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REPORTS OF ORIGINAL INVESTIGATIONS

The effectiveness of a multifaceted, group-facilitated audit and feedback intervention to increase tranexamic acid use during total joint arthroplasty

Efficacité d'un audit multidimensionnel et facilité par le groupe et d'une intervention de rétroaction pour augmenter l'utilisation de l'acide tranexamique pendant arthroplastie totale

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Abstract

Purpose *Intraoperative tranexamic acid (TXA) is used to reduce blood loss and the need for transfusions following total hip arthroplasty (THA) and total knee arthroplasty (TKA). Despite evidence in literature and local practice protocols supporting TXA as a part of standard of care for joint arthroplasty, TXA administration is underutilized. We aimed to use group-facilitated audit and feedback as the foundation of a knowledge translation strategy to increase TXA use for THA and TKA procedures.*

Methods *Anesthesiologists consented to receive two data reports summarizing their individual rates of TXA use and postoperative blood transfusions compared with site peers. Variables collected included patient demographics, TXA usage, and the frequency and volume of red blood cell transfusions administered in the 72-hr postoperative period. The facilitated feedback session discussed report findings and focused on factors contributing to local practice patterns and opportunities for change.*

Results *Tranexamic acid use increased for THA procedures at the intervention site from 66.6 to 74.4% (absolute change, 7.9%; 95% confidence interval [CI], 2.4 to 13.3). Likewise, TXA use for TKA procedures increased from 62.4 to 82.3% (absolute change, 19.9%; 95% CI 15.0 to 25.0).*

Conclusions *Physicians and their teams were able to review their practice data on TXA utilization, reflect on differences compared with evidence-based guidelines, discuss findings with peers, and identify opportunities for improvement. The intervention increased the use of TXA for both TKA and THA and shifted the dosage to better align with evidence-based practice guidelines.*

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Résumé

Objectif *L'acide tranexamique (ATX) peropératoire est utilisé pour réduire les pertes sanguines et les besoins transfusionnels après les arthroplasties totales de la hanche (ATH) et du genou (ATG). Malgré les données probantes et les protocoles de pratique locaux appuyant l'utilisation d'ATX dans le cadre de la norme de soins en cas d'arthroplastie, l'administration de cet agent est sous-utilisée. Notre objectif était d'utiliser l'audit et la rétroaction facilités par le groupe comme base d'une stratégie d'application des connaissances afin d'accroître l'utilisation de l'ATX lors des ATH et ATG.*

Méthode *Les anesthésiologistes ont consenti à recevoir deux rapports de données résumant leurs taux individuels d'utilisation d'ATX et de transfusions sanguines postopératoires par rapport à leurs pairs au sein du même établissement. Les variables recueillies comprenaient les données démographiques des patients, l'utilisation d'ATX et la fréquence et le volume des transfusions d'érythrocytes administrées au cours d'une période postopératoire de 72 heures. La séance de rétroaction facilitée a porté sur les conclusions du rapport et s'est concentrée sur les facteurs contribuant aux habitudes de pratique locales et aux possibilités de changement.*

Résultats *L'utilisation d'acide tranexamique a augmenté pour les procédures d'ATH au site d'intervention, passant de 66,6 % à 74,4 % (variation absolue, 7,9 %; intervalle de confiance [IC] à 95 %, 2,4 à 13,3). De même, l'utilisation d'ATX pour les procédures d'ATG est passée de 62,4 % à 82,3 % (variation absolue, 19,9 %; IC 95 %, 15,0 à 25,0).*

Conclusion *Les médecins et leurs équipes ont pu passer en revue leurs données de pratique sur l'utilisation d'ATX, réfléchir aux différences par rapport aux lignes directrices fondées sur des données probantes, discuter des résultats avec leurs pairs et identifier les possibilités d'amélioration. L'intervention a augmenté l'utilisation d'ATX pour l'ATG et l'ATH et a modifié la posologie pour mieux s'aligner sur les lignes directrices de pratique fondées sur des données probantes.*

