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Maintaining Stable Red Blood Cell Supply in Japan During the COVID-19 Pandemic: Role of the Japanese Red Cross Society

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ABSTRACT

With the emergence and spread of COVID-19 caused by SARS-CoV-2, numerous blood drives were suspended, raising concerns from late February 2020 about a potential decline in volunteer blood donors across Japan. This study aims to examine how whole blood donation, production, and inventory control of red blood cell (RBC) units at the Japanese Red Cross Society (JRCS) changed during this period. It further evaluates how the pandemic influenced blood collection activities and the delivery of RBC products to healthcare facilities requiring transfusion support. Because RBC units are the most commonly used transfusion components and their availability rapidly reflects shifts in donor activity during COVID-19, they were selected as the primary focus. Data provided by the JRCS from January 2020 through August 2021 were reviewed, covering whole blood collection volumes, RBC production data, inventory adjustments, and distribution to medical centers. Although some variation occurred after January 2020, overall estimates of collected whole blood, produced RBC units, stock levels, and supply to hospitals remained generally steady. Factors that likely contributed include the cooperation of registered repeat donors, accurate forecasting of supply needs by JRCS, donor recruitment aligned with these projections, timely redistribution of units among block centers, and the presence of an established and reliable supply framework. Consequently, even amid the pandemic, RBC inventories were sustained at levels that allowed uninterrupted clinical care.

Keywords: RBC, COVID-19, Blood donation, Japanese red cross society

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Introduction

In Japan, the JRCS serves as the sole organization responsible for collecting voluntary blood donations, and all transfusion components originate from these donated units. RBC products are the most frequently administered transfusion component, primarily used to provide oxygen delivery to peripheral tissues. When assessing changes in production, stock management, and distribution of blood products during the COVID-19 crisis, RBC units were emphasized because their 21-day post-donation shelf life allows rapid evaluation of pandemic-related effects.

Figure 1 illustrates the overall RBC supply chain in Japan. Collection of whole blood, RBC manufacturing, and final distribution to medical facilities are all overseen by JRCS. Whole blood obtained at fixed donation sites or mobile sessions nationwide (①) is gathered at regional blood centers (②), transported to a block center in each region, and processed into RBC units or limited quantities of whole blood products (④). Since whole blood products are rarely produced, nearly all whole blood donations effectively become RBC units. These RBC units are delivered back to the regional centers several times daily, stored, and supplied to hospitals when needed (⑤). Adequate surplus at the regional centers may also allow storage at block centers. Inventory management is handled at the block centers. These blocks—regional units created in April 2012 to centralize testing and processing—are shown in **Figure 2a**. Japan is divided into seven block regions, with one block center operating within each. Block-level population and gross regional product values are presented in **Figure 2b and 2c** [1, 2]. The Kanto-Koshinetsu block represents more than one-third of the nation's population

and total production volume, indicating its central role in national whole blood collection and RBC distribution. When shortages appear likely in any block, a system (③) enables transfers between other block centers to maintain supply.

Japan confirmed its first COVID-19 case on January 15, 2020, after which the number of infections expanded rapidly [3]. As case counts increased, blood drives were halted, and concerns arose in late February 2020 about reduced donor turnout [4]. By April 1, 2020, newly reported cases reached 257 in a single day. Under the revised "Act on Special Measures Against Pandemic Influenza, etc." passed on February 3, 2020, a national state of emergency was declared on April 7, 2020 [5, 6].

Unlike strict lockdowns implemented elsewhere, Japan's emergency declaration carried no legal penalties but requested public cooperation. Initially, seven prefectures—Saitama, Chiba, Tokyo, Kanagawa, Osaka, Hyogo, and Fukuoka—were designated from April 7 until May 6, 2020. As infections continued to spread, the remaining 40 prefectures were added on April 16, making all 47 prefectures subject to emergency measures. The emergency period was later extended to May 31, 2020 on May 4, 2020 [7].

Under these measures, residents were urged to limit outings, facilities were asked to restrict use, and standard infection-prevention behaviors (mask use, cough etiquette, hand hygiene, gargling) were reinforced. Temporary medical facilities were also established. Up to October 17, 2021, four emergency declarations had been issued (1st: April 7–May 25, 2020; 2nd: January 8–March 21, 2021; 3rd: April 25–June 20, 2021; 4th: July 12–September 30, 2021). The first declaration reportedly reduced person-to-person contact by roughly 86 % [8]; however, the degree of impact during later declarations remains unclear.

In the JRCS system, the online blood-donation membership platform "Love Blood" enables users to make reservations, receive donation requests, book appointments at permanent donation rooms, and arrange group donations via mobile blood collection vehicles sent to schools or workplaces. When COVID-19 began to spread, many donation activities using bloodmobiles and open events scheduled for February 2020 were cancelled relative to February 2019, leading to a sharp fall in donor turnout during that month **(Figure 3)**. On April 17, 2020, the Japan Society of Blood Transfusion and Cell Therapy issued a recommendation urging appropriate clinical use of blood components in line with established guidelines, since the expansion of emergency declaration areas raised concern that blood supplies might become insufficient [4]. However, the actual operational circumstances of blood services at that time had not been documented.

