Inadequate preanesthesia equipment checks in a simulator

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Purpose: To assess how completely anesthesiologists check their machinery and equipment before use, and to determine what influence seniority, age and type of practice may have on checking practices.

Methods: One hundred and twenty anesthesiologists were videotaped during a simulated anesthesia session. Each participant was scored by an assessor according to the number of items checked prior to the induction of anesthesia. A checklist of 20 items derived from well-publicized, international standards was used.

Results: Participants were grouped according to their type of practice. Overall, mean scores were low. The ideal score was 20. There were no differences among university anesthesiologists (mean score 10.1, standard deviation 4.3), community anesthesiologists (7.5 ± 4.3) and anesthesia residents (9.0 ± 3.8). Each of these groups scored, on average, better than medical students (3.6 ± 3.7) ($P < 0.05$). Neither age ($r = 0.15$, $P > 0.1$) nor number of years in practice ($r = -0.18$, $P > 0.1$) correlated with score.

Conclusions: Our study suggests that the equipment-checking practices of anesthesiologists require considerable improvement when compared with national and international standards. Possible reasons for this are discussed and some remedial suggestions are made.

Objectif : Évaluer le degré de vérification des appareils faite par les anesthésiologistes avant de les utiliser et déterminer l'influence de l'ancienneté, de l'âge et du type de pratique sur les habitudes de vérification.

Méthode : Cent vingt anesthésiologistes ont été filmés sur vidéocassette pendant une session d'anesthésie simulée. Chaque participant a été coté par un évaluateur selon le nombre d'éléments vérifiés avant l'induction de l'anesthésie. On a utilisé une liste de 20 éléments dérivée de normes internationales bien connues.

Résultats : Les participants ont été regroupés selon leur type de pratique. Globalement, les scores moyens ont été faibles. Le meilleur score a été de 20. Il n'y avait pas de différence entre les anesthésiologistes spécialistes (moyenne de 10,1 et écart type de 4,3), les anesthésiologistes omnipraticiens (7,5 ± 4,3) et les résidents en anesthésie (9,0 ± 3,8). Chacun de ces groupes a affiché des scores moyens meilleurs que ceux des étudiants de médecine (3,6 ± 3,7) ($P < 0,05$). Il n'y avait pas de corrélation entre l'âge ($r = 0,15, P > 0,1$) ou le nombre d'années d'exercice ($r = -0,18$, $P > 0,1$) et le score obtenu.

Conclusion : Notre étude permet de présumer que les habitudes de vérification de l'équipement des anesthésiologistes, comparées aux normes nationales et internationales, doivent être de beaucoup améliorées. Les causes possibles de cette situation sont examinées et certaines solutions sont proposées.

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FAILURE to check equipment and equipment failure have been repeatedly identified in published critical incident reviews as important, preventable contributors to anesthesia-related morbidity and mortality.[1–4]

In response to this, several national anesthesia organizations have published guidelines and checklists to improve knowledge of, and compliance with, pre-use anesthesia equipment checking practices.[5–7] The Canadian Anesthesiologists' Society requires that "a pre-anesthetic (equipment) checklist shall be completed prior to the initiation of anesthesia", and provides members with such a checklist annually.[8]

Despite such efforts, checking practices appear to remain poor.[9–11] The goal of this study was to examine how anesthesiologists check their equipment. We hypothesized that the completeness of the inspection would vary with the seniority, age and/or type of practice of the anesthesiologist.

Methods

After institutional research ethics board approval, written, informed consent was obtained from all participants. Four groups were identified according to type of practice: anesthesiologists in university practice (UA), anesthesiologists in community practice (CA), residents in anesthesia programs (Res), and medical students in their anesthesia rotation (MS). Medical students were in their final year and participated in the study during the second week of a two-week anesthesia clerkship. Residents were in their final six months of training and eligible to sit the national specialty examination. University and community anesthesiologists were drawn from multiple institutions from across Ontario. All subjects participated in a study involving a clinical scenario in an anesthesia simulator, in which the participant assumed the role of the anesthesiologist.

