Blood transfusions are among the most common therapeutic procedures performed in hospitalized patients. This study evaluates contemporary national trends in red blood cell (RBC), plasma, platelet, and cryoprecipitate transfusions. National Inpatient Sample, the largest all-payer inpatient database representing 94% to 97% of the US population, was evaluated from the fourth quarter (Q4) of 2015 through 2018. Quarterly trends for the percentage of hospitalizations with a transfusion procedure were separately examined for each blood product using log binomial regression and reported as quarterly percent change (QPC). The percentage of hospitalizations with an RBC transfusion decreased from 4.22% (2015Q4) to 3.79% (2018Q4) (QPC = 2.01; 95% confidence interval [CI], 0.57 to 3.44; \( P_{\text{trend}} = .006 \)). Significant quarterly reductions in RBC transfusions were also seen among many, but not all, strata of sex, race/ethnicity, patient risk severity, and admission type (elective vs nonelective). Despite significant declines in RBC transfusions among older adults, there were no significant changes among pediatric age-group (<18 years) and those 18 to 49 years. The decline in RBC and plasma transfusions suggests steady incorporation of robust evidence base showing safety of restrictive transfusions. Increased cryoprecipitate use may be reflective of wider adoption of hypofibrinogenemia management and hemostasis testing for coagulopathic patients.

**Introduction**

Blood transfusions are some of the most common therapeutic procedures performed in hospitalized patients. There are robust randomized clinical trial data that have guided transfusion practices, including trials demonstrating the safety and efficacy of restrictive red blood cell (RBC) transfusion strategies in diverse patient populations.\(^1\)\(^-\)\(^3\) Implementation of blood management programs based on high-quality data over the past few decades has improved patient outcomes while conserving a scarce resource and reducing health care costs.\(^5\) Organizations, such as the Joint Commission, American Board of Internal Medicine, American Society of Hematology, and AABB, have also advocated for reducing RBC
transfusions. Nationally representative administrative studies and surveys in the United States have previously shown a decline in blood utilization, particularly RBCs, with a concomitant reduction in blood collection of selected components. This study evaluated contemporary national trends in RBC, plasma, platelet, and cryoprecipitate transfusions among inpatient hospitalizations in the United States (2015-2018).

**Methods**

The National Inpatient Sample (NIS) is the largest all-payer inpatient database in the United States, developed by the Agency for Healthcare Research and Quality. NIS uses a multistaged clustering design to develop a stratified probability sample of 20% of all inpatient discharges, representing approximately 94% to 97% of the US population across the included years 2015 through 2018. Hospitals are stratified by location, teaching status, bed size, ownership/control, and US census divisions. The unit of this analysis was record-level hospitalization, and patients may be included more than once in the database.

Starting from the fourth quarter (Q4) of 2015, International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) procedure codes were reported in the NIS, which were used to identify percent of hospitalizations with ≥1 RBC, plasma, platelet, and cryoprecipitate transfusions (separate outcomes). All hospitalizations in the NIS from 2015Q4 to the end of 2018 were included in this study.

Calendar time was divided into quarters (3 months), yielding 13 quarters over the study period. Quarterly trends for the proportion of transfusion among all hospitalizations of each blood product were separately examined using log binomial regression (2015Q4 to 2018Q4). Quarterly percent change (QPC) in transfusions were estimated using \( (e^\beta - 1) \times 100\% \), where \( \beta \) was the coefficient for quarter in log binomial regression. \( P_{\text{trend}} \) values were estimated using log binomial regression. For RBC transfusions, subgroup analyses were performed stratified by individual-level factors (sex, age, race, All Patient Refined Diagnosis Related Group severity, primary payer, and admission type) and hospital-level factors (control/ownership of hospital). Analyses were weighted to account for the sampling design and generate nationally representative estimates. Standard errors were estimated using Taylor series linearization. Analyses were performed using *svy* commands in Stata/MP, v15 (Statacorp, College Station, TX) and R, V4.0 (R-Core Team, Vienna, Austria).

Because the NIS is a deidentified, publicly available data set, this study was deemed exempt from review by the Johns Hopkins institutional review board. It was conducted in accordance with the Declaration of Helsinki.

