosal injury due to endotracheal intubation occurred in 7.8% of errors and failed endotracheal intubation in 6.5% of newborn infants due to active errors [13].

The rate of errors related to MV during the studied six months was 0.43 errors/patient. The highest rate of errors during the study period was in March and the lowest rate was in June. This was coinciding with the assignment of new staff in March. Other studies showed variations of incidence of errors during time shifts and advocate for the need to support health-care system to minimize errors related to MV and medication errors [27], [28], [29]. Adequate training of NICU staff, implementation of guidelines, policies, and procedures as well as reporting system may help to decrease medical errors in general and errors from the use of ventilators too [30].

The limitation for this study was fear and anxiety of some junior staff, especially during the observation process. Assurance that the results will be used for training alleviates this anxiety and comfort them.

Conclusion

Mechanical ventilation trigger tool appears to be efficient and effective in identifying medical errors and adverse events related to mechanical ventilation with high sensitivity and specificity. Some triggers need to be augmented with more elements to increase its sensitivity for diagnosis. Focused on errors related to the use of ventilators in NICU, may strengthen the awareness to realize the sources of errors, hence improve mechanical ventilation related care. Further studies are needed to ensure validity and reliability of the ventilator trigger tools.

Ethical Considerations

An informed consent was obtained from all parents of neonates involved in the study. The confidentiality of data was ensured. The study was approved by medical ethics committee of Faculty of Medicine for Girls Number 2021101025 on 6-10-2021.

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Supplementary Tables

Supplement Table 1: List of respiratory support/mechanical ventilation trigger tool

Trigger	Definition of the trigger	Cause of trigger to appear	Potential adverse event
T1 Ventilator-associated pneumonia	A nosocomial pneumonia associated with mechanical ventilation support (by endotracheal tube or tracheostomy) that develops within 48 hours or more of hospital admission and which was not developing at the time of admission	Poor handling of ventilation circuit Inappropriate ETT insertion technique Aspiration, etc.	Ventilator associated pneumonia
T2 Antibiotic use	Any antibiotic used at any time during the NICU stay (includes prophylactic antibiotics, except prophylactic fluconazole)	Poor handling of IV lines - poor handling of ventilatory circuits Inappropriate insertion technique, etc.	Health care acquired infection
T3Unplanned Extubation	Any removal of an endotracheal tube that was not planned	Poor taping Under sedation Excessive ventilation Reintubation etc.	Accidental extubation - cardiorespiratory arrest
T4Development of air leak syndrome	Air leak in pleura, peritoneum, mediastinum or pericardium	Aggressive resuscitation at DR or NICU Use of high TV Use of high PIP/PEEP Malposition of ETT Prolonged ventilation Inappropriate ventilator setting Inadequate expiratory time Malfunction/incorrect of the ventilator and circuits Gas trapping Pulmonary graphics Abnormalities etc. Incorrect alarm Tube displayed to right side	Pneumothorax, Pneumothorax Pneumoperitoneum Pneumomediastinum Pneumopericardium Pulmonary interstitial emphysema
T5 Development of CLD	Prolonged need for ventilatory support, O_2 requirements, need for home oxygen and readmission with respiratory illness in the first year of life High Tco_2 O_2 requirement: >21% for ≥28 days Moderate: <30% O_2 • Severe: ≥30% O2 ± - PPV or NCPAP Oxygen dependency beyond 36 weeks postconceptual age or among infants >32 weeks. for 28–56 days of age Marked radio-opacity of the lungs - cystic bubbly, pattern hyper expansion, linear streaks and areas of emphysema Difficult weaning	Chorioamnionitis Prolonged use of oxygen Inappropriate ventilator setting Use of high Fio_2 High Tco_2 O_2 requirement: > 21% for ≥28 days etc.	BPD/BP
T6 Obstructed ETT	Any obstruction to ETT weather blood, mucus or kinked improper size	Inadequate suction Pulmonary hemorrhage Improper ETT size etc.	Cardiorespiratory arrest
T7 High FIO_2	Use of FIO_2 >60% Any O2 saturation >than targeted for GA	Use of high Fio_2 Prolonged use of ventilator Inappropriate ventilator setting etc.	BPD-Retinopathy
T8 Pulmonary hemorrhage		Perinatal asphyxia Inappropriate ventilator settings Hypoxia/desaturation Hypothermia Sepsis DIC Inappropriate use of humidifiers	Pulmonary hemorrhage
T9 Hypocarbia	$PaCO_2$ <40	Babies receiving surfactant Any unstable ventilated infant Inappropriate ventilator setting Prolonged ventilator etc.	Periventricular leukomalacia IVH Cerebral palsy CLD
T10 Hypercarbia	$PaCO_2$ >55–60	Inappropriate ventilator setting Low RR Inadequate expiratory time Disconnection of the circuit incorrect circuit set up etc.	IVH Impedance of brain stem auditory evoked response
T11 Endotracheal intubations trauma	Any edema of vocal cord, stenosis, perforation of esophagus, nasal atrophy/stenosis, subglottic stenosis palatal grove	Reintubation Difficult reintubation Radiology, double esophageal structure, etc.	Traumatic injury to vocal cords Traumatic injury to larynx, Traumatic injury to esophagus, Subglottic stenosis Palatal grove

