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Research Article

Microbiological safety and cost-effectiveness of weekly breathing circuit changes in combination with heat moisture exchange filters: a prospective longitudinal clinical survey

Mikrobiologische Sicherheit und Kosteneffektivität wöchentlicher Wechsel von Beatmungsschläuchen unter Verwendung von Atemsystemfiltern: eine klinische prospektive Longitudinalstudie

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Abstract

Aim: To assess the safety and cost effectiveness of a usage for seven days of breathing circuit systems (BCSs) in combination with heat moisture exchanger filters (HMEF) in operation room anesthesia.
Method: In a prospective longitudinal clinical study, the contamination on high-risk surfaces (HMEF together with inner and outer surface of BCS) was monitored over 1, 2, 5, and 7 days. Results of endogenous respiratory patient flora and contamination flora of BCS, HMEF and bag were compared. Costs of prolonged use of BCS together with HMEF up to 7 days were calculated.
Results: Neither physiological respiratory flora nor colonizing pathogens of the oropharynx of the ventilated patients were transmitted through the filters at any time. None of the included patients developed a post-operative pneumonia. Using the BCS for 24 hours provides a cost savings of up to 40% versus single use. Extending the change interval from 24 hours to 48 hours saved over 50% compared to change after each patient, and an additional 19% compared to change after 24 hours. In combination with a HMEF BCS can be used up to 7 days without clinical risk on multiple patients in operation room settings.
Conclusion: Expanding the usage of berating in combination with usage of moist exchange filters is feasible, microbiologically safe and cost effective, as 41% of material costs per ventilation may be saved. Further research is needed to confirm these results.

Keywords: ventilator-associated-pneumonia (VAP), anesthesia breathing circuit system, heat and moisture exchange filter (HMEF), cost effectiveness

Zusammenfassung

Zielsetzung: Es wurde die Sicherheit und Kosteneinsparung bei verlängerter Nutzung des Narkoseschlauchsystems für die Dauer von 7 d unter Verwendung eines Wärme- und Feuchtigkeitsaustausch (HME)-Filters analysiert.
Methode: In einer prospektiven longitudinalen klinischen Studie wurde die mikrobielle Kontamination von Hochrisikoflächen (HME zusammen mit der inneren und äußeren Oberfläche des Narkoseschlauchsystems) sowie des Handbeatmungsbeutels nach 1, 2, 5 und 7 d ermittelt. Dabei wurde die endogene respiratorische Flora des Patienten mit der Kontaminationsflora verglichen. Ferner wurde die Kosteneinsparung durch die verlängerte Nutzung des Narkoseschlauchsystems einschließlich der Filterkosten berechnet.

Ergebnisse: Weder physiologische respiratorische Flora noch kolonisierende Pathogene des Oropharynx passierten zu irgendeinem Zeitpunkt den Filter. Keiner der in die Studie eingeschlossenen Patienten entwickelte eine Pneumonie. Die Benutzung des Narkoseschlauchsystems für 24 h anstatt Einmalverwendung führt zu einer Kostenersparnis von 40%. Eine Nutzungsverlängerung auf 48 h führt zu einer Kostenersparnis von 50% bzw. im Vergleich zu täglichem Wechsel um 19%. In Verbindung mit dem HME-Filter kann das Narkoseschlauchsystem ohne erhöhtes Risiko und zugleich kosteneffektiv für aufeinanderfolgende Patienten eingesetzt werden.
Schlussfolgerung: Eine Verlängerung des Einsatzes des Narkoseschlauchsystems unter ständigem Einsatz von patientenbezogenen Atemsystemfiltern ist mikrobiologisch sicher und kosteneffektiv. Es können damit je Narkosebeatmung 41% der bestehenden Materialkosten eingespart werden. Zur Absicherung der Ergebnisse sind weitere Untersuchungen erforderlich.