Our Simulation Centre consists of a mock operating room containing an anesthesia gas machine (Ohmeda, Excel 210 SE), patient physiological monitors (Datex, AS3), anesthesia drug cart, operating table, instrument table, and electrocautery machine. Drapes, intravenous infusions and surgical instruments were used to enhance the realism of the simulation. The patient mannequin (MedSim Advanced Medical Simulations Ltd) was positioned on the operating table, and the role of the members of the operating room team, such as the surgeon and circulating nurse, were scripted and acted by the investigators. The details of our simulation centre have been described elsewhere.[12] All subjects were asked to participate in a study that evaluated the simulator as a testing tool and subjects were aware that simulated patient and/or technical problems would be presented to them, as part of the testing procedure. All participants received a 30 min familiarization with the mannequin, gas machine, physiological monitor and simulation facility. All participants were given the same clinical scenario and patient information. A research assistant (respiratory therapist) played the role of the circulating nurse, and was available to answer questions and provide assistance and information with respect to the equipment during the familiarization and the simulation session.

Participants were given a standardized patient in the simulator environment. All were told that the case they were about to manage was the first case of the day for that operating room. They were instructed to manage the patient and to start the case as was their customary practice, but subjects were not prompted to check the anesthesia machine for faults. The performance of each participant was videotaped for later review and assessment. All videotapes were analyzed by a single reviewer.

We constructed a checklist of 20 items (Figure 1), being an amalgamation and modification of several widely available checklists.[5–7] Our checklist was not designed as a comprehensive list of all items which should be checked at the beginning of each day, or at the beginning of any case. Items were included only if

	Checked	*Omitted*
1. High pressure system		
a. O_2 cylinder: contents	____	____
b. pipelines: connections	____	____
2. Low pressure system		
a. control valves/flow meters	____	____
b. vaporizers	____	____
c. precircuit leaks: check	____	____
d. breathing system		
i. assembly	____	____
ii. leaks	____	____
iii. unidirectional valves	____	____
iv. APL valve function	____	____
e. O_2 failure device	____	____
f. O_2 flush	____	____
3. Ventilator		
a. function	____	____
b. leaks	____	____
c. low pressure alarm	____	____
4. Scavenging system		
a. connections	____	____
b. suction on	____	____
5. Emergency ventilation system		
a. functional	____	____
6. Other apparatus		
a. airway equipment	____	____
b. suction: i. configuration	____	____
ii. adequate function	____	____

FIGURE 1 Checklist for preanesthesia equipment check

TABLE Demographic characteristics of groups

Group	*N*	*Age(years)**	*Years in Practice†*
University anesthesiologists	27	39.5 ± 7.1	8.0 ± 6.5
Community anesthesiologists	41	44.6 ± 8.9	14.2 ± 9.9
Residents	21	31.5 ± 3.7	NA
Medical students	31	26.6 ± 3.0	NA

Values are expressed as mean ± SD

*Age differences significant between all groups (Bonferroni $P < 0.05$) except Res *vs* MS (P = NS)

†No. of years in practice significantly different for UA *vs* CA ($P < 0.05$).

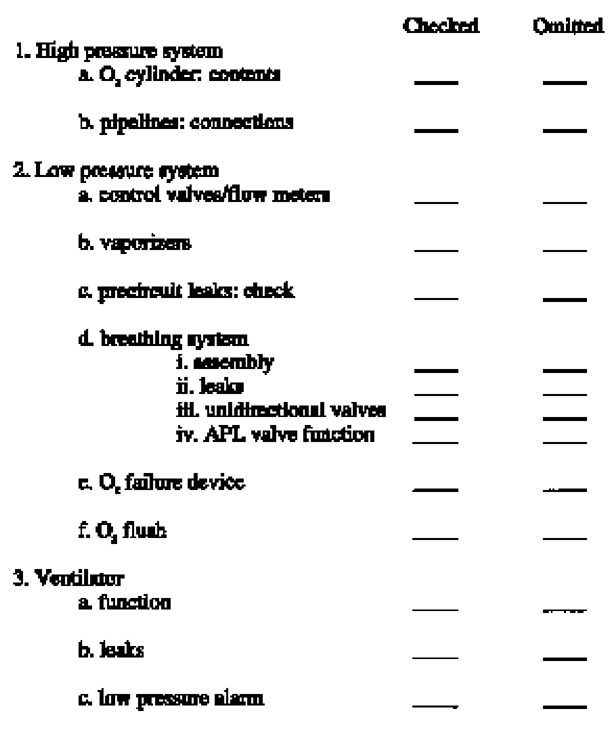

FIGURE 2 Number of participants checking each item on the checklist.

their performance or omission could be reliably discerned on the videotape.