Annual summaries of whole blood collection, RBC production, inventory handling, and distribution to hospitals are published on the JRCS website. These reports indicate that from 2016 through 2020, national whole blood donor counts, total collection volumes, and the number of RBC units provided to medical facilities remained generally stable [9]. Still, detailed month-by-month figures have not been publicly available, and no detailed analysis has addressed how COVID-19 and subsequent emergency declarations influenced these parameters. Examining the effects of the pandemic (1st through 5th waves) and the state-of-emergency periods on whole blood donation, RBC manufacturing and inventory, and product supply would help secure essential medical resources, including healthy volunteer donors, and allow assessment of inventory-control systems supporting stable transfusion product availability during periods of strain on healthcare. Thus, this work is considered important for designing future crisis-response frameworks.

The objective of this investigation is to evaluate how COVID-19 affected the provision of RBC units to healthcare institutions by analyzing JRCS statistical datasets—acquired via data disclosure requests—covering whole blood donations, RBC manufacturing, inventory management, and supply to medical institutions during the pandemic period (January 2020–August 2021).

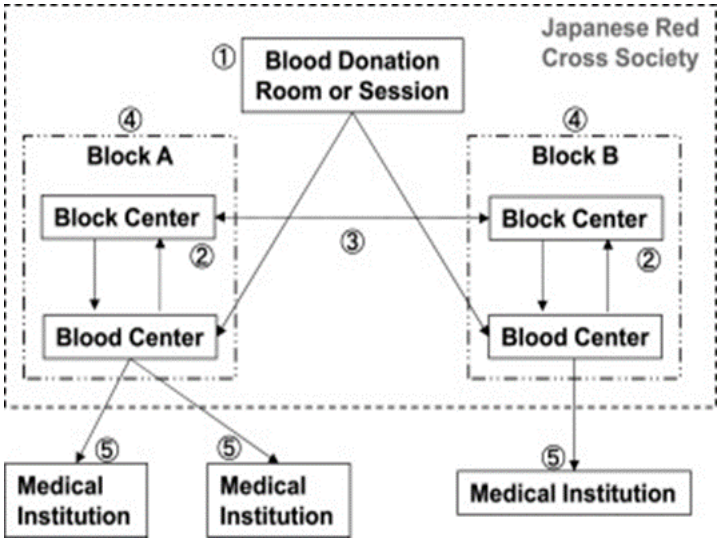

Figure 1. Flow of RBC product distribution in Japan. The numbered items correspond to: ① estimated whole blood donation volume, ② RBC product manufacturing volume, ③ inter-block transfers of RBC units, ④ block-level starting inventory at the beginning of each month, and ⑤ RBC supply to medical facilities.