Schlüsselwörter: Beatmungs-assoziierte Pneumonie, Atemsystemfilter, Wärme- und Feuchtigkeitsaustausch-Filter (HMEF), Kosteneinsparung

Introduction

To protect microbial contamination of anesthesia machines' breathing circuit system (BCS) used for patients undergoing general anesthesia, two possibilities are common: changing the complete BCS after each patient if no airway filter system is used, or prolonged use of BCS in combination with airway system filters, preferable heat and moisture exchange filters (HMEF). While the HMEF is intended for single use only, BCS can either be single used or reused. The filtration efficacy and safety of HMEF are well studied [1], [2], [3], however, there is still limited clinical evidence on the optimal duration for prolonged BCS usage when used for more than 24 hours in operating room settings [4], [5], [6], [7], [8]. Existing recommendations differ, e.g. the CDC (Centers for Disease Control and Prevention, USA) guidelines recommend the change of BCS after each patient without recommendation for the use of HMEF [9]. The German Robert Koch-Institute recommends the change of BCS after each patient or the change of BCS after 24 h when used together with HMEF [10]. And the Association of periOperative Registered Nurses (AORN) recommends maximum usage of BCS for up to one week only in combination with HMEF [11].
Because of the existing uncertainty on the duration of use, the goal of our study was to conduct a randomized longitudinal prospective trial to investigate the microbial contamination of an HMEF protected BCS over 1, 2, 5, and 7 days of usage.

Methods

Ultipor 25® (PALL AG, Dreieich, Germany) was used as HMEF. The BCS used was Tyco® 300/13324 (Mallinckrodt, Mirandola, Italy), the anesthesia-ventilators were Primus® (Draeger, Lübeck, Germany). All HMEF were changed after each patient. HMEF protected BCS were continuously used for multiple patients over 24 h, 48 h, 5 days or 7 days, respectively. A total of 378 patients were included into the study. In a total of 110 patients, BCS were changed completely after 24 h. In 75 patients, BCS were changed every 48 h. In 138 patients, BCS were changed after 5 days. And in 55 patients BCS were changed after 7 days. On average, 2 patients (range 1–6) were ventilated using the same BCS in 24 h. To avoid cross-contamination after each anesthesia, the surfaces of BCS and anesthesia bags were disinfected with a commercial alcohol-based product (Incidin Foam, Ecolab, Germany) with declared anti-HBV efficacy.
The study was approved by the ethics committee of the Ernst-Moritz-Arndt University of Greifswald (grant no. III UV 26/05). Informed consent was obtained from all participating patients. All general anesthesia were performed by anesthesiologists from the Department of Anesthesiology and Intensive Care Medicine of the University of Greifswald in the hospital's central operation rooms.
Basic demographic and medical data are presented in Table 1. Mean age over all groups was 56.6 years. Most participants were neurosurgical patients, typical indications for surgery being disc prolapses, spinal or cranial tumors. Age and type of surgery were pretty homogenous between groups.
Surgical interventions less than 0.5 hours were excluded as well as patients with ASA score ≥IV, patients with blood stream or respiratory tract infections, immuno-suppression and surgical interventions on the respiratory tract.
Furthermore, if BCS or HMEF were visibly soiled or damaged, results were excluded from the study. All BCS or HMEF were checked and monitored for visible contamination and damages during surgical intervention in the operating room and routinely 3 times daily during the whole post-operative period of ventilation. The ventilator's alarm function (leakage alarm) was used to detect leakages in the BCS.
The pharyngeal and tracheal flora of the patient, as well as the contamination of the inner and outer surface of the BCS were microbiologically investigated. From each

Table 1: Basic demographical (mean age, gender) and medical data (type of surgery) of participants

Change interval		24 h	48 h	5 d	7 d
Mean age		52.00	58.00	57.92	52.90
Ratio m/w		2.00	0.00	0.68	1.50
Neurosurgery	spinal %	33.3	50	29.7	70
	cranial %	0	0	21.6	10
	peripher nervous %	33.3	0	0	10
Eye surgery %		33.3	50	18.9	0
Traumatology%		0	0	29.7	10

patient, pharyngeal swabs were taken immediately before intubation and after extubation. Additionally, swabs from the tip of the endo-tracheal tube and from both inner lumen sides of the HMEF (patient and machine side) were taken after extubation. The contamination inside of the BCS tube was investigated after the last surgical procedure on a day by sampling the condensation water followed by consecutive cultivation over 48 hours at 36°C. The outer surfaces of the BCS and the anesthesia bag were swabbed after each patient. Furthermore, samples from the condensation water inside the ventilator were taken weekly and cultivated over 48 hours at 36°C. All swabs were cultivated on Columbia blood agar with 5% sheep blood (Oxoid, Wedel, Germany) and transferred into thioglycolate bouillon. Additionally, samples from the respiratory tract were cultivated on chocolate agar (Oxoid) for detection of micro-aerophils. The Columbia plates and the thioglycolate bouillon were incubated for 48 hours at 36°C under aerobic conditions, the chocolate agar for 48 hours under 5% CO_2 humid atmosphere at 36°C. Plates were visually evaluated after 6, 24, and 48 hours, and the grown colonies were differentiated morphologically and bio-chemically (ATB-System, Biomérieux, Nürtingen, Germany) using standard microbiological methods following recommendations of the German Society of Hygiene and Microbiology [12]. All included patients were followed up until discharge to detect any pneumonia.

