

## ORIGINAL RESEARCH

## TRANSFUSION

# Implementation of a dual platelet inventory in a tertiary hospital during the COVID-19 pandemic enabling cold-stored apheresis platelets for treatment of actively bleeding patients

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## Abstract

**Background:** To increase preparedness and mitigate the risk of platelet shortage without increasing the number of collections, we introduced a dual platelet inventory with cold-stored platelets (CSP) with 14-days shelf life for actively bleeding patients during the COVID-19 pandemic.

**Study design and methods:** We collected apheresis platelet concentrates with blood type O or A. All patients receiving CSP units were included in a quality registry. Efficacy was evaluated by total blood usage and laboratory analysis of platelet count, hemoglobin, and TEG 6s global hemostasis assay. Feasibility was evaluated by monitoring inventory and a survey among laboratory staff.

**Results:** From 17 March, 2020, to 31 December, 2021, we produced 276 CSP units and transfused 186 units to 92 patients. Main indication for transfusion was surgical bleeding (88%). No transfusion reactions were reported. 24-h post-transfusion patient survival was 96%. Total outdate in the study period was 33%. The majority (75%) of survey respondents answered that they had received sufficient information and training before CSP was implemented. Lack of information about bleeding status while issuing platelets, high workload, and separate storage location was described as main reasons for outdates.

**Discussion:** CSP with 14-days shelf life is a feasible alternative for the treatment of patients with bleeding. Implementation of a dual platelet inventory requires thorough planning, including information and training of clinical and laboratory staff, continuous follow-up of practice and patients, and an easy-to-follow algorithm for use of CSP units. A dual platelet inventory may mitigate the risk of platelet shortage during a pandemic situation.

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## KEYWORDS

bleeding, blood preparedness, cold-stored platelets, dual inventory, inventory management, pandemic, platelet concentrate, platelet transfusion, storage of blood components, surgery

## 1 | INTRODUCTION

As the COVID-19 pandemic led to a national lockdown in Norway on 12 March, 2020, we knew little about how this would affect the demand and availability of blood products. We anticipated that donor availability would decline but did not know whether blood demand would increase or decline as the pandemic progressed. In Norway, blood banks are hospital-based, which means that our department collects, produces, and issues blood products as well as performs immune hematological analyses. Our donor center has three collection facilities; at Haukeland University Hospital in Bergen, at Voss Hospital, a local hospital 1.5 h drive from Bergen, and one mobile blood collection unit. Mobile blood collection was canceled from the start of the lockdown of the general society since we could not maintain the required distance between staff and donors. Normally, we could increase collections at Haukeland University Hospital to compensate for the missing collections from the mobile blood collection unit. However, our capacity at the hospital donor center was reduced due to measures taken to protect staff and donors. To reduce the impact of possible quarantines during the initial lockdown we reduced the number of personnel working on site and used fixed teams. Additionally, the hospital had restricted the access for visitors including blood donors, who had to document their appointment to enter the hospital. We also feared the impact of an increase in infection rate in our donor population, which could lead to both reduced access to donors and increased wastage of blood components due to symptoms of infection post-donation.

Platelet concentrates (PCs), with a short shelf life of only seven days in Norway, would be the first blood component affected by reduced collections or increased transfusions. To increase preparedness without increasing number of collections we decided to introduce cold-stored platelets (CSP) with 14-days shelf life for actively bleeding patients. This decision was based on results from previous laboratory and clinical studies performed by our department.<sup>1,2</sup> In our laboratory study we found that *in vitro* assays measuring hemostasis and aggregation show CSP on day 14 to be comparable to room temperature-stored platelets (RTP) on day 7.<sup>1</sup> Further, the results from our study of cold-stored platelet transfusions for patients with complex cardiothoracic surgery

showed that CSP is able to reduce and stop bleeding, also after storage for up to 14 days.<sup>2</sup> Our results are in accordance with several international laboratory studies, which have shown preserved platelet function during extended cold storage.<sup>1,3-7</sup> Additionally, the risk of bacterial growth in CSP is low and platelet aggregation response is better preserved in CSP to RTP.<sup>1,8-13</sup>

In Norway, CSP has been transfused as cold-stored whole blood since 2015, when we started using low titer group O whole blood in the air ambulance service based in Bergen.<sup>14</sup> In 2017 we implemented whole blood stored for up to 21 days for bleeding patients at Haukeland University Hospital.<sup>15</sup> In 2015 the U.S. Food and Drug Administration approved CSP from apheresis stored unagitated for up to three days for use to actively bleeding patients.<sup>16</sup> In 2021 they expanded the allowed storage time to 14 days.<sup>17</sup> Early clinical studies from the 1970s indicate that CSP may have beneficial effects in the treatment of patients with bleeding and clinical guidelines from this period recommend the use of CSP for these patients.<sup>18-21</sup> In their review from 2020, Mack et al found a lack of controlled clinical trials to answer whether CSP or RTP is more efficacious to treat bleeding.<sup>22</sup> Analysis of data from six decades suggests a short-lasting hemostatic effect of CSP.<sup>22</sup>

Extended unagitated storage is important, as it will allow for platelet inventory in smaller hospitals and shipment to remote areas. There has been a renewed military and civilian interest in the use of CSP mainly because of the potential for extended storage, which may reduce the risk of platelet shortage, facilitate transport and inventory management. Several articles have described that lack of agitation during cold storage does not affect quality.<sup>10,23,24</sup> Delayed cold storage and CSP units with 7-14 days shelf life have also been suggested as a shortage mitigation strategy during the COVID-19 pandemic.<sup>17,25</sup> Most patients in our hospital require prophylactic transfusions. Therefore, a dual inventory with a small number of CSP units with 14 days shelf life was deemed sufficient for actively bleeding patients.<sup>19,20</sup>

In this publication, we describe the implementation of a cold-stored platelet program for patients with active bleeding and report the use of CSP in our institution during the COVID-19 pandemic. Based on our experience, we aim to provide guidance on potential benefits and challenges in managing a dual platelet inventory.