Keywords arthroplasty · audit · blood transfusion · feedback · quality improvement

The number of joint replacement surgeries is increasing in Canada. In 2018–2019, there were 62,000 total hip arthroplasty (THA) and 75,000 total knee arthroplasty (TKA) procedures—an increase of approximately 20.1% and 22.5%, respectively, over the past five years.[1] During and following these procedures, there is risk of substantial blood loss and subsequent need for blood transfusion. Adverse outcomes due to blood transfusion include acute hemolytic reactions, acute lung injury, postoperative infection, potential disease transmission, and even mortality.[2,3] Negative patient outcomes such as increased length of stay are also associated with blood transfusion.[4] Thus, interventions that lower the need for blood transfusion may improve outcomes for patients undergoing THA and TKA, and preserve this precious resource.

Tranexamic acid (TXA) is a synthetic derivative of the amino acid lysine that competitively blocks the lysine-binding sites of plasminogen, which inhibits fibrinolysis by preventing plasmin from breaking down fibrin.[5] Clinical trials[6] and systematic reviews[7] support TXA use, although the ideal dose and route of administration remains unclear. Intravenous administration of TXA is not associated with increased risk of thromboembolic events.[8] The occurrence of serious adverse events such as seizure, myocardial infarction, venous thromboembolism, or stroke is not significantly higher in patients given TXA.[9] Despite its inclusion in perioperative blood loss reduction strategies, TXA has not become a standard of care in joint arthroplasty.[10]

Anesthesiologists in Calgary noticed variability in the use of intravenous TXA for total joint replacement (TJR) procedures, where approximately one in three arthroplasty patients were not given TXA. Anesthesiologists observed inconsistent TXA use and dosage, and had varied opinions about its ideal route and timing of administration. Guidelines on TXA use were developed by Alberta Health Services Patient Blood Management Program in consultation with the Alberta Bone and Joint Health Institute and Department of Anesthesiology in July 2012. These guidelines highlight the strong evidence for intravenous TXA use in TKA and THA and strong evidence for intra-articular use in TKA.[11] Tranexamic acid variation in TJR was identified as an area where better alignment of practice to evidence-informed guidelines could improve patient outcomes. Therefore, the Physician Learning Program was recruited to support knowledge translation through the design of a multidisciplinary group, facilitated audit and feedback intervention. Audit and feedback provide physicians with a summary of clinical performance data to facilitate knowledge into practice. The Calgary Audit Feedback Framework (CAFF), previously developed by Physician Learning Program team members (L. J. C., S. K. D.), was designed to optimize the effectiveness of audit and feedback by integrating group facilitation to foster socially constructed learning.[12]

In this study, we examined dosing and administration of intravenous TXA by Calgary anesthesiologists during THA and TKA procedures, both at the South Health Campus (SHC) site and at three control sites that did not receive any

intervention. We aimed to use group-facilitated audit and feedback as the foundation of a knowledge translation strategy to increase TXA use for THA and TKA, with the indirect aim of reducing the frequency of blood transfusions during these procedures.

Methods

Population

We included all patients undergoing a primary THA or TKA at the South Health Campus (SHC) (intervention site) and patients requiring the same procedure at three other adult hospitals (control sites) in Calgary, AB, Canada. Anesthesiologists cared for a median [interquartile range] of 27 [6–74] patients during the study period. We excluded emergent cases, bilateral or combination procedures, fracture/trauma cases, hemiarthroplasties and revision surgeries since most if not all practitioners would use TXA in these cases. The Conjoint Health Research Ethics Board at the University of Calgary granted ethics approval for this study (ID: REB15-1025). Reporting of this study followed the revised Standards for Quality Improvement Reporting Excellence (SQUIRE2.0) guidelines.

