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Screening of platelet concentrates for bacterial contamination: spectrum of bacteria detected, proportion of transfused units, and clinical follow-up

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Abstract Screening of platelet concentrates (PCs) for bacterial contamination with cultivation methods is carried out as a routine procedure in some countries. The aim is to prevent the transfusion of contaminated PCs. The German Evaluation of Regular Monitoring Study Group conducted a prospective multicenter study on 52,243 PCs to investigate the prevalence of bacteria (BacT/ALERT, bioMerieux). This study describes the detected bacterial spectrum, the proportion of PCs with a positive test result that had been transfused, and the results of the clinical follow-up. One hundred thirteen (67%) of 169 potentially or confirmed positive units had

already been transfused at the time of the first positive signal. The transfusion of units contaminated by *Staphylococcus aureus*, *Serratia marcescens*, and 73% of the units contaminated with *Staphylococcus epidermidis*, *Staphylococcus capitis*, or *Staphylococcus saccharolyticus* was prevented. In contrast, 85% of units with *Propionibacterium acnes* were transfused. A clonal relationship of the isolates from the pooled PCs and from the associated red blood cell concentrates was found in all investigated cases. The follow-up revealed six febrile reactions to culture-positive PCs not classified as transfusion reaction (TRs) by treating physicians. This demonstrates the

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importance of hemovigilance. Serious septic reactions due to *Klebsiella pneumoniae* in two units of one apheresis PC that had tested false-negative were reported; one had a fatal outcome. Culture systems reduce the risk of transfusion of contaminated PCs but cannot guarantee sterility. Physicians must be aware of bacterial contamination of PCs as a potential cause of TRs and must report all adverse events.

Keywords Bacterial screening · Platelet concentrates · Contamination · Septic transfusion reaction

Introduction

As transfusion-associated sepsis has serious consequences for patients, various procedures have been incorporated into the preparation of blood components to reduce the risk of bacterial contamination [1]. These include a specific donor history to identify asymptomatic bacteremia, appropriate skin disinfection procedures before venipuncture, initial aliquot diversion, and consistent implementation of the principles of good manufacturing practice with defined hygiene standards [2, 3].

However, these measures might not prevent transfusion-transmitted bacterial infections in all cases [4]. In particular, platelet concentrates (PCs) that are stored at 20–24°C provide good bacterial growth conditions and are considered the main cause of bacterially induced transfusion disorders [5]. In the meantime, automated bacterial culture systems are used in some countries to screen PCs for bacterial contamination [6, 7]. BacT/ALERT™ (bioMérieux, Durham, NC, USA) is the system most commonly employed [8]. Product samples obtained near to the time of preparation of the PCs are transferred to culture bottles and incubated. PCs are delivered with a status as “negative-to-date”. PCs with a positive culture signal are either not delivered or recalled and the responsible physician notified if a transfusion has already been administered. The prevalence of bacteria in PCs under the current framework conditions in Germany were reported in previous studies [9–11]. The bacterial contamination risk was not significantly different between apheresis platelets and buffy coat derived pool-platelets.

This article is focussing on the proportion of bacterial-contaminated PCs, which were transfused, the characterization of the bacterial isolates, and, in particular, on the results of the clinical follow-up of these cases which was performed after completion of the test phase. According to the legal situation in Germany, physicians are obliged to report all adverse reactions related to transfusions to the manufacturer, regardless of their clinical severity.

Materials and methods

The study was integrated into the work schedule of nine centers of the German Red Cross as well as the Bavarian Red Cross blood donor service. Testing and analysis of data were performed between January 2004 and February 2006.

Platelet concentrate preparation

Production of PCs differentiated into apheresis PC (APC), pooled T-Sol PC (T-Sol PPC), and pooled plasma PC (plasma PPC) was described in detail by Hundhausen and Muller and Schrezenmeier et al. [9, 10]. In brief, arm disinfection was undertaken in two stages with a licensed disinfectant, which was left to act for at least 30 s. With all samples, pre-donation sampling involved the diversion of the first 30–40 ml of blood into a separate bag. Leukocyte depletion was incorporated into the preparation of apheresis and pooled PCs with a target value of $<10^6$ /unit. The shelf life of PCs was 5 days.

