Survey and Analysis of Current State of Ventilator Alarms in the Intensive Care Unit

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ABSTRACT

This article reports on a survey and analysis of ventilator alarm state in a children hospital. Based on the evaluation of the alarm effectiveness, we designed a survey statistical table for ventilator alarm investigation. We evaluated the alarm situation synthetically through investigation and statistical methods. Result shows that the current ventilator alarms are not sufficiently effective, 26.84% of them are meaningless alarms and those leading to clinician's intervention make up only 2.26% of all the alarms generated. The reliability of statistical data was also analyzed. According to the survey results, we identified and analyzed the causes of the problem and proposed the corresponding alarm management methods.

Keywords – *ventilator alarm information, alarm effectiveness, alarm management, survey statistics*

INTRODUCTION

The intensive care unit (ICU) is one of the most critical clinical departments for patients in a tertiary hospital. Yet, the volume of medical equipment equipped in this clinical area also presents great challenges in terms of alarm fatigue due to overwhelming alarm information generated during daily operation. There are simply too many alarms that do not result in medical intervention in the ICU.[1] It was reported that an alarm sounded every 92 seconds in the ICU in 2006.[2] This was shortened to every 66 seconds by 2010,[3] and shortened further to every 42 seconds by 2014.[4] Too many alarms bring about auditory and visual confusion for medical staff.[1] They can't identify the sources of the alarms effectively,[5] which is a serious threat to the safety of patient care.[6] According to one report from the ECRI Institute, the number of adverse events related to alarm management is increasing yearly.[7] A hospital may experience tens of thousands of alarm messages every day, but 85–99% of them are nuisance alarms or do not need clinical intervention.[8] The presence of these alarms leads medical staff a to state of alarm fatigue and can cause alarm ignorance or even the turning off of the alarm function.[9]

However, above reports mainly focus on alarm issues for adult patients, there are few reports based on the same issue for pediatric patients. Children, especially newborns, with their language, awareness, and behavioral abilities not yet fully developed, bring more challenges to a health care team. Based on the above background, this paper presents an analysis method that integrates the statistical design of the survey, the investigation experiment, and the statistical analysis of the data, and analyzes the state of ventilator alarms in the neonatal ICU in a children hospital.

MATERIALS AND METHOD

Based on the literature review and our experience, alarms can be categorized into meaningful alarms and meaningless alarms. Meaningful alarms are those alarms that require a clinician's quick attendance due to changes in patient condition or those technical alarms originating from equipment malfunctions that require timely correction. Meaningless alarms are those that don't reflect the true changes of a patient's condition, do not improve patient management, and may be caused by false alarm, improper alarm settings, or recoverable transient artifacts.

In order to carry out an assessment of the common ventilator alarms, we first consulted with clinicians to categorize the three main alarm interventions for ventilators in their routine practice: (1) clinician's medical intervention, (2) clinical engineering and nurse's equipment correction; and (3) alarm elimination by silencing. Clinician's medical intervention means patients with clinically changed conditions requiring timely intervention of medical staff; clinical engineering and nurse's equipment correction means a technical problems with the ventilator occurred requiring clinical engineering or nurse's action such as immediate repair; while alarm elimination by silencing means that both the patient and instrument were OK and the alarm did not recur after silencing. We also collected and analyzed common alarm contents, common alarm

intervention measures, and alarm causes. Since alarm limit settings are highly relevant with alarm occurrence, it is also important to record common alarm limit values accurately. Based on the key elements mentioned above, we design the Statistics of Clinical Meaningful Alarms, as shown in Table 1.

In this study, we selected the SLE5000 ventilator as an example, where this paper applies the designed survey table to the collection and observation of the SLE5000 ventilator alarms generated in daily use in the neonatal intensive care unit (NICU) over a period of 10 days.

RESULT

The Results of the Survey

This survey is based on 120 total questionnaires, with 486 events of recorded alarm information from 112 valid questionnaires, and 12 kinds of common alarms generated. The specific number of alarms shown in Figure 1. Among them, the high-pressure alarm, low pressure alarm, and cycle failure occur with higher frequency. The results of intervention are shown in Table 2.

According to the effectiveness of the alarm and the definition of meaningful alarms described earlier, we classify 354 alarms events as meaningful alarms, and the calculation of meaningful alarms rate per day is shown in Table 3.