Costs were calculated per patient for three possible scenarios: 1) change of BCS after each patient (without HMEF), 2) with HMEF and 3) change of BCS after 24 and 48 hours, and 7 days, respectively. Costs of used consumables are specific and negotiated list prices for the hospital where the study was conducted. Costs for personnel were obtained from the actual wage contract as provided by the Human Resource department, and time required for each procedures (preparation time, leak test, time to change HMEF, disinfection) was measured for each procedure directly under practical conditions.

Results

None of the patients developed postoperative pneumonia. In all cases, respiratory tract flora was not detected behind the HMEF in the BCS (Table 2), and all condensation water samples obtained from the BCS yielded no growth. In 11% of samples of the patient's side of the HMEF, organisms from the respiratory flora were present. In two samples obtained from the patient side of the HMEF, pathogenic organisms were detectable, once *Klebsiella pneumoniae* and in another sample *Proteus mirabilis* (Table 2). These samples, however, were positive in very small bacterial numbers and were detected only after bouillon enrichment. The origin of each of both pathogens was the respiratory tract flora of the corresponding patient. All patients' respiratory tract samples yielded micro-organisms, none of these micro-organisms were present in the machine side of the HMEF or the inner side of the BCS lumen.

Samples from the surface of the respiratory bags yielded high microbial numbers during all investigated time points with stable total bacterial counts but increasing proportion of pathogenic organisms over time, mostly Methicillin-sensitive *Staphylococcus aureus* (Table 2). *K. pneumoniae* was detected on the outside surface of the BCS and of the respiratory bag, while *P. mirabilis* grew only on the respiratory bag (Table 2). The outer surfaces of the BCS were less frequently contaminated. The origin of these contaminations were mainly tracheal flora (bags), followed by aerobe flora (bags and BCS). Contamination of respiratory bag was mostly higher than of BCS.

Single-use of the BCS showed to be less economical than using the combination of BCS and HMEF for consecutive patients (Table 3). Cost for the HMEF was more than compensated by sparing the use of a new BCS and indirectly by shorten the preparation time before the next patient; thus, using the BCS for 24 hours provides a cost savings of up to 40% versus single use. Extending the change interval from 24 hours to 48 hours saved over 50% compared to change after each patient, and an additional 19% compared to change after 24 hours.

Table 2: Contamination and pathogens* found in swabs from the patient side (ET/HMEF-patient side inner surface), machine side (HMEF-machine side, BCS inner surface), and outer surface of BCS and Bag

Change intervall, patients (n)	Contamination (%), *pathogens (%), pathogenic species*			
	Patient side	Machine side	Outer surface BCS	Bag
24 h (110)	7.2 *(0.9)* 1 Kpn**	0.0 *(0.0)*	12.0 *(2.0)* 1 EC, 1 Kpn	95.0 *(8.0)* 4 MSSA, 1 Kpn, 1 EC, 1 HSG, 1 Alwoff
48 h (75)	6.6 *(1.3)* 1 Pmir	4.0 *(0.0)*	21.0 *(7.0)* 3 MSSA, 1 EC, 1 Halv	97.0 *(4.0)* 1 MSSA, 1 EC, 1 Pmir
120 h (138)	29.6 *(0.0)*	11.1 *(0.0)*	23.0 *(1.2)* 1 MSSA*, 1 Eclo	93.2 *(7.4)* 8 MSSA, 4 NF
168 h (55)	7.8 *(0.0)*	2.0 *(0.0)*	19.4 *(0.0)*	95.8 *(19.7)* 6 MSSA, 7 NF,1 Asp

* EC: *E. coli*, Eclo: *Enterobacter cloacae*, HSG: hemolysing streptococci serogroup G, MSSA: *S. aureus*, methicillin susceptible, Kpn: *Klebsiella pneumoniae*, NF: non fermentating gramnegative rods, Pmir: *Proteus mirabilis*
** only after bouillon enrichment