Sampling, culturing in the BacT/Alert system, and action in the event of a positive signal

An aerobic and an anaerobic culture bottle (BPA and BPN, bioMérieux, Nuertingen, Germany) were each inoculated with 7.5–10 ml per PC under laminar airflow conditions. The culture bottles were incubated in BacT/Alert Classic 240 or BacT/Alert 3D (bioMérieux, Nuertingen, Germany) for 7 days, and the signals were recorded continuously. Initially, positive test results were verified according to a standardized procedure. Further, aerobic and anaerobic culture bottles were inoculated from the sample bag and, if still available, from the original PC bag, and the red blood cell concentrates (RBCs) involved and cultured for 7 days or until a positive signal.

All culture bottles with a positive signal were sent to microbiological reference laboratories (Departments of Microbiology, Universities of Bochum and Frankfurt, Germany) to identify and classify bacterial strains with biochemical methods as well as with molecular biological methods (nucleic amplification technique).

Definition and interpretation of test results

PCs that did not exhibit a positive signal over the 7-day incubation period in BacT/Alert were described as negative and not considered further. PCs with a positive signal in the first culture but without identifying of any bacterial strains were named as initial reactive. PCs with a positive signal in the first culture and with detection of microorganisms, but with a negative culture result in the second culture from the sample bag or original product were considered as

potentially positive. PCs with a positive first culture and identification of the microorganism and with a positive second culture and identification of the same microbial species were classified as confirmed positive.

Identification of bacteria and strain typing

Bottles were analyzed by Gram staining and subcultured on Columbia blood agar, chocolate agar, McConkey agar, Sabouraud dextrose agar, and anaerobically incubated Columbia blood agar (bioMérieux, Marcy l'Etoile, France). Plates were incubated for a minimum of 4 days at 36°C (5% CO₂). Bacterial identification was performed by standard biochemical test procedures (bioMérieux) including DNA profiling when necessary. Strain typing of *Staphylococcus* spp. was performed by pulsed-field gel electrophoresis; comparison of *Propionibacterium acnes* strains was performed by random amplification of polymorphic DNA-PCR (RAPD-PCR) with primer OLP-05 as described by Rossi et al. [12, 13].

Clinical follow-up

Reports on transfusion reactions (TRs) received during the study period were reviewed in the participating centers to establish whether they could be related to tested PCs. During the test phase, treating physicians were immediately informed in case of positive test results to prevent transfusion of involved PCs and RBCs or, in case of transfusion, to ask for any signs of TRs.

Following completion of the test phase, the doctors responsible were questioned about all transfused PCs and RBCs with potentially positive and confirmed positive test results and asked to review the patient's records to ascertain whether any reactions had been recorded that were chronologically related to the transfusion.

The follow-up was planned to be performed by a structured questionnaire. As it showed as impossible to gain complete data by this method, the study group decided to perform telephone interviews with the responsible physicians on basis of the transfusion protocols.

Results

As reported previously, 52,243 PCs (37,045 of these were PPCs and 15,198 APCs) were investigated for bacterial contamination by BacT/ALERT [10]. The APCs were divided into 27,020 therapeutic units. Until the first signal was recognized by BacT/ALERT, 10/24 (42%) of all PPCs and 19/21 (90%) of all therapeutic units of APCs with confirmed positive screening results were already transfused. Of the potentially positive PPCs, 29/50 (58%) and,

of the potentially positive APCs, 55/74 (74%) of the therapeutic units were already transfused before the first positive signal in BacT/ALERT.

