ORIGINAL RESEARCH

TRANSFUSION

Hospital red blood cell and platelet supply and utilization from March to December of the first year of the COVID-19 pandemic: The BEST collaborative study

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Abstract

Background: At the start of the coronavirus disease 2019 (COVID-19) pandemic, widespread blood shortages were anticipated. We sought to

Abbreviations: COVID-19, coronavirus disease 2019; PLT, platelet; RBC, red blood cell; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; WHO, World Health Organization; US, United States.

determine how hospital blood supply and blood utilization were affected by the first wave of COVID-19.

Study Design and Methods: Weekly red blood cell (RBC) and platelet (PLT) inventory, transfusion, and outdate data were collected from 13 institutions in the United States, Brazil, Canada, and Denmark from March 1st to December 31st of 2020 and 2019. Data from the sites were aligned based on each site's local first peak of COVID-19 cases, and data from 2020 (pandemic year) were compared with data from the corresponding period in 2019 (pre-pandemic baseline).

Results: RBC inventories were 3% lower in 2020 than in 2019 (680 vs. 704, $p < .001$) and 5% fewer RBCs were transfused per week compared to 2019 (477 vs. 501, $p < .001$). However, during the first COVID-19 peak, RBC and PLT inventories were higher than normal, as reflected by deviation from par, days on hand, and percent outdated. At this time, 16% fewer inpatient beds were occupied, and 43% fewer surgeries were performed compared to 2019 ($p < .001$). In contrast to 2019 when there was no correlation, there was, in 2020, significant negative correlations between RBC and PLT days on hand and both percentage occupancy of inpatient beds and percentage of surgeries performed.

Conclusion: During the COVID-19 pandemic in 2020, RBC and PLT inventories remained adequate. During the first wave of cases, significant decreases in patient care activities were associated with excess RBC and PLT supplies and increased product outdating.

KEYWORDS

blood inventory, COVID-19, days on hand, demand, outdate, par, SARS-CoV-2, supply, use

1 | INTRODUCTION

In 2019, the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative agent for coronavirus disease 2019 (COVID-19) was reported in Wuhan, China. On March 11, 2020, COVID-19 was declared a pandemic by the World Health Organization (WHO).[1] When the pandemic began, it was unknown how COVID-19 would affect the international blood supply.[2] Yet almost immediately, the WHO published guidelines to mitigate the threat of insufficient blood supplies.[2]

Concern over the blood supply increased as social distancing recommendations, stay-at-home orders, business closures, and lockdowns hampered mobile and onsite blood donations.[3–5] Reduced staffing and supply chain challenges further reduced blood product manufacturing capabilities.[3,6] Investigators around the world, in Canada, Italy, Asia, Africa, and the Middle East, reported decreases in blood donations and blood products produced.[6–15] In the United States (US), in March 2020, the American Red Cross alone canceled more than 4600 blood drives, reducing the available blood supply by 143,600 units.[16]

At the same time, in the spring of 2020, elective surgical procedures in many countries were canceled.[3,12–14,17] Non-urgent procedures, and in some instances, solid organ transplants and autologous stem cell transplants were postponed.[4,18] Many hospitals also transitioned to mainly caring for COVID-19 patients who were found to require few transfusions, even when critically ill.[3,18–21]

Published studies to date have reported on blood supply and utilization during the first few weeks to months of the pandemic in one region of the world.[3,6,7–15] Although it has been suggested that the initial reduced blood supply during the pandemic was counterbalanced by decreased clinical activity and thus blood use, few studies have tested this hypothesis.[4,12–15,20] We conducted a retrospective study of 13 institutions in 4 countries aimed at characterizing the impact of the COVID-19 pandemic on hospital blood supply and utilization from March through December of the pandemic in 2020. From each site, blood inventory, blood utilization, and clinical activity data from March 1, 2020 to December 31, 2020 were collected and a 38-week study period was compared to the corresponding pre-pandemic period in 2019.

2 | MATERIALS AND METHODS

2.1 | Study sites and data collection procedures

This was a multicenter retrospective observational study. Participating sites were hospital-based transfusion services with academic affiliations located in Brazil, Canada, Denmark, and the US. Because no individual patient data were collected, this study was not subject to institutional review board oversight. Data were obtained by local study staff from hospital records and blood bank laboratory information systems and recorded using Microsoft Excel (Microsoft Corporation, Redmond, WA).
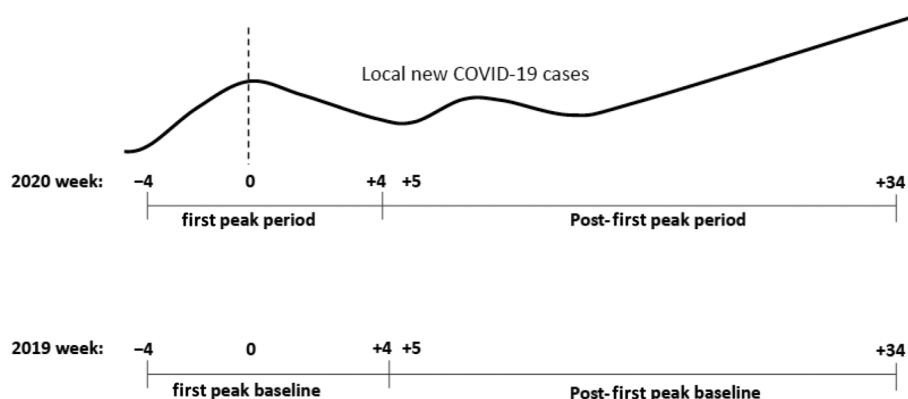
2.2 | Study periods