**Results and discussion**

The proportion of hospitalizations with an RBC transfusion decreased from 4.22% in 2015Q4 to 3.79% in 2018Q4 (QPC = −0.72; 95% confidence interval [CI], −1.26 to −0.19; \( P_{\text{trend}} = .008 \)) (Figure 1). Likewise, the proportion of hospitalizations with a plasma transfusion decreased from 0.57% in 2015Q4 to 0.48% in 2018Q4, QPC = −1.33 (95% CI, −2.00 to −0.65; \( P_{\text{trend}} < .001 \)). In contrast, hospitalizations with cryoprecipitate utilization increased from 0.07% in 2015Q4 to 0.08% in 2018Q4, QPC = 2.01 (95% CI, 0.57-3.44; \( P_{\text{trend}} = .006 \)) and those with platelet transfusions remained stable at 0.55% (2015Q4) and 0.52% (2018Q4); QPC = −0.13 (95% CI, −0.99 to 0.73; \( P_{\text{trend}} = .766 \)).

In subgroup analyses, significant quarterly reductions in RBC transfusions were also seen among many, but not all, strata of sexes, race/ethnicity, patient risk severity, insurance payer types, admission type (elective vs nonelective), and hospital ownerships (Table 1; supplemental Figures 1-7). For all quarters, pediatric hospitalizations with RBC transfusions were less common than adult hospitalizations (\( P < .001 \) for all comparisons). Further, there were no significant changes in RBC transfusion for pediatric age group (<18 years) and 18 to 49 years, highlighting that the declines in utilization are largely restricted to older US adults (Table 1; supplemental Figure 1). Although there was a significant declining trend in RBC transfusions among hospitalizations with Medicare as the primary payer (QPC = −1.09; 95% CI, −1.61 to −0.57; \( P_{\text{trend}} < .001 \)), there were no significant reductions in RBC transfusions for hospitalizations with Medicaid, self, or private insurance payments. In addition, although private investor-owned hospitals had a significant declining trend in RBC transfusions (QPC = −2.08; 95% CI, −3.29 to −0.88; \( P_{\text{trend}} < .001 \)), there were no significant trends for the government hospitals or private non-profit hospitalizations.

The overall continued decline in RBC and plasma transfusions through 2018 likely suggests an increased adherence to RBC transfusion guidelines and steady incorporation of the robust evidence base showing safety of restrictive transfusions into the routine transfusion practice.

Although RBC and plasma transfusions decreased; cryoprecipitate transfusions increased and platelet transfusions remained stable. RBCs are the most commonly transfused blood component in the United States, and RBC transfusion is the most common procedure among hospitalized patients. The Joint Commission and American Society of Hematology have targeted RBC transfusions as one of the most overused procedures in the US hospitals. Although data and guidelines pertaining to plasma utilization are limited, plasma use historically follows RBC transfusion trends. By contrast, this study demonstrated a national increase in cryoprecipitate utilization. This could stem from the increasing recognition that acquired hypofibrinogenemia contributes to hemorrhage, fibrinogen concentrates, and cryoprecipitate, garnered increased attention and wider adoption of hemostasis testing that leads to increased usage of cryoprecipitate. Although clinical practice guidelines recommend prophylactic platelet transfusions, the evidence supporting platelet transfusions in specific clinical indications has been rated as low/very-low quality by GRADE methodology and there are inconsistent recommendations across various guidelines. Although Patient Blood Management (PBM) initiatives appear to be effective in restricting RBC and plasma transfusions nationwide, targeted interventions are needed for platelets.

Although RBC transfusions decreased in most strata, they were unchanged among hospitalizations of younger individuals, non-Medicare payers, and government and private nonprofit hospitalizations. In general, the declines in transfusions followed these groups with the highest prevalence of transfusions in 2015. The pediatric age spectrum is broad with changing physiology and there are vastly different parameters to be considered for transfusion. A paucity of comparable data pertaining to transfusion thresholds in this vulnerable age group has precluded
establishment of evidence-based guidelines or pediatric PBM programs.2,20

This study has limitations including reliance on ICD-10 billing codes, which may lead to measurement error. Reassuringly, the NIS has previously been extensively validated against the National Hospital Discharge Survey and Medicare Provider Analysis and Review File, and also been shown to be applicable to transfusion practices.21,22 The laboratory data supporting indication for transfusion and the number of units transfused were unknown. This study being limited to the inpatient setting does not capture changes in outpatient utilization. Specifically for platelet utilization, a major component of the utilization is in the outpatient setting for cancer patients. Thus, this analysis could miss the overall platelet utilization trends. Notably, the 2019 National Blood Collection Utilization Survey (NBCUS) showed an overall 15% increase in transfusion between 2017 and 2019 for apheresis and whole blood-derived platelet units combined.23