NB: The trigger list and triggers data Collection form was developed based upon the global trigger tool. ELMeneza, Safaa. 2019/August/29. https://www.researchgate.net/publication/335465555_Ventilator_triggers_tool. DOI: 10.13140/RG.2.2.12900.94083/1. https://www.researchgate.net/publication/335465555_Ventilator_triggers_tool. CLD: Chronic lung diseases, PPV: Positive predictive value, BP: Blood pressure, T: Trigger, PEEP: Positive end expiratory pressure, NICU: Neonatal intensive care unit, BPD: Bronchopulmonary dysplasia .

Supplement Table 2: Individual trigger data collection form

Individual patient NICU triggers Data collection form								
Hospital	Patient number	Gestational age at birth (weeks) Length of stay in the NICU (min 2 days)	Birth weight (kg)	Gender Female male	*AE harm categories E: Contributed to or resulted in temporary harm to the patient and required intervention F: Contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization G: Contributed to or resulted in permanent patient harm H: Required intervention to sustain life I: Contributed or resulted in patients death			
Triggers		Times trigger is present	AE Associated With this trigger	Comments about Trigger	Description of adverse event	AE Harm category	Was AE preventable?	Did the AE/ADE Occur in the NICU?
T1 ventilator-acquired pneumonia							Yes/no	Yes/no
T2 Antibiotic use							Yes/no	Yes/no
T3 Unplanned Extubations							Yes/no	Yes/no
T4 Air leak syndrome							Yes/no	Yes/no
T5 High FIO_2t							Yes/no	Yes/no
T6 Development of CLD							Yes/no	Yes/no
T7 Obstructed ETT							Yes/no	Yes/no
T8 Hypercarbia							Yes/no	Yes/no
T9 Hypocarpia							Yes/no	Yes/no
T10 Pulmonary hemorrhage							Yes/no	Yes/no
T11 Endotracheal intubation trauma							Yes/no	Yes/no

From IHI Global trigger tools, 2009; and modified by EL Meneza *et al*., 2019 to adopt the MV trigger tool. DOI: https://doi.org/10.1016/j.pedneo. 2019.05.008. AE: Adverse event, CLD: Chronic lung diseases, T: Trigger, IHI: Healthcare improvement, NICU: Neonatal intensive care unit.

Supplement Table 3: Monthly summary sheet for neonatal intensive care unit adverse event

Patient	AE found? (Yes/No)	Total number of AEs for this patient
Patient number 1		
Patient number 2		
Patient number 3		
Patient number 4		
Patient number 5		
Patient number 6		
Total		

Months	Rate of MV related errors per patient
February	0.54
March	0.72
April	0.38
May	0.41
June	0.33
July	0.25
Per 6 month	0.43

MV: Mechanical ventilation.