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TRANSFUSION

Acquired platelet storage container leaks and contamination with environmental bacteria: A preventable cause of bacterial sepsis

Richard R. Gammon[1] | **Rita A. Reik**[1] | **Marc Stern**[2] | **Ralph R. Vassallo**[3] | **Dan A. Waxman**[4] | **Pampee P. Young**[5] | **Richard J. Benjamin**[6]

[1]Scientific, Medical, Technical Division, OneBlood, Orlando, Florida, USA

[2]Product Management, Cerus Corporation, Concord, California, USA

[3]Corporate Medical Affairs, Vitalant, Scottsdale, Arizona, USA

[4]Transfusion Medicine Blood Services, Versiti, Indianapolis, Indiana, USA

[5]Biomedical Services, American Red Cross, Washington, DC, USA

[6]Clinical Research and Medical Affairs, Cerus Corporation, Concord, California, USA

Correspondence
Richard J. Benjamin, Cerus Corporation, 1220 Concord Ave, Suite 600, Concord CA 94520, USA.
Email: rbenjamin@cerus.com

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Abstract

Background: Apheresis platelets (AP) may be contaminated by environmental bacteria via container defects acquired during processing, transport, storage, or transfusion, as highlighted by a recent series of septic reactions related to *Acinetobacter* spp. and other bacterial strains.

Study design and methods: The frequency and nature of acquired container defect reports to one manufacturer were evaluated from January 2019 to July 2020. The published incidence of contamination and sepsis due to environmental bacteria with culture screened AP in the United States was reviewed for the period of 2010–2019.

Results: Review of a manufacturers' records showed 23 US reports of leaks involving 24 containers attributed to postmanufacturing damage, at a rate of 44 per million distributed storage containers. Analysis of returned containers showed evidence of scratches, impressions, and/or piercings. Literature review of US hemovigilance data revealed that environmental bacteria comprised 7% of confirmed positive primary bacterial culture screens, were responsible for 14%–16% of reported septic, and 8 of 28 (29%) fatal reactions with bacterial-culture screened AP. Sepsis cases have been reported with culture screened, point-of-issue (POI) tested, or pathogen-reduced AP.

Discussion: Environmental contamination of AP is rare but can cause sepsis. Container damage provides a pathway for contamination after culture screening, POI bacteria testing, or pathogen reduction. Blood collectors and transfusion services should have procedures to ensure proper inspection, handling, storage, and transport of AP to avoid damage and should enhance efforts to detect defects prior to release and to eliminate bacteria from all contacting surfaces to minimize the risk of contamination.

KEYWORDS

Acinetobacter spp., apheresis platelets, bacterial contamination, handling, platelet container defects, septic transfusion reactions

1 | INTRODUCTION

Bacterial sepsis following apheresis platelet (AP) transfusion remains the most common transfusion-transmitted disease despite effective skin disinfection and initial sample diversion to reduce and culture screening to detect contamination. Pathogen reduction is an alternative to culture and further reduces the risk of sepsis.[1] Fifty years ago, Buchholz et al. documented that platelets may be contaminated at the time of collection by skin commensal, enteric, oral flora, and environmental bacterial strains.[2] Today, breakthrough sepsis cases are usually ascribed to the insensitivity of bacterial culture screening protocols to detect low-level contamination. The US Food and Drug Administration (FDA) final guidance requiring blood centers and transfusion services to institute improved culture techniques with or without POI testing for bacteria, or pathogen reduction without culture or POI, is now in force.[3]

