Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Impact of a Hospital-Wide Transfusion Management Program on Fresh Frozen Plasma Wastage: A 9-Year Quasi-Experimental Interrupted Time Series Study

Ji Young Seo
Samsung Medical Center, Sungkyunkwan University School of Medicine
Minjeong Nam
Samsung Medical Center, Sungkyunkwan University School of Medicine
Mira Kang
Samsung Medical Center, Sungkyunkwan University School of Medicine
Won Chul Cha
Samsung Medical Center
Duck Cho
duck.cho@skku.edu

Samsung Medical Center, Sungkyunkwan University School of Medicine

Research Article

Keywords: fresh frozen plasma, blood wastage, transfusion management, interrupted time series, patient blood management, quality improvement, tertiary hospital

Posted Date: November 17th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10833920/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Impact of a Hospital-Wide Transfusion Management Program on Fresh Frozen Plasma Wastage: A 9-Year Quasi-Experimental Interrupted Time Series Study

Ji Young Seo[1,2], Minjeong Nam[1], Mira Kang[2,3,4], Won Chul Cha[2,4,5], Duck Cho [1,2]

[1]Department of Laboratory Medicine and Genetics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

[2]Samsung Advanced Institute for Health Sciences and Technology, Sungkyunkwan University, Seoul, Korea

[3]Health Promotion Center, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

[4]Office of AI Transformation, Samsung Medical Center, Seoul, Korea

[5]Department of Emergency Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Running title: Transfusion Management Program and FFP wastage

Jiyoung Seo: jiyoung3513@gmail.com; 0000-0002-0418-6901

Minjeong Nam: mjnam0906@gmail.com; 0000-0003-3542-3487

Mira Kang: mira90.kang@samsung.com; 0000-0002-7842-0035

Won Chul Cha: wc.cha@samsung.com; 0000-0002-2778-2992;

Duck Cho: duck.cho@skku.edu; 0000-0001-6861-3282

*** Corresponding author: Duck Cho, M.D., Ph.D.**

Department of Laboratory Medicine and Genetics
Samsung Medical Center
Sungkyunkwan University School of Medicine, Seoul, Korea
Phone: +82-2-3410-2403
Fax: +82-2-3410-2719
E-mail address: duck.cho@skku.edu
*** Co-corresponding Author: Minjeong Nam, M.D., Ph.D.**
Department of Laboratory Medicine and Genetics
Samsung Medical Center
Sungkyunkwan University School of Medicine, Seoul, Korea
Phone: +82-2-3410-3592
Fax: +82-2-3410-2719
E-mail address: mjnam0906@gmail.com

ABSTRACT

Background: Blood component wastage is an important healthcare quality and resource stewardship challenge, particularly for fresh frozen plasma (FFP), which has a limited post-thaw shelf life. We evaluated the impact of a dedicated Transfusion Management Unit (TMU) and a hospital-wide integrated transfusion management program on FFP wastage in a tertiary-care hospital.

Methods: We conducted a retrospective quasi-experimental study using transfusion registry data from January 2017 to December 2025, aggregated into 36 quarterly intervals, of which 32 (16 pre-intervention and 16 post-intervention quarters) were included in the segmented regression models. A TMU-based integrated program was implemented in 2021, and changes in FFP wastage level and trend were assessed using segmented regression with Prais–Winsten estimation. Red blood cell (RBC) and platelet wastage rates were analyzed as comparison outcomes.

Results: Before the intervention, FFP accounted for approximately 12% of all blood components issued but 68.6% of total blood component wastage. The mean FFP wastage rate decreased from 4.46% before the intervention to 1.60% after the intervention ($p < 0.001$). Segmented regression showed a level change of -2.30 percentage points (95% CI -3.15 to -1.45, $p < 0.001$). Although a significant positive change in slope was observed after the intervention ($\beta_3 = 0.112$ percentage points per quarter, $p = 0.005$), the estimated post-intervention slope remained modest (0.041 percentage points per quarter), and the fitted FFP wastage rate remained below the projected counterfactual level throughout follow-up. No significant intervention-associated level changes were observed for RBC or platelet wastage.

Conclusions: Implementation of a dedicated TMU and a hospital-wide integrated transfusion management program was associated with a substantial reduction in FFP wastage. These findings suggest that system-level transfusion management can strengthen blood resource

stewardship and improve the operational efficiency of transfusion services.

Keywords: fresh frozen plasma; blood wastage; transfusion management; interrupted time series; patient blood management; quality improvement; tertiary hospital

INTRODUCTION

Blood components are limited, irreplaceable medical resources that require careful stewardship to ensure sustainable availability and high-quality transfusion services [1]. Increasing demand for transfusion, coupled with challenges in maintaining an adequate donor supply, has intensified the need to optimize blood utilization and minimize avoidable wastage throughout the healthcare system [2-4]. Consequently, blood component wastage has become an important quality indicator that reflects not only inventory management but also the efficiency of clinical workflows, multidisciplinary coordination, and hospital resource utilization.

Among blood components, fresh frozen plasma (FFP) is particularly susceptible to wastage because of its short post-thaw shelf life and strict storage and return requirements defined by the Korean Transfusion Guidelines and Association for the Advancement of Blood & Biotherapies (AABB) standards; FFP was stored at ≤ -18℃ for up to 1 year [5, 6]. In clinical practice, FFP is frequently thawed in advance to ensure urgent transfusion for major surgery, invasive procedures, trauma resuscitation, massive transfusion protocols, or treatment of severe coagulopathy[7, 8]. However, changes in patients' clinical status, procedure cancellations or modifications of treatment plans often result in unused thawed plasma. Because returned units must meet stringent temperature and time criteria before re-entry into inventory, inefficiencies in communication and inventory management can readily translate into avoidable wastage.

These challenges are particularly evident in large tertiary-care hospitals, where blood products are distributed across multiple clinical departments and rapid communication between clinicians, nursing staff, and transfusion services is essential. Beyond the biological limitations

of FFP, organizational factors – including fragmented workflows, delayed communication, and the absence of standardized return-and-reuse processes-can substantially contribute to wastage. Therefore, reducing FFP wastage requires not only appropriate clinical decision-making but also coordinated healthcare delivery supported by effective organizational systems.