Weekly blood product inventory, transfusion, and patient care data from 2019 (pre-pandemic) served as a baseline for comparison with data from the corresponding weeks during the 2020 COVID-19 pandemic (Figure 1). Each study site collected data for the period from March 1st through December 31st for 2019 and 2020. For each site, we determined the week during 2020 when the first local peak of new COVID-19 infections occurred (termed week 0). For US sites, week 0 was defined as the week when the 7-day average of new COVID-19 infections in the county reached a maximum according to a nonprofit civic compilation of government database (https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/, Dadax Limited, US). Outside of the US, week 0 was defined as the week when new infections first peaked in that country according to according to a global live database (https://www.worldometers.info/, Wordometer, US). Data from the 13 sites were aligned based on each site's week 0. Data from 38-weeks, within March 1st to December 31st of 2020 and 2019, are termed the *2020 study period* and the *2019 baseline period*, respectively. In 2020, the *first peak period* spanned from 4 weeks before ("−4") to 4 weeks after ("+4") week 0. The *post-first peak period* comprised of 30 weeks from week +5 to +34 in 2020. The week in 2019 that corresponded with week 0 of 2020 was identified. Weeks −4 to +4 in 2019 were identified and referred to as the *first peak baseline period*, and weeks +5 to +34 in 2019 as the *post-first peak baseline period*.

2.3 | Blood product inventory data

Study sites provided weekly inventory data, which included the total number of RBC units, group O RhD-negative RBC units, and PLT doses in stock on the shelf in the blood bank, and the number of RBCs and PLTs that outdated. Outdated products were defined as those that expired while in the blood bank's inventory. For PLT inventory and transfusion calculations, one dose was defined as either one apheresis unit, or one pool of whole blood-derived PLTs regardless of how many concentrates were in the pool. If the number of PLT concentrates in a pool was unknown, it was assumed to be four.

FIGURE 1 Data collection periods. Top 2020 Study Period: Participating study sites collected weekly data on RBC and PLT inventories, transfusions, numbers of inpatients, and numbers of surgeries in 2020. For each site, we determined the week in which the first local peak in COVID-19 cases occurred (week C0; vertical line). In 2020, the *first peak period* was defined as the 9-week period encompassing 4 weeks before ("−4") and 4 weeks after ("+4") week 0. The 2020 *post-first peak period* comprised 30 weeks from week +5 to +34. Weekly aggregate data from study sites during the first peak period (weeks −4 through +4) were compared with the post-first peak period (weeks +5 through +34). Bottom 2019 Baseline Period: Weekly data from the corresponding weeks in 2019 served as a baseline for comparison. The *first peak baseline period* encompassed weeks −4 to +4 in 2019 and the *post-first peak baseline period* weeks +5 to +34 in 2019. COVID-19, coronavirus disease 2019; PLT, platelet; RBC, red blood cell

2.4 | Blood product inventory metrics

RBC and PLT inventory data were described using three inventory metrics: (1) deviation from par, (2) days on hand, and (3) percent of outdated products.

Par is the desired operational target inventory level pre-established by each hospital transfusion service, which reflects the anticipated routine blood product need plus a margin of safety. If the par was modified by a site during the study period, the updated par was used for analysis for that timeframe. The degree to which a site's RBC or PLT weekly inventory deviated from par was calculated as:

$$\text{Deviation from par} = (\text{daily average number of units or doses in inventory for the week} - \text{site}$$
$$- \text{established par at the time})/\text{site}$$
$$- \text{established par at the time}.$$

A product inventory above par would be reflected by a positive deviation from par value, a product inventory below par, a negative deviation from par value.

Days on hand is the available stock of a blood product available for transfusion divided by the average number of units/doses transfused during a specified period.[13,22] RBC and PLT days on hand was calculated for each site as:

$$\text{Days on hand} = \text{daily average number of units or}$$
$$\text{doses in inventory for the week}/\text{daily average number of units or}$$
$$\text{doses transfused for the week}.$$

The percent of outdated blood products reflects the number of products that expired in the blood bank's inventory relative to the total number of that product in inventory[22] and was calculated for each site as:

$$\% \text{ outdated} = \text{average number of units or}$$
$$\text{doses outdated for the week}/\text{average number of units or}$$
$$\text{doses in inventory for the week} \times 100.$$

2.5 | RBC and PLT transfusion data

The weekly total number of RBC transfusions, group O RhD-negative RBC transfusions, PLT transfusions, and RBCs and PLTs transfused specifically to hematology/oncology patients were collected. These transfusion data include both inpatient and outpatient transfusions.