A recent series of septic reactions involving a unique *Acinetobacter baumannii complex* (ACBC) strain with or without co-contamination with *Staphylococcus saprophyticus* (SS) and/or *Leclercia adecaboxylata* (LA) has highlighted the risks of an alternative route of contamination: postcollection environmental contamination during platelet processing, transport, or storage.[4–7] This mode of contamination may not be prevented by the enhanced safety measures recommended by FDA Guidance. In three of the sepsis cases, including one fatality, the respective AP were screened for bacteria and found negative by primary aerobic bacterial culture, and in two of these cases, the bacteria were not detected by additional anaerobic primary culture screening or POI bacterial testing. In each case, contaminating bacteria were detected on the blood center and/or hospital transfusion service's platelet agitators or computer keyboards.[4] These findings clearly suggest that defects in the storage containers were likely the portal for contamination after bacterial culture screening. In the fourth case involving a pathogen reduced AP that was not culture screened, strong evidence of contamination postpathogen reduction was documented, with additional demonstration of effective bacterial inactivation of the implicated strains.[6] A more recent report of a fatal septic reaction with direct evidence of a leaking container and contamination with multiple environmental bacterial strains including ACBC, further highlights the risks of storage container defects and postprocessing contamination.[7] Two additional cases involving pathogen-reduced platelets mentioned in a recent FDA communication to the medical community remain under investigation.[8] The possibility that AP may be contaminated postcollection via storage container defects caused by acquired damage to the container has not been systematically described or adequately explored.

US reports of container defects to a manufacturer were evaluated. In addition, the literature on environmental bacterial strains involved in contamination detected by culture screening or discovered during investigation of septic transfusion reactions was reviewed. These data predate the widespread introduction of pathogen reduction for AP in the United States and represent bacterial mitigation strategies in place prior to FDA Guidance implementation.

2 | MATERIALS AND METHODS

2.1 | Investigation of container defects and leaks

Platelet storage containers are manufactured under controlled conditions with routine inspection during each manufacturing step, quality control testing of in-process and final products, end product sterilization, and validated processes for packaging, storage, and transporting the final product. In addition, customers are instructed to inspect the product on receipt and at appropriate steps during further manufacture and use for defects and to report these to the manufacturer, preferably with return of the damaged product.

Manufacturers are obliged to have rigorous procedures to evaluate all customer complaints and to inspect returned products with a view to determining the incidence, nature, and probable cause of defects. In addition, manufacturers must formulate corrective and preventive action (CAPA) plans to avoid future occurrence and are regularly audited by the regulatory authorities. Routine investigation of container leaks includes inspection of the storage container, pressure testing with water or with air-filled containers under water, and microscopy to evaluate the nature and probable cause of the damage.

2.2 | Literature review

The National Library of Medicine (PubMed.gov, National Center of Biotechnology Information, Bethesda, MD) was searched using the keywords: platelets; contamination; bacteria; and sepsis and restricted to publications dated 2010–2019. The resulting abstracts were reviewed and articles excluded using the following criteria: non-US reports; those describing <10,000 platelet components (as environmental bacterial contamination is a rare event); containing only data that were duplicated in other reports and non-English reports. An additional source was identified from review of the primary articles.[9] Environmental organisms were defined empirically as

bacterial strains that are known to be commonly found in the environment.

3 | RESULTS

Environmental bacteria may gain entrance to platelet components via defects in or damage to the storage containers. AP are required to be examined for defects and/or leaks whenever they are handled.[10] This includes prior to release from the blood center, prior to release from the hospital transfusion service, and finally, before the unit is administered. Following the discovery of an index case involving a nonvisible leak in a storage container associated with a septic transfusion reaction caused by environmental bacterial strains[7] (Figure 1A), reported leaks were analyzed to better understand the incidence, nature, and etiology of postmanufacturing damage.

The index case (Case #1) involved a fatal septic transfusion reaction[7] in which the same bacterial strains, including SS, ACBC, and LA, were cultured from the patient and the implicated AP. The AP had been repeatedly inspected visually before transfusion, and no leaks were reported at the blood center or hospital. The storage container was returned to the blood center after the patient experienced a transfusion reaction with ~200 ml of platelet content, and no leaks were macroscopically evident (although culture screening detected the implicated bacteria on the external container surface). Further evaluation by an independent laboratory showed a positive leak test when the container was inflated with air and held under water. On emptying the container, a small ~1 mm scratch could be seen near the base of the spiking port (Figure 1A). Microscopy revealed a gouge in the plastic with a hole estimated as <50 μM at its base. The evidence for loss of structural integrity of the container was a plausible conduit for postprocessing contamination by environmental bacteria.