Results on potentially positive PCs

Table 1 shows the bacterial species detected, the incubation time until the first positive signal occurred, the proportion of transfused PCs, and the results of the clinical follow-up for the potentially positively tested PCs. A broad spectrum of bacteria was found, predominantly of the transient and resident skin flora that was not confirmed in the second culture. From a clinical viewpoint, especially, the species *Staphylococcus aureus* and *Staphylococcus lugdunensis* should be classified as critical. On the basis of an early positive signal, both affected PPCs were excluded from distribution.

Positive test results of the first culture were obtained in 65 PCs (66.3%) in anaerobic culture, in 31 PCs (31.6%) in aerobic culture, and in 2 PCs (2.1%) in both cultures. *Propionibacteria* were the most common contaminants with 45 cases detected solely in anaerobic culture. The relatively late occurrence of the positive signal with *Propionibacteria* was the reason for the high rate (68%) of potentially contaminated PCs that were transfused. Repetition of the cultures revealed negative results in all cases that were potentially positive with *P. acnes*. It was not possible to take test material from the preparations for the second cultures in 84 of the total of 124 therapeutic units as these had been transfused. Therefore, it must remain open whether the transfused PCs contained viable bacteria or whether the contamination would no longer have been detectable, as in the test material from the sample bags.

No reports of adverse reactions related to transfusion of potentially positive PCs were actively recorded to the study group. Retrospective questioning of the treating physicians revealed reactions in the transfusion protocols of four patients, involving *P. acnes* in three cases and *Bacillus firmus* in one case. A causal relationship with the transfusion of PCs, however, was rejected in each case. No explanatory investigations were performed, and the reactions were attributed to other causes.

For the 50 PPCs with a potentially positive test result, 200 associated RBCs were identified. Of these, 147 (73.5%) tested sterile, 25 were transfused without TR, and 21 RBCs were destroyed. In seven of the associated RBCs, *P. acnes* were detected in anaerobic culture, i.e., identical species to those in the corresponding PCs.

Results on confirmed positive PCs

For the 37 confirmed positive PCs with identical bacteria species in the first and second culture, Table 2 shows

Table 1 Potentially positive PCs: bacterial species, incubation times until first positive signal, transfused PCs, and clinical follow-up

Species	Number and type of PC	Incubation time until first positive signal	Number and type of transfused PCs	Clinical data/transfusion reactions (TR)
<i>Propionibacterium acnes</i>	21 APCs, 38 units	4.9 days (3.7–6.3)	37 units out of 21 APCs	1× increase in temperature, not classified as TR by doctor
	24 PPCs	5.4 days (3.7–5.7)	14 PPCs	1× transient increase in temperature, regressing with antibiotic, not classified as TR by doctor 1× multimorbid patient with sepsis and neutropenia following bone marrow transplant rejection, patient died, not classified as TR by doctor
<i>Staphylococcus saccharolyticus</i>	2 APCs, 3 units	2×2.7 days	1 unit out of 1 APC	No TR
	3 PPCs	3.3 days (2.3–4.2)	3 PPCs	No TR
<i>Staphylococcus epidermidis</i>	5 APCs, 7 units	1.1 days (0.6–2.0)	2 units out of 2 APCs	No TR
	3 PPCs	20.3 h (20.0–20.9)	–	–
<i>Bacillus circulans, Bacillus endophyticus, Bacillus firmus, Bacillus licheniformis, Bacillus pumilus, Bacillus simplex, Bacillus stearothermophilus, Bacillus subtilis, Bacillus spp., Brevibacillus thermoruber, Paenibacillus turicensis</i>	7 APCs, 9 units	1.9 days (0.8–3.6)	4 units out of 2 APCs	No TR
	7 PPCs	1.8 days (0.8–6.8)	3 PPCs	1× increase in temperature to 39°C, confusion in neutropenic patient, not classified as TR by doctor (<i>Bacillus firmus</i>)
<i>Staphylococcus capitis</i> ^a , <i>Staphylococcus cohnii, Staphylococcus hominis, Staphylococcus warneri, Staphylococcus lugdunensis</i>	5 APCs, 6 units	1.5 days (0.6–4.0)	3 units out of 2 APCs	No TR
	1 PPC	19 h	–	–
<i>Corynebacterium afermentans, Corynebacterium coyleae, Corynebacterium imitans, Rothia dentocariosa, Brevibacterium casei</i>	4 APCs, 5 units	2.1 days (1.5–3.6)	5 units out of 4 APCs	No TR
	1 PPC	1.2 days	1 PPC	No TR
<i>Micrococcus lutens</i>	1 APC	3.3 days	1 APC	No TR
	7 PPCs	2.7 days (1.5–5.6)	5 PPCs	No TR
<i>Staphylococcus lugdunensis</i>	1 APC	1.2 days	–	–
<i>Staphylococcus aureus</i>	1 PPC	22.1 h	–	–
<i>Bacteroides capillosus</i>	1 PPC	1.6 days	1 PPC	No TR
<i>Clostridium bifermentans</i>	1 PPC	4.5 days	1 PPC	No TR
<i>Peptostreptococcus prevotii</i>	1 PPC	4.5 days	1 PPC	No TR
Uncultured Betaproteobacterium	1 APC, 2 units	1.4 days	1 unit out of 1 APC	No TR
Uncultured soil bacterium clone	1 APC, 2 units	1.2 days	1 unit out of 1 APC	No TR
Total	48 APCs with 74 units 50 PPCs		35 APCs with 55 units 29 PPCs	