Each item was classified as "checked" or "omitted". For reliability and simplicity, if the participant attempted to check an item (even if it was performed incompletely or ineffectively), the item was classified as having been checked.

Each participant was given a score out of twenty according to the number of items attempted. Only items performed prior to the "induction" of anesthesia were counted.

For statistical analysis, group differences were compared using analysis of variance, with $P < 0.05$ considered significant. Subjects' age and years in practice were compared using the Pearson correlation coefficient, using the square root transformation of the performance score for the machine check (to normalize distribution), and with $P < 0.05$ and $r > 0.8$ considered significant. Comparison of mean age and number of years in practice for all groups was made using one-way analysis of variance followed by pair-wise comparisons (t test with Bonferroni correction).

Results

The demographic characteristics of each group are summarized in Table. Differences in ages were statistically significant for all groups, except between MS and Res. CA had significantly more years in practice than UA.

The numbers of participants checking each individual item are displayed in Figure 2.

The group differences were not significant, except that MS scored on average lower than either UA, CA or Res (Figure 3).

We then compared the scores with the age of each participant (Figure 4). There was no correlation, either positive or negative, between the square root transformation of the score, and increasing age. Similarly, when the number of years in practice (for UA and CA participants) was analyzed with respect to the square root transformation of the score, there was no correlation between the two (Figure 5).

Discussion

We used a simulated anesthesia environment, and found that performance of preanesthesia equipment inspection was poor regardless of the age or experience of the anesthesiologist. The performance of some participants may have reflected their discomfort at being outside their normal environment, in a "test" situation. Most participants agreed at the end of their session in the simulator, however, that the simulation was realistic.[1 3] Only a small proportion of participants performed no checks at all, suggesting that most participants realized that an equipment check was required prior to this "first case of the day". We did not attempt to "weight" the criteria, although we recognize that the accurate checking of some criteria in our checklist may be more important to patient safety than others. Not all participants were familiar with the anesthetic machine and monitors before their simulator session. Extensive orientation was therefore given prior to the session, in order to minimize the potential bias this may have introduced to our study.

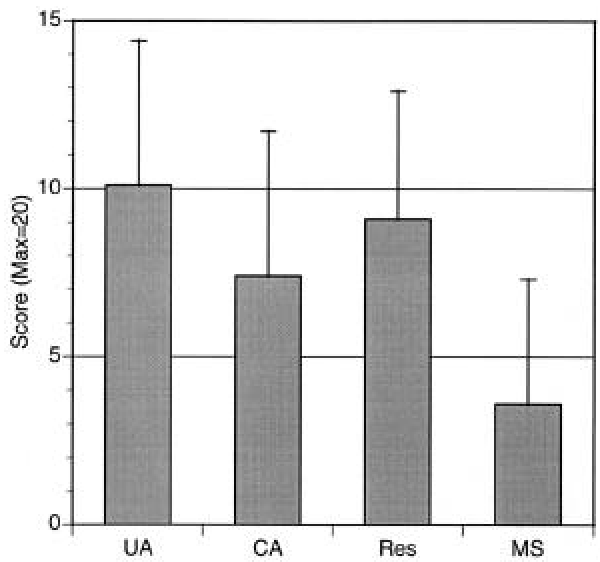

FIGURE 3 Mean scores (+SD) for each group. UA, university anesthesiologists; CA, community anesthesiologists; Res, anesthesia residents; MS, medical students. *MS mean score significantly lower than UA, CA and Res ($P < 0.05$).

