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Comparative Changes of Pre-Operative Autologous Transfusions and Peri-Operative Cell Salvage in the United States

Ruchika Goel^{1,2,3}, Molly R. Petersen¹, Eshan U. Patel¹, Zoe Packman¹, Evan M. Bloch¹, Eric A. Gehrie¹, Parvez M. Lokhandwala¹, Paul M. Ness¹, Beth Shaz⁴, Louis M. Katz², Steven M. Frank⁵, Aaron A. R. Tobian¹

¹Department of Pathology, Johns Hopkins Hospital, Baltimore, MD.

²Mississippi Valley Regional Blood Center, Davenport, Iowa

³Simmons Cancer Institute, Southern Illinois University School of Medicine, Springfield, IL

⁴New York Blood Center, NY, NY

⁵Department of Anesthesiology, Johns Hopkins Hospital, Baltimore, MD.

Abstract

Background: With improved safety of allogeneic blood supply, the use of preoperative autologous donations (PAD) and peri-operative autologous cell salvage (PACS) has evolved. This study evaluated temporal trends in PAD and PACS utilization in the United States.

Methods: The National Inpatient Sample (NIS) database, a stratified probability sample of 20% of hospitalizations in the U.S., was used to compare temporal trends in hospitalizations reporting use of PAD and PACS from 1995-2015. Factors associated with their utilization were examined between 2012-2015 using multivariable Poisson regression. Sampling weights were applied to generate nationally representative estimates.

Results: There was a steady decrease in hospitalizations reporting PAD transfusions from 27.90/100,000 in 1995 to 1.48/100,000 hospitalizations in 2015 (p-trend <0.001). In contrast, PACS increased from a rate of 1.16/100,000 in 1995 to peak of 20.51/100,000 hospitalizations in 2008 and then steadily declined (p-trend <0.001). Higher odds of PACS and PAD were observed in older patients, elective procedures (versus urgent), and urban teaching/non-teaching hospitals (versus rural hospitals) (p < 0.001). PACS was more common in hospitalizations in patients with higher levels of severity of illness as compared to those with minor severity (adjPR(95%CI)=2.39(2.08-2.73) p < 0.001), while PAD were performed less often in patients with higher underlying severity of illness [APR-DRG 4 vs 1, adjPR(95%CI)=0.61 (0.39-0.95); p=0.028].

Address for Correspondence: Dr. Aaron A.R. Tobian, Department of Pathology, Johns Hopkins University, 600 N. Wolfe St., Baltimore, MD 21287, 443-287-0527, atobian1@jhmi.edu.

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Conclusions: There was a significant decrease in PAD RBC transfusions, while PACS has increased and subsequently decreased; PACS plays an important role in surgical blood conservation. The subsequent decline in PACS likely reflects further optimization of transfusion practice through patient blood management programs and improvement of surgical interventions.

Keywords

blood; transfusion; preoperative autologous donations; peri-operative autologous cell salvage; National Inpatient Sample (NIS)

Introduction:

Various surgical blood conservation techniques have been employed to reduce patient exposure to allogeneic blood pre- and post-operatively. Some of these modalities include preoperative autologous donation (PAD) and peri-operative autologous cell salvage (PACS, also called cell salvage).

PAD involves patients donating one or more units of their own blood a few weeks preceding a scheduled operative procedure. Per AABB Standards, a PAD must be completed at least 72 hours prior to surgery, and the units expire along the same schedule of an allogeneic unit. Donated units are stored with a plan for transfusion to the donor during or after a scheduled surgical procedure. Use of PAD peaked in late 1980s/early 1990s with emerging risk of transfusion-transmitted diseases from allogeneic transfusions¹⁻⁶. However, there have been widespread public health measures including rigorous donor screening and donor blood testing, which have resulted in significantly improved safety of allogeneic blood supply^{7, 8}. The current risk of transmission per unit of blood in the United States for HIV and HCV is approximately 1 in every 2 million units⁹⁻¹². As a result, transfusions from PAD have been slowly declining^{1, 13}. Per National Blood Collection & Utilization Survey (NBCUS), only ~25,000 autologous RBC products were collected in 2015¹⁴.