## 2 | MATERIALS AND METHODS

### 2.1 | Study design

This report is based on data from our local quality registry on massive transfusions, which includes the use of CSP for actively bleeding patients at Haukeland University Hospital. The local data protection officer approved the registry (approval number 2016–07040). The registry includes all patients who received CSP units from 17 March 2020 until 31 December 2021. Additionally, an evaluation of practice was performed which includes management of inventory. In a letter detailing possible solutions to achieve sufficient blood supply during the COVID-19 pandemic dated 3 April 2020, the Norwegian Directorate of Health granted permission to implement CSP stored for up to 14 days if a sufficient supply of platelets could not be achieved.

### 2.2 | Implementation of cold-stored platelet concentrates

From 17 March, 2020, the Department of Immunology and Transfusion Medicine at Haukeland University Hospital collected and produced CSP units from apheresis (37% plasma/63% PAS IIIM, Trima, Terumo BCT) from donors with blood type O or A. After two hours rest at room temperature, units for cold storage were labeled as cold-stored with 14 days shelf life. Quality control of the PCs was performed according to routine procedures. We aseptically removed samples for bacterial testing (BacT/ALERT FA Plus, bio-Mérieux SA) on day 1 and incubated the samples for 13.5 days (BacT/ALERT 3D, bio-Mérieux SA). The CSP units were stored under continuous temperature monitoring without agitation at 2°C–6°C for a maximum of 14 days. Only PCs without aggregates were used and the units were stored cold from the day of collection. The majority of our apheresis PCs had aggregates after two hours rest. This often led to unnecessary donations of apheresis PC for cold storage when room temperature storage was sufficient. To simplify logistics without reducing quality or shelf life, we changed our procedure from 12 November 2020, to include PCs in which aggregates dissolved after agitation at room temperature to be transferred to cold storage one day after collection with 14 days shelf life.<sup>5,26</sup>

### 2.3 | Inventory and issue

The number of CSP units in inventory was decided based on an evaluation of demand. After the implementation phase, the minimum number of units was set to four CSP units with blood type A and/or O. Every weekday

morning the inventory was evaluated and new apheresis PCs were collected and produced, if needed. The inventory reports from the daily weekday meetings were used to supply a database with production, inventory, issue and outdate of every CSP unit.

When a request for PCs for transfusion was received, the biomedical laboratory scientists in charge of the issue of blood components dispensed CSP units to patients with active bleeding and RTP units to patients who required prophylactic transfusions.

### 2.4 | Data collection

All patients receiving CSP units were included in our patient quality registry. The following information was collected and registered in the database: Age, gender, blood type, and ward for each patient, the indication for transfusion as well as blood usage and transfusion reactions for each transfusion episode, which was defined as 24 h following the first CSP transfusion. Additionally, platelet count (PLT) and hemoglobin (HBG) before and within 24 h after each transfusion episode were registered if analyzed. Results were documented if TEG 6s global hemostasis assay (Citrated: K, KH, RT, FF, TEG 6s, Haemonetics Corporation) had been run before and/or after CSP transfusion. Briefly, the TEG 6s instrument uses resonance to detect clot strength in four chambers by exposing blood to a fixed vibration frequency range and detect vertical motion of the blood meniscus by light-emitting diodes. TEG 6s parameters were documented from two of the chambers. From Kaolin TEG with Heparinase (CKH), which eliminates the effect of heparin in the test sample we documented time to clot formation (CKH R), time from R until the clot reached 20 mm (CKH K), speed of clot formation at 20 mm (CKH angle) and maximum clot formation (CKH maximum amplitude). From TEG functional fibrinogen (CFF), which eliminates platelet contribution to the clot formation, we documented maximum clot formation (CFF maximum amplitude). For patients undergoing cardiothoracic surgery, we documented blood loss measured as chest drain output until the next day at 08:00 AM. Lastly, we documented survival one and 24 h after the first CSP transfusion.

### 2.5 | User survey

Blood bank staff was surveyed to evaluate the implementation and user experience of dual inventory of PCs. Invitations were sent by email to all staff issuing blood components and their responses were given anonymously in an electronic survey format. Information about

the survey were given in weekly staff meetings and the staff was encouraged to participate in the survey.