Previous studies have evaluated various approaches to reduce blood component wastage, including staff education, computerized decision support, extension of storage policies, and inter-hospital inventory sharing [9-13]. Although these interventions have demonstrated incremental improvements, most have focused on individual interventions rather than comprehensive, organization-wide quality improvement strategies [14, 15]. Furthermore, relatively few studies have evaluated the long-term effectiveness of integrated transfusion management programs using robust quasi-experimental designs.

To address these challenges, our institution established a dedicated Transfusion Management Unit (TMU) in 2021 and implemented a hospital-wide transfusion management program integrating a standardized operational protocol, an electronic return-and-reuse workflow, laboratory-linked prescribing alerts, and multidisciplinary governance. This study evaluated the long-term impact of this system-level intervention on FFP wastage over a nine-year period using interrupted time series (ITS) analysis. We aimed to determine whether the program was associated with an immediate and sustained reduction in FFP wastage while accounting for underlying temporal trends.

MATERIALS AND METHODS

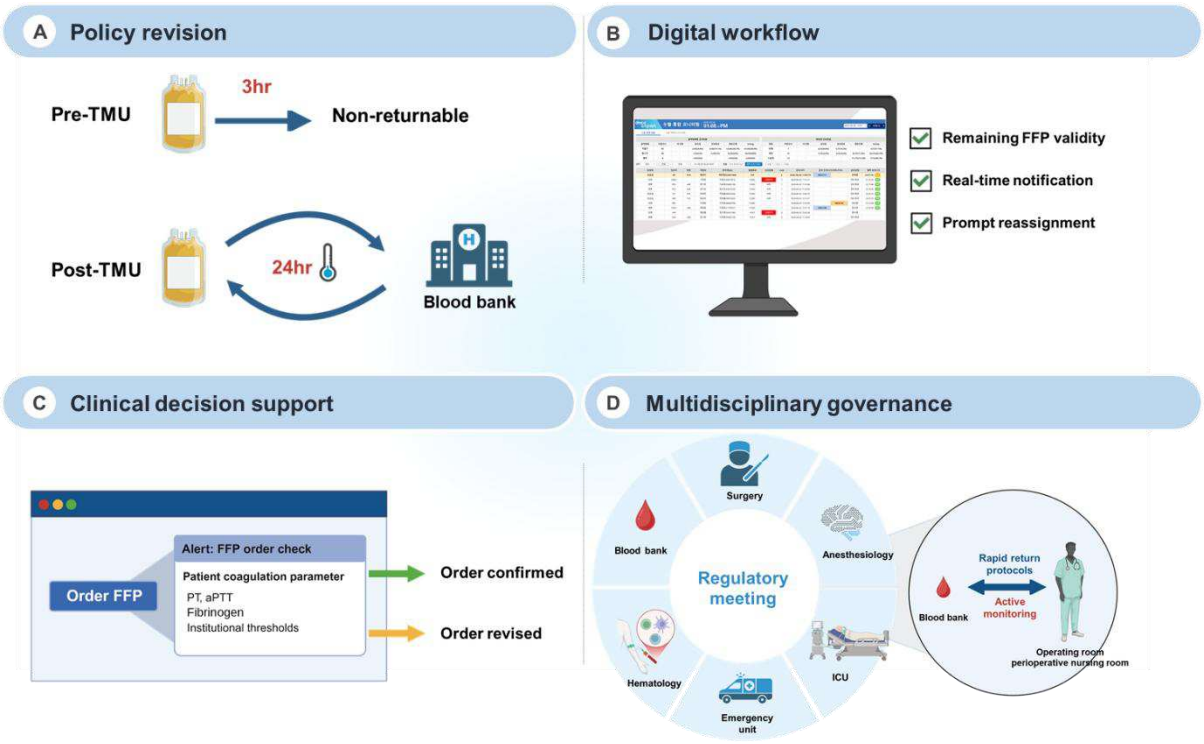
Study design

This retrospective quasi-experimental study was conducted using an ITS design at a tertiary-care hospital using routinely collected transfusion registry data from January 2017 to December 2025. The pre-intervention period was defined as 2017–2020 and the post-intervention period

as 2022–2025. The year 2021, during which the TMU was established and workflow modifications were implemented, was considered a transition period and excluded from comparative analyses. The study is reported in accordance with the SQUIRE 2.0 guidelines for quality improvement reporting [16]. The Institutional Review Board of Samsung Medical Center approved the study protocol and waived the requirement for informed consent due to the retrospective, de-identified nature of the data (SMC-2024-06-017).

Interventions

In 2021, a dedicated TMU was established, and a hospital-wide transfusion management program was implemented. The TMU served as a centralized operational unit responsible for coordinating blood inventory management, monitoring plasma utilization, facilitating communication between clinical departments and the blood bank, and overseeing implementation of institutional transfusion policies. The program comprised four integrated components: policy revision, a digital return-and-reuse workflow, computerized clinical decision support, and multidisciplinary governance (**Figure 1**).



131

132 **Figure 1.** The four-pillar Transfusion Management Unit-based transfusion management program
133 implemented to reduce FFP wastage. The intervention, implemented in 2021, consisted of four
134 complementary components designed to reduce fresh frozen plasma (FFP) wastage. **(A)** Policy revision.
135 Extension of post-thaw FFP storage from 3 to 24 hours in accordance with national regulations, enabling
136 return and reassignment of thawed units within the valid storage period. **(B)** Digital workflow.
137 Integration of an electronic real-time return-and-reuse workflow within the blood bank information
138 system, providing visibility of remaining FFP validity, automated notifications, and prompt
139 reassignment of unused units. **(C)** Clinical decision support. Implementation of coagulation-linked
140 prescribing alerts at order entry, displaying relevant laboratory parameters and institutional transfusion
141 criteria to support evidence-based plasma utilization. Orders potentially exceeding institutional
142 recommendations prompted confirmation or revision by the prescriber. **(D)** Multidisciplinary
143 governance. Multidisciplinary communication and governance coordinated through the TMU and
144 hospital Transfusion Committee. Active monitoring and rapid-return protocols facilitated timely return
145 and redistribution of unused FFP units.

