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Long-Term Sustainability of a Quality Initiative Program on Transfusion Rates in Total Joint Arthroplasty: A Follow-Up Study

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ABSTRACT

Background: There are significant variations in transfusion rates among institutions performing total joint arthroplasty. We previously demonstrated that implementation of an educational program to increase awareness of the American Association of Blood Banks' transfusion guidelines led to an immediate decrease in transfusion rates at our facilities. It remained unclear how this initiative would endure over time. We report the long-term success and sustainability of this quality program.
Methods: We reviewed the Michigan Arthroplasty Collaborative Quality Initiative data from 2012 through 2017 of all patients undergoing primary hip and knee arthroplasty at our institutions for preoperative and postoperative hemoglobin level, transfusion status, and number of units transfused and transfusions outside of protocol to identify changes surrounding our blood transfusion educational initiative. We calculated the transfusions prevented and cost implications over the course of the study.
Results: We identified 6645 primary hip and knee arthroplasty patients. There was a significant decrease in transfusion rate and overall transfusions in each group when compared to pre-education values. Subgroup analysis of TKA and THA independently showed significant decreases in both transfusion rate and overall transfusions. Over the final 3 years of the study, only 2 patients were transfused outside of the American Association of Blood Banks protocol. We estimate prevention of 519 transfusions over the study period.
Conclusion: Application of this quality initiative was an effective means of identifying opportunities for quality improvement. The program was easily initiated, had significant early impact, and has been shown to be sustainable.

The number of total joint arthroplasties performed annually in the United States is increasing rapidly. Current projections indicate that by 2030, the annual number of total knee (TKA) and total hip arthroplasty (THA) cases may reach approximately 4 million in the United States as a result of the increased demand of an aging population [1]. Consequently, the economic burden of total joint arthroplasty continues to rise, accounting for an excess of $7 billion in expenditure in 2014 alone [2,3]. Increased attention on total joint arthroplasty has demonstrated widespread variability in both costs and outcomes. This led CMS and both private groups and public institutions to adopt risk-sharing strategies like bundled payments for these procedures. As a result, the traditional pay-for-service model of healthcare has started to shift to value-based care with emphasis on controlling costs while maintaining the quality and safety of the care provided to total joint arthroplasty patients.

Total joint arthroplasty registries are increasingly used to identify areas for cost and quality improvement in healthcare [4,5]. In 2011, several Michigan Hospitals along with Blue Cross Blue Shield of Michigan formed the Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI) to improve the quality of care for patients undergoing elective hip and knee arthroplasty in the state. As of January 2019, there were 62 hospital members and 513 surgeons contributing data, and the registry captures 96% of all arthroplasty cases completed in the state. Approximately 250,000 cases have been abstracted to date, 35% of which were THA and 65%

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TKA. At each participating institution, clinical, administrative, and medical device data are collected on all THA and TKA cases. A probability sample of the data is audited annually. Additional administrative data are captured by linking MARCQI cases to the statewide database of hospital admissions, the Michigan Inpatient Database. Further details regarding the collaborative data collection and management were previously reported [6].

In total joint arthroplasty, much of the literature has reported on decreased length of stay (LOS), decreased discharge to skilled nursing or care facility, reduction in re-admissions, and preoperative modification of patient risk factors as mechanisms to reduce costs while improving the quality of care delivered to patients [7–9]. However, an area of heightened focus is postoperative transfusions in hip and knee arthroplasty [10–12]. Early in the analysis and reporting of the MARCQI data in 2012, the collaboration showed a wide variability in the administration of blood transfusions between the member hospitals, with transfusion rates as high as 33% for primary THA and 23% for primary TKA. This significant variation in care raised the possibility that a large number of transfusions were being performed that might not have been necessary. This included patients without clinical symptoms and postoperative hemoglobin ≥ 8 mg/dL [13]. Widespread variability in transfusion rates has been demonstrated frequently in the literature, indicating a nationwide problem that is not isolated to the Michigan databases [14–20].

Blood transfusions are not without risk and have many well-known adverse health effects. They can cause rare, life-threatening, complications including acute and delayed hemolytic reactions, acute lung injury, immunomodulatory effects, and disease transmission [21,22]. Recently, it was noted that transfusion of red blood cells stored >14 days was the strongest predictor for a prosthetic joint infection within 90 days after a primary TKA [23]. Several observational studies have raised concerns over the association of blood transfusion with poorer outcomes after surgery, including longer LOS, higher hospital costs, and increased infections and mortality [14,24–32].