Data by the AABB and Centers for Disease Control and Prevention that focused on number of units of blood collected suggested a decline in the total number of RBC units transfused may have begun as early as 2008.5,24 The current study demonstrates the trend has continued through at least 2018. Other published data such as the NBCUS also support an overall decline in red cell transfusion, at least through 2017. The more recent NBCUS shows that there may be no further decrease in utilization between 2017 to 2019 and that utilization of RBC in the United States might have reached a nadir.6 Although single-center studies assessing the effect of COVID-19 on blood transfusion utilization are emerging, national transfusion trend data assessing the impact of COVID-19 on blood utilization will be important but not available for a few years and likely not reflective of long-term trends.25

The overall national decrease of transfusions implies lower overall cost burden on hospitals and increased adoption of an evidence-based and patient-centric approach to transfusion medicine. However, decreased collections and distributions may also suggest potential worsening of financial stressors for blood collection centers that have long been under economic pressure. It is reassuring, nevertheless, to observe improved patient care based on sound medical evidence.

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**Figure 1. Temporal trends in transfusion among US hospitalizations between 2015Q4 and 2018Q4.** The line graphs represent the proportion of discharges transfused with a given blood component per quarter year. The data represent weighted estimates for ~10 million weighted discharges per quarter in the National Inpatient Sample (2015Q4-2018). The P_trend values shown were calculated by log binomial regression. For 2015, only data from Q4 were included because of the transition to ICD-10 coding scheme from that time point.
Table 1. Quarterly percent changes in RBC transfusions between 2015Q4 and 2018Q4 stratified by patient- and hospital-level characteristics

