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Research Article

Bacterial contamination of anesthesia machines' internal breathing-circuit-systems

Bakterielle Kontamination des inneren Kreissystems von Anästhesiemaschinen

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Abstract

Background: Bacterial contamination of anesthesia breathing machines and their potential hazard for pulmonary infection and cross-infection among anesthetized patients has been an infection control issue since the 1950s. Disposable equipment and bacterial filters have been introduced to minimize this risk. However, the machines' internal breathing-circuit-system has been considered to be free of micro-organisms without providing adequate data supporting this view. The aim of the study was to investigate if any micro-organisms can be yielded from used internal machines' breathing-circuit-system. Based on such results objective reprocessing intervals could be defined.
Methods: The internal parts of 40 anesthesia machines' breathing-circuit-system were investigated. Chi-square test and logistic regression analysis were performed. An on-site process observation of the re-processing sequence was conducted.
Results: Bacterial growth was found in 17 of 40 machines (43%). No significant difference was ascertained between the contamination and the processing intervals. The most common contaminants retrieved were coagulase negative Staphylococci, aerobe spore forming bacteria and *Micrococcus species*. In one breathing-circuit-system, *Escherichia coli*, and in one further *Staphylococcus aureus* were yielded.
Conclusion: Considering the availability of bacterial filters installed on the outlet of the breathing-circuit-systems, the type of bacteria retrieved and the on-site process observation, we conclude that the contamination found is best explained by a lack of adherence to hygienic measures during and after re-processing of the internal breathing-circuit-system. These results support an extension of the re-processing interval of the anesthesia apparatus longer than the manufacturer's recommendation of one week. However, the importance of adherence to standard hygienic measures during re-processing needs to be emphasized.

Keywords: anesthesia machine, breathing circuit system, contamination, infection control

Zusammenfassung

Hintergrund: Die bakterielle Kontamination von Anästhesiemaschinen und die von Ihnen ausgehende potentielle Gefahr für Pneumonien und Kreuzinfektionen zwischen anästhesierten Patientinnen ist bereits seit den 1950 Jahren ein Thema der Krankenhaushygiene. Um das Risiko einer Kreuzübertragung zu minimieren, wurden Einwegprodukte und Bakterienfilter eingeführt. Soweit gilt der innere Atemkreissystem der Maschinen als frei von Mikroorganismen, ohne dass das jemals mit adäquaten Daten untermauert wurde. Das Ziel der Studie war daher zu untersuchen, ob Mikroorganismen aus dem inneren Kreissystem benutzter Anästhesiemaschinen isoliert werden können. Auf dieser Grundlage könnte man objektive Aufbereitungsintervalle definieren.

Methoden: Der innere Kreisteil von 40 Anästhesiemaschinen wurde mikrobiologisch untersucht. Es wurden ein Chi-Quadrat Test und eine logistische Regressionsanalyse durchgeführt. Eine Prozessablaufbeobachtung der Aufbereitung fand vor Ort statt.
Ergebnisse: In 17 von 40 Maschinen (43%) wurde Bakterienwachstum festgestellt. Es konnte kein signifikanter Zusammenhang zwischen Kontamination und Aufbereitungsintervallen gefunden werden. Am häufigsten wurden Koagulase negative Staphylokokken, aerobe Sporenbildner und *Micrococcus species* isoliert. In einem Kreissystem wurde *Escherichia coli* und in einem anderen *Staphylococcus aureus* gefunden.
Schlussfolgerungen: In Anbetracht der Verwendung von Bakterienfiltern am Maschinenausgang, der isolierten Bakterienspezies und der Prozessablaufbeobachtung vor Ort schließen wir, dass die gefundene Kontamination am besten durch mangelhaft durchgeführte Hygienemaßnahmen während und nach der Aufbereitung der inneren Kreissysteme erklärbar ist. Unsere Ergebnisse befürworten eine Verlängerung der Aufbereitungsintervalle von Kreissystemen, die laut Herstellerangaben wöchentlich erforderlich sind. Grundsätzlich muss die Wichtigkeit von Standardhygienemaßnahmen während der Aufbereitung betont werden.