A broader review of reported container leaks was conducted. Between January 2019 and July 2020, the container manufacturer distributed processing platelet sets that incorporated 546,310 storage containers in the United States and received 23 reports of 24 storage containers with leaks not attributable to manufacturing causes (Table 1). In each case, the implicated AP was removed from inventory, not transfused, and not cultured. The overall defect rate, including the index case, was 1:22,800 (44 per million) distributed AP storage containers. Eight reports of defects were from blood centers, and 15 were reported by hospital transfusion services.

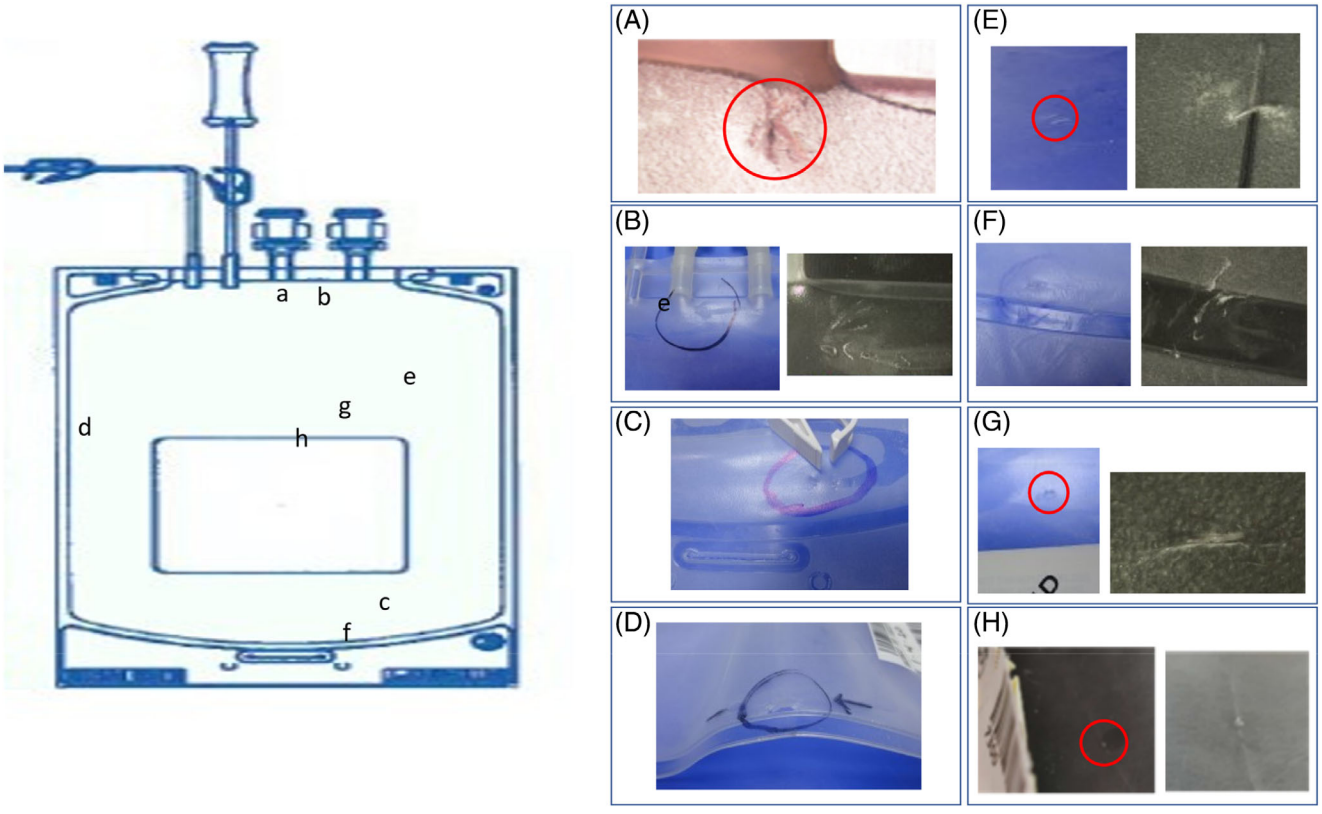

FIGURE 1 Site of damage and photographs of storage container damage as described in Table 1 under incident light and by microscopy