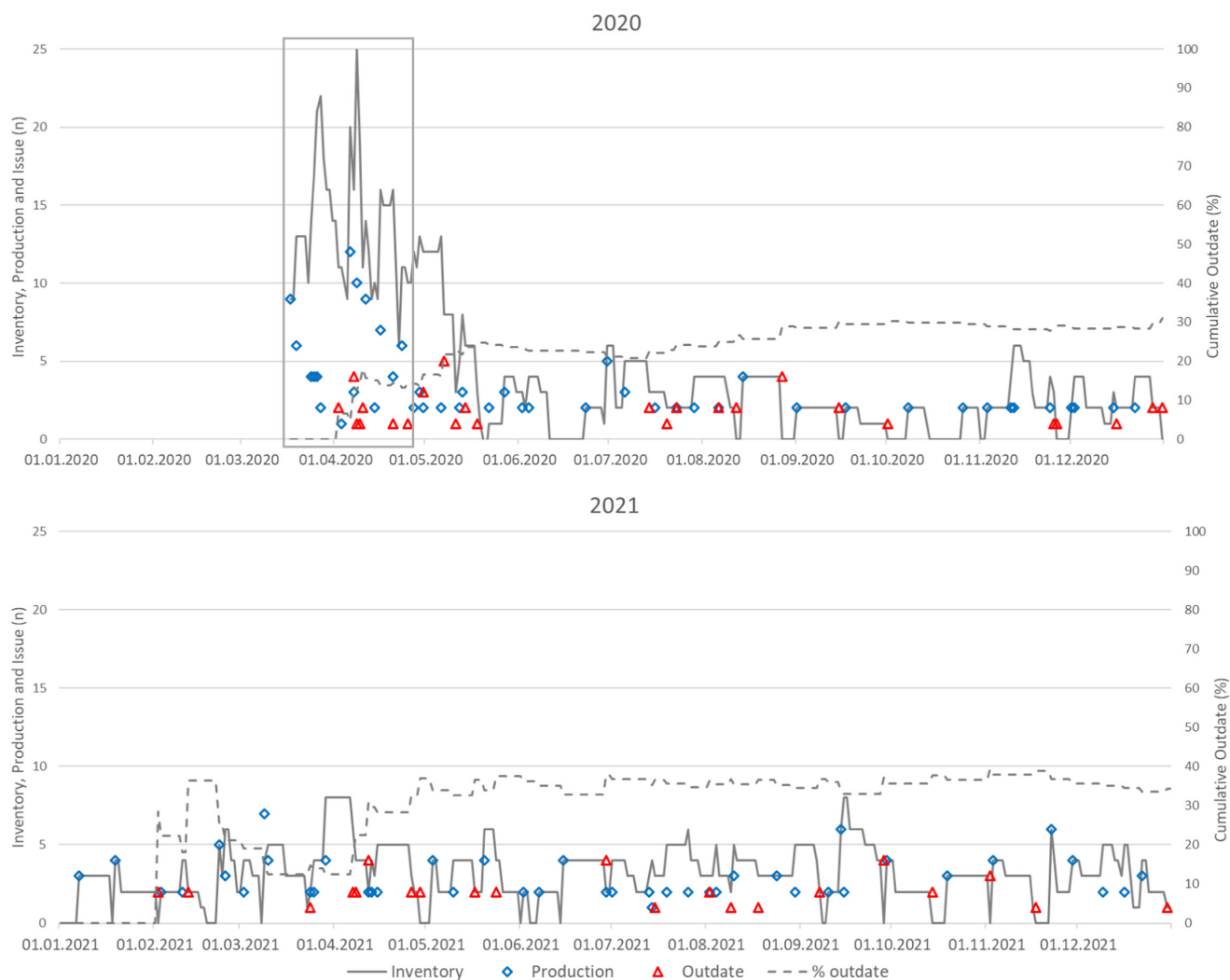
## 2.6 | Statistics

Statistical analyses were performed using IBM SPSS Statistics for Windows (Version 26, IBM Corp.). Results are presented as mean (95% confidence interval, minimum-maximum), median (interquartile range, minimum-maximum), or count (percentage). Figures were made using Microsoft Excel (2016, Microsoft Corporation).