PACS is the process by which blood from the surgical field is collected, filtered, and washed to produce autologous blood for transfusion back to the patient¹⁵. Autologous salvaged blood has several advantages as it is free from any possible adverse effects of blood storage and can be more cost-effective than allogeneic blood if carefully planned for various surgeries with large volume of anticipated blood loss¹⁵⁻¹⁷. With advances in patient blood management (PBM), PACS became popular two decades ago as an important tool for perioperative blood conservation¹⁶⁻¹⁸.

This study describes temporal trends in PAD RBC transfusions and PACS utilization over two decades and factors associated with the inpatient utilization of these modalities using a nationally representative database of the U.S inpatient hospital population.

Methods:

Data Source

This analysis utilizes data from the National Inpatient Sample (NIS), the largest publicly available inpatient health care database in the United States, for the years 1995-2015. The

NIS was developed by the Agency for Healthcare Research and Quality (AHRQ) for the Healthcare Cost and Utilization Project (HCUP)^{19, 20}. Following a redesign in 2012, the NIS uses a stratified probability sample of 20% of all HCUP participating hospital discharges for each calendar year. This sampling scheme represents over 97% of the US population²¹. Data from years prior to 2012 used a stratified probability sample of hospitals as opposed to discharges²². Each observation in the NIS represents a hospitalization; therefore a single patient may be represented in multiple observations. Observations were self-weighted and calculated by strata, which were defined by census division (census region prior to 2012), bed size, location, teaching status, and ownership^{20, 22}.

Each discharge record contains information on sociodemographics, diagnoses and procedures recorded during the hospitalization and patients' outcomes, such as length of stay, mortality, and hospital-level characteristics. The number of diagnoses and associated data elements increased from 15 to 25 beginning with 2009 data, and from 25 to 30 beginning with 2014 data and were thus included accordingly. This analysis included the first 15 recorded procedures during each hospitalization, as additional procedures were not available in the database. Teaching status of a hospital was determined by whether the hospital was a member of the Council of Teaching Hospitals (COTH), had a residency program approved through the Accreditation Council for Graduate Medical Education (ACGME), or if the ratio of full-time interns and residents to beds was 0.25 or larger. Rural hospitals were not classified by teaching status due to the low sample size. Bed size was split into three categories: small, medium, and large. The cutoff points for each bed size category was determined separately for each stratum of hospital location, teaching status, and region. Severity of illness and risk of mortality were estimated using All Patient Refined Diagnostic Related Groups (APR-DRGs). HCUP truncated the age of any patient above 89 years of age to 90 years.^{20, 21}

The NIS is a de-identified, publicly available data set. This study was deemed exempt from review from the Johns Hopkins Institutional Review Board. This analysis was conducted in accordance with the HCUP data use agreement guidelines.

Statistical Analysis

Data were analyzed using STATA, version 15 (Statacorp, College Station, TX), using survey analysis commands applying the sampling weights as determined by HCUP. Taylor series linearization was utilized to estimate design-adjusted standard errors.

Outcomes were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedure codes. The two primary outcomes of this analysis were one or more transfusions of perioperative cell salvage (*ICD-9-CM* code 99.00) and one or more previously preoperative collected autologous transfusions (*ICD-9-CM* code 99.02). The rate for transfusions of both PACS and PAD were calculated for the years 1995 through 2015. After the third quarter of 2015, billing codes switched from *ICD-9-CM* to the *Tenth Revision, Clinical Modification (ICD-10-CM)*. Since there has not been enough data validating the transition and specificity of codes between the transition and the accuracy of trend analysis thereof, we restricted the temporal trends to ICD-9 codes only and thus the data analyzed is up until the third quarter of 2015 (2015Q3). Due to the transition from

ICD-9-CM to ICD-10-CM in October 2015, for 2015 only average rates of discharges were calculated and the actual number of discharges were calculated till end of 2014 to allow for valid trend analysis.

The distribution of patient and hospital characteristics from year 2012-2015Q3 was evaluated. A Cochran-Armitage test for trend was performed for the years 2012-2015. Due to the redesign of the NIS in 2012, a formal test for trend was not used to compare rates of transfusion before and after the redesign.