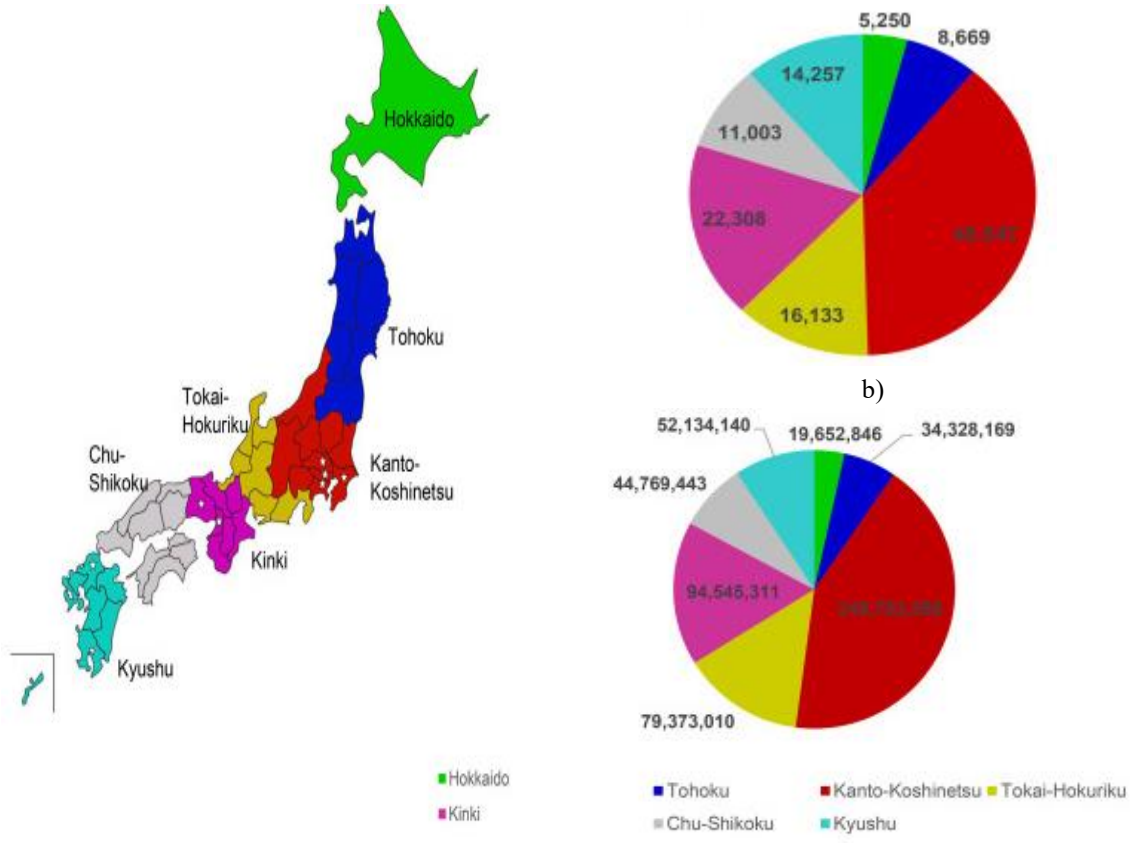

Figure 2. Comparison of block structure, population, and economic output: (a) block map, (b) block population (×1000 persons), and (c) block gross product (×1 million yen).

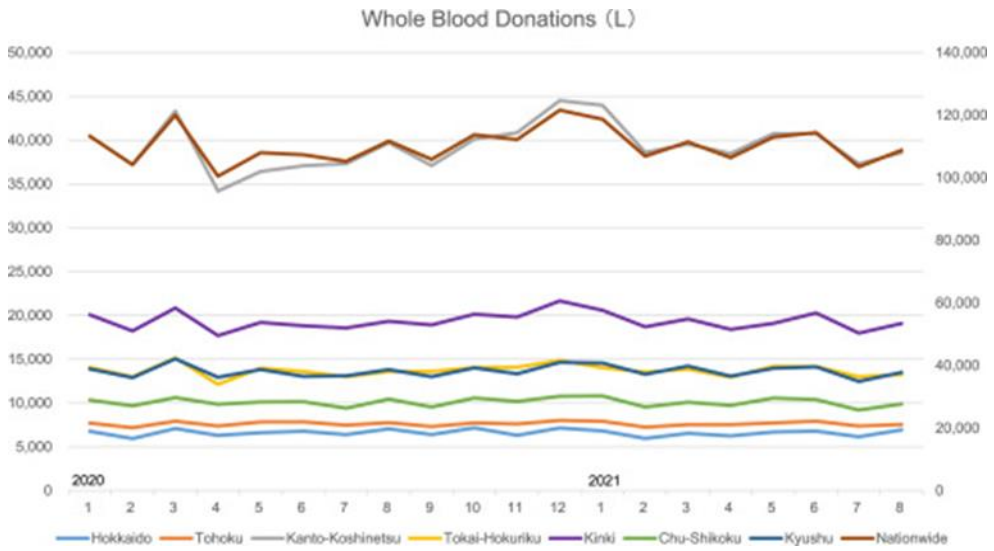

Figure 3. Whole blood donation volume (right axis shows national totals).

Materials and Methods

Using JRCS data from January 2020 to August 2021 on whole blood collection, RBC production, inventory adjustments, and distribution to hospitals, we assessed the status of whole blood donation and RBC transfusion activities during the COVID-19 outbreak. Portions of the dataset are also publicly accessible on the JRCS website [10]. Based on the supply pathway illustrated in **Figure 1**, the following parameters were compiled and evaluated at national and block levels **(Figure 2)**:

① Whole blood donation
② RBC product manufacturing
③ RBC transfers between blocks
④ Monthly opening inventory of RBC units
⑤ RBC supply to medical institutions

All datasets, prepared by JRCS staff with no missing entries, were analyzed by the authors using Microsoft Excel 2019.

Results and Discussion

As previously noted, RBC production, inventory management, and distribution to medical institutions are handled through blood centers and block centers across seven regional blocks. The results below present each parameter both by block and as a national total.

① Variations in whole blood donation volumes are shown in **Figure 3**. In 2019, national whole blood collection amounted to roughly 1,332,000 L [11], averaging about 111,000 L each month. For 2020, during January–August—which includes the first state-of-emergency period—the nationwide whole blood donation volume fell by 8.0 % in February, rose by 5.9 % in March, then declined by 11.3 %, 4.7 %, 5.3 %, and 7.1 % in April through July 2020, before returning close to the January 2020 level in August (1.4 % decrease). It is evident that donation volumes fluctuated substantially from February to July 2020 relative to the same months in 2019.

①

The pattern for 200 mL whole-blood collections **(Figure 4)** differed notably from the overall whole-blood donation volume (combined 200 mL + 400 mL). A clear rise appeared nationwide and across all regions in March 2020, followed by a sharp reduction from April through June, and a gradual rise beginning in July 2020. In contrast, 400 mL donations tracked almost identically with the total whole-blood trend, as 200 mL contributions were much smaller in scale. With the exception of Tokai-Hokuriku, Tohoku, and Hokkaido, most areas showed their highest point in December 2020, then a steady reduction toward August 2021, albeit with monthly variability.