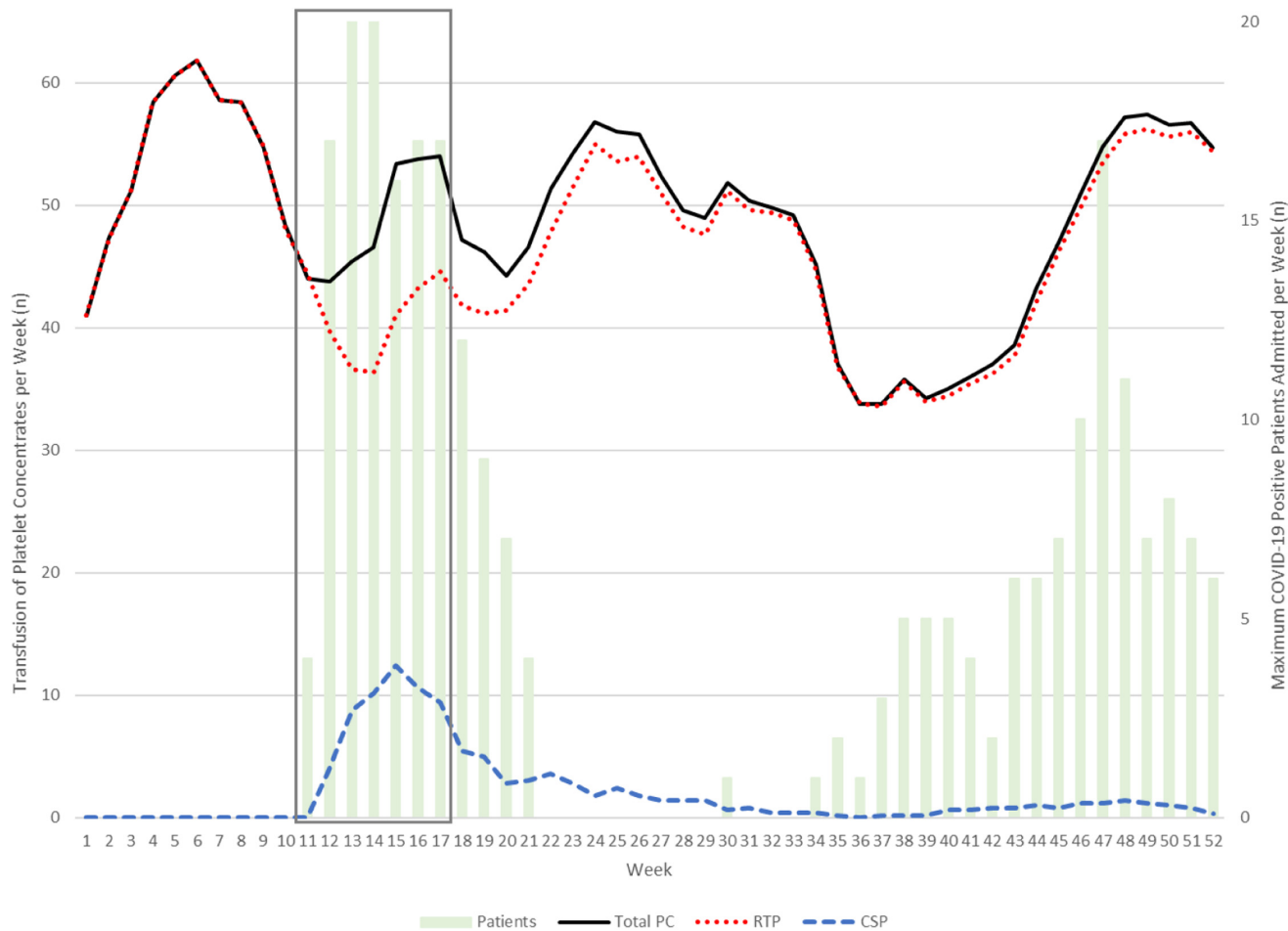
## 3 | RESULTS

From 17 March, 2020, to 31 December, 2021, a total of 5147 PC units were produced of which 276 (5%) were

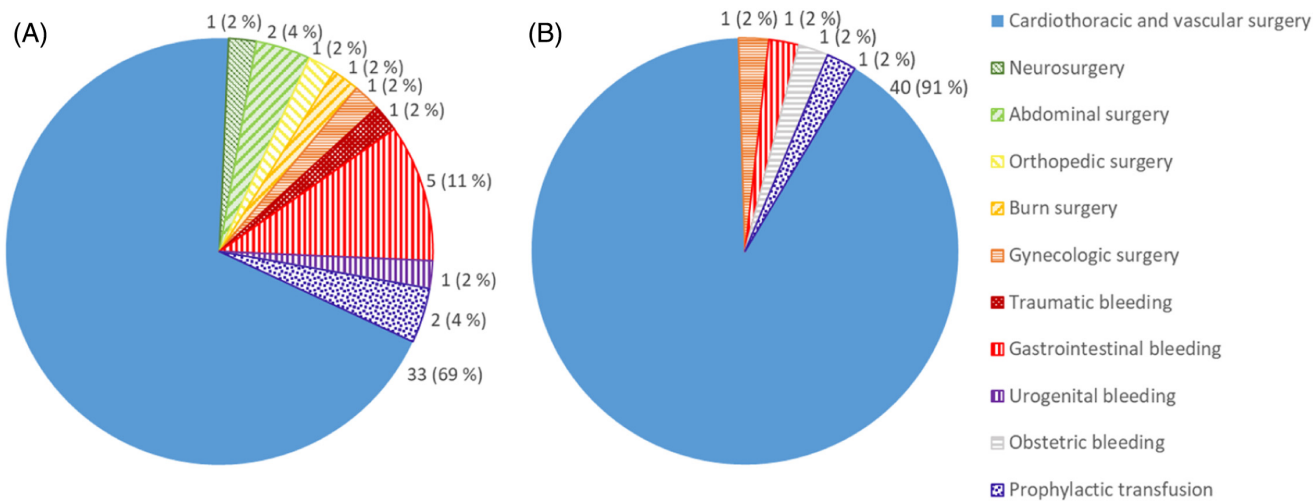
CSP units. Figure 1 shows an overview of inventory, production, and outdate of CSP units during the study period. Early in the Norwegian lockdown, as dual inventory of platelets was implemented, 66 of 345 PCs issued were CSP units (19%) and outdate of CSP units was low (gray frame in Figure 1). Figure 2 shows how transfusion of PCs varied in 2020 in relation to COVID-19 patients admitted to hospital. The use of CSP units was reduced after the first wave (Figure 2). Outdate of RTP units in 2019, 2020 and 2021 were 15%, 12% and 18% respectively. During the study period, there was an overall 33% outdate of CSP units. After an interim analysis revealed high wastage of CSP, the issue procedure was changed on 15 February 2021, after discussions with the clinicians to say that all patients undergoing cardiovascular surgery should receive CSP units. Additionally, several lectures were held detailing use of CSP and quality results from laboratory and clinical trials. This led to an initial drop in