Prevalence ratios (PRs) and prevalence ratios adjusted for confounding variables i.e adjusted prevalence ratios (adjPRs), along with corresponding 95% confidence intervals (95% CI) were estimated using Poisson regression models among the two most recent years (2014-2015Q3). The years 2012 and 2013 were not included due to relevance and the possibility that characteristics associated with PAD or PACS have changed over the years. Multivariable models included all covariates determined either to be clinically relevant *a priori* and/or significant in univariate models (two-sided p-value <0.05). The multivariable models included age, sex, race, APR-DRG severity, primary payer, transfer status, length of stay, hospital location/teaching status, and hospital region. Highly collinear factors were excluded from multivariable models (e.g. hospital control, number of diagnoses and APR-DRG risk of mortality). An available case analysis approach was performed to handle missing data; only those observations which had data for all variables included in the multivariable model were used to estimate the multivariable model parameters. We evaluated whether those who were excluded from the multivariable analysis were different as compared to those who were included (Supplemental Table 1). No hospital characteristics were associated with inclusion in the multivariable model, however hospitalized individuals who were included in the analysis were more likely to have received a PAD than those excluded.

Results:

Between 1995-2015, there was a steady decrease in hospitalizations reporting PAD RBC transfusions from a rate of 27.90/100,000 in 1995 to 1.48/100,000 hospitalizations in 2015 (p-trend <0.001, year 2012-2015Q3). In contrast, hospitalizations reporting PACS increased from a rate of 1.16/100,000 hospitalizations in 1995 to a peak of 20.51/100,000 hospitalizations in 2008 and has since declined (p-trend<0.001, year 2012-2015Q3) (Figure 1).

Table 1 shows the distribution of individual and hospital level characteristics for years 2012-2015Q3. Table 2 lists the top ten procedures associated with PACS. Of the top procedures ~60% are major orthopedic surgeries including total hip and total knee replacements and spinal fusion surgeries, and ~40% were cardiothoracic surgeries, including coronary artery bypass grafting surgeries and aortic valve surgeries. In assessing the factors associated with PAD and PACS between 2014-2015Q3 (Tables 3 and 4), these interventions were often used in the similar patient populations. Utilization of PACS or PAD were rare for pediatric hospitalizations. Both PAD and PACS were generally more common among hospitalizations among whites as compared to other racial groups. PACS was more common

among hospitalizations in men as compared to women. This could be because cardiac surgeries which often use PACS are more common in men. PAD and PACS were more common among hospitalizations with elective admissions than non-elective or urgent admissions. PAD transfusions as well PACS were also more likely performed in hospitalizations of patients who were privately insured or had Medicare coverage as compared to Medicaid. As far as hospital characteristics associated with these procedures both PAD and PACS were more likely to be performed in urban teaching or non-teaching hospitals versus rural hospitals.

However, PAD and PACS were not always consistently used among the same patient populations. Notably, the prevalence of PAD was lower in hospitalizations of individuals with higher severity of illness as compared to those with mild or no severity (APR-DRG category 4 vs 1, adjPR= 0.61 [95%CI 0.39-0.95]). In contrast, the prevalence of PACS was higher in hospitalizations with a higher severity of illness as compared to those with mild or no severity (APR-DRG category 4 vs 1, adjPR=2.39 [95%CI 2.08-2.73])

Discussion:

These data, spanning over 20 years from 1995 to 2015, show a significant and striking decrease in hospitalizations reporting PAD RBC transfusions, which reached historically low national rates in 2015. While similar trends have been projected for PAD in other studies and expert summaries, they have not been shown empirically¹⁷. We anticipate the numbers have continued to show similar trends with continuing decrease beyond the years anticipated. In contrast, PACS increased to a peak national rate of utilization in 2008 and has since then declined.

PAD had a great surge and peaked in usage in the 1980s and early 1990s with the emergence of transfusion-transmitted HIV and hepatitis C risk from allogeneic transfusions^{4-6, 23}. PBM programs led non-transfusion alternatives and significant risk mitigation of transfusion transmitted infections have together increasingly made PAD a less favorable option^{1, 8, 13, 24, 25}. It has also been proposed that the PAD's effectiveness may be limited by the blood storage limit (6 weeks at maximum, and for many hospital based transfusions services shorter duration of 3 weeks for whole blood), and inadequate time for erythropoiesis to recover the patient's RBC mass prior to surgery. Consequently, PAD may simply be rendering patients anemic prior to surgery and subjecting their blood to potentially detrimental effects of storage.²⁶⁻²⁸ Furthermore, PAD is expensive, and often the unused PAD units are discarded²⁹.