146

Policy revision The institutional post-thaw validity period for FFP was extended from 3 hours to 24 hours under refrigerated storage (1-6 ℃), in accordance with the Korean Transfusion Guidelines and AABB standards. Accordingly, thawed FFP became eligible for return to the blood bank within the approved storage period. This extension was supported by evidence that the activity of labile coagulation factors in thawed plasma remains within the haemostatic range for up to 5 days of refrigerated storage, well beyond the 24-hour period adopted here [17-20].

Digital workflow An electronic return-and-reuse workflow was implemented through the hospital blood bank information system. The system provided real-time notification of unused thawed FFP and displayed the remaining validity period, enabling timely return, reassignment, and reuse before expiration.

Clinical decision support A computerized prescribing alert was integrated into the electronic ordering system. Current coagulation test results, including prothrombin time, activated partial thromboplastin time, and fibrinogen levels, were automatically retrieved and compared with the institutional transfusion criteria. When an FFP order was potentially inconsistent with institutional recommendations, the system prompted the prescriber to review or modify the order before completion [21].

Multidisciplinary governance The TMU established regular multidisciplinary governance meetings involving the blood bank, surgery, anesthesiology, intensive care, emergency medicine, and hematology departments. Standardized communication pathways were implemented between the blood bank and perioperative teams, together with active monitoring of thawed FFP inventory and a rapid-return protocol to facilitate timely return, reassignment, and reuse of unused thawed FFP.

Outcomes and variable definitions

The primary outcome was the quarterly FFP wastage rate, defined as the number of discarded FFP units divided by the total number of FFP units issued (%). Secondary outcomes included the overall blood component wastage rate (discarded RBC, platelets, and FFP units divided by total units issued) and FFP proportion of total wastage. The proportion of FFP among all issued blood components, defined as FFP units issued divided by total blood component units issued, was additionally assessed to determine whether changes in wastage were associated with shifts in component utilization.

Statistical analysis

Annual issue volumes, wastage volumes, and wastage rates were summarized descriptively. Pre- and post-intervention periods were compared using chi-square tests for proportions. To evaluate the effect of the intervention on FFP wastage over time, ITS analysis with segmented regression was performed using quarterly data. The ITS model was specified as:

$$Y_t = \beta_0 + \beta_1 \cdot Time_t + \beta_2 \cdot Intervention_t + \beta_3 \cdot TimeAfter_t + \varepsilon_t$$

where $Time_t$ represents the pre-intervention time trend, $Intervention_t$ indicates the intervention period (0 before and 1 after intervention), and $TimeAfter_t$ represents post-intervention time. The coefficient β_1 represents the pre-intervention slope, and β_2 and β_3 estimate the immediate level change and change in slope associated with the intervention. The transition period (at 2021) was excluded from all ITS models.

Prais-Winsten regression was used to account for first-order autocorrelation. RBC and platelet wastage rates were analyzed as comparison outcomes, as these components were not directly affected by the intervention, following recommended approaches for the use of control series in ITS studies[22]. Statistical analyses were performed using Python version 3.11 (statsmodels package) and SPSS version 28.0 (IBM Corp., Armonk, NY, USA). All tests were two-sided, and p-values < 0.05 were considered statistically significant.

RESULTS

Blood components issued

During the 9-year study period, 1,581,003 units of blood components, including FFP, RBCs, and platelets, were issued (**Table 1**).

Table 1. Annual issue and wastage volumes of blood components, 2017–2025

Component		2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Overall	Issued, n	171,798	203,812	209,929	187,457	184,372	173,108	170,170	132,775	147,582	1,581,003
	Wasted, n (%)	1,588 (0.92)	1,762 (0.86)	1,599 (0.76)	1,440 (0.77)	1,344 (0.73)	817 (0.47)	827 (0.49)	628 (0.47)	740 (0.50)	10,745 (0.68)
FFP	Issued, n (%)	26,243 (15.3)	26,721 (13.1)	22,074 (10.5)	23,200 (12.4)	23,513 (12.8)	23,261 (13.4)	21,146 (12.4)	12,831 (9.7)	16,281 (11.0)	195,270 (12.4)
	Wasted, n (%)	1,250 (4.76)	1,258 (4.71)	979 (4.44)	897 (3.87)	722 (3.07)	302 (1.30)	344 (1.63)	257 (2.00)	276 (1.70)	6,285 (3.22)
RBC	Issued, n (%)	78,422 (45.6)	79,968 (39.2)	81,175 (38.7)	78,511 (41.9)	79,285 (43.0)	67,972 (39.3)	63,846 (37.5)	49,033 (36.9)	52,943 (35.9)	631,155 (39.9)
	Wasted, n (%)	200 (0.26)	197 (0.25)	163 (0.20)	185 (0.24)	154 (0.19)	120 (0.18)	109 (0.17)	50 (0.10)	97 (0.18)	1,275 (0.20)
Platelet	Issued, n (%)	67,133 (39.1)	97,123 (47.7)	106,680 (50.8)	85,746 (45.7)	81,574 (44.2)	81,875 (47.3)	85,178 (50.1)	70,911 (53.4)	78,358 (53.1)	754,578 (47.7)
	Wasted, n (%)	138 (0.21)	307 (0.32)	457 (0.43)	358 (0.42)	468 (0.57)	395 (0.48)	374 (0.44)	321 (0.45)	367 (0.47)	3,185 (0.42)

Percentages for issued units represent each component's share of total units issued in that year; percentages for wasted units represent the wastage rate, calculated as the number of units discarded divided by the number of units issued for that component in that year. The percentage for overall issued units is omitted because it is 100% by definition. Owing to rounding, issued percentages may not sum exactly to 100%.