2.6 | Patient care activity

At each site, patient care activity was assessed based on the daily average number of inpatient beds that were occupied per week and the total number of surgical procedures performed each week. The weekly percentage of inpatient hospital beds occupied was calculated using the following formula:

Each site's normalized weekly percentage of surgeries

$$\% \text{ occupancy} = (\text{daily average number of inpatient hospital beds occupied for the week}/$$
$$\text{maximum number of available inpatient hospital beds}) \times 100.$$

performed relative to an average week in a non-pandemic year (2019 baseline period weeks −4 to +34) was calculated as follows:

$$\% \text{ surgeries performed} = (\text{total number of surgeries performed during the week}/$$
$$\text{weekly average number of surgeries performed in 2019 baseline}) \times 100.$$

2.7 | Statistical analyses

Categorical variables were described using frequencies and percentages. Continuous variables were reported as means and standard deviations (SDs), or medians with interquartile range for skewed data when appropriate. The data were analyzed using three models. First, characteristics during the entire baseline period in 2019 (weeks −4 to +34) were compared to the entire study period in 2020 (weeks −4 to +34) using mixed effects models with a random intercept to account for weekly repeated measures within sites. Second, characteristics between first peak and post-first peak with baseline adjustment were compared using mixed effects models, where the baseline adjustment refers to the values in 2020 subtracted from the values in 2019 in the corresponding weeks. Third, to remove the impact of the first wave of COVID-19 in 2020, the post-first peak weeks were compared to the corresponding baseline weeks using mixed effects models with a random intercept to account for repeated measures within sites and adjusted for a fixed effect of percent occupancy of inpatient hospital beds. The weekly average aggregate trendlines smoothed using LOESS smoothing were plotted for 2019 and 2020 with the 95% CI. The associations between days on hand and percentage occupancy of inpatient hospital bed and percentage of surgeries performed were examined using Spearman correlation. To ensure meaningful comparisons, the measures for days on hand and the percentages of patient care activities (percentage occupancy of inpatient hospital bed and percentage of surgeries performed) were scaled using the min-max scaling method to the same range between 0 and 1. p values <.05 were considered significant. Data were analyzed using R version 3.6.3.[23]

3 | RESULTS

Data were collected from 13 institutions with hospital-based transfusion services located in the US ($n = 9$), Brazil ($n = 2$), Canada ($n = 1$), and Denmark ($n = 1$). Clinical services provided at all sites included medicine, surgery (general, cardiothoracic, and orthopedic), hematology/oncology, and solid organ and stem cell transplantation. Seven of 13 study sites (54%) relied on one blood supplier for their products; the others have two or more suppliers. Hospital size (measured by the number of inpatient beds) and RBC and PLT par levels used at each site in 2019 and 2020 are summarized in Table 1. At 10/13 (77%) sites, there was no change in the number of inpatient beds from 2019 to 2020. Two sites had a small increase in beds in 2020, and one site opened a new hospital building in 2020 that increased inpatient beds by 75%.

3.1 | Established par levels: 2020 (COVID-19) study period versus corresponding 2019 baseline period

Across all sites, the median RBC par level increased by 1.6% in 2020, going from a median of 443 RBC units in

TABLE 1 Characteristics of study sites

Site	Country	Blood suppliers (n)	Beds (n) 2019	2020	RBC par (n) 2019	2020	PLT par (n) 2019	2020
1	Brazil	1	592	626	224	222	None	None
2	Brazil	1	497	497	250	249	13	13
3	Canada	1	1029	1029	355	355	36	24
4	Denmark	1	2816	2816	1691	1691	132	132
5	US	2	793	833	820	820	40	40
6	US	5	395	395	300	225	15	10
7	US	3	957	979	443	467	40	40
8	US	2	525	525	450	450	45	45
9	US	1	350	613	410	450	35	40
10	US	1	800	800	515[a]	685	40	40
11	US	3	983	983	538	538	35	35
12	US	1	615	615	204	204	5	5
13	US	1	1331	1331	522	522	18	18

Abbreviations: PLT, platelet; RBC, red blood cell.
[a]515 from March to July 2020.

TABLE 2 Hospital RBC supply and utilization: 2019 (baseline) vs. 2020 (COVID)

Parameter	2019 (baseline) Mean (SD)	2020 (COVID) Mean (SD)	Baseline vs. COVID Mean difference[a] (95% CI)	p value
RBC units in inventory, n	704 (471)	680 (462)	−24 (−36 to −12)	<.001
RBC deviation from par	0.41 (0.59)	0.35 (0.45)	−0.06 (−0.09 to −0.03)	<.001
RBC days on hand, n	10.79 (4.79)	10.81 (4.23)	0.02 (−0.41 to 0.45)	.926
RBCs outdated, %	0.15 (0.17)	0.13 (0.14)	−0.02 (−0.04 to 0)	.059

Abbreviation: RBC, red blood cell.

[a]Mean difference shown is the effect estimate using mixed effects models with a random intercept to account for repeated measures within sites.