PACS is most commonly used during orthopedic, vascular, cardiac, neurologic, gynecologic, urologic, transplant and trauma surgeries³⁰⁻³². PACS reduces the patient's risk of transfusion hazards such as transfusion-transmitted infections and alloimmunization³³. In addition, PACS helps to conserve healthcare systems' allogeneic donor blood inventories in some settings, if used appropriately³³⁻³⁷. PACS had thus emerged as an important tool for surgical blood conservation over two decades ago. The Association of Anaesthetists 2018 Guidelines for Cell Salvage for Peri-Operative Blood Conservation 2018 support and encourage a continued increase in the appropriate use of PACS and recommend that PACS should be

available for immediate use 24 hours a day in any hospital undertaking surgery where blood loss is a recognized as a potential complication (other than minor/day case procedures)³⁸

Multiple randomized trials over the past two decades have shown restrictive (when compared to liberal) RBC transfusion strategies to be safe³⁹⁻⁴¹. There is also evidence validating the improved patient safety afforded by PBM programs, blood conservation techniques (e.g., PACS, pre-surgical hemostasis management, and enhanced and non-invasive surgical techniques) and adherence to transfusion guidelines. As a result, hospitals have implemented patient blood management programs to advance restrictive transfusion practices with a view to improve patient outcomes, reduce costs, and conserve blood for transfusion⁴²⁻⁴⁴. Hospitals have implemented PBM programs and PACS is a part of the PBM initiatives.

The peak of the PACS was in 2008 and—in general— follows the decreasing trend concomitant with decrease in RBC transfusions overall and is concurrent with an increase in PBM programs. There has also been improvement in surgical techniques, the expanded use of minimally-invasive surgery and hemostatic measures (e.g. prothrombin complex concentrates) among other PBM measures, which contributed to an overall decrease in allogeneic transfusions. Also, use of PACS, particularly along with allogeneic blood transfusion, appears cost-saving and cost-effective in various settings including obstetric, general surgical and some pediatric surgical indications⁴⁵⁻⁴⁷. The use of PACS for cases at high risk for obstetric hemorrhage was found to be economically reasonable, while routine PACS use for all cesarean deliveries was not ascertained as cost-effective⁴⁸. Despite the recommendations from perioperative transfusion guidelines supporting PACS, the recent decline in PACS observed in the last decade probably reflects overall optimization of transfusion practice³⁸. We anticipate similar direction in trends for further years since 2015.

Transfusions are associated with clinical severity and hospital factors. PACS was more commonly employed in individuals with higher severity of illness than individuals with mild severity of illness. This likely reflects that patients undergoing more complex procedures and bigger and more invasive surgeries with significant blood loss are more suitable for PACS. Contrasting patterns were seen in patients who received PAD with the lowest prevalence in sickest subjects as compared to patients with mild severity of illness scoring. These patterns likely reflect less overall clinical stability for the sickest patients to be able to undergo a preoperative donation and these patients likely receive an allogeneic transfusion instead. This might simply reflect patients with PAD being less sick and able to undergoing elective procedures more often as well as being less anemic at baseline to donate blood for PAD. As expected, there is a higher likelihood of both PACS and PAD transfusions in patients undergoing elective procedures versus urgent procedures. Further, privately insured—as compared to Medicaid and Medicare patients and privately owned (for-profit or non-profit) versus government-owned hospitals are associated with higher odds for these procedures. These trends suggest that decision for these interventions might at least in part be related to the insurance coverage and reimbursement patterns for these procedures. As expected, teaching/non-teaching urban hospitals tend to perform the PACS procedures more often compared to rural hospitals, which could simply reflect the more complex surgeries being performed there which may meet criteria for PACS.