APC apheresis platelet concentrate, PPC pool platelet concentrate, TR transfusion reaction

^a In one APC *S. capitis* and *P. acnes*

Table 2 Confirmed positive PCs: bacterial species, incubation times until first positive signal, transfused PCs, and outcome of clinical follow-up

Species	Number and type of PC	Incubation time until first positive signal	Number and type of transfused PCs	Clinical data/transfusion reaction (TR)
<i>Propionibacterium acnes</i>	10 APCs, 17 units	4.5 days (3.6–6.4)	17 units out of 10 APCs	1×patient with transfusion of both units of one double APC, febrile reaction, not clinically serious, not reported as TR by doctor
	10 PPCs	4.3 days (3.4–5.8)	8 PPCs	1×increase in temperature in patient with acute myeloid leukemia, rapidly regressing on antibiotic, not classified as TR by doctor
<i>Staphylococcus epidermidis</i>	1 APC, 2 units	15.7 h	1 unit out of 1 APC	No TR, patient on antibiotic
	7 PPCs	20.2 h (17.6–24.5)	–	–
<i>Staphylococcus saccharolyticus</i>	4 PPCs	2.7 days (2.3–3.1)	2 PPCs	No TR
<i>Staphylococcus capitis</i>	1 APC	15.1 h	1 APC	No TR
	2 PPCs	18.9 and 26 h	–	–
<i>Staphylococcus aureus</i>	1 APC	9.1 h	–	–
<i>Serratia marcescens</i>	1 PPC	12.8 h	–	–
Total	13 APCs with 21 units 24 PPCs		12 APCs with 19 units 10 PPCs	

APC apheresis platelet concentrate, PPC pool platelet concentrate, TR transfusion reaction

details. Of 29 transfused units, 25 were contaminated with *P. acnes*. It was not possible to prevent transfusion because of the long incubation period of 3.6 to 6.4 days until the first positive signal. In 30 PCs (81.1%), bacteria were detected in anaerobic culture only; in three PCs (8.1%), only the aerobic culture was positive; while in four PCs (10.8%), both the aerobic and the anaerobic cultures were positive.

There were no reports of adverse reactions to confirmed positive PCs near the time of transfusion. In two cases with *Propionibacteria*, febrile reactions were described in the patients concerned when the responsible physicians were questioned subsequently, and these reactions were classified as clinically non-serious and non-bacterially related TR. One of the affected patients received two units from one *Propionibacteria*-contaminated APC.