Interestingly, several studies have not shown an increased risk of adverse outcomes when transfusions are restricted [33,34]. In a meta-analysis of randomized trials comparing liberal and conservative transfusion strategies, the conservative strategy was associated with a decreased risk of serious infections, including the subgroup of patients undergoing orthopedic surgery [31]. This finding was substantiated through another meta-analysis concluding with moderate evidence that restrictive transfusion practices may decrease infections without increasing adverse outcomes [35]. The Surgical Hip Fracture Repair (FOCUS) study showed no increase in adverse events using a restrictive postoperative transfusion threshold (hemoglobin ≤ 8 g/dL) in asymptomatic patients with increased cardiovascular risk [36,37]. Reduction of liberal usage at academic centers has shown to significantly decrease costs without a rise in complications [38].

Blood transfusion is expensive. Conservative estimates for the cost of obtaining, storing, testing, and administering 1 unit of blood range from $700 to $1130 (USD) [39] compared to higher ranges of $1000 to $1500 [40]. Hospital costs associated with a single transfusion in TKA patients have been shown to reach $1777 per transfusion [41]. Despite clinical trials showing the safety and effectiveness of restrictive transfusion practices, a reduction in unnecessary transfusions in elective joint arthroplasty has taken time to become mainstream practice. An analysis of data from the National Inpatient Sample showed an increase in allogeneic blood transfusions from 2000 to 2009 (THA: 11.2%-19.1%, $P < .001$; TKA: 7.7%-12.4%, $P < .001$) [20]. In contrast, the PearlDiver Research Program has recently shown a significant decrease in transfusion within 3 days after surgery from 2007 to 2015 of 59% for THA (21.3% in 2007 to 8.7% in 2015; $P < .001$) and 74% for TKA (17.3% in 2007 to 4.4% in 2015; $P < .001$) [42].

The American Association of Blood Banks (AABB) and the American Red Cross (ARC) published a red blood cell transfusion clinical practice guideline in 2012. This "restrictive" guideline recommends consideration of transfusion for postoperative surgical patients with a hemoglobin concentration of ≤8 g/dL, or for symptomatic patients with chest pain, orthostatic hypotension, tachycardia unresponsive to fluid resuscitation, and/or congestive heart failure [10].

In November 2013, a quality improvement initiative to decrease unnecessary blood transfusions was introduced to the 28 hospitals participating in MARCQI at that time. The interventions occurred at the quarterly meetings where clinical data abstractors and clinical champion orthopedic surgeons were present for data and educational presentations. The co-director of MARCQI (B.H.), an orthopedic surgeon, presented slides showing the variation in standardized transfusion risk and risk of transfusion with nadir hemoglobin > 8 g/dL among participating hospitals. Forest plots, showing how each site compared to the MARCQI average for these measures, and identified outliers were distributed to the members quarterly. At the meetings, the co-director also presented reviews of the literature on the potential hazards associated with blood transfusions and the safety of restrictive transfusion protocols. He also encouraged implementation of the AABB/ARC guidelines at the hospital level. Later, in November 2014, the co-director recommended the intraoperative administration of tranexamic acid (TXA) in patients with no contraindications. This was based on a review of multiple, randomized, controlled clinical trials and meta-analyses reported in the literature, and on the safety and effectiveness of TXA in the MARCQI hospitals recently reported [43–45].

Little has been done relative to transfusion at our institutions since the quality project was initiated in 2013. This study reports the long-term outcomes and sustainability of the MARCQI project initiative to decrease unnecessary blood transfusions at our hospitals.

Methods

In October 2013, our institution instituted an educational quality initiative to raise awareness in the discrepancy of postsurgical blood transfusions in hip and knee arthroplasty and review the AABB transfusion guidelines (Table 1). The immediate impact of that initiative was previously reported [46]. In order to assess the sustainability of the program and long-term outcomes, we queried the MARCQI database to obtain data for the 6-year period, 2012 through 2017, for all patients undergoing elective primary hip and knee arthroplasty at our institutions. Patients with revision procedures or who underwent arthroplasty for fracture were excluded.

