Special Article

Development of An Assessment Test for An Anesthetic Machine

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Objective: *The study is aimed to develop and assess the quality of an evaluation form used to evaluate the nurse anesthetic trainees' skills in undertaking a pre-use check of an anesthetic machine.*

Material and Method: *An evaluation form comprising 25 items was developed, informed by the guidelines published by national anesthesiologist societies and refined to reflect the anesthetic machine used in our institution. The item-checking included the cylinder supplies and medical gas pipelines, vaporizer back bar, ventilator, anesthetic breathing system, scavenging system and emergency back-up equipment. The authors sought the opinions of five experienced anesthetic trainers to judge the validity of the content. The authors measured its inter-rater reliability when used by two achievement scores evaluating the performance of 36 nurse anesthetic trainees undertaking 15-minute anesthetic machine checks and test-retest the reliability correlation scores between the two performances in the seven days interval.*

Results: *The five experienced anesthesiologists agreed that the evaluation form accurately reflected the objectives of anesthetic machine checking, equating to an index of congruency of 1.00. The inter-rater reliability of the independent assessors scoring was 0.977 (p = 0.01) and the test-retest reliability was 0.883 (p = 0.01).*

Conclusion: *An evaluation form proved to be a reliable and effective tool for assessing the anesthetic nurse trainees' checking of an anesthetic machine before the use. This evaluation form was brief, clear and practical to use, and should help to improve anesthetic nurse education and the patient safety.*

Keywords: *Medical device, Anesthetic machine, Anesthetic nurse, Training, Assessment, Evaluation tool*

The importance of a pre-use checklist to detect and correct faults is reflected in guidelines issued by several national anesthesiology societies[1-4], and reports of life-threatening consequences of anesthetic machine faults[5-9]. Suntaranun, et al[4] developed the Thai anesthetic pre-use check model for use in the Department of Anesthesiology, Siriraj Hospital, Bangkok, Thailand in line with 1986 and 1993 United States Federal Drug Administration guidelines and in response to the findings of the Thai Anesthesia Incident Monitoring Study (Thai AIMS) in 1996, which reported that 71% of anesthetic equipment failures or malfunctions were preventable[9]. As a consequence of the increasing complexity of anesthetic machines and the proliferation in the number of different models and manufacturers, the American Society of Anesthesiologists (ASA) equipment and facilities subcommittee published guidelines in 2008 that

included 15 items required in machine- and institution-specific pre-anesthetic checklists[1].

There are several means of providing the necessary training, including didactic teaching, coaching, experiential teaching[11] and simulation[12], but it is important to assess how the trainees perform the skills taught. The authors have provided an anesthetic-machine checking workshop to verify our trainees' ability to completely check the machine and detect leaks for many years; however, a formal evaluation of their skills was not undertaken as part of the Siriraj Hospital training program. In the present study, the authors aimed to develop and validate an evaluation form used to assess the anesthetic machine checking skills of the nurse anesthetic trainees.

Material and Method

The prospective study of the evaluation form was approved by the Siriraj Institutional Review Board in 2012. The written inform consent was obtained from 36 anesthetic nurse trainees. The form consisted of an assessment of 25 individual actions, each required to check different anesthetic machine functions, including detecting leaks in the self-inflating bag, at incoming gas pipelines and back-up cylinder supplies, flow

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meters, vaporizers and vaporizer back bar, anesthetic breathing system, ventilator and scavenging systems. Anesthetic machines used were GE Datex Ohmeda Aestiva 5 and Excel 110 (GE Healthcare, Chalfont St Giles, Buckinghamshire, United Kingdom), both in routine use in our operating rooms. The completion of each item in the checklist was scored as 0, 1 or 2: 0 indicated that an action was not performed; 1 that the action was performed incompletely and/or incorrectly; and 2 that it was performed completely and correctly.

Five expert anesthesiologist trainers, each with more than 10 years' experience, were selected to validate how accurately the items on checklists reflected the objectives of anesthetic machine checking. The validity of the content of evaluation form was assessed by measuring the strength of the correlation between the five experts' opinions.