An early positive signal in aerobic culture after a few hours prevented the transfusion of two PPCs contaminated with *Serratia marcescens* and *S. aureus*. The majority of units contaminated with *Staphylococcus epidermidis*, *Staphylococcus capitis*, and *Staphylococcus saccharolyticus* were also not transfused.

Ninety-six RBCs were associated with the 24 confirmed positively tested PPCs. Seventy-nine RBCs (82.3%) were negatively tested, six (6.2%) were transfused without a TR being observed, and one RBC was disposed of. In 10 of the 24 confirmed positive PPCs, one associated RBC contam-

inated with identical microorganisms was identified. *P. acnes* were detected in nine cases and *S. capitis* in one case. In the case of contaminations with *S. marcescens* and *S. aureus*, the associated RBCs proved to be sterile.

Delivery and recall of PCs issues on a “negative-to-date” basis

The current culture status was checked before the distribution of all PCs, and delivery was done on a “negative-to-date” basis. Of 169 therapeutic units with potentially and confirmed positive test results, 111 (66%) had already been delivered and transfused by the time of the first positive signal. Analysis of the delivery days of the PCs tested in the study revealed that the majority of PCs issued were delivered and transfused on day 2 and day 3 of the shelf life [10]. Recalls were successful only in the case of one potentially positive APC (*Bacillus circulans*) and one confirmed positive PPC (*S. saccharolyticus*).

Serious transfusion reactions with APCs tested false-negative

Reports of serious TRs were received for one APC that was divided into two units and distributed on day 2 of the shelf life [10]. One case involved a female patient diagnosed with non-Hodgkin’s lymphoma who received an APC

4.1 days after the end of preparation following myeloablative chemotherapy and radiation in preparation for a bone marrow transplantation. After the transfusion, she developed respiratory insufficiency and circulatory instability. *Klebsiella pneumoniae* was detected in the patient's blood culture and also in the residual material from the APC bag. The patient died after 10 days from a septic process with multi-organ failure despite the immediate administration of antibiotics. A further patient with a diagnosis of acute myeloid leukemia received the second unit of the same APC 4.2 days after preparation and reacted with fever and circulatory collapse. Following the administration of catecholamines and antibiotics, her condition stabilized. The patient's blood culture and the residual material of the APC also contained *K. pneumoniae*.

A sample was taken from the APC for sterility testing 20 h after preparation and before division into two units and was investigated by BacT/ALERT and by Pall eBDS system, respectively. The cultures remained negative until the end of the 7-day culture phase, and the Pall eBDS test was negative. Subsequent examinations of the donor, the sample material obtained from the APC for sterility testing, and all materials used revealed no evidence of *K. pneumoniae*.

Strain typing of *Staphylococcus* spp. and *P. acnes*

A comparison of the *Propionibacteria* isolates was performed by RAPD-PCR in seven of nine confirmed positive PPCs with demonstrated contamination of one of the associated RBCs. A clonal relationship of the isolates from the PPCs and from the associated RBCs was found in all cases (Table 3). The contaminated whole blood donation

was thus clearly identified in each case. The associated plasma was not examined.

The *Staphylococcus* spp. detected in two APCs and five PPCs with a confirmed positive culture result were compared by pulsed-field gel electrophoresis and showed identical isolates in four cases and related isolates in one case. In one PPC contaminated with *S. capitis*, identical isolates were detected in one of the associated RBCs. In one APC with *S. capitis*, identical isolates to those in the sample bag and in the first culture bottle were found in the residual product after transfusion (Table 4). The APC was not recalled until after the transfusion, which was tolerated without any reaction, because the positive culture signal did not appear until after delivery.

Discussion

A series of studies reports on the screening results of PCs with automated culture systems [3, 4, 6, 7, 14–17]. Comparability of the results is limited. The times of sampling from the PCs, the inoculum volume, and the culture conditions— aerobic only or aerobic and anaerobic— were variously chosen.