②

Figure 5 presents the manufacturing output of RBC units, which mirrored the month-to-month shifts in the whole-blood donation volumes shown in **Figure 3**. Nationwide, RBC production dropped by 3.9% in February relative

to January, rose by 9.9% in March, and then fell by 12.5% in April. From May 2020 to August 2021, the maximum level again appeared in December 2020. Although small oscillations occurred, no abrupt swings were seen like those in March and April 2020. A broadly comparable pattern was observed in each regional block.

③

The movement of RBC products among regional blocks is summarized in **Figure 6**. Inter-block transfer values were calculated by subtracting items dispatched from items received; thus, positive values signify net receipt and negative values indicate net dispatch. In Kanto-Koshinetsu, a surplus of incoming units occurred in March 2020, followed by near-equivalence between incoming and outgoing volumes in April, and then large net inflows again during May and June. Except for January and August 2021, net receipts persisted after June 2020. The Kyushu, Tohoku, and Chu-Shikoku blocks generally helped counterbalance Kanto-Koshinetsu's excess receipts. The Kinki, Hokkaido, and Tokai-Hokuriku blocks showed different dynamics but overall remained close to neutral between sending and receiving. Broadly, most blocks compensated for Kanto-Koshinetsu's continuous receipt excess. In January 2021, marked net inflows occurred in Kyushu, Tokai-Hokuriku, and Tohoku, and Kanto-Koshinetsu and Kinki transferred units to them. These shifts likely reflected widespread cancellations of blood-collection activities caused by the extreme cold wave in Kyushu (January 7–10, 2021) [12], severe cold conditions in Tokai-Hokuriku with heavy snowfall (January 8–15, 2021) [13, 14], and major snowfall in Tohoku [15].

④

Beginning-of-month RBC product inventory levels are depicted in **Figure 7**. Nationwide stock rose from April through July 2020 compared with January 2020 (increases of 24.1%, 10.7%, 29.2%, and 18.6%, respectively), returned to roughly the January level in August, and then remained around 25,000 L through December without major changes. In 2021, inventories expanded markedly from January to March, reaching 37,403 L—a 45.2% increase relative to January 2020—then declined to about 25,000 L by May, followed by another rise through August. The Kanto-Koshinetsu region exhibited a broadly similar sequence but had a larger jump in March 2021 (81.4% above January 2020). The Kinki and Tokai-Hokuriku blocks also followed patterns comparable to the nationwide and Kanto-Koshinetsu trends. Other regions showed distinct month-to-month dynamics, yet all reached their maximum in March 2021.

⑤

Figure 8 displays the RBC supply to medical facilities. Relative to January 2020, national distribution dipped by 7.9% in February 2020, nearly returned to the January level in March (2.9% lower), fell further in April and May (8.1% and 9.5%, respectively), and rose again in June (only 2.5% below January). Supply in 2019, showing that the declines in April and May 2020 were notably more pronounced. Supplies peaked in October and December 2020, dropped sharply in February 2021, and reached another high in March 2021. A similar pattern was seen across nearly all regions. Notably February dips and October/December peaks occurred in 2019, suggesting these fluctuations may represent a typical annual rhythm.

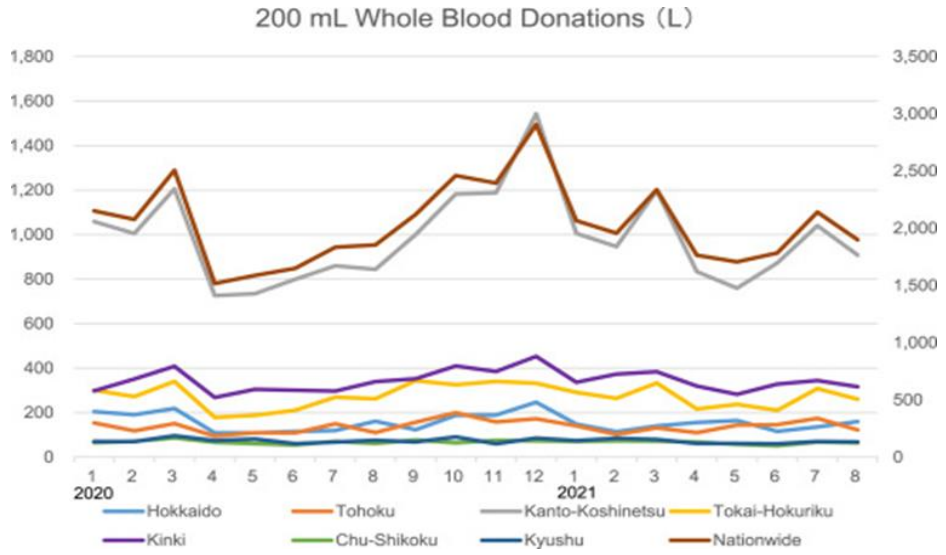

Figure 4. Volume of 200 mL whole-blood collections (right axis applies only to nationwide values).