TABLE 1 Descriptions of reported storage container damage

Reported case	Photograph[a]	Origin of complaint	Damage	Description	Cause
1 (index case)	A	Hospital	Scratch	No obvious leaks or damage to the container. Several scuff marks were noted on both sides. Abrasions were on the surface of the container and not very deep into the plastic.	Unknown Possible agitator damage
2	B	Hospital	Scratch	The sheeting bore a 18 mm-long horizontal scratch between the two outlet ports and a secondary scratch below the external outlet port. Magnification revealed that the sheeting had been pierced at the left side of the damage from left to right as if the front side sheeting had been pinched and had torn.	Unknown Possible agitator damage
3	D	Blood center	Scratch	Leak reported along the left part of the front side sheet. The container sheeting was crossed horizontally with a 5 mm-wide scratch above the base label, ended with large tearing of the plastic sheet along the bead of sealing and additional scratches on the flat seal. These observations suggested lateral friction effect on the container.	Unknown Possible agitator damage
4	F	Hospital	Scratch	The bottom right part of the container was seriously scratched with several deep imprints in both sides. Many long oblique scratches and the main imprint had pierced the two sheets, leading to the observed leak.	Unknown Possible agitator damage
5	n.s.	Hospital	Scratch	The container leaked from the back side, along the left side bead of sealing at the extremity of long horizontal scratches crossing the container width. The bead of sealing had been crushed and sliced, piercing the plastic sheet, and leading to the observed leak.	Unknown Possible agitator damage
6	n.s.	Hospital	Scratch	Container leaked in the top part of the front side through a little tear in the sheeting. Similar damage, lighter and not leaking, could be observed approximately 3 cm below. Oblique scratches formed of aligned curves led to these damages.	Unknown Possible agitator damage
7	e	Blood center	Imprint	Two little imprints, slightly oblique, could be observed in the top right part of the container, one in front and one in back, with similar aspect but a little lower in the back side. Magnification of the damages confirmed 3–4 mm wide tearing through the two sheets with upward scratch on the backside sheeting. The container looked pierced from the back with little upward friction effect.	Unknown Possible damage on agitator or during transport
8	C	Blood center	Imprint	Two deep oblique imprints in the bottom part of the container, at the back. The location and aspect of these imprints, piercing the back sheet and causing a leak, corresponded to the location and shape of the clamps in the individual overwrap.	Improper storage during illumination step

TABLE 1 (Continued)

Reported case	Photograph[a]	Origin of complaint	Damage	Description	Cause
9	G	Blood center	Imprint	Two containers bore a similar horizontal cut, in the same location, a little above the base label. No other scratch, imprint, or any other damage observed. The location of the two cuts matched when both containers were stacked. These data suggest the containers where pressed between two sharp, 2 mm-long elements.	Unknown Possible damage on agitator or during transport
10	H	Hospital	Pierce	Pin hole located at the top of the manufacturers label, covered by blood center label.	Unknown possible needlestick
11	No bag	Blood center	Unknown	Container leaking at level of external inlet port.	Unknown
12	No bag	Hospital	Unknown	Pinhole leak at the port.	Unknown
13	No bag	Hospital	Unknown	Pinhole leak at the port.	Unknown
14	No bag	Blood center	Unknown	Leaking through the port of the bag.	Unknown
15	No bag	Hospital	Unknown	Pinhole leakage at the top underneath the port of the unit.	Unknown
16	No bag	Hospital	Unknown	Pinhole leak in the body of the bag.	Unknown
17	No bag	Blood center	Unknown	Pin hole in the middle of the storage container.	Unknown
18	No bag	Hospital	Unknown	Pin-hole leak on the seam of final storage bag.	Unknown
19	No bag	Hospital	Unknown	Pinhole leak was discovered along the seam of one unit.	Unknown
20	No bag	Blood center	Unknown	Pinhole leak exact location on storage container unknown.	Unknown
21	No bag	Hospital	Unknown	Leak with indiscernible puncture on side of final storage bag.	Unknown
22	No bag	Hospital	Unknown	Pinhole near seam found during final storage.	Unknown
23	No bag	Hospital	Unknown	Pinhole leak was discovered along the seam of one unit.	Unknown