Data collected included gender, age, preoperative hemoglobin level, lowest postoperative hemoglobin level during admission, transfusion status, and number of units transfused. We categorized the data into six distinct time periods: 2012 to initiation of the quality initiative in October of 2013, the previously published immediate post-education period from November 2013 to May 2014,

Table 1
The American Association of Blood Banks (AABB) Transfusion Guidelines for Postoperative Surgical Patients.

Postoperative Surgical Patients—Transfusion Should be Considered at a Hemoglobin of 8 g/dL or Less or for Symptoms of:
Chest pain
Orthostatic hypotension
Tachycardia unresponsive to fluid resuscitation
Congestive heart failure

the remainder of 2014, all of 2015, all of 2016, and all of 2017. These data were organized to demonstrate a pre-education interval, the interval previously published, and 12-month intervals thereafter. October 2013 was excluded from the study as the original educational event took place during that month.

Descriptive statistics were used to evaluate for significance using an alpha factor of 0.05. Categorical variables were evaluated with chi-square testing analysis while continuous variables used analysis of variance. All statistical analyses were performed using IBM SPSS software version 25 (IMB, Armonk, NY).

Results

Through the MARCQI database we identified 6645 patients undergoing primary hip and knee arthroplasty at our institutions, accounting for 1707 and 4938 patients pre-transfusion and post-transfusion quality initiative, respectively. There were 1707, 616, 802, 1260, 1369, and 891 patients in the pre-education, pre-published, 2014, 2015, 2016, and 2017 groups, respectively. There was no statistical difference in patient age between any compared groups. Average age was 66.7, 65.8, 66.0, 66.9, 67.0, 67.0, and 67.1 years, respectively. There were no statistical differences in body mass index between any compared groups. Average body mass index was 32.18, 32.17, 32.06, 32.12, 31.90, and 31.82, respectively. There was a statistically significant negative trend ($P < .001$) with average LOS of 2.47, 2.54, 2.23, 1.94, 1.74, and 1.55 days for the pre-education group, pre-published group, 2014, 2015, 2016, and 2017 groups, respectively. Differences between individual groups were not analyzed. The incidence of preoperative bleeding disorders was 1.4%, 1.5%, 0.5%, 0.4%, 1.24%, and 1.57%, respectively, while 5.08%, 4.75%, 6.13%, 7.31%, 7.46%, and 7.43% of patients had a history of deep vein thrombosis or pulmonary embolism event. A history of smoking was seen in 36.7%, 51.0%, 51.7%, 50.2%, 52.3%, and 47.4% of patients while concurrent smoking at the time of surgery was seen in only 8.2%, 11.8%, 11.3%, 9.3%, 10.6%, and 7.7% of patients, respectively (Table 2). In terms of discharge disposition, there was a trend toward discharge home with or without home healthcare services with 75.7%, 82.0%, 84.0%, 84.0%, 87.3%, and 89.7% discharged with disposition in the pre-education, pre-published, 2014, 2015, 2016, and 2017 cohorts, respectively (Table 3).

There were 253 (14.82%) patients transfused in the total arthroplasty pre-education group, 37 (6.01%) in the pre-published group, 35 (4.36%) in 2014, 28 (2.22%) in 2015, 39 (2.85%) in 2016, and 10 (1.12%) in 2017. In the total arthroplasty population, we found significant decrease in transfusion rate in the immediate post-education group (6.01%, $P < .001$), 2014 group (4.36%, $P < .001$), 2015 group (2.22%, $P < .001$), 2016 group (2.85%, $P < .001$), and 2017 group (1.12%, $P < .001$) when compared to the pre-education group (14.82%). When compared to the immediate post-education group the, 2015 ($P < .001$), 2016 ($P = .001$), and 2017 ($P < .001$) experienced significant decreases in transfusions, with exception of 2014 ($P = .180$). However, there was a negative trend seen in the 2014 comparison (Table 4).