There are several limitations of this study. The national hospitalization data available from NIS via HCUP now extends up to 2017 and include over two years of ICD-10 coding as well. However, the analysis in this study was restricted to data from ICD-9 codes only due to lack of validation of specificity between ICD-9 and ICD-10 codes for these procedures and thus the study ends in 3rd quarter of 2015. We anticipate similar trends continuing for PAD as well as PACS due to the reasons outlined above. Additionally, due to a single ICD-9 code for perioperative cell salvage, we were unable to distinguish between intraoperative and post-operative cell salvage and when was each procedure performed. However, it should not affect the overall trends. In addition, the strength of this study is to evaluate trends over a 20 year period that represents the majority of the hospitalizations in the United States. Details of intraoperative management including blood loss, hemodynamic status, laboratory data (e.g., pre-operative and intra-operative hemoglobin level, coagulation profile) etc. were not available. The data were derived from an administrative dataset that is primarily used for billing purposes, so accuracy of the data is limited by billing and coding accuracy by physicians. However, hospital discharge and procedure codes have been shown to correlate well with self-report⁴⁹. While no specific studies have been performed using specificity for coding in PACS or PAD, hospital discharge codes for RBC transfusions have been previously validated against blood bank transfusion records (83% sensitivity; 100% specificity) at one large academic institution with a busy transfusion service⁵⁰. The NIS database has also produced comparable results to the National Hospital Discharge Survey and Medicare Provider Analysis and Review Files^{51, 52}. In addition, the NIS has also previously been used for transfusion-related research^{53, 54}. Another limitation is that individual patients may be multiply represented since the unit of observation is a hospital discharge. However, these limitations like do not impact the overall trends presented in this study.

These data provide information on temporal trends in national utilization of two blood conservation modalities over the past two decades. As PBM measures continue to evolve and improve, continued evaluation of utilization trends, cost effectiveness studies as well as assessments of clinical efficacy of these measures can offer key insights into continued improvement of surgical blood conservation methodologies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1:

Trends in the transfusion of perioperative cell salvage and autologous transfusions from 1995 to 2015 (through the third quarter of 2015) in the National Inpatient Sample. The p-trend has been calculated from year 2012 through 3rd Quarter of 2015.

Table 1:

Distribution of individual and hospital level characteristics for all hospitalizations for years 2012-2015Q3

Characteristics	2012 (n= 36,484,846)		2013 (n= 35,597,792)		2014 (n= 35,358,818)		2015* (n= 26,896,858)	
Age (median [IQR])	53 [28-71]		54 [28-71]		54 [28-71]		54 [28-71]	
Pediatric ‡ (%)								
No	30712524	84.2	29969451	84.2	29751964	84.1	22690308	84.4
Yes	5755617	15.8	5620416	15.8	5595114	15.8	4193960	15.6
Sex (%)								
Male	15436338	42.3	15154195	42.6	15095708	42.7	11544884	42.9
Female	21043668	57.7	20436357	57.4	20255555	57.3	15346764	57.1
Race (%)								
White	22759225	62.4	22044880	61.9	21914442	62.0	16520696	61.4
Black	5073490	13.9	4951772	13.9	4944337	14.0	3903757	14.5
Hispanic	4076682	11.2	4079463	11.5	4038136	11.4	3084127	11.5
Asian or Pacific Islander	933061	2.6	940199	2.6	962795	2.7	764830	2.8
Native American/Other	1550030	4.2	1344994	3.8	1401104	4.0	992060	3.7
APR-DRG Risk Mortality (%)								
1	21593739	59.2	20634776	58.0	20146323	57.0	14963573	55.6
2	8170491	22.4	7936249	22.3	7800957	22.1	5956555	22.1
3	5022511	13.8	5209712	14.6	5415597	15.3	4325020	16.1
4	1648355	4.5	1787694	5.0	1966276	5.6	1626085	6.0
APR-DRG Severity (%)								
1	12972346	35.6	12159727	34.2	11575197	32.7	8457248	31.4
2	13702618	37.6	13235550	37.2	13025518	36.8	9838089	36.6
3	7753341	21.3	8016576	22.5	8380167	23.7	6657255	24.8
4	2006791	5.5	2156579	6.1	2348271	6.6	1918640	7.1
Primary Payer (%)								
Medicare	14276970	39.1	13986550	39.3	13795116	38.0	10622654	34.5
Medicaid	7620265	20.9	7417129	20.8	7993545	22.6	6163565	22.9
Private	11171409	30.6	10851650	30.5	10833048	30.6	8177264	30.4
Self-pay	1899716	5.2	1862518	5.2	1513071	4.3	1027239	3.8
Other	1425826	3.9	1424815	4.0	1156659	3.3	870716	3.2
Transfer Status (%)								
No transfer	33769790	92.6	32934858	92.5	32600008	92.2	24786278	92.2
Transfer from acute care hospital	1657531	4.5	1709539	4.8	1772540	5.0	1390050	5.2
Transfer from other health facility	860365	2.4	795145	2.2	768881	2.2	575495	2.1
Elective Admission (%)								
No	28210917	77.3	27618076	77.6	27540471	77.9	21041697	78.2
Yes	8148929	22.3	7859731	22.1	7701297	21.9	5763681	21.4
Length of Stay (median [IQR])	3 [2-5]		3 [2-5]		3 [2-5]		3 [2-5]	