Abbreviations: n.s., not shown; No bag, the storage container was not returned to the manufacturer for examination.
[a]Photographs as shown in Figure 1.

Six containers, five of which were reported by hospitals (Figure 1B,D,F), showed evidence of scratches consistent with damage inflicted by platelet agitators, that could occur if the containers were squeezed between shelves or between a shelf and the incubator walls with repetitive reciprocal motion leading to container damage. Four container leaks described in three reports by blood centers (Figure 1C,E,G) had holes or cuts associated with imprints into the plastic, compatible with contact with a foreign object with applied pressure, leading to damage. In a pair of cases reported by a blood center, the imprint was consistent with the outline of a plastic hemostatic clip used to stop flow from one bag to another. These cases suggest improper folding or stacking of platelet containers with a foreign object or the clip situated between the containers and applied pressure.

One case reported by a hospital described a pin hole leak in the plastic sheeting. Microscopic examination revealed a cored-out hole compatible with a needlestick injury in one sheet only (Figure 1H) underneath the blood center's label, suggesting injury before labeling. In 13 reports, the containers were not returned and the damage could not be assessed; however, five cases described the leaks as being related to the ports, four related to a seam, three had pinhole leaks in the sheeting, and one was not described.

3.1 | Contamination surveillance reports

On the assumption that loss of structural integrity of the container predisposes the AP to postprocessing

TABLE 2 Environmental bacterial strains detected by routine primary culture screening of platelet concentrates before release into inventory, by secondary screening at the hospital or implicated in transfusion septic reactions or fatalities in the United States (2010–2019)

Assessment	Primary culture screen	Primary culture screen	Secondary culture screen	Secondary culture screen	Secondary point of issue test	Secondary point of issue test	Sepsis	Sepsis	Fatality
Years	2010–2014	2008–2016	2016–2019	2004–2017	2010–2015	2008–2010	2010–2014	2010–2016	2009–2019
Site and reference	American Red Cross[9]	Vitalant Blood Services[11]	Johns Hopkins University[12]	Case Western Reserve University[13]	Baylor College of Medicine[14]	18 Hospitals[15]	American Red Cross[9]	NHSN[a] US Hospitals[16]	FDA Fatality Reports[17]
Culture or Transfusion events	2,158,843	347,487	55,896	97,595	16,839	27,620	2,158,843	1,536,115	~20 Million
Fatalities	-	0	0	2	-	-	2	3	28
Sepsis	-	-	0	8	-	-	33	31	-
Confirmed culture/ test positive	450	46	23	34	26	9	-	-	-
Skin, oral, or enteric strains	423	43	18	31	1	7	29	27	21
Environmental Strains									
Bacillus spp.	9	1	3	1	-	2	-	-	-
S. marcescens	18	2	-	1	-	-	-	-	3
Clostridium perfringens	-	-	-	-	-	-	1	-	3
Acinetobacter spp.	-	-	1	1	-	-	2	2	2
Achromobacter spp.		-	-	-	-	-		1	-
Brevundimonas diminuta		-	-	-	-	-		1	-
Ralstonia pickettii	-	-	-	-	-	-	1[b]	1[b]	-
Leclercia adecarboxylata			1	-	-	-	-	-	-
Total Environmental strains	27	3	5	3	0	2	4	5	8
Percentage	7%	7%	22%	9%	0%	22%	14%	16%	29%
Rate per Million	12.5	8.6	89.5	30.7	0.0	72	1.8	3.5	~0.40

[a]NHSN, National Healthcare Safety Network.
[b]Fatality. These data may represent the same clinical case.