Schlüsselwörter: Anästhesiemaschinen, Atemkreissystem, Kontamination, Infektionskontrolle, Krankenhaushygiene

Introduction

Possible bacterial contamination of anesthesia breathing machines (ABM) has been an infection control issue since the 1950s [1], [2], [3], [4]. A number of studies explored bacterial contamination of ABMs concentrating on disposable breathing-circuit-systems (BCS), yet, focusing on the inspiratory and expiratory port of the ABMs or the machine's absorber as reported [5], [6], [7], [8], [9]. These studies did not observe clinically relevant contamination at the investigated locations, nor could they provide evidence of an association between patient's pharyngeal micro-flora and the bacteria retrieved from the ABM. This lead to the assumption, that the internal BCS of ABM is free of micro-organisms. Thus, both the U.S. Center for Disease Control and Prevention and the German Robert Koch Institute (RKI) do not advise routine sterilization or disinfection of the internal BCSs of ABM [10], [11].
In our institution, a 2,200 beds tertiary care medical university teaching hospital, preventive infection control measures include the use of disposable bacterial filter for each anesthetised patient. One filter is situated on the patient side, inserted between breathing mask or tracheal tube and the breathing tube's Y-piece. Two additional filters are routinely positioned on the machine side, placed on the outlet of the inspiratory and expiratory ports of the BCS. Anesthesia gases are applied using disposable inspiratory and expiratory tubes, which are changed daily. The disassembled internal machinery parts are re-processed once monthly by use of a washer-disinfector. After the components are left to dry in a clean storage room, they are reassembled, wrapped in clean green fabric and then stored in a closet. Shortly before utilisation, the BCS is re-assembled and placed into the ABM.

The possibility of contamination of the internal BCS and the most appropriate interval for its re-processing has not been sufficiently investigated. The aim of the study was to investigate if any micro-organisms can be yielded from the internal BCS of ABM. Based on these results objective reprocessing intervals for the BCS of ABM could be established.

Material and methods

A total of 40 ABMs (Primus, Draeger Medical, Germany) were analysed after have been used for a mean of 30 days (range 14–59 days). Samples were taken from 6 defined locations inside the ABM's internal BCS: the inspiratory port, the expiratory port, the inspiration compartment, the expiration compartment, the rubber gaskets of the centrepiece, and the rubber gasket located towards the CO_2 absorber (Figure 1).
Specimens were collected with sterile swabs moistened with sterile 0.9% NaCl solution. The swabs were transported immediately to the microbiological laboratory in 1 mL physiological saline solution. 100 µl of the samples were plated on Columbia agar (BD; Becton, Dickinson and Company, Franklin Lakes, New Jersey) by fractionated smearing and then incubated at 37 °C for 2 days. 8 mL brain-heart-infusion was added to the residual 0.9 mL solution and incubated at 37 °C for 5 days. Turbid turned infusions were plated on Columbia agar to count the number of colony forming units (CFU) and identify organisms.
An on-site process observation through the infection control team was performed during re-processing of ABMs and BCSs.