TABLE 3 Hospital PLT supply and utilization: 2019 (baseline) vs. 2020 (COVID)

Parameter	2019 (baseline) Mean (SD)	2020 (COVID) Mean (SD)	Baseline vs. COVID Mean difference[a] (95% CI)	p value
PLT doses in inventory, n[b]	36 (17)	36 (18)	−0.54 (−2.55 to 1.48)	.602
PLT deviation from par[b]	0.45 (0.97)	0.51 (1.00)	0.06 (0 to 0.13)	.044
PLT days on hand, n[b]	1.52 (0.53)	1.60 (0.62)	0.08 (−0.02 to 0.19)	.107
PLTs outdated, %[b]	1.98 (1.83)	1.93 (2.12)	−0.05 (−0.46 to 0.35)	.796

Abbreviation: PLT, platelet.

[a]Mean difference shown is the effect estimate using mixed effects models with a random intercept to account for repeated measures within sites.

[b]At 2/13 sites, the number of PLT doses in inventory was unavailable.

2019 to 450 RBC units in 2020. Seven of 13 sites (54%) did not change their RBC par level in 2020. Three sites increased their RBC par levels by 5%–33% in 2020; three sites reduced their RBC par levels by less than 2%. Across 12 sites with a PLT par, the median par level increased by 5.6%, going from 36 PLT units in 2019 to 38 units in 2020.

3.2 | RBC and PLT supply and utilization: 2020 (COVID-19) study period versus corresponding 2019 baseline period from weeks −4 to +34

We compared supply and utilization metrics for RBCs and PLTs during the 38-week study period in 2020 with the corresponding 38 weeks in 2019 (Tables 2 and 3) On average, the 13 study sites maintained 3% fewer RBCs in inventory during the COVID-19 study period (weeks −4 to +34) in 2020 compared to the baseline period (weeks −4 to +34) in 2019 (680 vs. 704, 95% CI −36 to −12, p < .001). The mean RBC deviation from par was slightly but significantly lower in 2020 versus 2019 (0.35 vs. 0.41, 95% CI −0.09 to −0.03, p < .001). The mean RBC days on hand and the mean percentage of RBCs outdated did not differ significantly between the 2020 study period and the 2019 baseline period. Utilization of RBCs was lower during the 2020 study period than in 2019: approximately 5% fewer RBCs

were transfused per week in 2020 (477 RBC units vs. 501, 95% CI −33 to −14, p < .001).

At 11 study sites, the average total weekly doses of PLTs in inventory, PLT days on hand, and percent of outdated PLTs were not significantly different during the 2020 study period compared to the corresponding 2019 baseline period (Table 3). PLT inventory data were not available at 2/13 (15%) sites. The only PLT inventory metric that differed significantly during the pandemic compared to baseline was deviation from par, which increased by 0.06 in 2020 (0.51 vs. 0.45, 95% CI 0–0.13, p < .05). Utilization of PLT transfusion decreased significantly by 6% in 2020 (169 PLT doses per week vs. 179, 95% CI −13 to −6, p < .001).

3.3 | Patient care activity: 2020 (COVID-19) study period versus corresponding 2019 baseline period

We collected data on inpatient bed occupancy and the number of surgeries performed as measures of patient care activity. In 2020, patient care activity decreased significantly compared with 2019 (Table 4). The average weekly inpatient occupancy decreased by 9% in 2020 (1116 inpatients vs. 1226, 95% CI −76 to −144, p < .001). After normalizing for site-specific inpatient bed capacity (percentage occupancy of hospital beds), the decrease was even greater (12%). Across study sites, inpatient bed

TABLE 4 Hospital RBC and PLT utilization and patient care activity: 2019 (baseline) vs. 2020 (COVID)

Parameter	2019 (baseline) Mean (SD)	2020 (COVID) Mean (SD)	Baseline vs. COVID Mean difference[a] (95% CI)	p value
RBC units transfused per week, n	501 (259)	477 (237)	−23 (−33 to −14)	<.001
PLTs transfused per week, n	179 (94)	169 (87)	−10 (−13 to −6)	<.001
Inpatient bed occupancy, %[b]	93 (14)	80 (8)	−12 (−14 to −11)	<.001
Surgeries performed, % normal[c]	100 (2)	90 (12)	−12 (−14 to −9)	<.001

Abbreviations: PLT, platelet; RBC, red blood cell.

[a]Mean difference shown is the effect estimate using mixed effects models with a random intercept to account for repeated measures within sites.

[b]At 1/13 sites, occupancy of inpatient beds was unavailable.