environmental contamination, a literature review was performed to assess how often environmental bacteria were found contaminating AP or were involved in septic reactions. Nine published reports describing the US experience met the inclusion and exclusion criteria (Table 2). These predate the widespread use of platelet pathogen reduction technologies and the use of platelet additive solutions in the United States. Culture screening reports from the two largest US blood collection services for various time periods between 2009 and 2016 revealed that environmental bacteria were detected in 7% of confirmed positive cultures, at a relatively low rate of 8.6–12.5 per million cultures (Table 2). These services collect predominantly apheresis AP and utilize the Amicus (Fresenius Kabi, Lake Zurich, ILL) or Trima (Terumo, Lakewood, CO) separator technologies. The contaminants were all *Bacillus* spp. or *S. marcescens* strains (Table 2). Secondary culture screening of AP previously cultured using the BacT/ALERT (Biomerieux, Durham, NC) or eBDS (Haemonetics, Braintree, MA) systems at two large hospital services between 2004 and 2019, similarly detected a small number of *Bacillus* spp. and *Serratia* spp., but also occasionally detected environmental Gram-negative *Acinetobacter* spp. and LA strains.[12, 13] Secondary POI testing of previously culture screened AP detected *Bacillus* spp. but did not detect any AP contaminated with Gram-negative environmental bacteria.[14, 15]

3.2 | Reported cases of transfusion-transmitted bacterial infections due to environmental contaminants

Septic reactions over a 5-year period (2010–2014) reported to one large blood collector similarly involved environmental strains in 14% (4/33) of reports, but these included neither *Bacillus* spp. nor *S. marcescens*; but rather *Acinetobacter* spp., *Clostridium perfringens* and *Ralstonia pickettii* were implicated (Table 2).[7] A national survey of 195 US hospitals during an overlapping time frame (2010–2016) reported septic reactions with 16% (5/31) implicating environmental strains including *Acinetobacter* spp., *Achromabacter* spp., *Brevundimonas diminuta*, and *R. pickettii*, although some of these may be duplicates of the blood center reports.[16]

FDA fatality reports over a 10-year period from 2009–2019 documented 8 of 28 (29%) of fatalities were due to environmental organisms, some of which were not detected in routine bacteria screening, including *Acinetobacter* spp., *C. perfringens*, and *Serratia marcescens*, an uncommon cause of septic fatality that is also occasionally detected at primary culture screening. No fatalities were due to *Bacillus* spp. The fatal case of sepsis caused by the environmental organism *R. pickettii* in a nonpathogen reduced AP reported by the blood center was not included in the FDA reports.[7] This organism was not detected in routine culture screening. While the lack of routine anaerobic culture screening may explain the fatalities due to *C. perfringens*, this is not the case for *Acinetobacter* spp. and other Gram-negative strains. These data from review of the literature prior to the widespread implementation of platelet additive solution or pathogen reduction support the hypothesis that environmental bacterial strains were rare contaminants at collection but can cause severe sepsis and that contamination may have occurred as a result of postmanufacturing container damage after primary bacterial culture screening.

4 | DISCUSSION

AP contamination with environmental bacterial strains is a rare and underrecognized risk of transfusion. Despite progressively implemented safety steps to reduce and detect bacterial contamination during AP collection, fatalities continue to be reported and are generally attributed to false-negative culture screening tests prior to release into inventory.[4, 18] Over the last 11 years, FDA-reported fatalities are increasingly attributed to environmental organisms,[17] causing 29% of fatal septic reactions in 2009–2019.[8] Many implicated environmental organisms that should be readily detected by culture are in fact not routinely detected thus reinforcing the concept that contamination occurs after AP collection, processing, and sampling for bacteria contamination. Environmental organisms were reported in 14%–16% of nonfatal septic reactions reaffirming that although rare, they are important as a cause for severe, life-threatening reactions. We presume that container defects undetected by routine inspection or too small to cause visible leaks are likely to permit environmental contamination. Increasing awareness of bacterial contamination and sepsis since the first description 50 years ago,[2] with improvements in the prevention and detection of contamination and more recently, pathogen reduction of residual contaminants, and the report of seven sepsis cases linked to a common strain of ACBC with or without SS and/or LA strains,[8] emphasizes the issue of environmental contamination after collection.[4] In three cases that were not prevented by (1) bacterial culture screening or (2) POI testing (2 cases), evidence of container leakage was confirmed by the culture of identical bacterial strains from either the hospital transfusion service and/or blood center platelet agitators or computer keyboards.[4] The same report described a pathogen-reduced AP implicated in a nonfatal reaction where effective pathogen reduction was