Annual blood component issuance generally declined after peaking at 209.9 × 10³ units in 2019, reaching its lowest level of 132.8 × 10³ units in 2024 before increasing to 147.6 × 10³ units in 2025 (**Figure 2**). Despite this overall decline, the proportion of FFP among all blood components issued remained broadly similar, decreasing only modestly from 12.7% during the pre-intervention period to 11.8% during the post-intervention period.

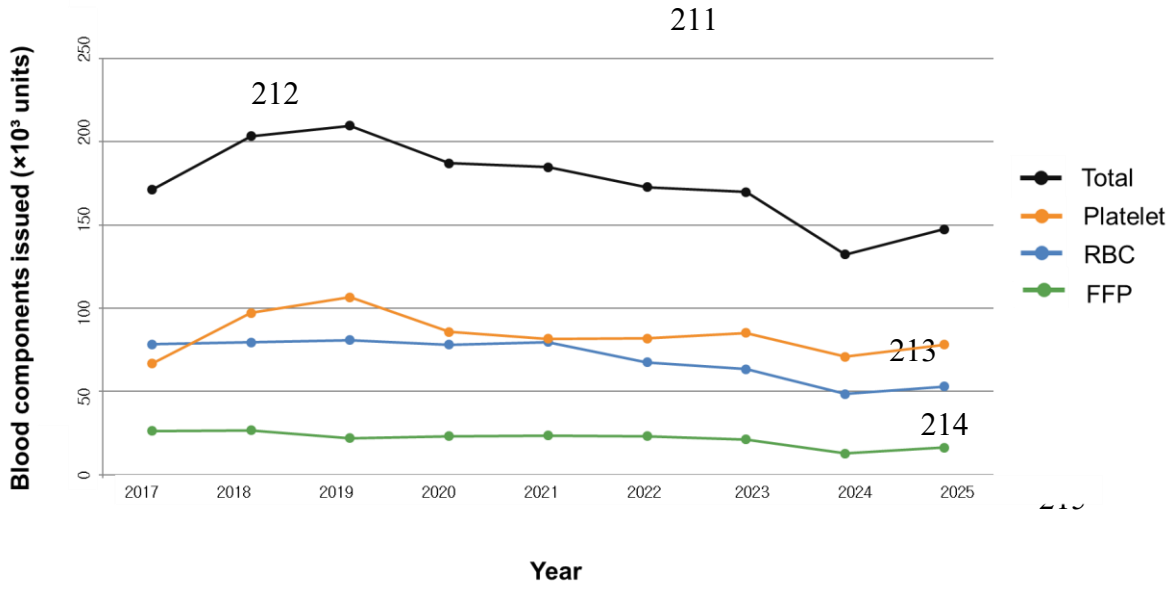


Figure 2. Annual blood component issuance by component (2017-2025). Annual issued volumes of RBCs, platelets, and fresh frozen plasma (FFP), together with overall blood component issuance, during the study period. Values are expressed as issued units (×10³).

Blood component wastage rates

The annual number of discarded blood component units decreased following implementation of the TMU-based program (**Figure 3A**). Excluding the 2021 transition year, the mean annual number of discarded units declined from 1.60 × 10³ units during the pre-intervention period (2017–2020) to 0.75 × 10³ units during the post-intervention period (2022–2025). Among individual components, the largest reduction was observed for FFP, with the mean wastage rate

decreasing from 4.46% to 1.60%, representing a 64.1% relative reduction (χ^2 = 1096.7, p < 0.001). RBC wastage decreased modestly, whereas platelet wastage increased (0.353% to 0.461%, 30.4% relative increase).

The overall blood component wastage rate remained below 1% throughout the study and generally decreased over time (**Supplementary Figure S1**). Annual FFP wastage rates remained consistently lower after implementation of the TMU-based program, ranging from 1.3% to 2.0% during the post-intervention period compared with 3.9% to 4.8% during the pre-intervention period (**Figure 3B**).

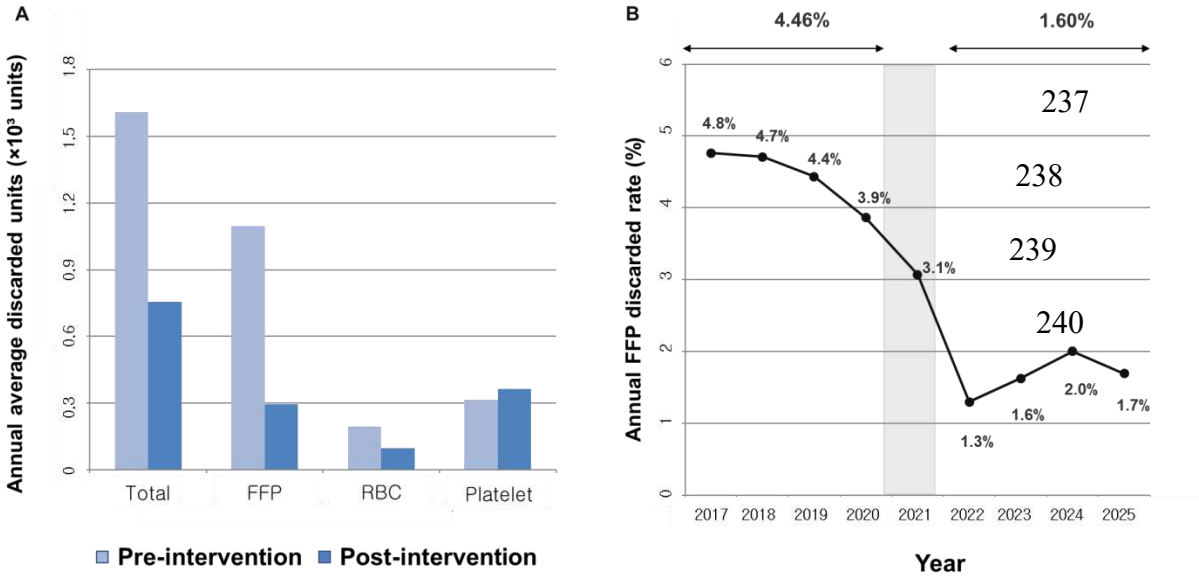


Figure 3. Changes in blood component wastage before and after implementation of the TMU-based transfusion management program. **(A)** Mean annual numbers of discarded units by blood component during the pre-intervention (2017–2020) and post-intervention (2022–2025) periods. **(B)** Annual FFP wastage rates across the study period. The vertical line denotes implementation of the TMU-based transfusion management program in 2021.