Intervention and study periods

Of the 26 eligible anesthesiologists at the SHC, 23 (88%) consented to receive two data reports summarizing their individual rates of TXA use and postoperative blood transfusions compared with site peers. Figure 1 provides a summary of the study timeline and key dates. The first data report included cases between 1 January 2014 and 30 June 2015 (baseline period) and was presented at a multidisciplinary group-facilitated feedback session (GFFS) hosted by our team on 14 October 2016 to anesthesiologists, nurses, and residents. The development of a GFFS begins with program staff working with a group of physicians to clarify the clinical question, addressing perceived practice gaps, and highlighting the clinical importance of the topic. A trained facilitator guides GFFS attendees through data reports using theories such as the R2C2 model (build relationship, explore reactions, explore content, coach for performance change). During the GFFS, physician data are discussed, incorporating contextual nuances and facilitators/barriers to practice change. By reflecting on shared practices and highlighting best evidence, participants transition to change and action plans. As an output of the first GFFS, we hosted a joint anesthesia-orthopedic surgery rounds on 27 January 2017 with key stakeholders from the Alberta Bone and Joint Health Institute and Alberta Health Services Patient Blood Management Program to review the protocol and build consensus for TXA use in THA and TKA.

A second GFFS, which included anesthesiologists, surgeons and nurses, followed on 28 May 2018. To assess the effects of this intervention, we presented anesthesiologists with a second individual practice data report comparing their clinical performance during the baseline period (1 January 2014 to 14 October 2016) to the subsequent two years (15 October 2016 to 31 October 2017; intervention period). Aggregate site peer data were also included for comparison.

Measures

The primary outcome was the use of TXA before and after the first GFFS. Use of TXA during TJR followed protocols established by the Department of Anesthesia, Alberta Bone and Joint Health Institute, and Alberta Health Services Patient Blood Management Program (Electronic Supplementary Material, eAppendix). Secondary

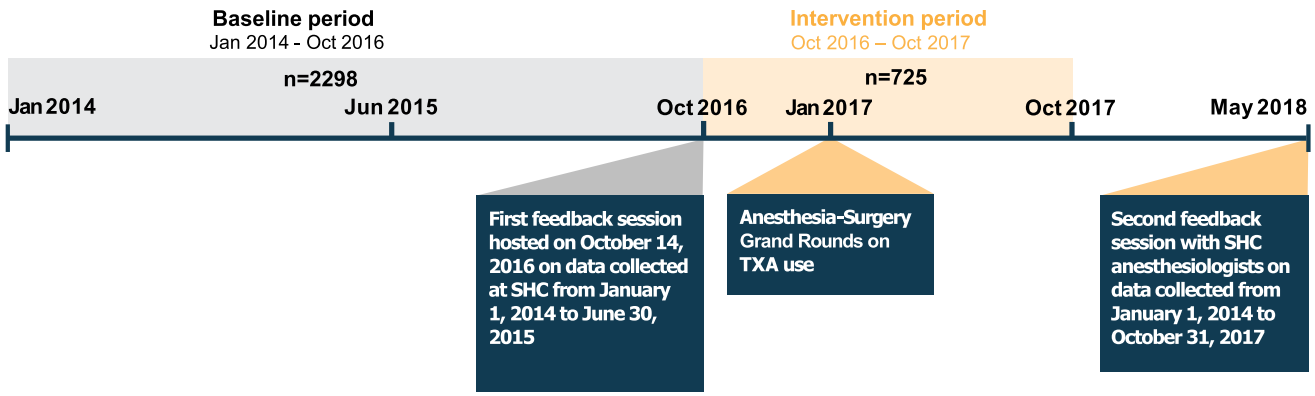

Fig. 1 Timeline of audit and feedback sessions, data collection periods for baseline and intervention periods for South Health Campus (SHC) anesthesiologist use of tranexamic acid (TXA).

measures included the dose of intravenous TXA administered, the frequency of red blood cell (RBC) transfusions, and the number of units transfused 72 hr post surgery. Balancing measures included the occurrence of myocardial infarction, pulmonary embolism, deep vein thrombosis, and cerebrovascular accident during the postoperative hospital stay. Biologically implausible body mass index values outside the normal ranges (men, 14.9–65.0 $kg \cdot m^{-2}$; women, 13.4–76.1 $kg \cdot m^{-2}$)[13] were excluded from the patient characteristics table.