demonstrated by examination of a noncontaminated sister unit that was split after pathogen reduction was performed, and laboratory evidence that demonstrated robust inactivation to sterility of high concentrations of the implicated organism.[4] The data were consistent with postprocessing environmental contamination as the cause.

More recently, a pathogen reduced AP was implicated in a fatal septic reaction involving contamination by LA, in addition to ACBC and SS.[7] 16S genotyping revealed that the ACBC and SS strains were identical to the previously reported case in California.[6] While the inclusion of two strains that were the same in widely distant locations 2 years apart has not been adequately explained, the data described as the index case clearly demonstrate an acquired breach in the integrity in the storage container, possibly caused by damage inflicted during storage on a platelet agitator (Figure 1A). The FDA recently reported two further septic reaction cases, one of which was fatal, of pathogen-reduced platelets contaminated by the common strain of ACBC, with or without SS and/or LA. While these unpublished cases remain under investigation, it is known that the container from the one case was not available for evaluation and the other container had multiple (3) clustered leaks in the plastic sheeting on the nonlabel side that were only evident on pressure testing and another leak on the label-side sheeting associated with a microscopic surface scrape and pinch that was so obvious that it probably occurred after the event (unpublished data, R. Benjamin). The nonlabel side findings in the second case are compatible with environmental contamination through a defect in the integrity of the container. The review of the incidence of reported container leaks suggests that acquired bag defects are uncommon although the possibility of underreporting is likely. Indeed, the proportion of damaged containers that do not result in macroscopically apparent container leaks is unknown, as is the proportion of these that allow contamination by environmental bacteria. These data reemphasize the importance of routine inspection for container defects and leaks at every step of the PC collection, processing, transport, and storage on the journey to the patients' bedside, as well as the need for clean environments.

AP storage containers are sterilized as a final manufacturing step and must meet international standards for their physical, chemical, and bacterial resistance properties.[19] Containers are manufactured from highly specialized plastics that are required to be oxygen and carbon dioxide permeable to permit gas exchange and platelet metabolism. Containers from various manufacturers encompass multiple geometries and plastic sheet thicknesses, ranging from 0.28 to 0.50 mm.[19] These gas permeable containers lack the durability of the more robust sheeting used for other blood products. Furthermore, AP are stored on platelet agitators exposing them to the risk of abrasions, impact from neighboring containers, the edges of the agitator shelves, and the stationary walls of the agitator should they move during agitation. AP are also routinely transported from the blood center and within the hospital using less controlled conditions in transport boxes, hand-carried, and pneumatic tube shuttles. While there is an expectation that AP should be stored and transported under clean conditions, there are no US requirements for cleaning, sterilizing, or culture screening of the environment in which AP are stored or transported. To mitigate these risks, it is routine practice to inspect AP containers for leaks before distribution and use, with leaking containers being discarded. POI testing would theoretically detect AP contaminated during shipping and storage; however, the technology used in the described case did not detect the implicated *Acinetobacter* spp. or *SS* strains.

Environmental contamination is not unique to any single manufacturers' containers. Acquired container defects and septic reactions have been reported with containers manufactured by different companies using different plastic sheeting.[4] Platelet storage containers are required to meet international standard EN ISO 3826-3:2006. Specification of physical, chemical, and biological requirements is rigorous and includes resistance to leakage and impermeability to microorganisms.