[c]At 1/13 sites, the number of surgeries performed was unavailable.
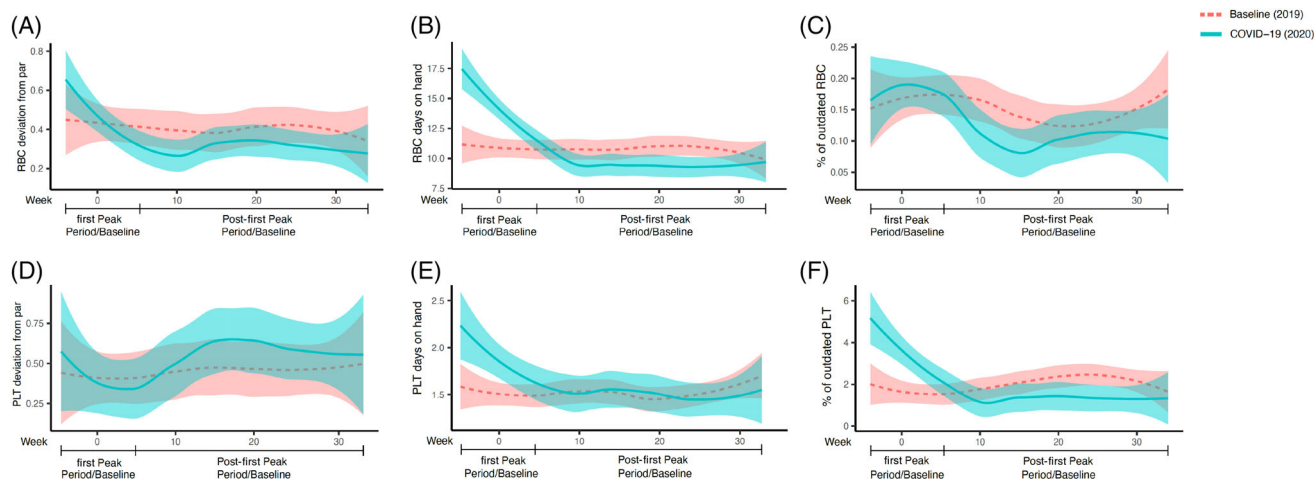

FIGURE 2 RBC and PLT inventory trends in 2019 and 2020. (A) Weekly RBC inventory levels expressed as deviation from par are shown for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). The periods shown on the X axis are as defined in Figure 1 (Materials and Methods). Deviation from par, on the Y axis, is the ratio of the difference between inventory and par relative to the established par (Materials and Methods). The trend lines are the aggregate weekly deviation from par for all 13 sites smoothed using LOESS smoothing; 95% CIs are shown in the shaded areas. (B) Weekly RBC inventory levels expressed as days on hand are shown for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). X axis, aggregate trendlines, and 95% CIs are shown as described previously in (A). (C) Weekly RBC outdate trends expressed as the percent of outdated RBCs are shown for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). (D) The aggregate weekly PLT inventory trends are shown as deviation from par for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). (E) The aggregate weekly PLT inventory levels are shown as days on hand for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). (F) The aggregate weekly PLT outdate trends expressed as the percent of outdated PLTs for the baseline period in 2019 (dash red line) and the COVID-19 study period in 2020 (solid blue line). COVID-19, coronavirus disease 2019; PLT, platelet; RBC, red blood cell [Color figure can be viewed at wileyonlinelibrary.com]

occupancy decreased at 11/12 sites (92%); inpatient bed occupancy data were not available at one site. Inpatient bed occupancy was 16% lower during the 2020 first peak period relative to the post first-peak period (Supplemental Table 1). The average weekly number of surgeries performed was 14% lower in 2020 than in 2019 (738 procedures vs. 854, 95% CI −152 to −80, p < .001). There were 43% fewer surgeries performed during the 2020 first peak period compared with the post first-peak period (Supplemental Table 1).

3.4 | Hematology/oncology blood utilization: 2020 (COVID-19) study period versus corresponding 2019 baseline period from weeks −4 to +34