Table 3: Calculated costs per day and patient based on costs for material, time for procedures and staff costs

Item	Time (min)	Costs[d] (€)	Duration of operation (incision to closure time)			
			Single use	24 h	48 h	7 d
BCS (Tyco)		6.24	24.96	6.24	3.12	0.89
HME-F (patient)[c] (Pall Ultipor)		2.00	0.00	8.00	8.00	8.00
HME-F (ventilator)[a] (Draeger 654ST)		0.26	0.26	0.00	0.00	0.00
Logistic costs BCS[b]		0.30	1.20	0.30	0.15	0.05
Logistic costs HME-F[b]		0.10	0.00	0.40	0.40	0.40
Preparation	0.98	0.39	1.55	0.39	0.19	0.06
Leak test	1.74	0.69	2.74	0.69	0.69	0.69
Change HME-F	0.50	0.20	0.00	0.79	0.79	0.79
Disinfection	1.01	0.40	0.00	1.59	1.59	1.59
Total costs per day			30.71	18.39	14.93	12.46
Total costs per patient			7.68	4.60	3.73	3.12

[a] per service, costs for sterilization excluded
[b] single patient use
[c] total costs for personnel/transport/storing
[d] list prices/time for procedures measured/based on 4.0 patients/d/OR and on actual wage agreement

Discussion

Our study confirmed previous findings from other authors that a HMEF effectively protects the BCS and from microbial contamination, thus allowing to use the BCS over 7 days on multiple patients [2], [4], [13], [14], [15], [16], [17]. All samples obtained from the ventilators and the condensation water yielded no growth. If the HMEF would have been an ineffective bacterial barrier, it would be expected to yield qualitatively the same flora on the machine side of the filter [17]. Based on the results of our study, the Ultipor 25® appears to be a reliable bi-directional barrier against bacterial contamination. An additional benefit of the usage of HMEF is protection of the ventilator itself. This is of special importance for portable ventilators (e.g. Draeger Oxylog®), as disinfection of its inner part is complicated and time consuming.

High contamination on the surface of the respiratory bags and to a lesser extent on the outer surface of the BCS itself were observed. The contamination of the bags might have occurred during induction and extubation by transmission of respiratory tract flora via hands of anesthesia personnel or aerogenous route from the patient. Most interestingly, in two samples obtained from the patient side of the HMEF, pathogenic organisms were detectable, once *Klebsiella pneumoniae* and in another sample *Proteus mirabilis*. Although these samples were positive in very small numbers and were detected only after bouillon enrichment, the origin of each of both pathogens was the respiratory tract flora of the corresponding patients, most

likely indicating that the organisms contaminated the environment during intubation or extubation.

For the environmental organisms detected also accidental dropping of the reparatory bag on the floor is not uncommon during anesthesia and can easily lead to additional contamination with environmental organisms. Contamination of bags close to the airway system, however, is critical because of the risk of contamination of staff and horizontal transmission via hands. The results underline the necessity of disinfection of the respiratory bags and the outer surface of BCS after each patient, independently of the changing intervals of HMEF and BCS. Further research is needed to quantify the possible risk of cross-infection via this route.

In order to calculate the cost-benefit situation by prolonged use of the BCS in combination with a HMEF, we analyzed staff and material costs for each change. As expected, staff costs were the biggest part of the total costs. Reducing the number of changes reduced the costs mainly by reducing the time of staff allotted to this task. Of course this might be only the case in high-wage countries, and the potential of financial saving in other regions of the world might be much less. Also, shorter preparation times before the next surgical procedure do not automatically free staff for other tasks, as peak staffing requirements will remain unchanged and the time saved is often too short for other meaningful work. However, the saved time can be better used for higher levels of patient care as well as to improve inter-staff communication, ultimatively leading to a higher quality of care and optimized processes in the operation theatre. Changing of the BCS after each patient is the most expensive variant and offers no clinical or economic benefit. In our study extending the changing interval of the BCS from single use to 24 and 48 hours, and to 7 days allowed cost saving of 41% per surgical procedure. Finally, using BCS together with HMEF on multiple patients saves thousands of tons of medical waste and plastics per year, helping to protect the environment.