Statistical analysis

We compared patient characteristics, outcomes, and balancing measures before and after the first GFFS on 14 October 2016, stratified by intervention and control sites. Two-sample independent proportion tests calculated differences and confidence intervals (CI) for outcomes and balancing measures.

Statistical process control charts described the monthly use of TXA. The baseline period before the intervention was used to calculate the centre line (mean). The control limits, $\pm$ 3 standard deviations (SDs) of the mean, were calculated using the formula for p-charts.[14]

P-chart and Laney p'-chart control limits were similar, suggesting a small likelihood for possible under- or over-dispersion in the data.[15] Points outside the control limits indicated special cause variation based on the Institute for Healthcare Improvement rules: 2 of 3 consecutive points above or below two SDs of the centre line, 8 points in a row above or below the centre line, 6 points in a row increasing or decreasing, or 15 points in a row within one SD of the centre line.[16]

We estimated the effect of the feedback session on the primary outcome using an interrupted time series (ITS) design with segmented regression models. We anticipated an immediate effect, so we did not have a lag period after the date of the intervention. Due to the relatively short intervention period, we did not have enough data to reliably estimate a slope. Therefore, we estimated a common slope in the baseline and intervention periods and a level change at the time of the GFFS intervention.

From the interrupted time series analysis, we reported crude estimates of the level change. We estimated *P* values and CIs using robust standard errors (Huber sandwich estimator). All analyses were conducted using R version 3.5.0 (The R Foundation, Vienna, Austria) and a two-sided *P* value of < 0.05 was considered statistically significant. *P* values and CIs comparing secondary outcomes and balancing measures did not adjust for multiple comparisons and should be interpreted as exploratory.

Results

A total of 12,454 patients were included in the analysis: 5,046 underwent primary THA and 7,408 underwent primary TKA. Table 1 summarizes patient characteristics at the intervention and control sites. Overall, there were no significant differences in patient characteristics, with the exception of the proportion of patients at the intervention site who underwent THA *vs* TKA, which was 40% *vs* 60% at baseline and 54% *vs* 46% in the intervention period ($P < 0.001$).

Table 2 summarizes the primary outcomes from the intervention. Baseline TXA use was similar among sites; however, TXA use increased for both THA and TKA procedures at the intervention site compared with baseline by 7.9% and 20.0%, respectively. An increase in TXA use was also observed in the control sites for TKAs only (6.3%). Dosing of intravenous TXA for TKA also changed at the intervention sites, where the proportion of patients receiving doses of 0.1–1.0 g decreased and the proportion of patients receiving doses of 1.1–2.0 g increased (recommended by guidelines), while the proportion of patients receiving doses > 2.0 g remained unchanged. A significant decrease in RBC transfusions within 72 hr post surgery was observed for TKA at both the intervention and control sites. Absolute reductions in RBC transfusions for TKA were observed at both the intervention and control sites. Additionally, the number and proportion of procedures using greater than or equal to two units of RBCs decreased for TKA and THA at both intervention and control sites. No changes in balancing measures were observed at the intervention and control sites.

Special cause variation in the process control charts shown in Fig. 2 indicated increased TXA use for both THA (Fig. 2A) and TKA (Fig. 2B) at the intervention site, with 8 consecutive points above the centre line for both procedures. At control sites, special cause variation was only observed for TKA procedures (Fig. 2D). Because of the relatively flat trend lines of TXA use at the control sites, we decided to not consider the control sites for the interrupted time series analysis and did not conduct a difference-in-difference analysis (slope for THA, control sites: 1.3% points per year, 95% CI 0.0 to 2.6; slope for TKA, control sites: 2.9% points per year, 95% CI 1.8 to 4.0). Interrupted time series analyses suggested an absolute decrease of -4.9% (95% CI -13.6 to 3.9) for THA and an absolute increase of 7.5% for TKA use (95% CI -0.9 to 15.9) at the intervention site; nevertheless, these findings were not statistically significant (Fig. 3).