RBC and PLT utilization in hematology/oncology patients in 2020 were compared to that of 2019. On average, RBC transfusion decreased by 12% (120 RBC units vs. 136, 95% CI −13 to −18, p < .001) across the 13 study sites. The proportion of RBC units transfused
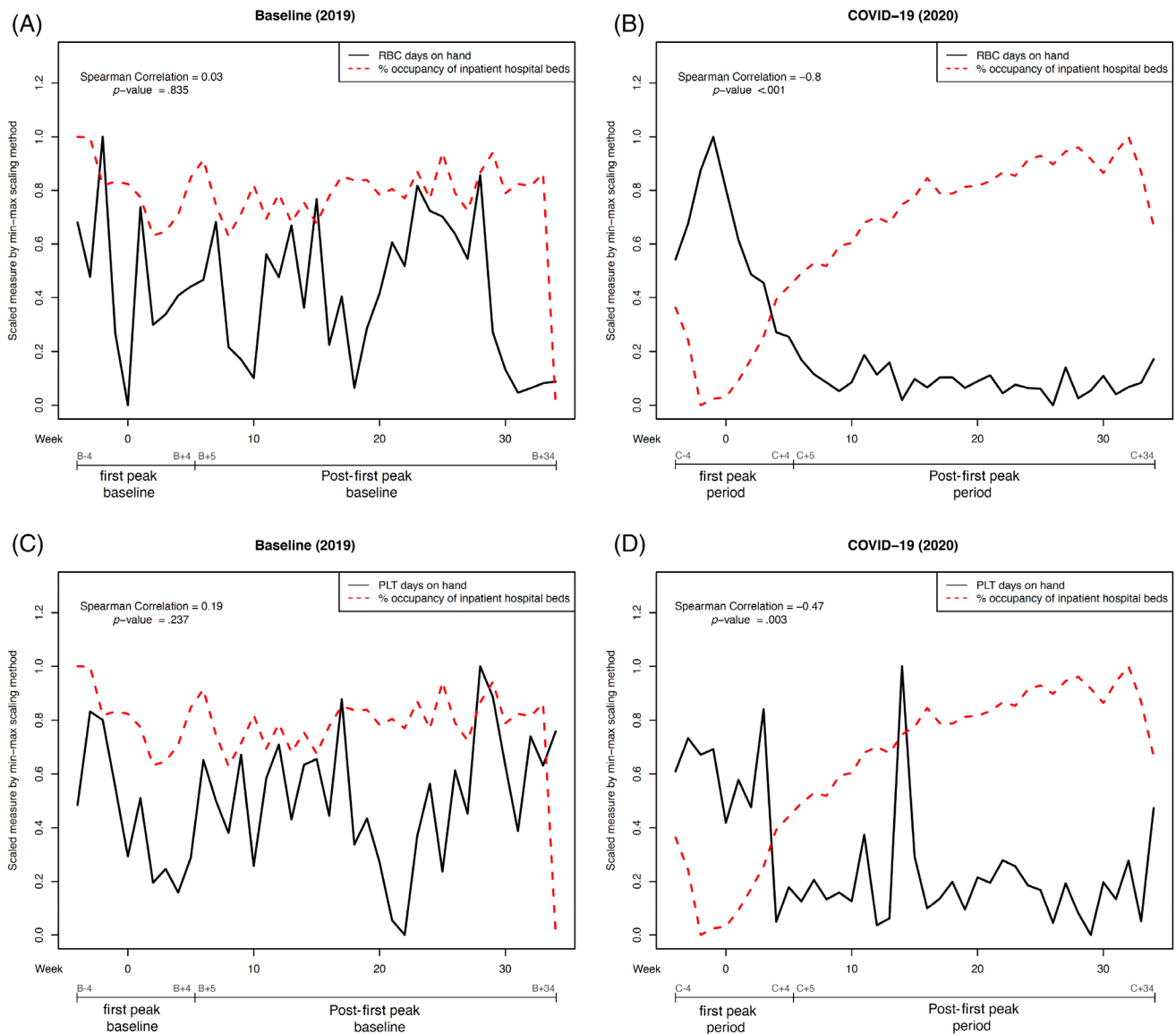
FIGURE 3 Days on hand and percent occupancy of inpatient hospital beds in 2019 and 2020. Top: Days on hand of RBCs (solid black line) and percent occupancy of inpatient hospital beds (dashed red line) are shown for the baseline period in 2019 (A) and the COVID-19 period in 2020 (B). The Y axis was scaled (0–1) using min-max scaling with the formula $Y = [Y - \min(Y)]/[\max(Y) - \min(Y)]$. The periods shown on the X axis are as defined in Figure 1 (Materials and Methods). Spearman correlation was performed to identify statistical significance. In the COVID-19 study period in 2020 (B), there was a statistically significant negative correlation between RBC days on hand and percent occupancy of inpatient hospital beds (Spearman correlation $= -0.8$, $p < .001$). Bottom: Days on hand of PLTs (solid black line) and percent occupancy of inpatient hospital beds (dashed red line) are shown for the baseline period in 2019 (C) and the COVID-19 study period in 2020 (D). During the COVID-19 pandemic (2020), there was a statistically significant negative correlation between PLT days on hand and percent occupancy of inpatient hospital beds (Spearman correlation $= -0.47$, $p = .003$). COVID-19, coronavirus disease 2019; PLT, platelet; RBC, red blood cell [Color figure can be viewed at wileyonlinelibrary.com]

to hematology/oncology patients, relative to the total, was comparable in 2020 (25%) and 2019 (27%). Likewise, the average weekly PLT doses transfused to hematology/oncology patients decreased by 10% (87 PLT doses vs. 97, 95% CI −8 to −12, $p < .001$) while the proportion provided to hematology/oncology patients was similar (51% vs. 54%).