There were 526 transfusions in the entire pre-education cohort (2.08 per patient), 96 transfusions (2.59 per patient) in the pre-published cohort, 60 (1.71 per patient) in 2014, 50 transfusions (1.79 per patient) in 2015, 76 transfusions (1.95 per patient) in 2016, and 16 transfusions (1.60 per patient) in 2017. In comparison to the pre-education cohort, the decrease in total transfusions was significant across all groups: pre-published ($P < .001$), 2014 ($P < .001$), 2015 ($P < .001$), 2016 ($P < .001$), and 2017 ($P < .001$). Comparison to the pre-published cohort demonstrated decreases in each subsequent group: 2014 ($P = .341$), 2015 ($P = .002$), 2016 ($P = .019$), and 2017 ($P < .001$).

Subgroup analysis for the TKA patients demonstrated reduction in post-education transfusion rate in each group: pre-published (15 patients, 3.58% transfused, $P < .001$), 2014 (12 patients, 2.12% transfused, $P < .001$), 2015 (0.59%, $P < .001$), 2016 (1.78%, $P < .001$), and 2017 (0.47%, $P < .001$) when compared to the pre-education group (11.37%). When compared to the pre-published group, only 2015 ($P < .001$) and 2017 ($P < .001$) demonstrated a significant reduction in TKA transfusions, while all other post-education intervals displayed a strongly negative trend: 2014 ($P = .172$) and 2016 ($P = .052$). Subgroup analysis of the TKA patients demonstrated reduction in post-education transfusions in each group: 2014 (17 units, 1.42 units/patient, $P < .001$), 2015 (9 units, 1.80 units/patient, $P < .001$), 2016 (32 units, 2 units/patient, $P < .001$), and 2017 (6 units, 2 units/patient, $P < .001$) when compared to the pre-education group (260 units, 1.94 units/patient) with the exception of the pre-published (96 units, 2.59 units/patient, $P < .232$). When compared to the pre-published, only 2015 ($P = .034$) demonstrated a significant reduction in TKA transfusions, while all other post-education intervals displayed a strongly negative trend: 2014 ($P = .316$), 2016 ($P = .268$), and 2017 ($P = .054$; Table 4).

Subgroup analysis of THA revealed a significant reduction in the transfusion rate of each cohort when compared to the pre-education group (119 patients transfused, 22.54% transfused, $P < .001$): pre-published group (22 patients transfused, 11.17%

Table 2
Patient Demographics.

Demographic	Pre-Education	Pre-Published	2014	2015	2016	2017
Number of patients (n)	1707	616	802	1260	1369	891
Age (mean ± SD, y)	66.7 ± 10.6	65.8 ± 10.4	66.0 ± 10.7	66.9 ± 10.0	67.0 ± 9.6	67.1 ± 9.4
Sex (n [%])						
Males	586 (34)	229 (37)	304 (38)	445 (35)	516 (38)	293 (33)
Females	1121 (66)	387 (63)	498 (62)	815 (65)	853 (62)	598 (67)
Body mass index (mean ± SD, kg/m^2)	32.2 ± 7.0	32.2 ± 6.6	32.1 ± 6.9	32.2 ± 6.5	31.9 ± 6.4	31.8 ± 6.4
Procedure (n [%])						
TKA	1179	419	566	842	898	640
THA	528	197	236	418	469	251
Smoking status (n [%])						
Current smoker	139 (8.2)	72 (11.8)	90 (11.3)	117 (9.3)	145 (10.6)	69 (7.7)
Any history	625 (36.7)	313 (51.0)	415 (51.7)	632 (50.2)	729 (52.3)	422 (47.4)
Coagulopathy status (n [%])						
Bleeding disorder by history	23 (1.4)	9 (1.5)	4 (0.5)	5 (0.4)	17 (1.24)	14 (1.57)
DVT or PE by history	86 (5.08)	28 (4.75)	49 (6.13)	92 (7.31)	102 (7.46)	66 (7.42)

The study demographic data divided by cohort are demonstrated. This includes age, sex, body mass index, procedure, smoking status, and coagulopathy status including DVT and PE occurrence.
DVT, deep vein thrombosis; PE, pulmonary embolism; SD, standard deviation; TKA, total knee arthroplasty; THA, total hip arthroplasty.

Table 3
Discharge Disposition.