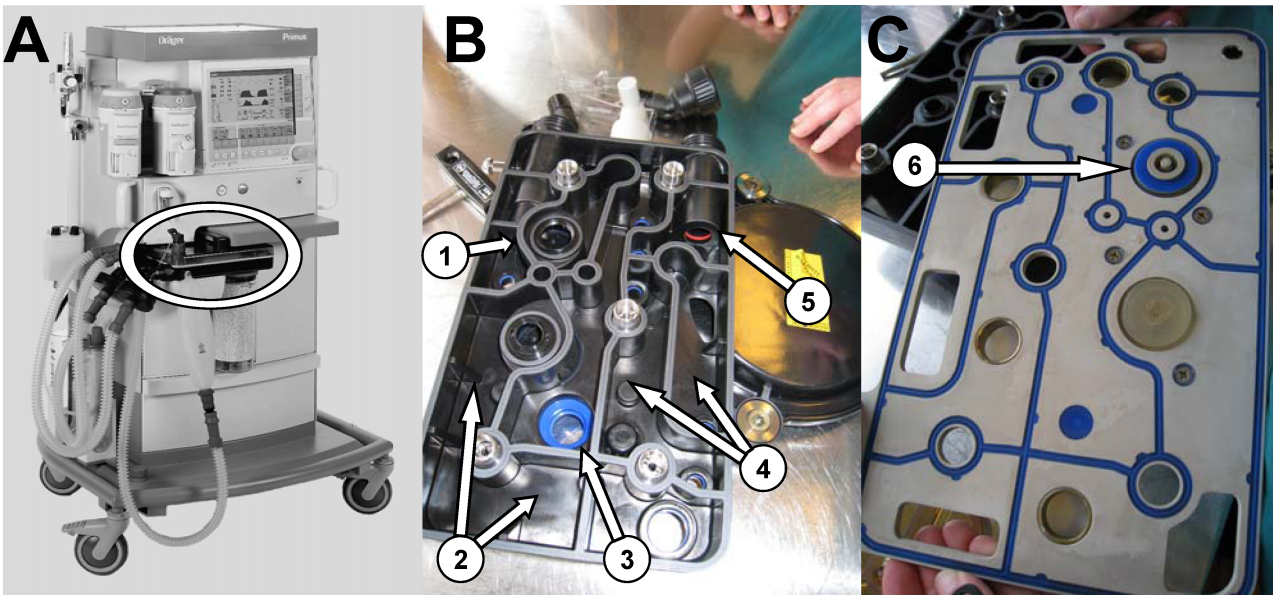

Figure 1: Sampled locations of the internal breathing-circuit-system (BCS) of anesthesia machine (Primus, Draeger Medical, Germany): A, anesthesia machine „Primus": encircled the BCS. B, bottom side: (1) inspiratory port, (2) compartment of inspiration, (3) rubber gasket toward CO_2 absorber, (4) compartment of expiration, (5) expiratory port. C, centrepiece: (6) rubber gasket of the centrepiece.

Statistical analysis

A Chi-square Test was performed to investigate if any significant difference in contamination exists over the time. For this purpose the time interval between two reprocessing of the same internal BCS was stratified into 4 groups (1–15 days, 16–30 days, 31–45 days, and 46–60 days).
Furthermore, a logistic regression analysis between bacterial growth and the time in days passed from the last processing was performed. A P-value of <0.05 was considered to indicate statistically significant difference. Analysis was performed with SPSS 15.0 (SPSS Inc., Chicago).

Results

Viable bacteria were found in the internal BCS in 17 of 40 sampled ABMs (43%). In 53% of the contaminated machines, bacteria were yielded from the rubber gasket of the centre piece. The rubber gasket toward the CO_2 absorber, the compartment of inspiration and the compartment of expiration were contaminated each in 4 of 40 ABMs (Table 1). The most commonly retrieved contaminants were coagulase negative Staphylococci (35%) and aerobe spore forming rods (26%). *Micrococcus sp.* and *Corynebacterium sp.* were recovered in 3/40 and 2/40 machines, respectively. In one internal BCS each, viridans streptococci, *Neisseria species*, *Staphylococcus aureus* and *Escherichia coli* were yielded (Table 2).

Table 1: Occurrence of microbial contamination by sampled locations within the internal circle system of anesthesia machines (Primus, Draeger Medical, Germany)

Location	No.	%
Rubber gasket - centrepiece	9	53%
Inspiratory port	1	6%
Compartment of expiration	4	24%
Expiratory port	2	12%
Rubber gasket - CO2 absorber	4	24%
Compartment of inpiration	4	24%

Table 2: Distribution of bacterial species yielded from the internal circle system of anesthesia machines (Primus, Draeger Medical, Germany)

Pathogen	No.	%
Coagulase neg. Staphilococcus	8	35%
Aereob spore-forming bacteria	6	26%
Micrococcus species	3	13%
Neisseria species	1	4%
Viridans Streptococci	1	4%
Staphilococcus aureus	1	4%
Escherichia coli	1	4%
Corynebacterium species	2	9%

No significant association was found in Chi-square test between contamination in the internal BCSs of the ABMs and different time intervals (Table 3). Similarly, logistic regression analysis did not show any significant association between re-processing intervals and contamination. After re-processing, the odds ratio for contamination increased each day by a ratio of 1.07 (Table 4).

Table 3: Number of anesthesia machines (Primus, Draeger Medical, Germany) processed after different time intervals per bacterial contamination and Fischer's exact P-value in Chi-Square Test.
+ contaminated, - non-contaminated machine

Processing interval	-	+	Total	P-value
1-15 days	2	0	2	
16-30 days	14	11	25	
31-45 days	6	4	10	0.65
46-60 days	1	2	3	
Total	23	17	40	

Table 4: Logistic regression analysis between bacterial contamination and processing interval in days

	Regression Coefficient B	Standard Error	P-value	OR
Time interval	0.06	0.04	0.1	1.07
Constant	-2.23	1.22	0.07	0.11

During the on-site observation of re-processing we found that hand disinfection, the use of disposable gloves, and wearing of disposable surgical masks were either not properly or not at all followed by health care workers. The ABMs components were left to dry in a storage room in which also paperboard container were stored.