TABLE 1. Statistics of Clinical Meaningful Alarms

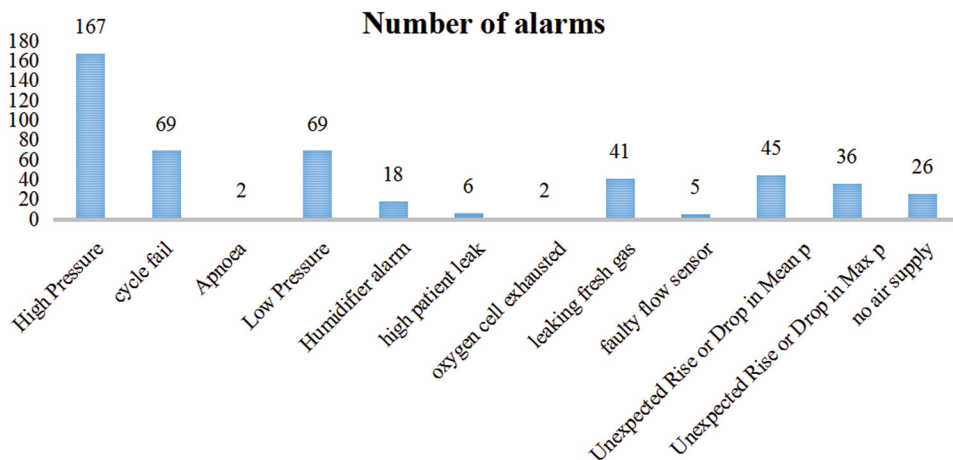| Ventilator Model:				Patient Hospital Number:		Date:	
Set value	PEEP H: L:	Amplitude	Hz	Frequency H: L:	Tidal volume H: L:	Minute ventilation H: L:	
Alarm content	Intervention measures and their causes (multiple choice)					The result of the intervention	
Event hints:	☐ Mute ☐Endotracheal secretions are much, should suck them out ☐ Abnormal machine and accessories ☐The patient is restless ☐ There is water in the tube ☐Replacement of the sensor ☐ Adjust the position of the endotracheal intubation ☐ pipeline discount, off ☐other☐					☐ Alarm elimination by silencing ☐ Clinician's medical intervention ☐ Clinical engineering and nurse's equipment correction	
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FIGURE 1. Alarm name and number of alarms.

TABLE 2. The Result of the Intervention

	Clinician's medical intervention	Clinical engineering and nurse's equipment correction	Alarm elimination by silencing
Number of alarms	11	343	132
Proportion	2.26%	70.58%	27.16%

TABLE 3. Overview of Alarm Data

Time	Total	Meaningful alarm	Meaningless alarm	Rate of meaningful alarm
1st day	50	43	7	86.00%
2nd day	46	31	15	67.39%
3rd day	36	28	8	77.78%
4th day	45	39	6	86.36%
5th day	59	46	13	77.97%
6th day	69	44	25	63.77%
7th day	48	31	17	64.58%
8th day	48	34	14	70.83%
9th day	45	29	16	64.44%
10th day	40	29	11	72.50%
Total	**486**	**354**	**132**	——
Average	**46.8**	**35.4**	**13.2**	**73.16%**

The rate of meaningful alarms was 73.16% of all alarms generated. This included those alarms that really reflect the changes of patient condition which need the clinician's quick attendance or those technical alarms for equipment malfunction that require correction immediately or soon. Yet, the alarms that required clinician medical intervention reached only 2.26%. There is quite a large proportion of meaningless alarms, which consists of 26.84% of all alarms generated. This indicates that the alarm conditions should and could be improved greatly.

Reliability Test

Reliability refers to the degree of questionnaire results repeatability. The coefficient of Cronbach's Alpha is between 0 and 1, and the larger the value, the better the relevance of the items in the questionnaire and the higher the degree of internal consistency.[10] In general, the internal consistency is considered excellent, good, or poor accordingly if the coefficient of Cronbach's Alpha is greater than 0.8, within 0.6~0.8, and less than 0.6 respectively. Using the SPSS19.0 software to analyze the experimental data, the results show that the Cronbach's Alpha coefficient of our survey is 0.915, which indicates that the statistical experiment is credible and statistically significant.

DISCUSSION

The survey uses the designed form to collect and analyze the state of the SLE5000 ventilator alarms management. There were 486 recorded alarm events collected over a time period of 10 days. Though we believe the survey only collect the most common relevant alarms occurring, the actual alarms generated by a ventilator may be higher than this survey collected. Yet, the internal consistency reliability of the 10 days' survey data is analyzed by SPSS19.0 software and it shows overall survey data are solid and strong.

Survey results show that 26.84% of the alarm data is meaningless alarms, which means that those alarms did not contribute to better patient management and could have been avoided in the first place. Even some of those classified as meaningful alarms, in particular some technical alarms, there is still room to reduce their occurrence. Alarm management is teamwork. All stakeholders including hospital leadership, medical staff, clinical engineers, manufacturers, and independent service organizations should participate. We suggest the following strategies:

- First, urge manufacturers to improve the quality and reliability of equipment and improve the design of alarm system.
- Second, assure clinical engineering staff to perform service and preventive maintenance of relevant medical equipment timely and appropriately.
- Third, strengthen user training in terms of medical equipment operation as well as alarm management including setting alarm limits appropriately.
- Fourth, develop and apply alarm integration and management systems based on IT technology.

CONCLUSIONS

The article aims are a survey and analysis of the current state of ventilator alarms in an ICU. The results show that the current ventilator alarm management in the ICU needs to be improved. As well. collaboration among clinicians, clinical engineering staff, and ventilator manufacturer is important and necessary in terms of providing a better solution based on training, smart alarm design, and alarm integration management.

We believe the methodology mentioned in this paper is not only suitable for SLE5000 ventilator alarms information survey and assessment, but also could be used as reference for other types of ventilators or medical equipment such as monitors, infusion pumps, etc. Nevertheless, the systematic management of all instruments' alarm is a complex project. Further research is needed to learn best practices of other facilities currently and into the future.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest involved this paper.

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