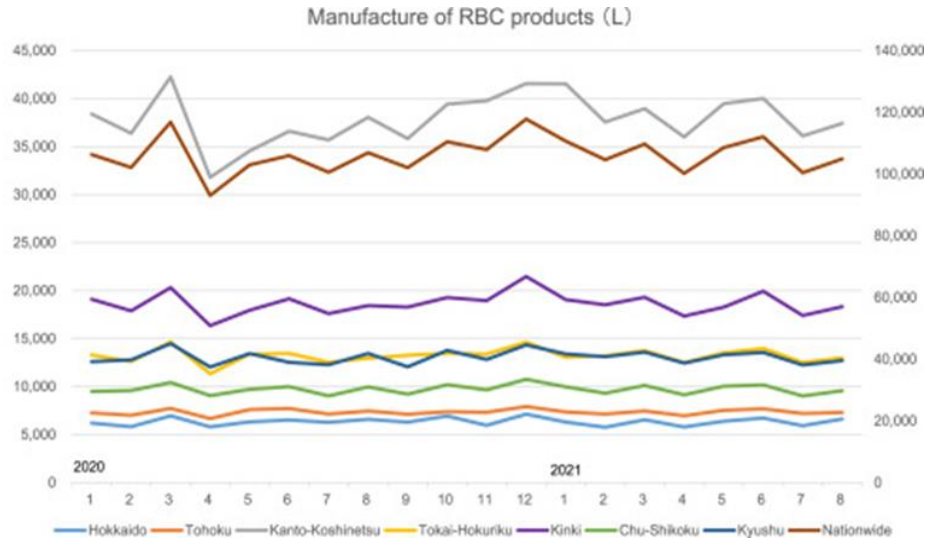

Figure 5. Quantity of RBC units produced (right axis used only for national totals).

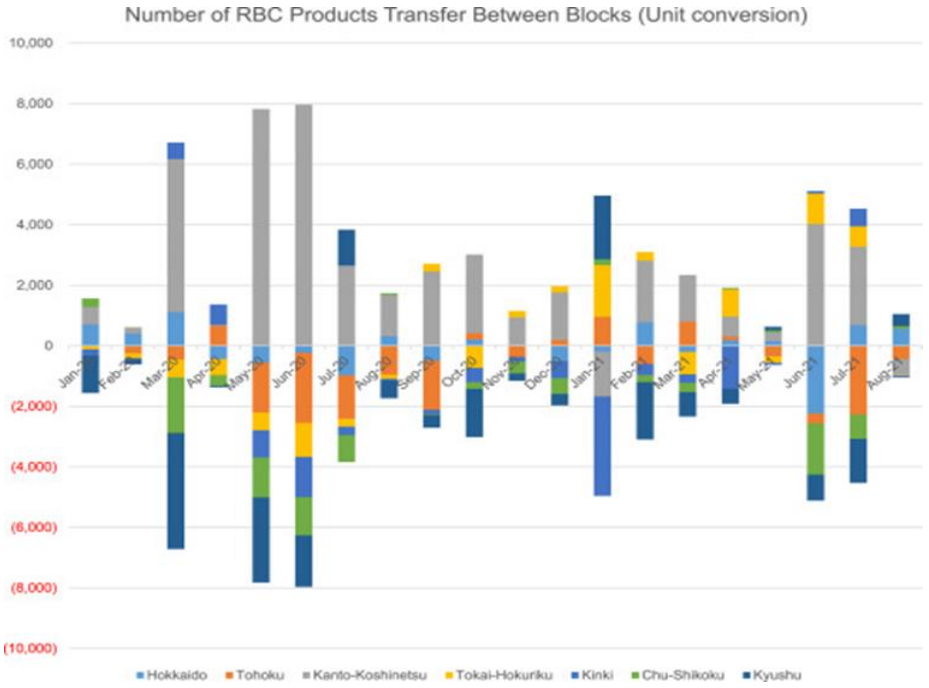

Figure 6. Volume of inter-regional RBC transfers (after unit conversion).

During the period surrounding the state of emergency (February–June 2020), the downturn in national blood donations noted in February 2020 stemmed from a shrinkage in the donor pool. The likely driver was the widespread public reluctance to go outside as COVID-19, a previously unfamiliar pathogen, spread rapidly. This situation sharply reduced volunteer donors at fixed sites and mobile sessions, and all school- and workplace-based blood drives conducted by mobile units were suspended [6]. Donor numbers at national collection sites from January to June 2020 declined, with February 2020 showing fewer participants at bus and open-site locations than February 2019.