The contribution of FFP to total blood component wastage also decreased substantially following the intervention. Excluding the 2021 transition year, FFP accounted for 68.6% of all

discarded blood components during the pre-intervention period, compared with 39.1% during the post-intervention period ($\chi^2 = 736.1$, $p < 0.001$; **Figure 4A**). Consistent with this finding, the annual proportion of FFP among all discarded blood components declined from 78.7% in 2017 to 37.3% in 2025, with the largest decline occurring between the 2021 transition year and the first full post-intervention year in 2022 (**Figure 4B**).

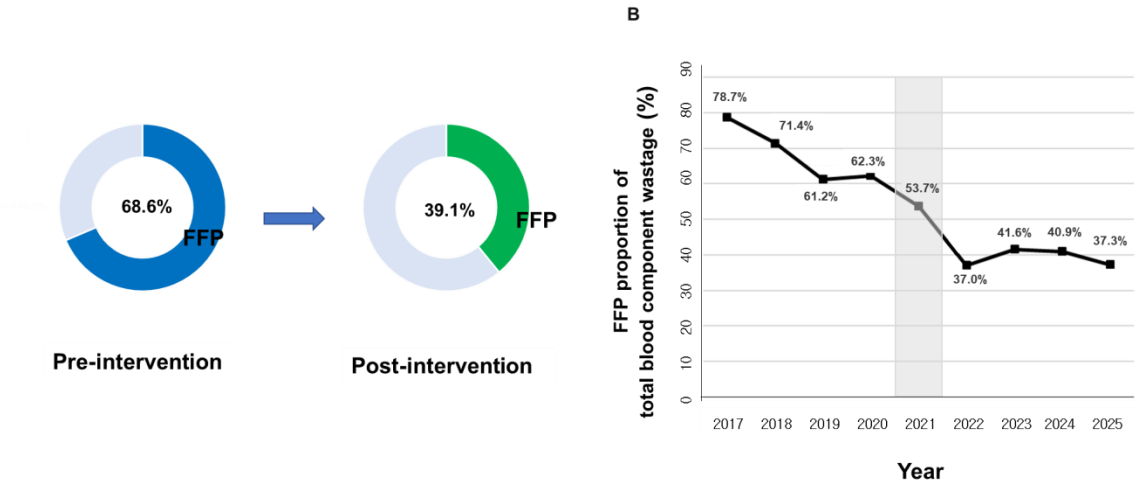


Figure 4. FFP proportion of total component wastage. **(A)** Mean proportion of total wastage attributable to FFP in the pre-intervention and post-intervention periods. **(B)** Annual FFP proportion of total blood component wastage during the study period. The vertical line denotes implementation of the TMU-based transfusion management program in 2021.

Interrupted time series analysis

The ITS analysis demonstrated significant changes in the level and slope of FFP wastage following the intervention (**Table 2**). Before the intervention, the FFP wastage rate had been decreasing by 0.071 percentage points per quarter ($\beta_1 = -0.071$ percentage points, 95% CI: -0.125 to -0.017, $p = 0.012$). At the start of the post-intervention period, following the 2021 transition period, an immediate reduction of 2.30 percentage points was observed ($\beta_2 = -2.30$ percentage points, 95% CI: -3.150 to -1.450, $p < 0.001$). The intervention was also associated with a significant positive change in slope of 0.112 percentage points per quarter ($\beta_3 = 0.112$

percentage points per quarter, $p = 0.005$), resulting in an estimated post-intervention slope of 0.041 percentage points per quarter ($\beta_1 + \beta_3$).

Table 2. Segmented regression estimates of level and slope changes in blood component wastage rates

Outcome	β_1 Pre-intervention (95% CI)	β_2 level change (95% CI)	β_3 Slope change (95% CI)	Post-intervention trend ($\beta_1 + \beta_3$)
Total	-0.015(-0.023 – -0.006)*	-0.180 (-0.314 – -0.047)*	0.015 (0.003 – 0.027)*	0.000
FFP	-0.071 (-0.125 – -0.017)*	-2.300 (-3.150 – -1.450)*	0.112 (0.038 – 0.187)*	0.041
RBC	-0.003 (-0.010 – 0.004)	-0.028 (-0.130 – 0.074)	0.001 (-0.008 – 0.011)	-0.002
Platelet	0.019 (0.008 – 0.031)*	-0.090 (-0.271 – 0.090)	-0.022 (-0.038 – -0.006)*	-0.003

* < 0.05

Despite this modest upward post-intervention trend, the fitted FFP wastage rate remained below the projected counterfactual trend throughout the follow-up period (**Figure 5A-D**).

RBC and platelet wastage rates were analyzed as comparison series. Neither showed a significant immediate level change at the start of the post-intervention period (RBC: $\beta_2 = -0.028$, 95% CI -0.130 to 0.074, $p = 0.580$; platelet: $\beta_2 = -0.090$, 95% CI: -0.271 to 0.090, $p = 0.300$). No significant change in slope was observed for RBC ($\beta_3 = 0.001$, 95% CI: -0.008 to 0.011), whereas platelet wastage showed a significant negative change in slope ($\beta_3 = -0.022$, 95% CI: -0.038 to -0.006).