The spectrum of detected microorganisms derives predominantly, as expected, from the transient and resident skin flora and shows the limits of skin disinfection [3]. The microbial spectrum is comparable to that of other studies which also performed aerobic and anaerobic cultures [3, 4, 7]. The high proportion of PCs contaminated with *Propionibacteria* is striking, accounting for 54% of confirmed positive PCs and 46% of potentially positive PCs. *Propionibacteria* reside in hair follicles and sweat

Table 3 RAPD-PCR results: *Propionibacteria* isolates from confirmed positive PPCs and associated RBCs

ID number	Culture results of RBCs	Test material source	Test result: clonal relationship
479	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^a sample bag, RBC	Confirmed
671	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^b sample bag, PPC, RBC	Confirmed
1373	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^a sample bag, RBC	Confirmed
5466	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^a sample bag, RBC	Confirmed
5716	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^b sample bag, PPC, RBC	Confirmed
6306	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^a sample bag, RBC	Confirmed
7158	3 RBCs negative 1 RBC: <i>Propionibacterium acnes</i>	PPC ^a sample bag, RBC	Confirmed

^a PPC transfused, no TR

^b PPC not delivered

Table 4 Pulsed-field gel electrophoresis: strain typing of *Staphylococcus* spp.

ID number	Type of PC	Species	Culture result of RBCs	Test material source	Test result
656	APC ^a	<i>Staphylococcus aureus</i>		APC sample bag, second culture bottle, APC	Identical isolates
2576	APC ^b	<i>Staphylococcus capitis</i>		APC sample bag, first culture bottle, remainder of APC after transfusion	Identical isolates
1198	PPC ^a	<i>Staphylococcus capitis</i>	1 RBC: <i>Staphylococcus capitis</i> 3 RBCs: negative	First culture bottle, PPC, RBC	Identical isolates
802	PPC ^a	<i>Staphylococcus epidermidis</i>	4 RBCs: negative	PPC sample bag, PPC	Related isolates
2772	PPC ^a	<i>Staphylococcus capitis</i>	4 RBCs: negative	First culture bottle, PPC	Identical isolates
4516	PPC ^a	<i>Staphylococcus epidermidis</i>	4 RBCs: negative	First culture bottle, PPC sample bag, PPC	Identical isolates
5339	PPC ^a	<i>Staphylococcus epidermidis</i>	4 RBCs: negative	PPC sample bag, PPC	Identical isolates

^a PC not delivered

^b PC transfused, no transfusion reaction

ducts in the skin and are mostly protected from surface skin disinfection. As they predominantly proliferate slowly and therefore only produce a positive culture signal belatedly, the probability of transfusing a *Propionibacteria*-containing PC is high.

Propionibacteria are deemed to be fairly weakly pathogenic. Störmer et al. [18] studied the growth behavior of *Propionibacteria* in PCs and concluded that clinically relevant microbial counts are not reached because of the slow proliferation. The same authors reported on six traceability procedures with transfused PCs contaminated with *P. acnes* and found no evidence of a bacterially related reaction in the patients concerned [18]. The clinical significance of *Propionibacterium acnes* has been questioned. However, there are well-documented cases of infections in various clinical settings including endocarditis, arthritis, lung infections, and abscesses in spleen and brain [19–21]. In particular, it can cause silent late chronic infections in prosthetic joints [21]. There are reports of moderate febrile TRs in immunosuppressed patients who received PCs contaminated with *Propionibacteria*, and it has been described as cause of transient febrile episodes even in an immunocompetent host [22–24]. Therefore, this contaminant should not be considered as clinically insignificant bacteria for all cases.

Whether there is a causal relationship with the clinical data on the five patients in this study with transfusion of potentially or confirmed contamination by *Propionibacteria* can be neither confirmed nor excluded.