A nationwide surge in donations in March (roughly 7.5% above March 2019 and 7.7% above March 2021) is largely attributed to significant media attention after swimmer Rikako Ikee shared a message on Twitter [16]. This is visible in the notable rise in 200 mL donations **(Figure 4)**. Consequently, RBC production increased in March, and national inventory levels climbed in April **(Figure 5)**. Whole-blood volumes had generally been decreasing from 2015 to 2021, yet March 2020 displayed a sharp jump relative to February 2020 (15.2%). This far exceeded the usual month-to-month increases: 3.4% (2015), 4.6% (2016), 5.2% (2017), 5.0% (2018), 1.1% (2019), 4.2%

(2021). Also donors at rooms, buses, and blood centers rose considerably in March 2020 compared with March 2019.

The higher manufacturing output of RBC units in March contributed to a net inflow of products into the Kanto-Koshinetsu area that same month, and national supply to hospitals rose **(Figure 8)**, likely reflecting increased demand for surgeries completed shortly before the April emergency declaration. At the same time, the additional fabrication of RBCs enabled Kanto-Koshinetsu inventories to grow in April **(Figure 7)**.

In April 2020, the distribution of RBC units to medical facilities dropped due to postponements of surgical procedures requiring transfusion following the declaration of emergency [17] **(Figure 8)**. Moreover, mobile drives were halted in accordance with the declaration [6], and whole-blood collections fell sharply nationwide during the same period **(Figure 3)**. Indeed compared with March, April saw reductions across donation rooms, buses, blood centers, and open donation spaces. Nevertheless, the Kanto-Koshinetsu region, which maintained the greatest stockpile, provided sufficient supply for national use **(Figure 7)**. The reduced frequency of 200 mL donations during this time suggests inventory management adjustments, since this volume is often limited when RBC stocks are high **(Figure 4)**. As a result, transfers in Kanto-Koshinetsu remained balanced in April, preventing net receipt surpluses.

Similarly, in May, hospital use of RBC products stayed low **(Figure 8)**. However, inventories at the start of May dropped both nationally and within Kanto-Koshinetsu and Tokai-Hokuriku **(Figure 7)**. In contrast, whole-blood donation began to rebound **(Figure 3)**, and RBC manufacturing—while still modest—also began recovering across nearly all regions **(Figure 5)**. Consequently, Kanto-Koshinetsu recorded net over-receipt of RBC units in May and June, causing inventory increases locally and nationwide at the start of June and July **(Figures 6 and 7)**.

The first emergency declaration was considered the most influential in reducing population movement, although concrete numerical evidence has rarely been displayed. The government issued the first declaration on April 7, 2020, initially targeting Saitama, Chiba, Tokyo, Kanagawa, Osaka, Hyogo, and Fukuoka (marked by ☆ in **(Figures 2a and S4(1))**). As infections continued climbing, the government expanded the declaration to all prefectures on April 16, 2020. Later, as case growth slowed, the covered regions were revised: on May 14, the list was reduced to Hokkaido, Saitama, Chiba, Tokyo, Kanagawa, Kyoto, Osaka, and Hyogo; on May 21, to Hokkaido, Saitama, Chiba, Tokyo, and Kanagawa; and finally, the declaration was fully lifted on May 25. Hence, the period from April 7 to May 25, 2020 had substantial societal consequences.

According to the Cabinet Secretariat's COVID-19 countermeasure site [18], we can view weekly changes in commuting frequency, the percentage of trips contained within one's residential municipality, and alterations in daily travel distance for an urban commuter using mainly rail. Once the declaration took effect, commuting activity dropped noticeably in Ibaraki, Saitama, Chiba, Tokyo, and Kanagawa, indicating that remote work accelerated and that daily movement increasingly stayed within local boundaries. Even after restrictions were removed, commuting activity remained below levels seen in January–March 2020, and residents of central districts continued to avoid long-distance travel. In short, rail usage among city commuters stayed suppressed even after the declaration ended. These lifestyle shifts in the Tokyo metropolitan region—more telework, more local travel, and less rail-based movement—continued beyond the emergency period. This shift likely contributed to the downturn in the number of whole-blood donors beginning in June 2020, prompting JRCS to intensify efforts to preserve or improve donor numbers.

In June, the resumption of surgeries after the lifting of the emergency order led to an increase in RBC supply to hospitals **(Figure 8)**. However, broader adoption of telecommuting and remote schooling meant that blood donation volumes and RBC production did not rise nationally **(Figures 3 and 5)**. Consequently, inventories at the beginning of July saw marked decreases across all regions **(Figure 7)**.

From July to October 2020, hospital use of RBC products expanded, which in turn boosted whole-blood donations and RBC production **(Figures 3, 5 and 8)**. Nevertheless, inventory levels fell from July to August and stayed low through December **(Figure 7)**. Between January and March 2021, the influence of the third wave, spanning December 2020–February 2021, caused inventories to rise sharply in every block **(Figure 7)**, owing to decreased hospital consumption paired with increases in donation and manufacturing **(Figures 3, 5 and 8)**. This suggests that JRCS's inventory-stabilizing strategies were effective during this phase of the pandemic.