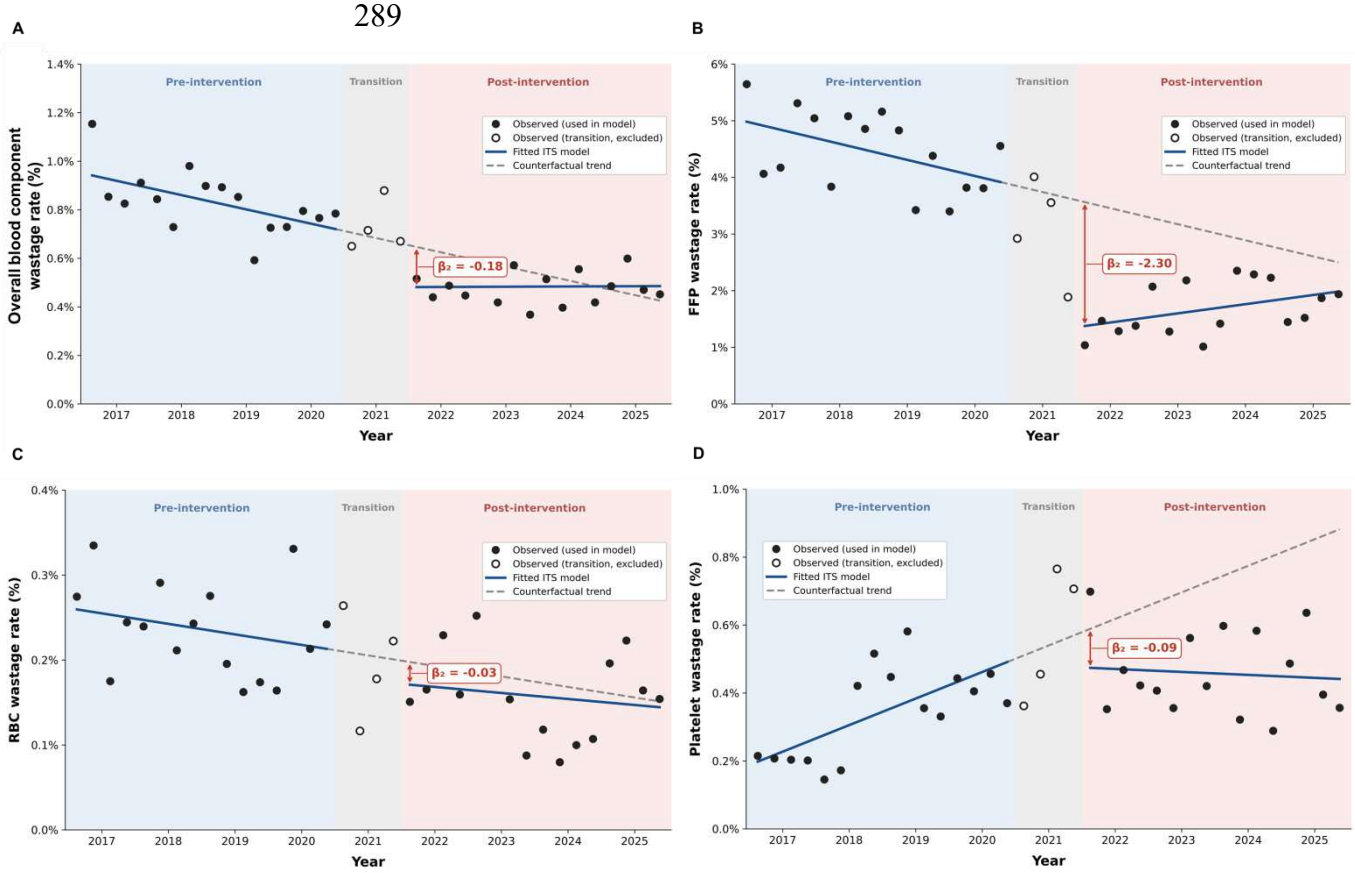


Figure 5. Interrupted time series analysis of blood component wastage rates before and after implementation of the TMU-based transfusion management program. Quarterly wastage rates for **(A)** overall blood components, **(B)** FFP, **(C)** RBCs, and **(D)** platelets. Solid lines represent fitted ITS models and dashed lines represent counterfactual trends. Open circles indicate transition-period observations (2021), which were excluded from model estimation. Shaded areas denote pre-intervention, transition, and post-intervention periods. β_2 represents the estimated immediate level change following intervention.

DISCUSSION

Implementation of a dedicated TMU and a hospital-wide transfusion management program was associated with a substantial immediate reduction in FFP wastage. The FFP wastage rate decreased from 4.46% to 1.60%, representing a 64.1% relative reduction, while the proportion of FFP among all issued blood components remained largely unchanged. These findings suggest that changes in the relative proportion of FFP issued alone are unlikely to account for the observed reduction, which may instead reflect improved transfusion management processes.

A key strength of this study is the use of ITS analysis to evaluate intervention-associated changes over time. Although the FFP wastage rate showed a declining trend before implementation of the TMU-based program (β_1 = -0.071 percentage points per quarter), ITS analysis identified a marked immediate level change beyond the pre-existing trend (β_2 = -2.300 percentage points). Compared with conventional pre-post analyses, ITS provides stronger evidence that the observed reduction was associated with the intervention while accounting for underlying temporal trends, thereby strengthening the inference that the observed change was associated with the intervention in the absence of randomized evaluation [23-25].

A noteworthy finding was the modest but statistically significant upward trend in the FFP wastage rate during the post-intervention period ($\beta_1 + \beta_3 = 0.041$ percentage points per quarter). This gradual increase following the marked immediate reduction may reflect several factors. As the intervention became embedded in routine practice, the fidelity of implementation and adherence to newly introduced processes may have attenuated over time [26]. Alternatively, unmeasured changes in the clinical characteristics and complexity of the patient population, clinical workload, staffing patterns, or turnover of medical personnel may have influenced protocol adherence and FFP management. Because these factors were not directly evaluated, the underlying reasons for the post-intervention increase cannot be determined from the present

data.

Importantly, the modest upward trend should be interpreted in the context of the substantial immediate level reduction. Despite the subsequent increase, FFP wastage rates remained consistently below both the pre-intervention level and the projected counterfactual trend throughout the four-year follow-up period. Thus, the post-intervention trajectory does not negate the initial intervention-associated reduction but suggests that the magnitude of benefit may have gradually attenuated over time. This finding also highlights the potential importance of continued monitoring, reinforcement of standardized practices, and periodic feedback to sustain the benefit of system-level transfusion stewardship.