There are some similarities between the bacterial contamination of platelet products and another well-

known problem in hemato-oncology, i.e., catheter-related infections: in both situations, the most common source of the bacteria is the skin. Bacterial contamination of blood products is mostly due to contamination by skin bacteria that gain access to the unit of blood collection [25]. Migration of bacteria on the skin at the insertion site into the cutaneous catheter tract with colonization of the catheter tip is the most common route of catheter-related infections [26]. Therefore, it is not surprising that in both situations, bacteria from the skin flora are the most predominant contaminants.

Coagulase-negative staphylococci are by far the most commonly isolated agents [26–28]. In a recent study, *P. acnes* was identified as the second most frequent genus which is colonizing catheter-tips after *Staphylococcus* spp. [29]. Similar to our study, which demonstrates that anaerobic culture and prolonged incubation is required to detect *Propionibacteria acnes* contamination of PCs, the study by Martin-Rabadan et al. [29] demonstrates that there is a risk of underestimation of *P. acnes* as a potential cause of catheter-related infections due to methodological shortcomings.

Thus, there is need for further well-designed studies to assess the potential role of *P. acnes* and also the various coagulase-negative *Staphylococcus* spp. for infections in immunocompromised patients.

If the six cases in this study in which follow-up revealed clinical reactions following the transfusion of potentially or confirmed contaminated PCs are considered unelucidated, 80 patients remain who were transfused with potentially positive PCs and 26 patients received confirmed positive

blood products. In none of these cases, there was evidence of bacterially related reactions. In the majority of screening studies, no TRs occurred in patients receiving PCs with positive culture results [4, 6, 7, 14, 16, 17]. However, it is noteworthy that none of the six cases of mild clinical reactions in our study was reported actively but was revealed only by solicited feedback after the treating physicians had been questioned in the study follow-up by the blood service. This might indicate substantial under-reporting of mild reactions in clinical practice and should remind the important part of transfusing physicians regarding to their responsibility in hemovigilance system [30]. In thrombocytopenic patients, in particular in hemat oncology patients with concomitant neutropenia, bacterial contamination of blood products must be considered as one potential cause of febrile episodes. Transfusing physicians must be aware that in case of TRs, other blood products which were prepared from the same donation might still be untransfused. Thus, if the Blood Service is notified on time of a suspected septic transfusion reaction (STR), it might be possible to block issues or recall other blood products prepared from the involved donations and thus prevent further STRs.

Several blood donors services reported that PCs tested as false-negative by culture methods have caused 26 STRs, five of them fatal [4, 7, 10, 17]. The deaths involved PCs contaminated with *S. lugdunensis*, *S. aureus* (two cases), *S. marcescens*, and *K. pneumoniae*.

Overall, published studies demonstrate the reduced clinical efficiency of screening PCs with culture systems [31, 32]. The residual risk of STRs due to false-negative culture results is estimated to be as high as approximately 1:45,000 transfusions [33]. Transfusing physicians should always be aware of bacterial contamination as a potential cause of TRs. This study also demonstrates the importance of hemovigilance. Therefore, all participants in blood transfusions (employees in the blood transfusion service as well as nurses and physicians in hospitals and outpatient clinics) should be trained periodically regarding transfusion-related side effects to improve either the attention for STRs as well as the reporting of all adverse events.

Bacterial contamination of blood products focuses mainly on PCs, but this study demonstrates convincingly identical bacterial strains in PCs and RBCs confirmed by RAPD-PCR and pulsed-field gel electrophoresis, respectively. Although the residual risk of STRs for RBCs is approximately one log phase below the residual risk of STRs for PCs, the absolute number of annually transfused RBCs is one log phase higher. Based on these assumptions, the ideal bacterial screening methods or pathogen reduction systems should include all blood products to reduce the risk for bacteria transmission significantly [34–36]. Therefore,

new screening technologies or pathogen inactivation systems are eagerly awaited.

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