3.5 | Trends in inventory metrics over time

RBCs inventories were higher than normal during the first peak period of COVID-19. Both RBC deviation from par and RBC days on hand were highest during the first peak period and lowest during the post-first peak period,
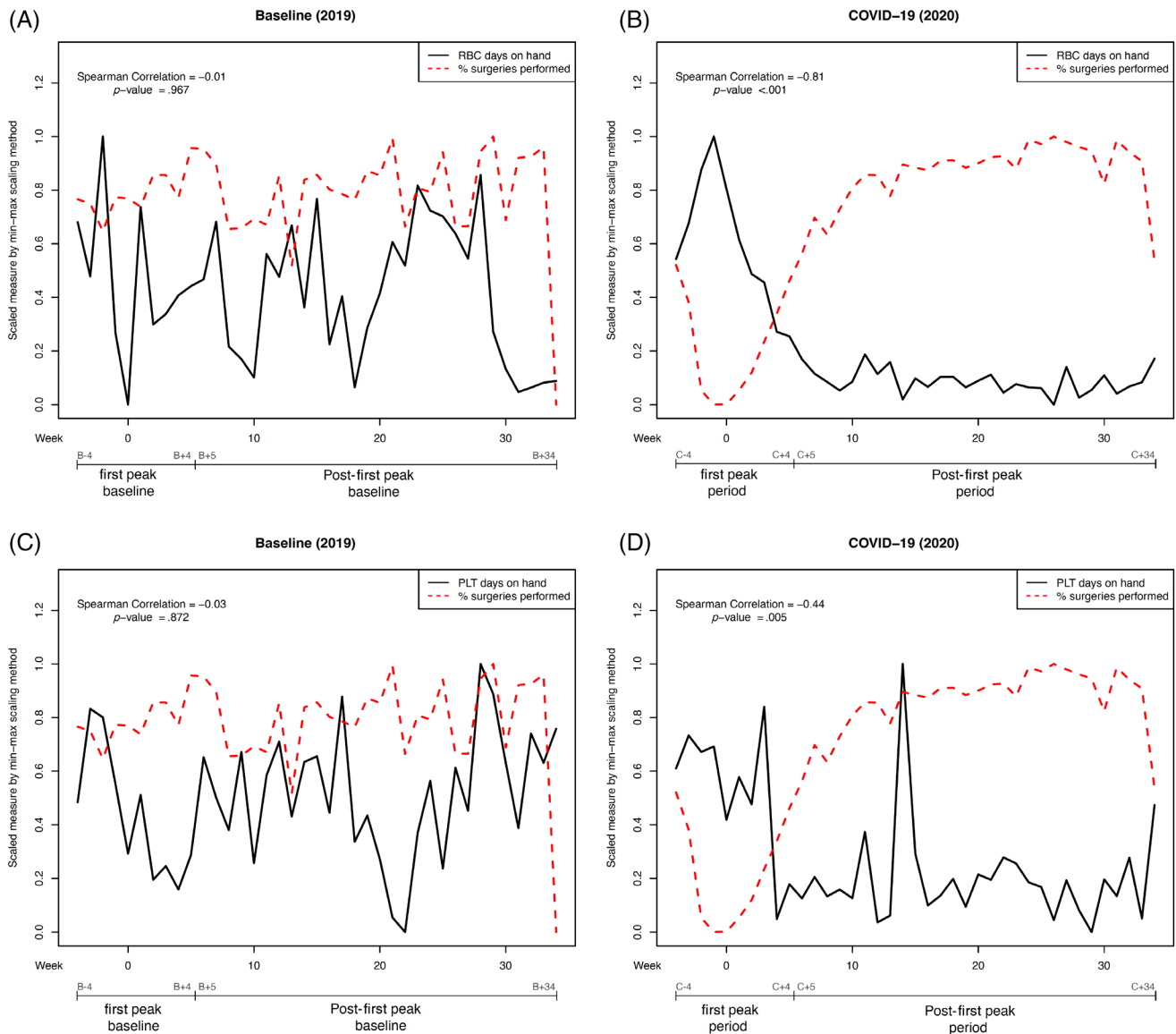
FIGURE 4 Days on hand and percent surgeries performed in 2019 and 2020. Top: Days on hand of RBCs (solid black line) and percentage of surgeries performed (dashed red line) are shown for the baseline period in 2019 (A) and the COVID-19 study period in 2020 (B). The Y axis was scaled (0–1) using min-max scaling with the formula $Y = [Y − \min(Y)]/[\max(Y) − \min(Y)]$. The periods shown on the X axis are as defined in Figure 1 (Materials and Methods). Spearman correlation was performed to identify statistical significance. In the COVID-19 period in 2020 (B), there was a statistically significant negative correlation between RBC days on hand and percentage of surgeries performed (Spearman correlation = −0.81, $p < .001$). Bottom: Days on hand of PLTs (solid black line) and percentage of surgeries performed (dashed red line) are shown for the baseline period in 2019 (C) and the COVID-19 period in 2020 (D). During the COVID-19 pandemic (2020), there was a statistically significant negative correlation between PLT days on hand and percentage of surgeries performed (Spearman correlation = −0.44, $p = .005$). COVID-19, coronavirus disease 2019; PLT, platelet; RBC, red blood cell [Color figure can be viewed at wileyonlinelibrary.com]

with more variation in 2020 than in 2019 (Figure 2A,B). RBC inventory was never below par (negative deviation) in 2020 nor 2019. In aggregate, RBC days on hand for the 13 study sites was approximately 50% higher at the beginning of the first peak period compared to the post-first peak period. Concomitantly, the percentage of RBCs outdating was higher during the first peak period than the post-first peak period (Figure 2C).

Similarly, PLT supply was greater than utilization during the first peak period of 2020 and fluctuated more than in 2019. The sites' aggregate PLT deviation from par was more variable in 2020 than in 2019 (Figure 2D) but always positive in both years. There were significantly more days on hand of PLTs during the 2020 first peak period compared to the post-first peak period (1.97 vs. 1.49, 95% CI 0.27–0.75, $p < .001$, Figure 2E).

At the beginning of the first peak period in 2020, nearly three times more PLTs outdated compared with the other study periods (Figure 2F).