Characteristics	2012 (n= 36,484,846)		2013 (n= 35,597,792)		2014 (n= 35,358,818)		2015* (n= 26,896,858)	
Number of Diagnoses* (median [IQR])	8 [4-13]		8 [4-13]		9 [5-14]		9 [5-15]	
Hospital Bedsize (%)								
Small	5095607	14.0	4884892	13.7	6553063	18.5	4880695	18.1
Medium	9711513	26.6	9512936	26.7	10398925	29.4	7982098	29.7
Large	21677726	59.4	21199964	59.6	18406830	52.1	14034064	52.2
Hospital Location/Teaching Status (%)								
Rural	4142560	11.4	3954149	11.1	3360976	9.5	2539716	9.4
Urban, nonteaching	13736270	37.6	13234709	37.2	9226476	26.1	7107620	26.4
Urban, teaching	18606016	51.0	18408934	51.7	22771366	64.4	17249521	64.1
Hospital Region (%)								
Northeast	6981645	19.1	6730965	18.9	6623697	18.7	4979195	18.5
Midwest	8238220	22.6	8004912	22.5	7942913	22.5	6015864	22.4
South	14113101	38.7	13818031	38.8	13774248	39.0	10577765	39.3
West	7151880	19.6	7043884	19.8	7017960	19.8	5324034	19.8
Hospital Control (%)								
Government, nonfederal	4382366	12.0	4291755	12.1	4310458	12.2	3234464	12.0
Private, non-profit	26846590	73.6	26111822	73.4	25831562	73.1	19596928	72.9
Private, invest-own	5255890	14.4	5194215	14.6	258315628	14.8	4065465	15.1

Notes: All data is weighted using survey weights provided by the Healthcare Cost and Utilization Project (HCUP). Autologous transfusion defined as having at least one autologous transfusion (ICD-9-CM Code 99.02) during hospitalization. Pediatric defined as being less than 18 years old. Cell salvage defined as having at least one cell salvage (ICD-9-CM Code 99.00) during hospitalization. Data includes missingness, and therefore may not add up to 100%.

Table 2:

Top 10 primary procedures among hospitalizations with at least one cell salvage transfusion Of the top procedures ~60% are major orthopedic surgeries and ~40% were cardiothoracic surgeries.

ICD 9 Code	Procedure	Percent
81.51	Total hip replacement	10.56
81.54	Total knee replacement	9.21
35.21	Open and other replacement of aortic valve with tissue graft	6.97
81.07	Lumbar and lumbosacral fusion of the posterior column, posterior technique	6.90
36.12	(Aorto)coronary bypass of two coronary arteries	6.71
36.13	(Aorto)coronary bypass of three coronary arteries	5.07
81.05	Dorsal and dorsolumbar fusion of the posterior column, posterior technique	4.91
81.08	Lumbar and lumbosacral fusion of the anterior column, posterior technique	4.41
36.11	(Aorto)coronary bypass of one coronary artery	3.17
36.15	Single internal mammary-coronary artery bypass	2.50

Table 3:

Patient and hospital-level factors associated with collected autologous transfusions in the National Inpatient Sample, 2014-2015Q3