During the fourth wave (April–June 2021), hospital demand for RBC units fell from March to May, but still stayed above levels from the previous year **(Figure 8)**. Both whole-blood collections and RBC production reached a low point in April **(Figures 3 and 5)**, generating a trough in inventories in May. Inter-block adjustment remained minimal at the time. Thus, June saw increased shipments toward Kanto-Koshinetsu, together with higher

production, enabling inventory recovery in June and July. Because the analysis ends in August 2021, the effects of the fifth wave cannot be evaluated fully. Still, by August 2021, shortages had not materialized, as stocks remained high.

In January 2021, the substantial net receipt of RBC units in Kyushu, Tokai-Hokuriku, and Tohoku resulted from organized responses to widespread cancellations of donation drives caused by the severe cold event of January 7–10, 2021 in Kyushu [12], the serious cold conditions and heavy snowfall from January 8–15, 2021 in Tokai-Hokuriku [13, 14], and the intense snowfall in Tohoku [15]. Furthermore, RBC supply to hospitals in these blocks during January 2021 did not exhibit particular instability.

Overall, despite repeated emergency declarations during the COVID-19 pandemic, whole-blood donation volumes and RBC production remained largely at standard levels, and hospital supply was maintained with no national shortages. Quality control continued uninterrupted, and safety-test failure rates for donor units changed only slightly (1.8% (2019), 1.9% (2020), 1.8% (2021)) [10]. The data also indicate that donor motivation increased when a prominent public figure (Ms. Rikako Ikee) encouraged participation, but declined when infection risk was high or when weather conditions were poor. Several reports have described substantial operational difficulties—staff shortages, reduced collection, and logistical disruptions—affecting blood services globally during the pandemic [19–25].

Possible explanations for Japan's relatively stable RBC supply during COVID-19 are considered below.

• In Japan, individuals were still able to leave home to donate blood because the COVID-19 state of emergency did not carry legal enforcement similar to lockdown protocols elsewhere. Donors recognized the necessity of contributing, considering the potential risk of reduced RBC product availability.

• Throughout the pandemic period, Japan did not experience reagent shortages or delivery delays that would affect RBC product production.

• On April 17, 2020, the academic organization (The Japan Society of Transfusion Medicine and Cell Therapy) released Urgent Recommendations for Shortage of Blood Product Supply Due to the Spread of Novel Coronavirus [4], encouraging more restrained use of RBCs.

• During COVID-19, JRCS acted as the central coordinator for blood collection, processing, and distribution to medical facilities—an operational structure that many developing nations [26, 27] do not have.

1. JRCS provided frequent reports to the Ministry of Health, Labour and Welfare (MHLW) about national RBC supply and demand to ensure that MHLW remained informed.
2. JRCS maintained steady communication with major hospitals—particularly those with high surgical volume—to anticipate future RBC requirements.
3. JRCS increased internal strategic meetings to forecast demand and avoid shortages of RBC products at healthcare institutions.
4. JRCS supervised RBC stock at the block level and facilitated transfers among block centers based on projected needs **(Figure 6)**.
5. JRCS consistently promoted blood donation through public media channels.
6. JRCS's "Love Blood" online platform, introduced in 2018, strengthened donor engagement and shortened on-site donation time, thereby decreasing possible COVID-19 exposure.

Compared to the situations reported from other countries lacking Japan's system-wide coordination in blood collection and supply [26, 27], the following considerations are vital to maintain a resilient blood supply during crises such as pandemics:

• Depending on the severity of the outbreak, governments must assess whether movement restrictions like lockdowns are necessary. If imposed, potential disruption of essential services—such as blood donation—should be carefully evaluated, including which level of restriction might hinder these activities.

• Establishing digital services for donors (e.g., online booking, remote information sessions) can shorten time spent at donation sites, reduce infection risk, and help sustain blood availability.

• Creating a unified body to oversee the entire blood-supply chain—encompassing health authorities, RBC manufacturing, transport partners, and hospitals—is strongly advised. Such an entity would function as a final safeguard ensuring uninterrupted supply in major emergencies.