**FIGURE 1** Overview of inventory, production, and outdate of cold-stored platelet concentrates in 2020 and 2021. Spotted lines indicate the cumulative outdate of each year. Early lockdown, with the most severe restrictions and reduced in-hospital activity, is marked with gray frame



**FIGURE 2** Transfusion of platelet concentrates per week in 2020, presented as moving average of five weeks, compared to a maximum number of COVID-19 patients admitted each week. Early lockdown, with the most severe restrictions and reduced in-hospital activity, is marked with gray frame. CSP, Cold-stored platelets; PC, Platelet concentrates; RTP, Room temperature-stored platelets



**FIGURE 3** Indication for transfusion of cold-stored platelet concentrates per transfusion episode. A: Indication for transfusion before 15 February 2021, and B: Indication for transfusion after 15 February 2021

outdates to below 15%. The drop did not last throughout the study period, but a shift in patient population receiving CSP was seen (Figure 3a,b).

There was no other reason than outdated for wastage of CSP during the study period and no increase in wastage of PCs due to infected donors during the COVID-19 pandemic. Technical or medical reasons for discarding PCs before the issue did not increase during the COVID-19 pandemic either, with 8%, 6%, and 4% in 2019, 2020, and 2021, respectively. In total, 186 CSP units (3.6%) were transfused to 92 patients in 103 transfusion episodes (Table 1). Median storage time of CSP units at issue was six days (3–9, 0–14). Patient characteristics are described in Table 1. The main indication for CSP transfusion was surgical bleeding (Figure 3). A total of 81 (88%) patients had surgical bleeding, and most of these patients underwent cardiovascular surgery. After the change in procedure in February, 2021, there was an increase in issues in this ward from 59% to 93% of the total number of issued

TABLE 1 Patient characteristics ( $n = 92$ )

		Mean (95% CI, min-max) or count (percent)
CSP units		2 (2, 2, 1–9)
Age (years)		65 (62, 68, 17–90)
Gender (female)		26 (28)
ABO type	O	40 (44)
	A	40 (44)
	B	9 (10)
	AB	3 (3)
Rh(D) type	Pos	75 (82)
	Neg	16 (17)
	Inconclusive	1 (1)
Indication for transfusion of CSP	Cardiothoracic and vascular surgery	73 (79)
	Neurosurgery	1 (1)
	Abdominal surgery	2 (2)
	Orthopedic surgery	1 (1)
	Burn surgery	1 (1)
	Gynecologic surgery	2 (2)
	Traumatic bleeding	1 (1)
	Gastrointestinal bleeding	6 (7)
	Urogenital bleeding	1 (1)
	Obstetric bleeding	1 (1)
Prophylactic transfusion	3 (3)	

Abbreviation: CSP, cold-stored platelets.

CSP units. The proportion of CSP transfusions when compared to the total number of PC transfusions in the Department of Cardiovascular Surgery also changed after this. During the 20 weeks leading up to the change in procedure, 14 of 134 PCs (10%) were CSP while 31 of 173 (18%) were CSP during the 20 weeks following the change.

Only four of the 186 (2%) issued CSP units were transfused to patients without bleeding. Two patients received CSP in an emergency order or when admitted to the emergency ward but were not actively bleeding. The third patient, admitted to the postoperative thoracic surgery ward, received two prophylactic CSP units before the procedure. None of these patients required immediate transfusions of additional platelets. Of the 92 patients, 86 (93%) received additional blood components and/or whole blood and 22 (24%) also received RTP units (Table S1).

All patients (100%) survived after one hour and 88 (96%) survived 24 h after the first transfusion. No deaths were associated with transfusion of CSP units. Two of the patients who did not survive were on venous–arterial extracorporeal membrane oxygenation (ECMO), one had post-operative complications after a fifth ileus operation and the fourth patient had an untreatable cancer diagnosis. No transfusion reactions were attributed to CSP units. However, a young patient with postoperative bleeding developed transfusion-associated lung injury (TRALI) with symptoms starting after an emergency transfusion with two units of packed red cells. This patient underwent an emergency reoperation shortly after where he received additional transfusions of three units of packed red cells, two units of plasma, and one unit of CSP. A postoperative chest radiography demonstrated bilateral opacities of the lungs. The attending anesthesiologist suspected TRALI which was confirmed

TABLE 2 Platelet count and hemoglobin before and within 24 h after the issue of first cold-stored platelet unit for patients with active bleeding

	<i>n</i>	Mean (95% CI, min-max)
PLT ( $10^9/L$ ) before transfusion of CSP	100	154 (135, 173, 5–394)
PLT ( $10^9/L$ ) within 24 h after transfusion of CSP	97	107 (95, 119, 5–290)
HGB (g/dL) before transfusion of CSP	102	9.6 (9.2, 10.1, 3.6–16.1)
HGB (g/dL) within 24 h after transfusion of CSP	101	9.5 (9.3, 9.7, 7.5–14.4)

Abbreviations: CSP, cold-stored platelets; HGB, hemoglobin; PLT, platelet count.

by the immunohematology senior consultant. However, since silent hypoxia started before the transfusion of CSP, they were not considered the cause of the transfusion reaction. During the study period, our department documented ten transfusion reactions to room temperature-stored PCs, five mild allergic reactions, three transfusion-associated circulatory overload (TACO) reactions, one febrile reaction, and one anaphylactic reaction.