	No. transfused	Per 100,000	PR (95% CI)	adjPR (95% CI)
Age * †	-	-	1.11 (1.10-1.12)	1.18 (1.12-1.24)
Pediatric				-
No	10205	19.5	Reference	-
Yes	320	3.3	0.17 (0.11-0.26)	-
Sex				
Male	4745	17.8	Reference	Reference
Female	5780	16.2	0.91 (0.81-1.03)	0.87 (0.77-0.98)
Race				
White	8095	21.2	Reference	Reference
Black	875	9.9	0.47 (0.35-0.62)	0.89 (0.71-1.11)
Hispanic	610	8.6	0.41 (0.30-0.56)	0.85 (0.64-1.12)
Asian or Pacific Islander	130	7.5	0.36 (0.24-0.53)	0.53 (0.36-0.78)
Native American/Other	455	19.0	0.90 (0.43-1.88)	1.41 (0.67-2.95)
APR-DRG € Risk Mortality				
1	7405	21.1	Reference	-
2	2010	14.6	0.69 (0.49-0.98)	-
3	800	8.2	0.39 (0.25-0.61)	-
4	310	8.6	0.41 (0.25-0.67)	-
APR-DRG Severity				
1	4125	20.6	Reference	Reference
2	4420	19.3	0.94 (0.60-1.48)	0.90 (0.57-1.42)
3	1595	10.6	0.52 (0.30-0.89)	0.67 (0.41-1.08)
4	385	9.0	0.44 (0.24-0.81)	0.61 (0.39-0.95)
Primary Payer				
Medicare	4890	20.0	Reference	Reference
Medicaid	395	2.8	0.14 (0.10-0.19)	0.49 (0.34-0.69)
Private	4770	25.1	1.26 (0.91-1.73)	1.88 (1.23-2.86)
Self-pay	115	4.5	0.23 (0.14-0.36)	0.84 (0.45-1.56)
Other	360	17.8	0.89 (0.65-1.21)	1.34 (0.99-1.80)
Transfer Status				
No transfer	10220	17.8	Reference	Reference
Transfer from acute care hospital	250	7.9	0.44 (0.19-1.03)	0.48 (0.22-1.08)
Transfer from other health facility**	-	-	-	-
Elective Admission				
No	1475	3.0	Reference	Reference
Yes	9045	67.2	22.13 (14.24-34.37)	19.19 (13.38-27.51)
Length of Stay *	-	-	0.99 (0.95-1.02)	1.01 (0.98-1.02)

	No. transfused	Per 100,000	PR (95% CI)	adjPR (95% CI)
Number of Diagnoses *	-	-	0.99 (0.95-1.02)	-
Hospital Bedsize				
Small	2555	22.3	Reference	-
Medium	2700	14.7	0.66 (0.36-1.19)	-
Large	5270	16.2	0.73 (0.37-1.43)	-
Hospital Location/Teaching Status				
Rural	265	4.5	Reference	Reference
Urban, nonteaching	2675	16.4	3.65 (2.15-6.19)	4.07 (2.59-7.77)
Urban, teaching	7585	19.0	4.22 (2.45-7.25)	5.34 (2.97-9.61)
Hospital Region				
Northeast	1905	16.4	Reference	Reference
Midwest	3375	24.2	1.47 (0.58-3.72)	1.59 (0.59-4.29)
South	3450	14.2	0.86 (0.45-1.66)	0.89 (0.47-1.70)
West	1795	14.5	0.89 (0.48-1.63)	0.93 (0.52-1.68)
Hospital Control				
Government, nonfederal	510	6.8	Reference	-
Private, non-profit	8430	18.6	2.75 (1.54-4.88)	-
Private, invest-own	1585	17.1	2.53 (1.18-5.42)	-

Notes: All data is weighted using survey weights provided by the Healthcare Cost and Utilization Project (HCUP). Autologous transfusion defined as having at least one autologous transfusion (ICD-9-CM Code 99.02) during hospitalization. Pediatric defined as being less than 18 years old. Data from 2015 include the first three quarters of the year due to transition to ICD-10-CM codes. Number of diagnoses, APR-DRG mortality risk and hospital control not included in multivariable model due to collinearity.

€ The All Patient Refined DRGs (APR-DRGs) are assigned using software developed by 3M Health Information Systems. This severity measure includes the base APR-DRG, the severity of illness subclass, and the risk of mortality subclass within each base APR-DRG. The prefix "APRDRG" has been included in the data element names to distinguish APR-DRG measures from other HCUP data elements.

* Data are median and corresponding interquartile range (IQR).

† per five year increase

** Estimates suppressed due to low cell size (<10) as per HCUP data use restrictions.

Table 4:

Patient and hospital-level factors associated with perioperative cell salvage transfusions in the National Inpatient Sample, 2014-2015Q3.