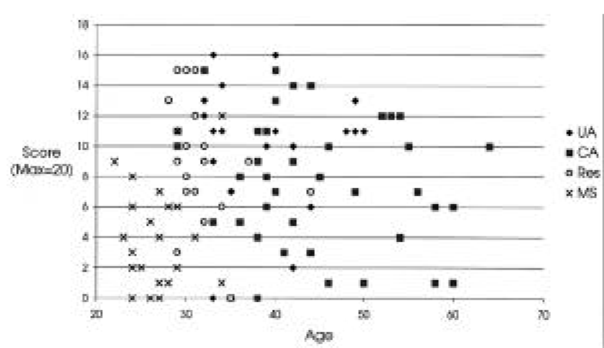

FIGURE 4 Individual score *vs* age. UA, university anesthesiologists; CA, community anesthesiologists; Res, anesthesia residents; MS, medical students. No correlation found between age and score ($r = 0.15$, $p = 0.1$).

Most participants entered the simulator session with the expectation that something was going to go wrong. (This is in contrast to the inherent safety and relative predictability of day-to-day anesthesia practice.) This expectation should have motivated participants to be even more thorough than they might usually be in checking the equipment in the simulator. We feel, therefore, that it is likely that our results

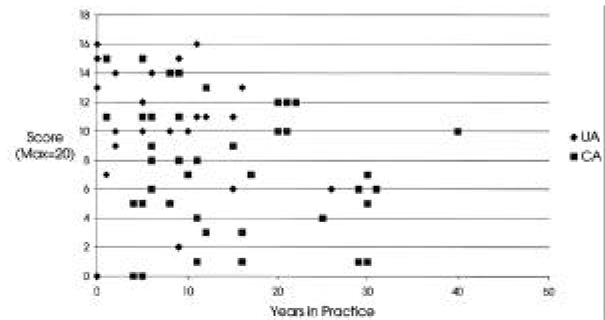

FIGURE 5 Individual score *vs* number of years in practice. UA, university anesthesiologists; CA, community anesthesiologists. No correlation found between score and number of years in practice ($r = -0.18$, $P = 0.14$).

reflect the habitual checking practices of many anesthesiologists.

This raises the question of why pre-use checking practices may be inadequate. It has been suggested that thorough checking takes too long,[14] although this may be operator- and experience-dependent. Time taken for equipment checking may be perceived by some as reducing the time available for surgery, and these anesthesiologists may believe there is a trade-off between patient safety and increased time efficiency in the operating room. Some anesthesiologists may delegate checking of equipment to others,[9] although ultimate (and legal) responsibility for the proper functioning of the equipment is currently deemed to be with the anesthesiologist.[9,15]

Knowledge of the structure, physics and function of the anesthetic machine is integral in the training of specialist anesthetists. Lack of knowledge of the equipment should therefore not be an impediment to adequate pre-use checking practices. In a study designed to look at the ability of the FDA checklist to improve equipment fault detection by anesthesiologists, March and Crowley[16] used a multiple-choice questionnaire (MCQ) about machine function to compare the ability of participants to detect machine faults with their theoretical knowledge of equipment. Overall fault detection rates were low, and although there was a statistically positive correlation with MCQ score, the authors commented that the correlation was not as strong as they had expected. They suggested that in their study, "practitioners may understand the function of the machines but may be unable to apply that understanding to practical clinical skill".

Olympio *et al.*[11] demonstrated that even when residents attempt to check their equipment, the check is frequently incorrectly or incompletely performed, which further limits their ability to identify machine faults. In our study, we did not assess the effectiveness of checking procedures; we do not know if the participants understood what they were doing, or how effective were the checks they performed.

It is possible that, with continued improvements in monitoring over the last 15-20 yr, anesthesiologists have come to rely on a combination of vigilance and monitoring to warn them when there is something wrong with their equipment. In the Australian Incident Monitoring Study of 2000 critical incidents, about 75% of equipment failures were, or could have been, identified by a combination of standard monitors and anesthetic vigilance.[17] To rely on monitors in this way is to reduce the margin of patient safety, as monitors often indicate problems only after considerable harm or physiological disturbance has occurred. In the confusion which can surround a critical incident, it should be reassuring to the anesthesiologist that the equipment was checked and in working order at the start of the case. This of course does not preclude the possibility of unexpected equipment failure, emphasizing the need for effective emergency response and crisis management.[4]

Given the results of this and previous studies, how can the performance of preanesthesia checks be improved? As detailed above, recommendations from national professional bodies and warnings from critical incident reviews have not been sufficient.