For the patients with active bleeding there was a reduction in mean PLT and HGB measured before and within 24 h after issue of the first CSP unit (Table 2). TEG 6s global hemostasis assay was ordered for a total of 30 patients, 18 before transfusion and 22 after transfusion (Table S2). Results from the ten patients with analysis both before and after CSP transfusions are displayed in Table 3. The results show an improved hemostasis and aggregation ability after transfusion of CSP. For these ten patients mean PLT declined from  $121 \times 10^9/L$  (56, 187, 5–280) to  $115 \times 10^9/L$  (75, 155, 5–201) after transfusion of CSP, while HGB increased from 9.2 g/dL (7.9, 10.6, 5.6–11.8) to 9.4 g/dL (8.4, 10.4, 8.0–13.1).

Blood loss measured as chest drain output until 08:00 AM the next morning was measured for the 65 patients who had thoracic drains post-operatively. There was a median blood loss of 800 ml (480–1570, 180–10,810). PLT declined similarly for these 65 patients from mean  $187 \times 10^9/L$  (168, 206, 31–394) pre-operatively to  $127 \times 10^9/L$  (114, 140, 44–290) post-operatively while HGB declined from 10.0 g/dL (9.4, 10.5, 5.6–16.1) to 9.4 g/dL (9.1, 9.6, 7.6–11.4).

Eighteen of 24 (75%) blood bank personnel issuing blood components responded to the user survey regarding the issue of CSP (Table 4). 83% of the respondents had issued CSP. The majority (75%) responded that they had received sufficient information and training before CSP was implemented. Lack of information on the bleed-

TABLE 4 User survey: Issue of cold-stored platelet concentrates

<i>Have you ever issued cold-stored platelet concentrates?</i>	
Yes	15 (83%)
No	3 (17%)
<i>Did you get sufficient information and training before cold-stored platelet concentrates were implemented in the inventory?</i>	
Yes	12 (75%)
No	4 (25%)
<i>To which patients would you consider issuing cold-stored platelet concentrates? (Multiple choice)</i>	
Bleeding patients	16 (89%)
Patients at the cardiothoracic ward	16 (89%)
All patients if the inventory of room-temperature stored platelet concentrates is low	2 (11%)
As part of a massive transfusion package if this contains blood components	12 (67%)
None	0 (0%)
Unsure	1 (6%)
Other	0 (0%)
<i>We have had a relative high outdate of cold-stored platelet concentrates.</i>	
<i>What do you think could be the reason for this? (Multiple choice)</i>	
I am not sure which patients should receive cold-stored platelet concentrates	2 (11%)
I do not receive enough information about the patient to know whether cold-stored platelet concentrates are the right component to issue	6 (33%)
It is so busy that I forget that I can issue cold-stored platelet concentrates	12 (67%)
Since the cold-stored platelet concentrates are stored separate from the room-temperature stored, it is easy to forget them	15 (83%)
Other	3 (17%)

TABLE 3 TEG 6s global hemostasis assay before and after transfusion of cold-stored platelets

TEG 6s global hemostasis assay	n	Median (IQR, min-max)	n	Median (IQR, min-max)
CKH R (min)	10	8.95 (5.9–10.9, 4.2–19.2)	10	6.75 (5–9, 3.8–10.2)
CKH K (min)	8 <sup>a</sup>	2.5 (1.45–3.6, 0.9–4)	8 <sup>a</sup>	1.65 (1.2–5.95, 1.1–9.8)
CKH angle (degree)	10	57.5 (53.8–70.8, 36.9–76.7)	10	67.75 (58.5–73.5, 38–75.7)
CKH maximum amplitude (mm)	10	48.5 (38.9–59.4, 1.2–66.9)	10	58.05 (47.7–59.3, 23.9–64.9)
CFF maximum amplitude (mm)	9 <sup>b</sup>	14 (6.3–18, 2.2–25.8)	9 <sup>b</sup>	19 (16.2–19.3, 3.1–24.1)

Note: CKH R: Time to clot formation, CKH K: Time from R until the clot reaches 20 mm, CKH angle: Speed of clot formation at 20 mm, CKH maximum amplitude: Maximum clot formation, and CFF maximum amplitude: Maximum clot formation without platelet contribution.

<sup>a</sup>20 mm not achieved for two patients.

<sup>b</sup>No result for one patient.

ing status of the patient together with high workload and storage location of CSP was described by the staff as the main areas where improvements can be made to reduce the outdate of CSP.

## 4 | DISCUSSION

The decision to implement a dual platelet inventory was swift and based on immediate needs due to the pandemic situation. Our staff were familiar with the procedures for cold storage from our previous clinical trial, and procedures were swiftly changed. The production and issue of CSP units quickly increased, before the cold-stored inventory was reduced to approximately four units after eight weeks.