AABB Standards require that the blood center or transfusion service shall have a process to ensure that blood and blood components are handled, stored, and transported in a manner that prevents damage.[10] The exact means to meet these requirements are not standardized and left to the individual facility's policies and procedures. In addition, routine environmental monitoring for microorganisms is not required in the United States as it is in some European countries, although the environment is generally required to be clean (not sterile). The manufacturers of platelet agitators, transport boxes, temperature stabilizing packs, and overwraps do not prescribe how often to clean or disinfect their equipment. The recent finding of the same *ACBC* strain involved in septic reactions over wide geographies and time periods suggests that the platelet storage environments may become colonized by adapted strains.[4] Blood products are routinely shipped across the United States to areas of greatest need from a limited number of blood centers with repeated use of the same platelet agitators and transport boxes. The spread of a specific strain of *ACBC and SS* suggests the possibility that microorganisms can use this distribution network to disseminate across the country. Consideration should be given on how to routinely sterilize the environment in

which AP are stored and transported and procedures should be put in place. The use of protective plastic overwraps during transport should be evaluated and consideration given to individual AP protection with a fresh overwrap each time, although the impact of restricted gas permeability on AP metabolism, particularly during longer transport times, would need to be assessed.

All efforts should be made to avoid damage to AP storage containers. These include common sense advice such as avoiding the proximity of blades and needles; avoiding using box cutters to open packaging; minimizing handling of AP by storing with the label side up or down as recommended by the manufacturer to reduce the need to turn over the containers to read the label or to maximize gas exchange, respectively; ensuring agitators and their incubators are level to prevent movement, are cleaned and disinfected regularly with a disinfectant capable of killing *Acinetobacter* spp. and inspected for sharp edges or burrs; ensuring that containers are not in contact with each other or the incubator; positioning container ports to avoid their falling over an edge; not using clips or weights to hold containers in place as these may imprint or tear the sheeting; inspecting agitators regularly to ensure that containers have not moved; avoiding or controlling how AP are folded or stacked when shipping and ensuring that AP are not packed in shippers too tightly; ensuring that clips or extraneous objects are not trapped between containers; avoiding PC centrifugation in the storage container when "washing" platelets as storage containers are usually not validated for centrifugation while containing platelets; and packing carefully whenever using a pneumatic tube transport system. This list is not exhaustive, and blood centers and hospital transfusion services should consult their suppliers for specific advice on handling their products. A set of basic recommendations is included (Figure S1). One supplier has recently released lateral agitator guard barriers that may be magnetically attached to existing shelves to limit PC movement. A simple method of detecting leaks by applying manual hand pressure to AP concentrates resting on paper towels, by moving platelets to one-half of the bag with a sweeping motion of one hand and gently pushing the platelets with the fingertips of the other hand as described by Fadeyi et al., may enhance detection.[7] An active role by the blood center and hospital transfusion service to promote education at the time of hire and on a periodic basis regarding the importance of proper handling of blood containers may help to mitigate some of these cases of contamination and potential unnecessary loss of a donated unit.

Finally, container defects are underreported and under-appreciated as a risk to transfusion safety. It is likely that the actual rate of defects is much higher than that reported to the manufacturer and the proportion of defects not detected that place patients at risk is unknown. Hospitals and blood centers are required to inspect AP, and container leaks should be reported to the manufacturer. A major limitation of this study was that 13 of 23 reports were not accompanied by the leaking container for inspection by the manufacturer, and the contents were not cultured. It is only through rigorous investigation that the mechanisms of damage may be understood, and handling and engineering improvements be implemented to avoid future occurrences.

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CONFLICT OF INTEREST

RJB and MS are employees of Cerus Corporation. RRG, RAR, DAW, and PPY have no conflicts to declare. RRV is a scientific advisor for Fresenius Kabi and DSMB member for clinical studies sponsored by Cerus Corporation.

ORCID

Richard R. Gammon https://orcid.org/0000-0002-1175-9579
Ralph R. Vassallo https://orcid.org/0000-0001-8754-047X
Richard J. Benjamin https://orcid.org/0000-0001-6618-4744

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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