Discussion

Although in general the ABMs' internal BCSs are regarded to be free of micro-organisms [5], [6], [7], [8], [9], we could demonstrate the presence of bacterial contamination. Our findings raise old questions concerning the origin of the bacteria, the potential risk they may harbour in terms of cross-contamination within patients, and the consequences for infection control. Supposing the patient as source of the contamination, we would presume a leakage of the bacterial filters which are routinely disposed between each patient or a possible health-care workers non-compliance with established standards. The second assumption, indeed, seems more possible, as leakage of bacterial filters would mean an almost 50% performance failure, which is in contrast to published literature as shown by Leijten et al. [12].
Moreover, we would also expect a positive association between the frequency of contamination and the re-processing intervals of the ABMs in terms of a longer processing interval determining more contaminated machines. However, no such a trend was found. Therefore, these arguments rule out the patient or leakage of filters as source of the yielded micro-organisms.
The second possibility for bacterial contamination could be the handling and storage of re-processed internal BCS. Indeed, the on-site observation of the BCS and ABM's re-processing showed a number of potential moments supporting this possibility. Pre-processed components of the ABM were left unprotected air-dry after machine-based cleaning and disinfection. The reassembled BCSs was then wrapped in clean green fabric, and stored on a cupboard in a storage room until their next use. Looking closer at the bacterial species recovered further strengthens the hypothesis of contamination during re-processing the BCSs. More than half of the bacteria belonged to the normal microbial flora of human skin. The presence of *Escherichia coli*, a typical representative of intestinal human flora, which was found in one BCS, can be explained by low compliance to hand hygiene. Aerobe spore forming Gram-positive bacteria are ubiquitous in the air. *Neisseria species*, non-diphtheiroid Corynebacteria and viridans Streptococci are commonly found in the human pharyngeal region and could represent oral contamination through speaking and non-wearing of face masks during wrapping and handling. The possibility of BCS contamination due to possible breaches of preventive measures during handling and storage of internal BCS is also supported by Grote et al. [6], who attributed one of his findings to exogenous contamination while assembling and handling such systems.
According to the Austrian federal Law of Medical Products any manufacturer or distributor of medical products must provide adequate reprocessing guidelines for the used medical product [13]. While very few manufacturers do not address cleaning and disinfection of BCSs at all, Draeger Medical, manufacturer of the analysed ABM and BCS in this study, specifically state directives for cleaning and reprocessing including time intervals. For ABM Type Primus, Draeger Medical recommends a weekly re-processing of the machine's BCS. For other models Draeger advices either a re-processing after operation or no timeline at all. Other manufacturers, such as General Electrics (GE; Fairfield, Connecticut), provide a detailed instruction for re-processing the BCS of ABM Type Aespire 7900, without specifying the intervals for it. Draeger, GE, and MAQUE recommend cleaning and disinfection of the internal breathing circuit, while manufacturers such as Air Liquid Medical Systems (e.g. Ventor Dual or Felix Dual) recommend manual cleaning of the internal BCS and routine sterilization. All of this result in lack of clarity and uncertainty of the user.
However, the analysis of the on-site re-processing process observation suggests a contamination of the internal BCS during the reprocessing routine, if not performed with protective personnel equipment such as gloves or masks under dusty environmental conditions. In view of this possibility, decreasing the time interval for BCS re-pro-

cessing might even result in higher contamination of BCSs, and the supposed benefit of frequent re-processing will turn even opposite. If bacterial filters are used in front of the BCS inlets, our results might rather support an extension of the re-processing intervals.

In conclusion we have demonstrated that the internal BCS of ABMs can harbour bacteria despite the use of bacterial filters and a monthly routine re-processing of internal BCSs. The most likely cause for bacterial contamination of the internal BCS found to be lack of adherence to protective measures during BCS re-processing and assembly of parts. Therefore, our results suggest an extension of the re-processing intervals of BCSs, provided standard hygienic measures during re-processing, handling and reassembly of internal BCS are adhered as well as the routinely use of bacterial filters changed for each patient are implemented.

Notes

Competing interests

The authors declare that they have no competing interests.

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