The Norwegian authorities implemented comprehensive restrictions to abate the COVID-19 pandemic in Norway. With exception of patients on ECMO, the COVID-19 patients used few blood products. Elective surgeries and other procedures were canceled and/or postponed during the first months (Figure 3), which led to reduced blood usage. At the same time, blood donors experienced home offices, travel restrictions, and restricted social contact, which also gave them more free time to donate blood.<sup>27</sup> The expected increase in blood wastage from new COVID-19 symptoms after donation did not appear. Due to these factors and implementation of a dual platelet inventory, there was never a challenge to meet blood demands at Haukeland University Hospital.

The patients in this quality database received transfusions due to active bleeding, where platelets are needed to form clots and thereby stop bleeding. Additionally, the majority of patients who underwent surgery are expected to have a fluid overload post-operatively compared to pre-operatively. This can explain the reduced PLT and HGB at the end of the transfusion episode. TEG 6s global hemostasis assay is the only clinical measurement of hemostasis in the quality registry, and shows improved platelet aggregation despite a reduction in PLT. This is consistent with laboratory studies finding CSP to have better aggregation response compared to RTP.<sup>1,8-10</sup>

The lack of reported transfusion reactions is in accordance with what we see for all types of blood components in patients undergoing surgery. It is not fully understood if there is a reduced risk of transfusion reactions during surgery or if there is an underreporting of events due to reactions being construed as a normal symptom post-operatively. Our previous clinical trial did not show any difference in transfusion reactions or thromboembolic events in the CSP groups compared to the RTP group.<sup>2</sup> A 24-h survival of 95.5% may at first glance seem low, however, all four patients that did not survive were high-risk patients where transfusion did not appear to affect the outcome.

The transition to dual inventory may be difficult to appreciate and manage for the laboratory staff. We experienced a higher outdate percentage of CSP units than estimated, which may be explained by the very limited clinical information available to the laboratory personnel issuing blood products in a busy work situation. Most orders for bleeding patients are received by telephone, and a possible solution may be to ask whether the patient has an active bleeding for every order of PC. Additionally, the storage location of the CSP units should be stored close to the room temperature-incubator to save time during issuing, and at the same time remind personnel of the dual inventory by the proximity.

Three patients who did not have an active bleeding received CSP units during the study period. Although not very frequent, our department has looked into measures to avoid this. Regular educational sessions, training in procedures, and an algorithm with clear transfusion guidelines are being prepared, which will lessen uncertainty during issues and further improve transfusion practice and reduce wastage (Table 5).

During the study period, mean inventory of CSP was four units. In 2020, the mean weekly transfusion of PCs to cardiovascular surgery patients was seven units. Therefore, in theory, there should be no outdate. To avoid outdates and ensure that CSP units are given to the intended patient group, an algorithm with clear guidelines should be made prior to implementation of a dual inventory with CSP for actively bleeding patients. Additionally, a

TABLE 5 Lessons learned

Lesson
<p><i>Clear algorithms for use and return of CSP</i></p> <p>Clear algorithms for production, issue, and return of CSP units should be in place before implementation of dual platelet inventory. This will lessen uncertainties about the issue and ensure transfusion of CSP to patients with bleeding.</p>
<p><i>Information and training of blood bank staff</i></p> <p>The key workers should be involved in the implementation. Discussions with blood bank staff could pinpoint each laboratory's challenges before they appear.</p>
<p><i>Information to clinical staff</i></p> <p>When implementing CSP as a new blood product, clinical staff need information about the product including indications, effects on quality, and safety for their patients. A clear transfusion algorithm ensures CSP units being used to actively bleeding patients. Information on difference in appearance, like bags being cold to the touch and lack of swirling will reduce insecurities.</p>
<p><i>Storage</i></p> <p>Location of the cold storage is important. Room temperature storage and cold storage should ideally be in close proximity to lessen workload and decrease outdating.</p>



follow-up on indication for each CSP transfusion is recommended to evaluate the clinical use and estimate the appropriate inventory size. We conclude that CSP with a storage time of 14 days is a feasible treatment alternative for patients with bleeding and that implementation of a cold-stored platelet program may mitigate of risk of platelet shortage during a pandemic situation. Implementation of a dual platelet inventory including CSP units requires thorough planning and continuous follow-up of practice, which should include information and training of clinical and laboratory staff as well as a clear algorithm for use.

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## CONFLICT OF INTEREST


The authors declare that they have no conflicts of interest relevant to the manuscript submitted to TRANSFUSION.