The relative specificity of the immediate intervention effect was further supported by the non-FFP comparison outcomes. Despite concurrent patient blood management initiatives and an overall decline in blood component utilization, RBC and platelet wastage rates did not demonstrate significant intervention-associated level changes [4]. However, platelet wastage showed a significant change in slope, from an increasing pre-intervention trend to an essentially stable post-intervention trend. Therefore, the comparison outcomes support, but do not definitively establish, the specificity of the immediate FFP reduction, and broader institutional influences cannot be completely excluded.

The magnitude of improvement observed in this study (64.1%) compares favorably with reductions reported in previous initiatives aimed at reducing blood component wastage [27-29]. However, direct comparisons should be interpreted cautiously because previous studies differed in wastage definitions, intervention components, clinical settings, and follow-up duration. Previous studies have primarily evaluated isolated interventions, such as staff education, protocol modification, computerized decision support, or dedicated transfusion teams, often within a single department or over relatively short follow-up periods [14, 30-32]. In contrast, our study evaluated a hospital-wide implementation package that combined policy

revision, digital workflow optimization, clinical decision support, and multidisciplinary governance within a centralized TMU framework. The sustained reduction observed over four years suggests that integrated system-level interventions may provide greater long-term benefit than isolated process improvements.

Several complementary mechanisms likely contributed to the observed reduction in FFP wastage. First, extending the institutional post-thaw validity period from 3 to 24 hours increased opportunities for redistribution and reuse of thawed FFP before expiration. Because this change directly increased the time available for reissue, it may have been a major contributor to the observed reduction. Second, implementation of an electronic return-and-reuse workflow was designed to enable real-time identification, tracking, and reassignment of unused thawed FFP, thereby improving inventory management and reducing avoidable discard [15]. Third, computerized coagulation-linked prescribing alerts provided point-of-care clinical decision support, encouraging evidence-based plasma utilization and reducing potentially unnecessary FFP orders [10, 11, 21]. Finally, the TMU strengthened multidisciplinary communication among the blood bank, surgery, anesthesiology, intensive care, emergency medicine, and hematology departments through standardized governance meetings, active monitoring, and rapid-return protocols. Rather than functioning as independent interventions, these components redesigned multiple stages of the transfusion pathway into a coordinated hospital-wide stewardship model. This system-based approach likely contributed to both the magnitude and durability of the observed reduction in FFP wastage.

This study has several strengths. First, the intervention was evaluated under routine clinical practice using nine years of real-world transfusion registry data, providing evidence of effectiveness in a large tertiary-care hospital. Second, the extended observation period, including four years of post-intervention follow-up, enabled assessment of both the immediate and sustained effects of the TMU-based program. Third, the application of ITS analysis

strengthened the evaluation by accounting for baseline temporal trends, while the inclusion of RBC and platelet wastage rates as comparison outcomes enhanced confidence that the observed changes were largely specific to the FFP-focused intervention.

Several limitations should also be acknowledged. First, this was a retrospective single-center study, which may limit the generalizability of the findings to institutions with different patient populations, transfusion practices, or organizational structures. Second, because the intervention was implemented as an integrated TMU-based program, the individual contribution of each component could not be quantified. Third, although ITS analysis accounts for underlying temporal trends, the potential influence of other contemporaneous institutional changes cannot be completely excluded. Finally, detailed information regarding the specific causes of FFP wastage, such as product expiration, delayed return, or storage deviations, was unavailable, and formal economic evaluation was not performed. Future multicenter studies incorporating cost-effectiveness analyses and cause-specific wastage data would further clarify the value and scalability of TMU-based transfusion management programs.

In conclusion, implementation of a dedicated TMU and a hospital-wide transfusion management program was associated with a marked immediate reduction in FFP wastage. Although a modest upward trend was observed after implementation, FFP wastage remained below the pre-intervention and projected counterfactual levels throughout follow-up. By integrating policy revision, clinical decision support, digital inventory management, electronic return-and-reuse processes, and multidisciplinary governance, the TMU-based program was associated with improved blood resource stewardship while the relative share of FFP among all issued blood components remained stable. The intervention effect was supported by ITS analysis and comparison outcomes, providing supportive evidence that the observed reduction was associated with FFP-focused process improvement. Beyond transfusion medicine, these findings demonstrate how integrated organizational redesign and digital workflow

interventions can strengthen stewardship of scarce healthcare resources in routine hospital practice. TMU-based, system-level transfusion stewardship may therefore represent a practical and scalable model for improving healthcare quality and resource utilization in tertiary-care hospitals.

Abbreviation lists

AABB: Association for the Advancement of Blood & Biotherapies

CI: Confidence Interval

FFP: Fresh Frozen Plasma

ITS: Interrupted Time Series

RBC(s): Red Blood Cell(s)

TMU: Transfusion Management Unit

Declarations

Ethics approval and consent to participate: This study was approved by the Institutional Review Board of Samsung Medical Center (IRB approval number: SMC-2024-06-017). The study was conducted in accordance with the principles of the Declaration of Helsinki. The requirement for informed consent to participate was waived by the Institutional Review Board of Samsung Medical Center due to the retrospective nature of the study and the use of de-identified registry data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated or analyzed during the current study are not publicly available due to confidentiality policies but are available from the corresponding author upon reasonable

request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

J.Y.S collected data, interpreted the data, and drafted the manuscript. M.N drafted and revised the manuscript. D.C designed this study and contributed to critical revisions of this manuscript. M.R.K and C.W.C contributed to crucial revisions of this manuscript. All authors contributed to the preparation and editing of this manuscript, and approved the final version of this paper.

Acknowledgements

Not applicable.

Reference

1. Kim HO. Current state of blood management services in Korea. Ann Lab Med. 2022;42:306-13.
2. Caulfield J. Blood supply management: experience and recommendations from Australia. ISBT Sci Ser. 2013;8:41-5.
3. Fredrick J, Berger JJ, Menitove JE. Strategic issues currently facing the US blood system. Transfusion. 2020;60:1093-6.
4. Kim OS, Ji S, Jung HW, Matthews SA, Cha YJ, Moon SD, et al. Future blood debt: projecting blood supply and demand of Korea based on subnational population projections (2021-2050). J Korean Med Sci. 2024;39:e168.