Variable	Pre-Education	Pre-Published	2014	2015	2016	2017
Number of patients (n)	1707	616	802	1260	1369	891
Length of stay (average days)	2.47	2.53	2.23	1.94	1.74	1.55
Discharge disposition (n [%])						
Home	1288 (75.7)	505 (82.0)	674 (84.0)	1058 (84.0)	1195 (87.3)	799 (89.7)
To facility	418 (24.6)	111 (18.0)	128 (16.0)	202 (16.0)	174 (12.7)	92 (10.3)

The average length of stay and discharge disposition of patients. Facility includes skilled nursing facility and subacute rehabilitation. Home includes discharge home with home health assistance.

transfused, P < 01), 2014 group (23 patients transfused, 9.75% transfused, $P < .001$), 2015 (23 patients transfused, 5.5% transfused, $P < .001$), 2016 (23 patients transfused, 4.90% transfused, $P < .001$), and 2017 (7 patients transfused, 2.79% transfused, $P < .001$). When compared to the pre-published group, there was no appreciable statistical difference between groups: 2014 ($P = 1.000$), 2015 ($P = .586$), 2016 ($P = .482$), and 2017 ($P = .085$). Yet, there was a consistent decreasing rate. Subgroup analysis of THA revealed a significant reduction in transfusions of each cohort when compared to the pre-education group (266 units, 2.24 units/patient): pre-published group (42 units, 1.91 units/patient, $P < .001$), 2014 group (43 units, 1.87 units/patient, $P < .001$), 2015 (41 units, 1.78 units/patient, $P < .001$), 2016 (44 units, 1.91 units/patient, $P < .001$), and 2017 (10 units, 1.42 units/patient, $P < .001$). In comparison to the pre-published group, there was no appreciable statistical difference in between any of the cohorts: 2014 ($P = 1.000$), 2015 ($P = .586$), 2016 ($P = .482$), and 2017 ($P = .085$). Yet, there was a consistent decreasing trend (Table 4).

Preoperative and postoperative hemoglobin levels were 13.33 and 9.76 for the pre-education cohort, 13.48 and 10.00 in the pre-published group, 13.38 and 10.07 in 2014, 13.51 and 10.48 in 2015, 13.44 and 10.50 in 2016, and 13.43 and 10.65 in 2017, respectively. We observed a trend of decrease in the preoperative and postoperative change in hemoglobin over the course of the study with postsurgical hemoglobin loss of 3.59, 3.49, 3.31, 3.04, 2.96, and 2.77 in the pre-education, pre-published, 2014, 2015, 2016, and 2017 cohorts, respectively. This decrease was significant in each group, with the exception of the pre-published group ($P = .851$) when compared to the pre-educational group ($P < .001$ in each scenario). Additionally, with the exception of the pre-education and 2014 cohorts ($P = .851$ and $P = .145$, respectively), the decrease in hemoglobin change was significant in all groups when compared to the pre-published data ($P < .001$ in all situations; Table 5).

We analyzed the dataset for the number of transfusions and rate of transfusions outside of the established protocol. In the total cohort, we found 93 patients (6.1%, 173 total units) in the pre-education group, 7 patients (1.2%, 10 total units) in the pre-published group, 0 patients in 2014, 2 patients (0.1%, 3 total units) in 2015, and 0 patients in 2016 and 2017. Subgroup analysis of the pre-education subunit demonstrated 47 patients transfused (4.4%, 82 total transfusions) in TKA patients and 46 patients transfused (10.5%, 91 total transfusions) in THA patients. Pre-published cohort results were 2 patients (0.5%, 2 total units) and 5 patients (2.9%, 8 total units) for TKA and THA patients, respectively. In 2015, no TKA patients were transfused; however, 2 patients (0.5%, 3 total units) were transfused in the THA group (Table 6).

Using the pre-education transfusion rate for each time point and subtracting the amount of transfusions actually given, we calculated the number of transfusions prevented in each cohort. We found 55 (pre-published), 84 (2014), 134 (2015), 149 (2016), and 98 (2017) transfusions prevented for both TKA and THA patients over the course of our study. This accounted for a total of 519 transfusions prevented. Analysis of TKA patients alone indicated 28, 41, 63, 66, and 48 transfusions prevented, respectively. This accounted for 246 transfusions prevented. Analysis of THA patients alone demonstrated the prevention of 28, 41, 75, 90, and 47 transfusions, respectively, for a total of 281 transfusions prevented. Subgroup analysis used the pre-education rate of transfusion for TKA and THA rather than the combined rate (Table 7).