Olympio *et al.*[11] attempted to improve the performance of resident anesthetists by intensive training sessions, involving videotaping of residents' performances, followed by review with faculty and then repeat examination of checkout procedures several weeks later. Subjects who received the extra training and review sessions scored higher than controls on repeat testing, but there was no long-term follow-up and it is unclear whether differences would have been sustained.

Checklists and visual aids have been formulated with the aim of making it easier for anesthesiologists to perform pre-use checks rapidly and completely.[5–7,18] Use of these is not widespread in clinical practice. There is some debate as to whether their use improves performance when compared with an anesthesiologist's usual checkout methods.[15,19] Groves *et al.*[14] found that the use of the visual aid produced by Adams[18] (based on the checklist of the Association of Anaesthetists of Great Britain and Ireland) resulted in overall improvement in fault detection, although some of their prearranged machine faults were discovered less often when the aid was used.

There have been criticisms of these checklists because of perceived incompleteness or ineffectiveness,[20] and because of time constraints as discussed above. Some effort has been made to produce abridged versions of the checklists,[21] but it is unclear whether this produces unacceptable reductions in the ability to identify equipment faults.

Berge *et al.*[22] have used an anesthesia simulator in a novel approach to training personnel in the detection of machine faults. Their simulator uses an anesthetic machine which is normal in external appearance but which is internally modified such that multiple machine dysfunctions may be reproduced. This has the potential to improve the understanding of the machine by trainees, by mimicking faults which may be infrequent but important in clinical practice. Such technology is expensive and not widely available, however, limiting its usefulness.

Our study indicates that the performance of residents is as poor as the performance of consultants, suggesting that experience alone is unlikely to improve checking practices. Current teaching places little emphasis on this vital part of anesthesia practice. There may be a role for compulsory inclusion of refresher courses in pre-use checking procedures in continuing medical education.

To improve compliance with checking procedures, measures may be taken at an institutional or national level to require anesthesiologists to document what checks they have performed at the start of each case. If pre-use checks are truly a patient safety issue, it is no longer sufficient to make these checks an optional part of an anesthetic. Failure to check represents a rule-based error in anesthesia, which should be reducible.[23]

There is widespread acknowledgment in the field of anesthesia that pre-use equipment checking procedures are important in patient safety. Although there are no randomized, controlled trials published to prove that efficient checking procedures reduce the frequency of incidents or accidents in anesthesia, "failure to perform an adequate check" is repeatedly identified as the primary error in one-quarter to one-third of all critical incidents.[1–3]

It is not uncommon to find major faults in equipment in routine use. Barthram and McClymont,[24] using the Association of Anaesthetists of Great Britain and Ireland's checklist for anesthetic machines, found faults in 60% of machines checked. 18% of these were deemed to be serious, i.e. having the potential to lead to rapid disaster.

In other areas of human endeavour, where the results of an error may be catastrophic (the analogous nature of aviation is often cited), formal equipment checking procedures are frequently instituted.

Anesthesia is such an area, but there is, as yet, no compulsion on the part of the anesthesiologist to check that all equipment is in working order.

In summary, the type of practice, age or number of years in practice of the anesthesiologist has no effect on the completeness of the pre-use anesthesia equipment check; a consultant was as likely to check his or her equipment as well as the residents they teach.

Lack of correlation between score and number of years in practice suggests that familiarity does not breed complacency with regard to checking equipment. Rather, our study suggests that anesthesiologists check their equipment inadequately from early in their careers and do not tend to improve with experience. We suggest that our professional organizations need to review their current policies on equipment checks, and attempt to improve education as the first step in improving patient safety in this area.

Addendum

Updated versions of anesthesia equipment checking standards may be found at:

www.asahq.org/ProfInfo/FDA.html
www.aagbi.org/docs/checklist.doc
www.cas.ca/public/

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