| Characteristics                        | 2015Q4, % (95% CI)     | 2018Q4, % (95% CI)     | QPC, % (95% CI)* | P_{trend}†  |
|----------------------------------------|------------------------|------------------------|-----------------|-------------|
| All subjects*                          | 4.22 (4.07-4.38)       | 3.79 (3.63-3.96)       | -0.72 (-1.26 to -0.19) | .008        |
| **Sex**                                |                        |                        |                 |             |
| Male                                   | 4.33 (4.16-4.50)       | 3.87 (3.70-4.05)       | -0.70 (-1.26 to -0.15) | .013        |
| Female                                 | 4.14 (3.99-4.29)       | 3.73 (3.57-3.90)       | -0.74 (-1.26 to -0.22) | .006        |
| **Age, y**                             |                        |                        |                 |             |
| <18                                    | 1.05 (0.91-1.21)       | 1.00 (0.85-1.17)       | -0.38 (-2.32 to 1.56)  | .700        |
| 18-29                                  | 1.95 (1.84-2.07)       | 1.82 (1.69-1.95)       | -0.21 (-1.96 to 0.53)  | .574        |
| 30-39                                  | 2.28 (2.16-2.41)       | 2.30 (2.16-2.44)       | 0.18 (-0.53 to 0.88)   | .623        |
| 40-49                                  | 4.06 (3.86-4.27)       | 3.81 (3.60-4.04)       | -0.47 (-1.11 to 0.18)  | .156        |
| 50-59                                  | 4.55 (4.36-4.76)       | 4.09 (3.88-4.31)       | -0.68 (-1.29 to 0.07)  | .028        |
| 60-69                                  | 5.65 (5.41-5.89)       | 4.88 (4.65-5.13)       | -1.01 (-1.59 to -0.43) | .001        |
| 70-79                                  | 6.51 (6.26-6.77)       | 5.61 (5.36-5.88)       | -1.05 (-1.58 to -0.52) | <.001       |
| ≥80                                    | 7.00 (6.76-7.26)       | 5.84 (5.60-6.09)       | -1.32 (-1.81 to -0.84) | <.001       |
| **Race‡**                              |                        |                        |                 |             |
| White                                  | 4.12 (3.95-4.29)       | 3.56 (3.39-3.73)       | -0.88 (-1.45 to -0.31) | .003        |
| African American                       | 5.52 (5.24-5.81)       | 5.09 (4.78-5.41)       | -0.57 (-1.33 to 0.18)  | .139        |
| Hispanic                               | 3.86 (3.64-4.10)       | 3.55 (3.30-3.81)       | -0.95 (-1.80 to -0.10) | .029        |
| Asian or Pacific Islander              | 4.54 (4.16-4.96)       | 4.61 (4.23-5.03)       | 0.36 (-0.69 to 1.41)   | .498        |
| Other                                  | 4.14 (3.82-4.47)       | 3.47 (3.16-3.81)       | -1.40 (-2.56 to -0.24) | .019        |
| **APR-DRG risk severity§**             |                        |                        |                 |             |
| 1                                      | 1.04 (1.00-1.09)       | 0.83 (0.79-0.88)       | -2.11 (-2.65 to -1.58) | <.001       |
| 2                                      | 3.04 (2.93-3.15)       | 2.44 (2.34-2.55)       | -1.95 (-2.44 to -1.46) | <.001       |
| 3                                      | 7.08 (6.82-7.36)       | 5.95 (5.69-6.23)       | -1.39 (-1.92 to -0.87) | <.001       |
| 4                                      | 14.42 (13.77-15.10)    | 10.70 (10.15-11.28)    | -2.31 (-2.93 to -1.69) | <.001       |
| **Primary payer**                      |                        |                        |                 |             |
| Medicare                               | 6.31 (6.08-6.54)       | 5.39 (5.16-5.63)       | -1.09 (-1.61 to -0.57) | <.001       |
| Medicaid                               | 2.75 (2.62-2.88)       | 2.69 (2.54-2.84)       | -0.17 (-0.84 to 0.49)  | .610        |
| Private                                | 2.91 (2.77-3.06)       | 2.70 (2.55-2.85)       | -0.51 (-1.19 to 0.17)  | .140        |
| Self-pay                               | 3.12 (2.84-3.43)       | 2.83 (2.59-3.09)       | -0.33 (-1.43 to 0.76)  | .553        |
| No charge||                             | 3.72 (3.11-4.46)       | 2.32 (1.72-3.12)       | -4.44 (-6.95 to -1.93) | .001        |
| **Admission type**                     |                        |                        |                 |             |
| Nonelective                            | 4.53 (4.37-4.69)       | 4.11 (3.93-4.29)       | -0.64 (-1.16 to -0.12) | .016        |
| Elective                               | 3.18 (3.01-3.36)       | 2.57 (2.41-2.73)       | -1.55 (-2.28 to -0.83) | <.001       |
| **Hospital control**                   |                        |                        |                 |             |
| Government, nonfederal                 | 4.33 (3.85-4.87)       | 4.12 (3.62-4.68)       | -0.41 (-2.02 to 1.20)  | .618        |
| Private, nonprofit                     | 4.21 (4.02-4.40)       | 3.88 (3.68-4.08)       | -0.54 (-1.18 to 0.09)  | .092        |
| Private, investor-owned                | 4.21 (3.94-4.50)       | 3.12 (2.81-3.46)       | -2.08 (-3.29 to -0.88) | <.001       |

The data represent weighted estimates for approximately 40 million weighted discharges per year in the National Inpatient Sample (2015Q4-2018).

APR-DRG: All Patient Refined Diagnosis Related Group.

*QPC = (r² - 1)×100%, where r is the coefficient for the quarter variable in log binomial regression.

†P_{trend} was calculated using log binomial regression.

‡The race categories were predefined by Healthcare Cost and Utilization Project (HCUP) and includes race and ethnicity in 1 data element (RACE). If the source supplied race and ethnicity in separate data elements, ethnicity takes precedence over race in setting the HCUP value for race.

§APR-DRG: Severity of illness subclass: (0) no class specified, (1) minor loss of function (includes cases with no comorbidity or complications), (2) moderate loss of function, (3) major loss of function, (4) extreme loss of function. APR-DRG classes 1 and 2 are considered low risk and classes 3 and 4 are considered high risk.

||No payment/charity care/free care for indigent population.

The hospital’s ownership/control category is obtained from the American Hospital Association Annual Survey of Hospitals and includes categories for government nonfederal (public), private not-for-profit (voluntary), and private investor-owned (proprietary). These types of hospitals tend to have different missions and different responses to government regulations and policies.
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