Discussion

In this era of value-based purchasing, there is increased emphasis on perioperative management and quality improvement. In our previously published work, we identified variability in postoperative blood transfusions at our institution and implemented an educational intervention, in October 2013, to standardize transfusion protocols [46]. There has been no organized educational intervention since that time at our institution. The data demonstrated a significant and sustained decrease in transfusion rate over the next 6 months; however, the effect over time remained unclear.

Table 4
Change in Hemoglobin.

Variable	Pre-Education	Pre-Published	2014	2015	2016	2017
Preoperative hemoglobin (average g/dL)						
TKA + THA	13.33	13.48	13.38	13.51	13.44	13.43
TKA	13.34	13.52	13.44	13.47	13.37	13.43
THA	13.31	13.40	13.24	13.61	13.57	13.41
Postoperative hemoglobin (average g/dL)						
TKA + THA	9.76	10.00	10.07	10.48	10.50	10.65
TKA	9.93	10.20	10.31	10.66	10.68	10.86
THA	9.38	9.56	9.52	10.14	10.19	10.14
Change in hemoglobin (average g/dL)						
TKA + THA	3.59	3.49	3.31	3.04	2.96	2.77
TKA	3.31	3.32	3.14	2.82	2.71	2.57
THA	3.96	3.83	3.72	3.46	3.45	3.27

Preoperative and postoperative hemoglobin and difference in hemoglobin are indicated in average g/dL.
TKA, total knee arthroplasty; THA, total hip arthroplasty.

Table 5
Transfusions.

Variable	Pre-Education	Pre-Published	2014	2015	2016	2017
Number of patients (n)						
TKA + THA	1707	616	802	1260	1369	891
TKA	1179	419	566	842	898	640
THA	528	197	236	418	469	251
Transfusions (total [average units transfused])						
TKA + THA	526 (2.08)	96 (2.59)	60 (1.71)	50 (1.79)	76 (1.95)	16 (1.60)
TKA	260 (1.94)	54 (3.60)	17 (1.42)	9 (1.80)	32 (2.00)	6 (2.00)
THA	266 (2.24)	42 (1.91)	43 (1.87)	41 (1.78)	44 (1.91)	10 (1.42)
Transfusion rate (number of patients [%])						
TKA + THA	253 (14.82)	37 (6.01)	35 (4.36)	28 (2.22)	39 (2.85)	10 (1.12)
TKA	134 (11.37)	15 (3.58)	12 (2.12)	5 (0.59)	16 (1.78)	3 (0.47)
THA	119 (22.54)	22 (11.17)	23 (9.75)	23 (5.50)	23 (4.90)	7 (2.79)

The total number of transfusions, average units transfused per patient, transfusion rate, and number of patients transfused among each time interval are indicated.
TKA, total knee arthroplasty; THA, total hip arthroplasty.

Using our MARCQI database, 6645 patients were identified as meeting the inclusion criteria. When compared to the pre-education cohort, each post-education group demonstrated a statistically significant decrease in postoperative blood transfusions, indicating the quality initiative and educational intervention that was maintained over a period of years. To monitor the progress over time and assess for continued improvement, the post-educational cohorts were compared to the previously published initial group (the 6 months immediately following educational intervention). We found a significant decrease in postoperative transfusions in each group with the exception of 2014. This suggests that we not only maintained lower transfusion rates but improved over the course of several years. There was a negative trend in each year until we achieved a final transfusion rate of 1.12%, lower than recently published figures of 3.9% and 2.4% for THA and TKA, respectively [20]. Evaluation of transfusions performed outside of criteria demonstrated drastic improvements since the educational event, from 6.1% in the pre-education cohort to 0% in both 2016 and 2017.