3.6 | Relationship between blood product inventory and patient care activity

We examined the relationship between RBC and PLT days on hand to two metrics of patient care activity: percentage of inpatient bed occupancy and percentage of normalized surgical activity. In contrast to 2019 when there was no significant correlation, in 2020 there was a significant negative correlation between RBC days on hand and both percentage occupancy of inpatient beds (Figure 3B) and percentage of surgeries performed (Figure 4B). We observed a similar significant negative correlation between PLT days on hand with percentage occupancy of inpatient beds (Figure 3D) and percentage of surgeries performed (Figure 4D).

4 | DISCUSSION

The scale and severity of the COVID-19 pandemic was unlike anything in recent experience and required blood collection centers to make rapid and drastic changes. By mid-March of 2020, during the first wave of COVID-19, blood drive cancellations provoked widespread fear of blood shortages.[3–6,15,24] In this study, we sought to characterize the effect of the COVID-19 pandemic on RBC and PLT inventories at hospitals in different countries. Despite concerns that the pandemic would deplete hospitals of their blood stocks, we found that RBC and PLT utilization decreased overall—even among hematology/ oncology patients. RBC inventories during the first year of COVID-19 decreased by 3% compared to the pre-pandemic baseline period in 2019. Likewise, anticipated PLT shortages did not develop in 2020. In fact, despite collecting fewer donors during the first peak period of 2020, both RBC and PLT days on hand and percentage outdated increased significantly. A decrease in utilization of blood products during the first COVID-19 wave, reflected in this study by reduced inpatient bed occupancy and surgical volumes, appears to have counterbalanced the reduced collections.

Other studies have similarly reported a decrease in blood product supply accompanied by a reduction in utilization and increased wastage during the pandemic.[3,10,14,15,25] In a 2020 survey, 472/861 (54.8%) of responding AABB-accredited hospitals reported receiving alerts from blood suppliers of challenges filling blood orders.[25] In Canada, RBC collections reached their nadir in March 2020;

collections were 25% lower than originally planned.[14] Kracalik et al. analyzed monthly hemovigilance data from 72 US sites and reported RBC and PLT utilization decreased by 9.9% and 13.6%, respectively, and discards increased for RBCs (30.2%) and PLTs (60.4%) following notice to delay non-essential medical procedures in March 2020. However, there was not a statistically significant interaction between surgical volume and blood utilization before and after March 2020. Our results, using different analytical methods, frequency of data collection, and participating sites showed significant negative correlations between inventory and patient care activities.

Our study had important limitations and only included hospitals with academic affiliations in high human development index countries. Therefore, the conclusions drawn might not be generalizable to hospitals and areas not included in this study. Although study sites treated pediatric patients, none were specialist pediatric hospitals. The weekly data presented are not granular enough to demonstrate day-to-day or within-the-day shortages that can acutely impact patient care. Additional detailed data such as surgical versus nonsurgical transfusions, inpatient versus outpatient hematology/oncology volumes, and patient care activity metrics in addition to the number of inpatient beds occupied and the number of surgeries performed were not captured. Data collection ended in December of 2020 while the pandemic continued. This manuscript only reflects the first 10 months of the pandemic, when vaccination was not widely available. Finally, we focused on supply and utilization and did not study changes in transfusion triggers and newly implemented patient blood management programs.

Strengths of our study include that data were collected from 13 large academic affiliated sites in 4 countries that provide a wide range of clinical services to patients of all ages. All sites were affected by COVID-19 in the same year but at different times. By aligning our data based on the first local peak of COVID-19, it was possible to meaningfully compare the effects of the pandemic on blood inventories at each of the participating sites. Using a combination of inventory metrics—deviation from par, days on hand, and percent outdated—allowed us to obtain a clearer and more complete picture of hospital blood inventories. Patient care activities were compared using both absolute numbers and normalized for variations in hospital size and pre-pandemic surgical volume to ensure appropriate comparisons.

Deviation from par reflects anticipated need, and days on hand incorporates actual utilization. Deviation from par is calculated from the established par which is more static and based on anticipated utilization and varying levels of comfort with different margins of safety in the inventory. With a novel virus exerting myriad effects on society and healthcare systems, it is difficult to predict

blood utilization and adjust accordingly. In addition, each site's margin of safety depends on logistical considerations such as transport time and delivery frequency of blood products, and perhaps also on whether the hospital collects its own blood products. Days on hand is calculated from real-time transfusion data and thus utilization. It is therefore a better gauge of whether the blood inventory at a given time adequately met utilization. As such, days on hand was used to examine the relationship between inventory and patient care activity. This analysis revealed that hospital transfusion services may not have aptly reacted to decreased RBC and PLT utilization as patient care activity declined. It may be of interest to repeat our analysis later during the COVID-19 pandemic after 2020 when there may have been a greater mismatch between blood supply and utilization. Additional studies to assess the relationship between patient care activity and days of product on hand may also help hospital transfusion services improve the balance between supply and utilization during other unprecedented and unpredictable times.

5 | CONCLUSION

Our study showed that, while labile, RBC and PLT inventories at hospital transfusion services were sufficient, and in fact sometimes excessive, during the COVID-19 pandemic in 2020 relative to the pre-pandemic baseline (2019). During the first wave, RBC and PLT supply and waste increased when patient care activity decreased.

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SUPPORTING INFORMATION

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