Our study has a number of limitations. Several groups of patients with increased risk of infection were excluded because of patient safety concerns. Furthermore, soiling of the BCS was only checked visually by anesthesia personnel, reflecting the normal way in everyday practice. Most noticeably, microbial monitoring was limited to cultural assessment of bacterial contamination. The rational for this was that detection of bacteria is a sensitive indicator for the total microbial contamination.

Notes

Conflicts of interest

The authors declare that they have no competing interests.

References

1. Wilkes AR. Heat and moisture exchangers. Structure and function. Respir Care Clin N Am. 1998;4(2):261-79.
2. Vézina DP, Trépanier CA, Lessard MR, Gourdeau M, Tremblay C. Anesthesia breathing circuits protected by the DAR Barrierbac S breathing filter have a low bacterial contamination rate. Can J Anaesth. 2001;48(8):748-54. DOI: 10.1007/BF03016689
3. Lloyd G, Howells J, Liddle C, Klineberg PL. Barriers to hepatitis C transmission within breathing systems: efficacy of a pleated hydrophobic filter. Anaesth Intensive Care. 1997;25(3):235-8.
4. Carter JA. The reuse of breathing systems in anesthesia. Respir Care Clin N Am. 2006;12(2):275-86.
5. Hogarth I. Anaesthetic machine and breathing system contamination and the efficacy of bacterial/viral filters. Anaesth Intensive Care. 1996;24(2):154-63.
6. Lessard MR, Trépanier CA. Should we use breathing filters in anesthesia? Can J Anaesth. 2002;49(2):115-20. DOI: 10.1007/BF03020480
7. Neft MW, Goodman JR, Hlavnicka JP, Veit BC. To reuse your circuit: the HME debate. AANA J. 1999;67(5):433-9.
8. van Hassel S, Laveaux M, Leenders M, Kaan JA, Mintjes J. Bacterial filters in anesthesia: results of 9 years of surveillance. Infect Control Hosp Epidemiol. 1999;20(1):58-60. DOI: 10.1086/501549
9. Tablan OC, Anderson LJ, Besser R, Bridges C, Hajjeh R; CDC; Healthcare Infection Control Practices Advisory Committee. Guidelines for preventing health-care – associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. MMWR Recomm Rep. 2004;53(RR-3):1-36. Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5303a1.htm
10. Prävention der nosokomialen Pneumonie. Mitteilung der Kommission für Krankenhaushygiene und Infektionsprävention am Robert Koch-Institut. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2000;43(3):302-9. DOI: 10.1007/s001030050257
11. AORN Recommended Practices Committee. Recommended practices for cleaning, handling and processing anesthesia equipment. AORN J. 2005;81(4):856-7, 860-70. DOI: 10.1016/S0001-2092(06)60365-7
12. Mauch H, Lütticken R, Gatermann S, eds. MiQ: Qualitätsstandards in der mikrobiologisch-infektiologischen Diagnostik. München: Urban Fischer; 1999.
13. Vezina DP, Trépanier CA, Lessard MR, Gourdeau M, Tremblay C, Guidoin R. An in vivo evaluation of the mycobacterial filtration efficacy of three breathing filters used in anesthesia. Anesthesiology. 2004;101(1):104-9. DOI: 10.1097/00000542-200407000-00017
14. Shibata M, Asano M. Prevention of contamination with a heat-and-moisture-exchanger (HME) and bacterial filter during clinical anesthesia. Masui. 1998;47(12):1464-70.
15. Chalon J, Markham JP, Ali MM, Ramanathan S, Turndorf H. The pall ultipor breathing circuit filter – an efficient heat and moisture exchanger. Anesth Analg. 1984;63(6):566-70. DOI: 10.1213/00000539-198406000-00003
16. Daggan R, Zefeiridis A, Steinberg D, Larijani G, Gratz I, Goldberg ME. High-quality filtration allows reuse of anesthesia breathing circuits resulting in cost savings and reduced medical waste. J Clin Anesth. 1999;11(7):536-9. DOI: 10.1016/S0952-8180(99)00083-5

17. Rathgeber J, Kietzmann D, Mergeryan H, Hub R, Züchner K, Kettler D. Prevention of patient bacterial contamination of anaesthesia-circle-systems: a clinical study of the contamination risk and performance of different heat and moisture exchangers with electret filter (HMEF). Eur J Anaesthesiol. 1997;14(4):368-73. DOI: 10.1097/00003643-199707000-00005

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