In light of the differences in the numbers of TKA and THA procedures over the course of our study, 4544 and 2099, respectively, we performed subgroup analysis for each procedure of the total arthroplasty dataset. There was a significant decrease in each TKA cohort when compared to the pre-education cohort. This indicates that not only did the educational intervention decrease transfusion rates, but the impact was sustainable. The other groups demonstrated strongly negative trends, suggesting improvement over time; however, the differences were not significant. Over the study period, THA patients also experienced a significant decrease in total transfusions and transfusion rate as subgroup analysis demonstrated significantly decreased rates of postoperative transfusion among each cohort. Furthermore, there was a linear decrease in transfusion rate over time, indicating improvement during this interval. The differences in 2014-2017 were not significant when compared to the pre-published data; however, there was a strong correlation. Through evaluation of patients outside of protocol (<8 g/dL), we found decreased transfusion rates, from 4.4% and 10.5% for TKA and THA in the pre-education cohort, respectively, which reached 0 transfusions outside of protocol over the final 2 years of the study. This demonstrates we were able to decrease transfusion rates over time in both TKA and THA independently and combined through an educational intervention.

The financial implications of the reduction in transfusion rates over the course of the study are staggering. Using pre-study rates of postoperative transfusions, we calculated the number of transfusions outside of protocol prevented over each time interval. We found a total of 519 transfusions saved across the entire cohort: 55 in the pre-published group, 84 in 2014, 134 in 2015, 149 in 2016, and 98 in 2017. This accounts for an estimated cost savings of $519-$935,000 using $1000 and $1800 as the lower and upper limits for the cost of a single transfusion. Evaluation of the total knee and total hip cohorts demonstrated prevention of 246 and 281 transfusions, respectively, for a total cost savings of $246,000-$443,000 and $281,000-$505,000. This displays the dramatic financial implications of adherence to protocol.

There were limitations to the study. During the study period, there was an increased and more standardized use of TXA. While this would impact the transfusion rate, it would not impact transfusions given outside of the criteria so we believe the quality initiative program was still impactful. Additionally, our appreciated cost savings represent calculated values rather than the actualized savings.

Table 6
Transfusions Outside of Protocol.

Variable	Pre-Education	Pre-Published	2014	2015	2016	2017
Patients outside of protocol						
TKA + THA	1513	567	736	1197	1299	856
TKA	1073	395	539	818	864	629
THA	440	172	197	379	435	227
Units transfused outside protocol (number [average units])						
TKA + THA	173 (1.9)	10 (1.43)	0 (0)	3 (1.5)	0 (0)	0 (0)
TKA	82 (1.7)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)
THA	91 (2.0)	8 (1.6)	0 (0)	3 (1.5)	0 (0)	0 (0)
Patients transfused outside protocol (number [%])						
TKA + THA	93 (6.1)	7 (1.2)	0 (0)	2 (0.1)	0 (0)	0 (0)
TKA	47 (4.4)	2 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)
THA	46 (10.5)	5 (2.9)	0 (0)	2 (0.5)	0 (0)	0 (0)

The number of patients transfused outside of AABB guidelines across each timepoint is indicated. The number of units transfused outside protocol, average units transfused per patient, number of patients transfused outside of protocol, and rate of patients transfused outside of protocol are depicted.
TKA, total knee arthroplasty; THA, total hip arthroplasty.

Table 7
Estimated Cost Savings.

Variable	Pre-Education	Pre-Published	2014	2015	2016	2017	Total
Transfusions prevented							
TKA + THA	n/a	55	84	134	149	98	519
TKA	n/a	28	41	63	66	48	246
THA	n/a	28	41	75	90	47	281
Estimated cost savings (USD in thousands)							
TKA + THA	n/a	55-99	84-152	134-241	149-267	98-176	519-935
TKA	n/a	28-51	41-74	63-113	66-119	48-87	246-443
THA	n/a	28-50	41-73	75-136	90-162	47-85	281-505

The calculated number of transfusions prevented during each time interval is indicated. Transfusions prevented are based upon transfusions outside of criteria from our pre-education cohort and the number of patients outside of protocol for each cohort. Additionally, estimated cost savings are depicted. Cost savings are based on cost of transfusion in USD (thousands) per transfusion with a range of 1000 to 1800 per transfusion.
TKA, total knee arthroplasty; THA, total hip arthroplasty; n/a, not applicable.

Conclusion

Use of a total joint registry (MARCQI) was an effective means of identifying areas for cost and quality improvement in healthcare as well as monitoring its effectiveness over time. In this study, we demonstrated that a quality improvement initiative aimed at decreasing transfusions, and keeping transfusions within the AABB guidelines was effective initially and was subsequently sustained over a long time course. The data support use of registry data as a means to drive quality and quality improvement.

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