Thirty-six nurse anesthetic trainees in the 2012 academic year were also selected for the study. Their performance during a 15-minute anesthetic machine check was evaluated by the two independent assessors using the evaluation form. The reliability of the evaluation form was assessed by the strength of the correlation of scores given by each of the two assessors (inter-rater reliability), and two assessments undertaken 7-10 days apart (test-retest reliability). Another five anesthetic nurses gave their opinions on the convenience and the practical use of the evaluation form.

Statistical analysis

The content validity was measured by the index of congruency, and the reliability by Pearson's product-moment correlation. A p-value of <0.01 was considered to be statistically significant. All analyses were undertaken by using the statistical software package SPSS for Window version 18 (SPSS Inc., Chicago, IL).

Results

The correlation between the five experts who validated the accuracy between the items on the evaluation form and the objectives of anesthetic machine checking was 1.00. Pearson's correlation coefficient for test-retest reliability in two independently assessed anesthetic machine checks performed 7-10 days apart was 0.883 ($p = 0.01$). Inter-rater reliability, assessed by the strength of the correlation between scores given by the two independent assessors, was 0.977 ($p = 0.01$). The convenience and practical use of the evaluation form was evaluated by five nurse anesthetists. They were in complete agreement that the evaluation form was convenient and practical.

The content of the evaluation form was found to be valid, and the form itself was found to be reliable, with good correlations on both test-retest and inter-rater reliability (correlation coefficients of 0.833 and 0.977, respectively). Based on these findings, the authors can conclude that the developed evaluation form was a reliable tool for evaluating anesthetic machine checking skills during the anesthetic nurse-training program in our institution.

Discussion

The training program was effective in enhancing knowledge and practices of nursing students. In the present study, the mean of post-test practice score was higher than the mean of pre-test practice score. This was a preliminary test to ensure that the trainees communicated adequately and understood the broad outline of anesthetic machine assessment. Our pre-use anesthetic machine checklist focuses only on the anesthetic machine and self-inflating manual ventilation devices: airway equipment, suction and monitors are not included in the checks, unlike those recommended by the ASA and the Association of Anesthetists of Great Britain and Ireland (AAGBI)[1,2]. Our evaluation form is designed for the anesthetic machines that are currently used in Siriraj Hospital, and trainees are made aware that they will likely encounter different models and manufacturers in their later careers.

Therefore, the evaluation form tests basics of anesthetic machine checking that will be applicable to other machines used in other institutions. The evaluation form can also be used as a record of a comprehensive pre-use anesthetic machine check[2]. The evaluation tool will also need to be revised and refined to reflect the development of new anesthetic machines, and although many modern machines have automated checking systems, errors cannot be completely eliminated and a manual check is still mandatory[1,13,14]. Additional machine complexity may increase the risk of malfunction. The Emergency Care Research Institute (ECRI), an evidence-based practice center operating under the US. Agency for Healthcare Research and Quality, has recently reported that incomplete pre-use inspection of the anesthetic machine was among the top ten technology hazards in 2012[15]. The nurse anesthetist, who is ultimately responsible for the anesthetic machine, must focus on preventing both equipment and human errors, so

should be well trained and competent in pre-use anesthetic machine checking.

The AAGBI had been created the checking anesthetic equipment guideline in 2012. This guideline recommended that the pre-use check to ensure the correct functioning of anesthetic equipment was essential to patient safety. The anesthesiologist has a primary responsibility to understand the function of anesthetic equipment and to test it before the use. Anesthesiologists must not use equipment unless they had been qualified to use it and are proficient to do so. A self-inflating bag must be immediately available in any location where anesthesia might be given. Moreover, a two-bag test should be performed after the breathing system, vaporizers and ventilator had been checked individually. Finally, a record should be kept with the anesthetic machine that these checks had been completed[2].