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## REFERENCES

- Braathen H, Sivertsen J, Lunde THF, Kristoffersen EK, Assmus J, Hervig TA, et al. In vitro quality and platelet function of cold and delayed cold storage of apheresis platelet concentrates in platelet additive solution for 21 days. *Transfusion*. 2019;59:2652–61.
- Strandenes GSJ, Bjerkvig CK, Fosse TK, Cap AP, Del Junco DJ, Kristoffersen EK, et al. A pilot trial of platelets stored cold versus at room temperature for complex cardiothoracic surgery. *Anesthesiology*. 2020;133:1173–83.
- Bynum JA, Meledeo MA, Getz TM, Rodriguez AC, Aden JK, Cap AP, et al. Bioenergetic profiling of platelet mitochondria during storage: 4 degrees C storage extends platelet mitochondrial function and viability. *Transfusion*. 2016;56(Suppl 1):S76–84.
- Getz TM, Montgomery RK, Bynum JA, Aden JK, Pidcoke HF, Cap AP. Storage of platelets at 4 degrees C in platelet additive solutions prevents aggregate formation and preserves platelet functional responses. *Transfusion*. 2016;56:1320–8.
- Wood B, Johnson L, Hyland RA, Marks DC. Maximising platelet availability by delaying cold storage. *Vox Sang*. 2018;113:403–11.
- Marini I, Aurich K, Jouni R, Nowak-Harnau S, Hartwich O, Greinacher A, et al. Cold storage of platelets in additive solution: the impact of residual plasma in apheresis platelet concentrates. *Haematologica*. 2019;104:207–14.
- Stolla M, Bailey SL, Fang L, Fitzpatrick L, Gettinger I, Pellham E, et al. Effects of storage time prolongation on in vivo and in vitro characteristics of 4°C-stored platelets. *Transfusion*. 2020;60:613–21.
- Nair PM, Pidcoke HF, Cap AP, Ramasubramanian AK. Effect of cold storage on shear-induced platelet aggregation and clot strength. *J Trauma Acute Care Surg*. 2014;77:S88–93.
- Nair PM, Pandya SG, Dallo SF, Reddoch KM, Montgomery RK, Pidcoke HF, et al. Platelets stored at 4°C contribute to superior clot properties compared to current standard-of-care through fibrin-crosslinking. *Br J Haematol*. 2017;178:119–29.
- Reddoch KM, Pidcoke HF, Montgomery RK, Fedyk CG, Aden JK, Ramasubramanian AK, et al. Hemostatic function of apheresis platelets stored at 4°C and 22°C. *Shock*. 2014;41(Suppl 1):54–61.
- Currie LM, Harper JR, Allan H, Connor J. Inhibition of cytokine accumulation and bacterial growth during storage of platelet concentrates at 4 degrees C with retention of in vitro functional activity. *Transfusion*. 1997;37:18–24.
- Ramirez-Arcos SK D, McDonald C, T ISBT TTID WP Bacteria Subgroup. Bacterial proliferation in cold-stored platelet concentrates Vox sang. 31st regional ISBT congress, ISBT in focus, virtual meeting. *Vox Sang*. 2021;116:5–188.
- Ketter PM, Kamucheka R, Arulananandam B, Akers K, Cap AP. Platelet enhancement of bacterial growth during room temperature storage: mitigation through refrigeration. *Transfusion*. 2019;59:1479–89.
- Bjerkvig C, Sivertsen J, Braathen H, Lunde THF, Strandenes G, Assmus J, et al. Cold-stored whole blood in a Norwegian emergency helicopter service: an observational study on storage conditions and product quality. *Transfusion*. 2020;60:1544–51.
- Hagen KG, Strandenes G, Kristoffersen EK, Braathen H, Sivertsen J, Bjerkvig CK, et al. A whole blood based resuscitation strategy in civilian medical services: experience from a Norwegian hospital in the period 2017–2020. *Transfusion*. 2021;61(Suppl 1):S22–s31.
- Stubbs JR, Tran SA, Emery RL, Hammel SA, Haugen AL, Zielinski MD, et al. Cold platelets for trauma-associated bleeding: regulatory approval, accreditation approval, and practice implementation—just the "tip of the iceberg". *Transfusion*. 2017;57:2836–44.
- Warner MA, Kurian EB, Hammel SA, van Buskirk CM, Kor DJ, Stubbs JR. Transition from room temperature to cold-stored platelets for the preservation of blood inventories during the COVID-19 pandemic. *Transfusion*. 2021;61:72–7.
- Becker GA, Tuccelli M, Kunicki T, Chalos MK, Aster RH. Studies of platelet concentrates stored at 22 C nad 4 C. *Transfusion*. 1973;13:61–8.
- Kattlove HE. Platelet preservation—what temperature? A rationale for strategy. *Transfusion*. 1974;14:328–30.

20. Valeri CR. Circulation and hemostatic effectiveness of platelets stored at 4 C or 22 C: studies in aspirin-treated normal volunteers. *Transfusion*. 1976;16:20–3.
21. Silva VA, Miller WV. Platelet transfusion survey in a regional blood program. *Transfusion*. 1977;17:255–60.
22. Mack JP, Miles J, Stolla M. Cold-stored platelets: review of studies in humans. *Transfus Med Rev*. 2020;34:221–6.
23. Zhao HW, Serrano K, Stefanoni D, D'Alessandro A, Devine DV. In vitro characterization and Metabolomic analysis of cold-stored platelets. *J Proteome Res*. 2021;20:2251–65.
24. NasrEldin E. Effect of cold storage on platelets quality stored in a small containers: implications for pediatric transfusion. *Pediatr Hematol Oncol J*. 2017;2:29–34.
25. Stanworth SJ, New HV, Apolseth TO, Brunskill S, Cardigan R, Doree C, et al. Effects of the COVID-19 pandemic on supply and use of blood for transfusion. *Lancet Haematol*. 2020;7:e756–e64.
26. Schubert PC Z, Culibrk B, Zhao W, Devine D, McTaggart K. Impact of cold storage delay time on cold stored platelet quality. *Transfusion*. 2018;58:143A.
27. Wiig FL. Pandemien ga blodbankene et luksusproblem. *Bioingeniøren: NITO*. Volume 9. Bioingeniørfaglig institutt, Oslo; 2021.

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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