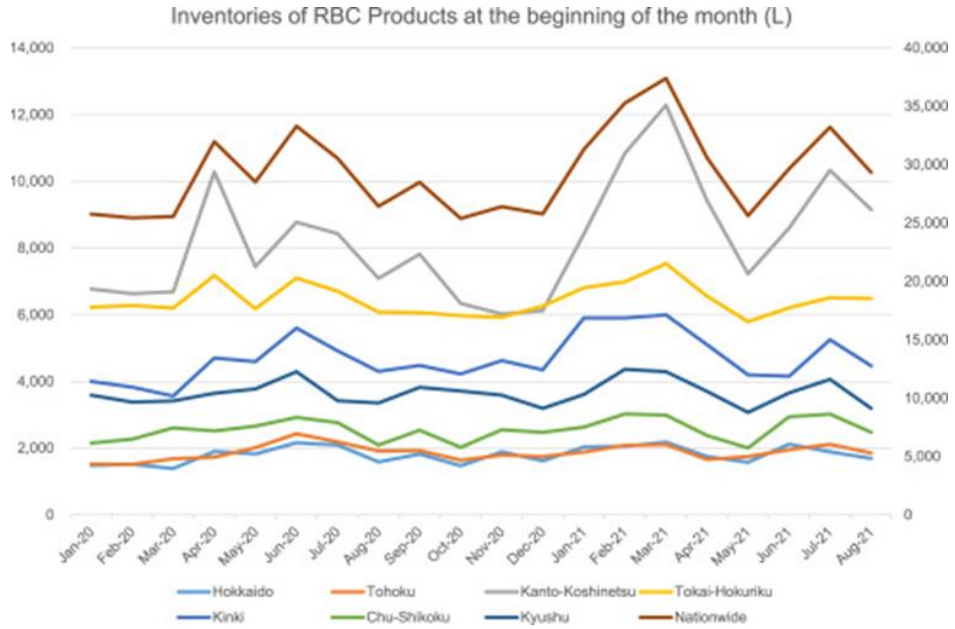

Figure 7. Inventory amount of RBC products at the beginning of the month (right axis only for nationwide).

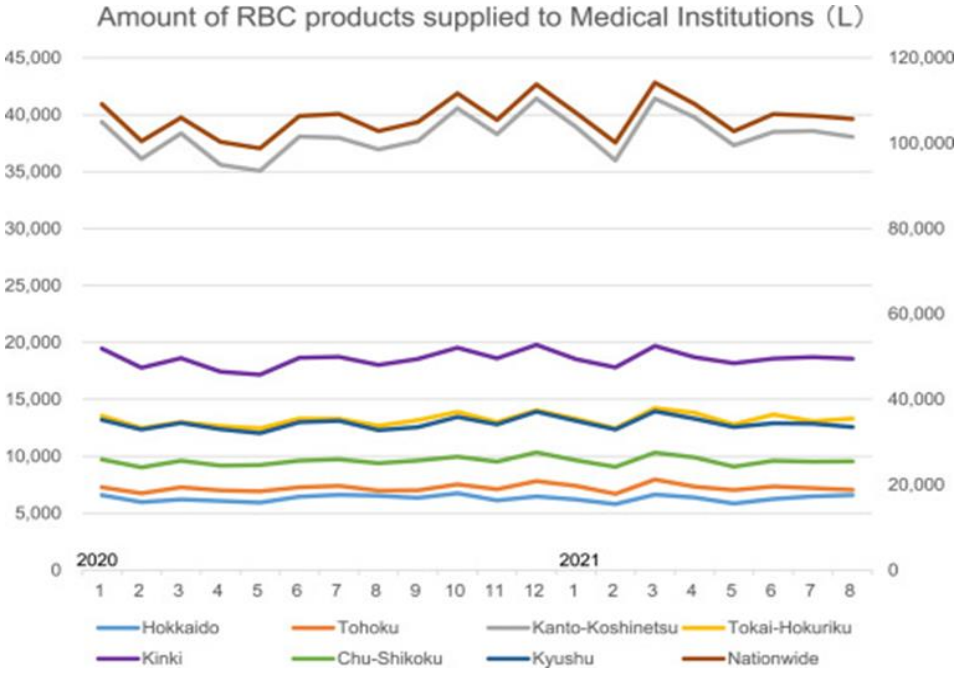

Figure 8. Amount of RBC products supplied to medical institutions (right axis only for nationwide).

Strengths and limitations

A major advantage of this study lies in its month-by-month assessment of blood donation and RBC supply patterns for each block in Japan, using precise monthly datasets from JRCS. This enabled direct comparison of 2020 (COVID-19 period) with 2019 (pre-pandemic) and allowed detailed documentation from January 2020 to August 2021, covering the first, second, third, fourth, and partial fifth waves. However, the study only analyzes JRCS-provided operational data and does not explore JRCS's internal decision-making processes.

The Japanese Society of Blood Transfusion and Cell Therapy conducted a nationwide annual survey to evaluate transfusion services and blood product use [28]. No major shifts in RBC consumption across medical departments or usage locations were detected between 2019 and 2021. This suggests that yearly surveys are insufficient for detecting short-term variations triggered by emergency declarations, making it difficult to capture actual medical demand fluctuations during the COVID-19 crisis.

This work also did not examine RBC donation or supply patterns after August 2021, despite the fact that COVID-19 had not fully subsided in Japan.

Conclusion

Although whole blood donation levels were heavily affected during the COVID-19 outbreak, JRCS maintained a stable distribution of RBC products by preserving adequate inventories across its regional blocks and reallocating supplies when needed. Japan's inter-block support system—developed over years of responding to earthquakes, typhoons, and other natural events—offers a model for building resilient social security frameworks capable of withstanding both infectious disease emergencies like COVID-19 and large-scale national disasters.

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Conflict of Interest: None

Financial Support: None

Ethics Statement: Review and/or approval by an ethics committee was not needed for this study because the data used for this research are published on the web site of Japan Red Cross (https://www.jrc.or.jp/donation/blood/data/) and do not include any personal information (only include the amount of blood volume).

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