Currently, anesthetic machine and monitoring equipment have evolved to integrate various mechanical, electrical and electronic components to be more appropriately[16]. Modern machines have overcome many drawbacks associated with the older anesthetic machines. However, addition of several mechanical, electronic and electric components has contributed to recurrence of some of the older problems such as leaks or obstruction. Actually, no single checklist can satisfactorily test the integrity and safety of all existing anesthetic machines due to their complex nature. Human factors have contributed to greater complications than the machine faults[17]. Therefore, better understanding of the basics of anesthetic machine and testing each component of the machine is an important issue. Clear documentation of regular and appropriate servicing of the anesthetic machine, its components and their satisfactory functioning following servicing and repair is also equally essential. Goneppanavar and coworkers reviewed the anesthetic machine including checklist, hazards and the scavenging system. This report confirmed the fact that problems could occur despite the incorporation of several safety characteristics to the anesthetic machine. Human factors had impacted to higher complications than the machine faults. Consequently, better understanding of the basics of anesthetic machine and testing each component of the machine for appropriate functioning before the use is essential to diminish these hazards. Although advanced technology is utilized, however, a life-threatening possibility of intra-operative machine malfunction exists[17].

Moreover, Sweeney, et al studied the level two and level three checks on anesthesia delivery systems performed at three hospitals in South Australia[18]. This prospective audit evaluated the adherence of the anesthetic practitioners to a selection of those recommendations. Covert observations of the anesthetic practitioners were completed while they were checking their designated anesthetic machine. The results of this study demonstrated poor compliance with the recommendations. The backup oxygen cylinders' pressure/contents were not checked in 45% of observations. The breathing circuit was not tested between patients in 79% of observations. In addition, the emergency ventilation device was not checked in 67% of observations, and the documentation of the checks performed was not finished in any cases[18].

However, there are several limitations of this study that should be noted. First, the present report used only an evaluation form for assessing the trainees' checking of an anesthetic machine. Second, this is a single-center study in a developing country. These results could not be constantly duplicated in other settings. This reflects anesthetic practice in Thailand. Third, a sample size of the study was relatively small due to limitation of time and the total number of trainees. Fourth, there are several anesthesiologists participated in this study. A wide variability of the experience might be occurred. However, the authors, therefore, assume that the data are realistic and reveal daily clinical practice. Fifth, this report requires further studies for the construct, concurrent and predictive validity in the targeted population. Finally, our results may not be applicable to the settings in the other developed countries.

In conclusion, the evaluation form that we developed was found to be an effective tool for evaluating the anesthetic nurse trainee in the anesthetic machine checking performance. Additionally, it can itself be used as a written record of a comprehensive pre-use check of the anesthetic machine. This evaluation form was brief, clear and practical to use, and should help to improve anesthetic nurse education and the patient safety.

What is already known on this topic?

There are the guidelines to minimize equipment-related risks on checking anesthetic machine issued by several national anesthesiology societies. The pre-use effective evaluation form is used as a tool for evaluating trainee nurse anesthetists' anesthetic machine checking performance. Importantly, the correct

and complete performed pre-use checkup of anesthetic machine is an essential skill to prevent the machine faults and human errors. In Thailand, no standard guidelines were utilized for anesthetic machine checklists. Each center has been created its guideline.

What this study adds?
No single checklist can satisfactorily test the integrity and safety of all existing anesthetic machines due to their complex nature. Human factors have contributed to greater complications than machine faults. Therefore, better understanding of the basics of anesthetic machine and checking each component of the machine for proper functioning prior to use is essential to minimize these hazards.

Potential conflicts of interest
None.

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Appendix 1.

The Pre-used Anesthetic Machine Checklist for Anesthetist Nurse Trainee
Trainee …………………………   Examiner ……………………………….
Date............…..………….………….   Machine   ………………………………
The score as the following.
0 = Undo, 1 = Incorrect or/and Incomplete Performance, 2 = Correct and Complete Performance