	No. transfused	Per 100,000	PR (95% CI)	adjPR (95% CI)
Age^{*†}	-	-	1.09 (1.08-1.10)	1.08 (1.06-1.09)
Pediatric				
No	76235	145.4	Reference	-
Yes	5165	52.8	0.36 (0.29-0.45)	-
Sex				
Male	45230	169.8	Reference	Reference
Female	36160	101.6	0.60 (0.57-0.63)	0.58 (0.56-0.61)
Race				
White	59595	155.1	Reference	Reference
Black	5960	67.4	0.43 (0.39-0.48)	0.65 (0.59-0.72)
Hispanic	5815	81.6	0.53 (0.43-0.64)	0.88 (0.74-1.04)
Asian or Pacific Islander	1210	70.0	0.45 (0.39-0.53)	0.59 (0.50-0.70)
Native American/Other	2740	114.5	0.74 (0.62-0.88)	0.97 (0.81-1.15)
APR-DRG[€] Risk Mortality				
1	39160	111.5	Reference	-
2	20760	150.9	1.35 (1.23-1.49)	-
3	14295	146.8	1.32 (1.14-1.52)	-
4	7170	199.6	1.79 (1.56-2.05)	-
APR-DRG Severity				
1	19290	96.3	Reference	Reference
2	31230	136.6	1.42 (1.32-1.52)	1.38 (1.29-1.48)
3	22450	149.3	1.55 (1.36-1.76)	1.89 (1.67-2.16)
4	8415	197.2	2.05 (1.78-2.35)	2.39 (2.08-2.73)
Primary Payer				
Medicare	39535	161.9	Reference	Reference
Medicaid	6360	44.9	0.28 (0.25-0.31)	0.68 (0.62-0.75)
Private	30605	161.0	0.99 (0.94-1.05)	1.32 (1.23-1.41)
Self-pay	1240	48.8	0.30 (0.24-0.39)	0.87 (0.69-1.09)
Other	3515	173.3	1.07 (0.95-1.21)	1.51 (1.33-1.70)
Transfer Status				
No transfer	74435	129.7	Reference	Reference
Transfer from acute care hospital	5975	188.9	1.46 (1.24-1.71)	1.15 (0.97-1.35)
Transfer from other health facility	870	64.7	0.50 (0.34-0.73)	0.45 (0.31-0.67)
Elective Admission				
No	20935	43.1	Reference	Reference
Yes	60405	448.6	10.41 (9.42-11.51)	11.71 (10.58-12.95)
Length of Stay[*]	-	-	1.01 (1.01-1.02)	1.01 (1.01-1.01)

	No. transfused	Per 100,000	PR (95% CI)	adjPR (95% CI)
Number of Diagnoses *	-	-	1.06 (1.05-1.07)	-
Hospital Bedsize				
Small	14330	125.3	Reference	-
Medium	19575	106.5	0.85 (0.67-1.08)	-
Large	47500	146.4	1.17 (0.91-1.49)	-
Hospital Location/Teaching Status				
Rural	4210	71.3	Reference	Reference
Urban, nonteaching	16835	103.1	1.44 (1.03-2.03)	1.93 (1.38-2.71)
Urban, teaching	60360	150.8	2.11 (1.52-2.93)	2.60 (1.87-3.62)
Hospital Region				
Northeast	18705	161.2	Reference	Reference
Midwest	22075	158.1	0.98 (0.67-1.44)	0.86 (0.57-1.30)
South	26650	109.4	0.68 (0.51-0.91)	0.66 (0.50-0.88)
West	13975	113.2	0.70 (0.51-0.96)	0.72 (0.52-0.98)
Hospital Control				
Government, nonfederal	4740	62.8	Reference	-
Private, non-profit	67335	148.2	2.36 (1.66-3.35)	-
Private, invest-own	9330	100.5	1.60 (1.10-2.23)	-

Notes: All data is weighted using survey weights provided by the Healthcare Cost and Utilization Project (HCUP). Cell salvage defined as having at least one cell salvage (ICD-9-CM Code 99.00) during hospitalization. Pediatric defined as being less than 18 years old. Data from 2015 include the first three quarters of the year due to transition to ICD-10-CM codes. Number of diagnoses and hospital control not included in multivariable model due to collinearity.

€ The All Patient Refined DRGs (APR-DRGs) are assigned using software developed by 3M Health Information Systems. This severity measure includes the base APR-DRG, the severity of illness subclass, and the risk of mortality subclass within each base APR-DRG. The prefix "APRDRG" has been included in the data element names to distinguish APR-DRG measures from other HCUP data elements.

* Data are median and corresponding interquartile range (IQR)

† per five year increase