5. The National Institute of Organ, Tissue and Blood Management, The Korean Society of Blood Transfusion. Transfusion guideline. 5th ed. Seoul, Korea: The National Institute of Organ, Tissue and Blood Management; 2022.
6. Cohn CS, Delaney M, Johnson ST, Katz LM, Schwartz J. Technical Manual. 21st ed. Bethesda, MD: AABB; 2023.
7. Holcomb JB, Tilley BC, Baraniuk S, Fox EE, Wade CE, Podbielski JM, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: the PROPPR randomized clinical trial. JAMA. 2015;313:471-82.
8. Taylor N, Haines A, Brady T, Mintz P, Wehrli G. Instituting a thawed plasma procedure: it just makes sense and saves cents. Transfusion. 2009;49:2625-30.
9. Collins RA, Wisniewski MK, Waters JH, Triulzi DJ, Yazer MH. Effectiveness of multiple initiatives to reduce blood component wastage. Am J Clin Pathol. 2015;143:329-35.
10. Yazer MH, Triulzi DJ, Reddy V, Waters JH. Effectiveness of a real-time clinical decision support system for computerized physician order entry of plasma orders. Transfusion. 2013;53:3120-7.
11. Shah N, Baker SA, Spain D, Shieh L, Shepard J, Hadhazy E, et al. Real-time clinical decision support decreases inappropriate plasma transfusion. Am J Clin Pathol. 2017;148:154-60.
12. Kim SY, Bae GH, Lee HR. The effect of the transfusion indication verification program on the appropriateness of fresh frozen plasma transfusion. Korean J Blood Transfus. 2020;31:43-54.

13. Zhang C, Ayer T, White CC, Bodeker JN, Roback JD. Inventory sharing for perishable products: application to platelet inventory management in hospital blood banks. Oper Res. 2023;71:1756-76.
14. Mitra B, Garland R, Catalano J, O'Reilly G, Nevill A. Reducing blood wastage through introduction of a transfusion team. Scand J Trauma Resusc Emerg Med. 2025;33:136.
15. Metcalf RA, Baker SA, Goodnough LT, Shah N. Transportation cooler interventions reduce plasma and RBC product wastage. Am J Clin Pathol. 2016;146:18-24.
16. Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for Quality Improvement Reporting Excellence): revised publication guidelines from a detailed consensus process. J Contin Educ Nurs. 2015;46:501-7.
17. Yazer MH, Cortese-Hassett A, Triulzi DJ. Coagulation factor levels in plasma frozen within 24 hours of phlebotomy over 5 days of storage at 1 to 6 degrees C. Transfusion. 2008;48:2525-30.
18. Scott E, Puca K, Heraly J, Gottschall J, Friedman K. Evaluation and comparison of coagulation factor activity in fresh-frozen plasma and 24-hour plasma at thaw and after 120 hours of 1 to 6 degrees C storage. Transfusion. 2009;49:1584-91.
19. Naghadeh HT, Maghsudloo M, Tabatabaei MR. Coagulation factors V, VIII, and X, prothrombin time and activated partial thromboplastin time test results in thawed plasma stored at 1-6 °C for 5 days. Blood Transfus. 2011;9:95-8.
20. von Heymann C, Keller MK, Spies C, Schuster M, Meinck K, Sander M, et al. Activity of clotting factors in fresh-frozen plasma during storage at 4 degrees C over 6 days. Transfusion. 2009;49:913-20.
21. Khandelwal A, Minuk L, Liu Y, Arnold DM, Heddle NM, Barty R, et al. Plasma transfusion practices: a multicentre electronic audit. Vox Sang. 2022;117:1211-9.

22. Lopez Bernal J, Cummins S, Gasparrini A. The use of controls in interrupted time series studies of public health interventions. Int J Epidemiol. 2018;47:2082-93.
23. Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. J Clin Pharm Ther. 2002;27:299-309.
24. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. Int J Epidemiol. 2017;46:348-55.
25. Bernal JL, Soumerai S, Gasparrini A. A methodological framework for model selection in interrupted time series studies. J Clin Epidemiol. 2018;103:82-91.
26. Stirman SW, Kimberly J, Cook N, Calloway A, Castro F, Charns M. The sustainability of new programs and innovations: a review of the empirical literature and recommendations for future research. Implement Sci. 2012;7:17.
27. Shahshahani HJ and Taghvai N. Blood wastage management in a regional blood transfusion centre. Transfus Med. 2017;27 Suppl 5:348-53.
28. Walter K, Ahmad I, Groeneveld T, Chander A, Refaei M. A quality improvement initiative to reduce inappropriate plasma transfusions across community hospitals in the Niagara region. Vox Sang. 2026;121:593-602.
29. Tounsi WA, Alzahrani OA, Bukhari AG, Garout RM, Felimban RI, Al-Musallam RH, et al. Reducing blood component wastage through targeted interventions: a four-year retrospective study at a Saudi tertiary hospital. Transfus Med. 2025;35:556-63.
30. Khan S, Allard S, Weaver A, Barber C, Davenport R, Brohi K. A major haemorrhage protocol improves the delivery of blood component therapy and reduces waste in trauma massive transfusion. Injury. 2013;44:587-92.

31. Dunbar NM, Olson NJ, Szczepiorkowski ZM, Martin ED, Tysarcyk RM, Triulzi DJ, et al. Blood component transfusion and wastage rates in the setting of massive transfusion in three regional trauma centers. Transfusion. 2017;57:45-52.
32. Paganini M, Abowali H, Bosco G, Balouch M, Enten G, Deng J, et al. Quality improvement project of a massive transfusion protocol (MTP) to reduce wastage of blood components. Int J Environ Res Public Health. 2021;18:274.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryfigureS12026.09.03.pptx