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Performance	0	1	2

1. Verify self-inflating manual ventilation device are available & function.
    - Verify self-inflating bag and mask are ready to use.
    - Check the manual ventilation by squeeze the bag, there is gas vent out to mask.
    - Verify the bag and valve functions properly by squeezing the bag while occluding
    the outlet port, the bag should not deflate.
2. Prepare no flow inside the low pressure system.
    - Turn off the machine master switch.
    - Dial up O_2 and N_2O flow control knob to let all gases out.
    - Observe the O_2 bobbin N_2O bobbin at zero position.
3. Perform leak check of machine low pressure system.
    - Verify suction bulb fully collapsed for at least 30 second during connect to
    common gas outlet.
4. Perform leak check of machine low pressure system with vaporizer.
    - Turn on vaporizer at 1%.
    - Perform leak check of machine low pressure system as 3.
    - Turn off vaporizer.
5. Turn on anesthesia delivery system and confirm that AC power is available.
    - Reconnect fresh gas inlet of breathing system with common gas outlet.
    - Plug machine AC power.
    - Turn on master switch.
6. Verify backup gas cylinder and cylinder key.
    - Verify O_2 cylinder and N_2O cylinder supply (include Air cylinder if available).
    - Check for availability and perform turn cylinder key on-off.
7. Perform prepare O_2 cylinder ready to use.
    - Use Key to turn on the cylinder valves.
    - Turn on O_2 cylinder and reassure pressure gauge show more than 1,000 psi.
    - Adjust O_2 flowmeter to 3 litres/minute.
8. Perform prepare N_2O cylinder ready to use.
    - Turn on N_2O cylinder and check pressure.
    - Adjust N_2O flowmeter to 3 litres/minute.
9. Verify low O_2 supply failure alarm and pressure sensor shutoff valve.
    - When close the O_2 cylinder, the sequence of the N_2O bobbin fall, O_2 supply failure
    alarm and O_2 bobbin fall occur.
10. Check O_2 pipeline and cross connection.
    - Plug in O_2 pipeline correctly.
    - O_2 Pipeline gauge read 50-55 psi, N_2O Pipeline gauge read 0 psi.
    - The bobbin of O_2 flowmeter and N_2O flowmeter raised up.
11. Check N_2O pipeline and cross connection.
    - Plug in N_2O pipeline correctly.
    - N_2O Pipeline gauge read 50-55 psi.
    - The bobbin of O_2 flowmeter and N_2O flowmeter in the same position.
12. Check flow proportioning device.
    - Decrease O_2 flow down to create hypoxic O_2/N_2O mixture.
    - The N_2O bobbin automatically fall.

Appendix 1.   Cont.

Performance	0	1	2

13. Install the breathing circuit and check CO_2 absorber.
   - Connect the cleaned, undamaged corrugate breathing tubes to inspired and expired limb.
   - Connect breathing bag to Y-piece.
   - Connect ventilating bag.
   - Check color and volume of sodalime in CO_2 absorber.
14. Perform leak check of breathing system.
   - Turn off all gas flow controlled knob to zero (or minimum for O_2 flow).
   - Close APL valve and occlude Y-piece to make a closed system.
   - Press O_2 flush to pressurized breathing system to 30 cm H_2O.
   - Pressure remains unchanged for at least 10 seconds.
15. Check adjustable pressure limiting (APL) valve.
   - Open the APL valve, the pressure drop freely.
16. Adjust and check scavenging system function.
   - Plug in vacuum pipeline correctly.
   - Ensure proper connections between scavenging limb and both APL valve and
   ventilator relief valve.
   - Adjust optimum pressure waste gas vacuum by observe the waste gas reservoir bag.
17. Verify Negative pressure relief valve.
   - Turn on minimum O_2 flow to use.
   - Open APL valve and occlude Y-piece of breathing system.
   - Adjust the scavenging valve to maximum suction.
   - Observe scavenging reservoir bag collapse completely and verify that absorber pressure gauge
   ≥ 0 cm H_2O.
18. Verify Positive pressure relief valve.
   - Press O_2 flush.
   - Observe scavenger reservoir bag fully distend and verify that absorber pressure gauge
   <10 cm H_2O.
19. Test ventilation systems and unidirectional valves.
   - Install corrugates to ventilator.
   - Plug the power line of ventilator.
20. Set appropriate ventilator parameters.
   - Set appropriate ventilator mode, tidal volume/minute volume, respiratory rate and I: E ratio.
21. Verify the ventilator function.
   - Place a reservoir bag (represent lung) on Y-piece of breathing system.
   - Switch to ventilator mode.
   - Turn on the ventilator.
   - Verify bellow movement and appropriate tidal volume.
22. Verify proper action of unidirectional valves.
   - Observe the proper opening-closing movement of the inspired and expired valves.
23. Verify low pressure alarm.
   - Audible low pressure alarm occur after disconnect the reservoir bag.
   - Turn off the ventilator.
24. Verify the manual ventilated function.
   - Place a reservoir bag (represent lung) on Y-piece of breathing system.
   - Switch to bag mode.
   - Manual ventilation.
   - Verify reservoir bag movement.
25. Prepare the ready to use breathing system.
   - Replace the mask in position of the reservoir bag from Y-piece.
Total = …………

การพัฒนาแบบประเมินเครื่องดมยาสลบ

สุภิญญา ติวิรัช, เบญจรัตน์ หยกอุบล, สมชาย อมรโยธิน

วัตถุประสงค์: เพื่อสร้างและตรวจสอบคุณภาพแบบประเมินที่ใช้ประเมินความสามารถของนักศึกษาวิสัญญีพยาบาล ในการตรวจสอบเครื่องให้ยาดมสลบ ก่อนการใช้งาน

วัสดุและวิธีการ: แบบประเมินนี้ประกอบด้วย 25 ข้อ ที่พัฒนาจากแนวทางปฏิบัติเพื่อการตรวจสอบเครื่องให้ยาดมสลบก่อนการใช้งานของราชวิทยาลัย วิสัญญีแพทย์แห่งประเทศไทยที่ใช้ในโรงพยาบาลศิริราช ประกอบด้วยการตรวจระบบท่อบรรจุก๊าซ ท่อส่งก๊าซ ท่อติดตั้งเครื่องทำไอระเหยยาสลบ เครื่องช่วยหายใจ วงจรระบบหายใจ ระบบกำจัดก๊าซทิ้ง และอุปกรณ์สำรองช่วยหายใจ ผู้นิพนธ์ได้ตรวจสอบความตรงเชิงเนื้อหาโดยให้ผู้มีประสบการณ์สอน 5 คน ตรวจสอบความเที่ยงของแบบประเมิน ผู้นิพนธ์วัด inter-rater จากคะแนนที่ได้จากผู้ประเมิน 2 คน ประเมินนักศึกษาวิสัญญีพยาบาล 36 คน ในการตรวจเครื่องดมยาสลบภายในเวลา 15 นาทีต่อคน และ test-retest reliability จากการประเมิน 2 ครั้ง ห่างกัน 7 วัน

ผลการศึกษา: วิสัญญีแพทย์ทั้ง 5 คนประเมินว่าแบบประเมินการตรวจสอบเครื่องให้ยาดมสลบก่อนการใช้งานมีความถูกต้องตามวัตถุประสงค์ มีดัชนี ความสอดคล้อง ความตรง (index of congruency) เชิงเนื้อหาเท่ากับ 1.00 ความเที่ยงของการให้คะแนนโดยผู้ประเมิน 2 คน มีความสัมพันธ์กัน (r = 0.977) อย่างมีนัยสำคัญทางสถิติ นอกจากนี้ความเที่ยงของแบบประเมินโดยการวัดซ้ำพบว่าคะแนนการวัดครั้งที่ 1 สัมพันธ์กับคะแนนการวัดครั้งที่ 2 (r = 0.883) อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.01

สรุป: แบบประเมินการตรวจสอบเครื่องให้ยาดมสลบก่อนการใช้งานโดยนักศึกษาวิสัญญีพยาบาลสามารถพิสูจน์ได้ว่า เป็นเครื่องมือที่มีคุณภาพและเชื่อถือได้ แบบประเมินนี้ สั้น มีความชัดเจนและสะดวกในการใช้ นอกจากนี้ยังช่วยในการเรียนรู้ของนักศึกษาวิสัญญีพยาบาล และเพิ่มความปลอดภัยในการดูแลผู้ป่วย