Table 1 Patient characteristics at baseline and during the intervention period stratified by site

Characteristic	Intervention site			Control sites		
	Baseline period (N = 2298)	Intervention period (N = 725)	P value[a]	Baseline period (N = 6890)	Intervention period (N = 2541)	P value[a]
Surgery type, *n*/total *N* (%)						
Total hip arthroplasty	924/2,298 (40%)	391/725 (54%)		2,721/6,890 (39%)	1,010/2,541 (40%)	
Total knee arthroplasty	1,374/2,298 (60%)	334/725 (46%)	< 0.001	4,169/6,890 (61%)	1,531/2,541 (60%)	0.84
Age (yr), median [IQR]	66 [59–73]	66 [60–73]	-	66 [59–73]	66 [60–73]	-
Age missing, *n*/total *N* (%)	3/2,298 (0.1%)	0/725 (0%)	-	0/6,890 (0%)	0/2541 (0%)	-
Female, *n*/total *N* (%)	1,424/2,298 (62%)	457/725 (63%)	0.63	3,979/6,890 (58%)	1,441/2,541 (57%)	0.46
Sex missing, *n*/total *N* (%)	3/2,298 (0.1%)	0/725 (0%)	-	2/6,890 (0.02%)	0/2,541 (0%)	-
Body mass index ($kg \cdot m^{-2}$), *n*/total *N* (%)						
Underweight (< 18.5)	8/2,298 (0.4%)	6/725 (0.8%)	0.10	47/6,890 (0.7%)	11/2,541 (0.4%)	0.25
Normal weight (18.5–24.9)	354/2,298 (16%)	109/725 (15%)	0.81	1,029/6,890 (15%)	386/2,541 (15%)	0.75
Overweight (25.0–29.9)	692/2,298 (31%)	208/725 (29%)	0.47	2,194/6,890 (32%)	809/2,541 (32%)	0.99
Obese class I (30.0–34.9)	601/2,298 (27%)	204/725 (28%)	0.29	1,824/6,890 (26%)	715/2,541 (28%)	0.10
Obese class II (35.0–39.9)	358/2,298 (16%)	110/725 (15%)	0.79	882/6,890 (13%)	351/2,541 (14%)	0.19
Obese class III (≥ 40.0)	247/2,298 (11%)	82/725 (11%)	0.67	662/6,890 (10%)	210/2,541 (8%)	0.05
Missing[b]	38/2,298 (2%)	6/725 (0.8%)	-	252/6,890 (4%)	59/2,541 (2%)	-

IQR = interquartile range

[a] Chi square test

[b] Body mass index values outside biologically plausible ranges (men, 14.9–65.0; women, 13.4–76.1) were assigned to missing.[13]

Discussion

In this study, we examined the effects of a multifaceted knowledge translation and quality improvement intervention (CAFF model) aimed at changing anesthesiologist's practice behaviour on administration and dosing of intravenous TXA during THA and TKA procedures. Physicians and their teams were able to review their practice data, reflect on differences compared with evidence-based guidelines, discuss findings with peers, and identify opportunities for improvement. We found that the intervention increased the use of TXA for both TKA and THA, and shifted the dosage to better align with evidence-based practice guidelines. We observed no changes in balancing measures, suggesting that the intervention did not adversely affect patient safety or care. It appears that local physician champions and the use of the CAFF intervention resulted in significant physician practice behaviour change. It remains to be observed whether there will be spread of practice change from the intervention site to control sites as awareness of the project outcomes are discussed among colleagues.

We observed significant reductions in RBC transfusions (% of patients receiving blood, and % of patients receiving two or more units) at both intervention and control sites, indicating that the learning intervention may not have caused this change. During the study period, concurrent interventions aimed at reducing RBC transfusions in TKA and THA had been underway and could not be controlled for. These include the activities of the Alberta Bone and Joint Health Institute and the Alberta Health Services Patient Blood Management Program aimed at blood use,[17] and the Choosing Wisely Canada campaign, Why Give Two When One Will Do.[18] We were unable to separate the effects of those activities and our intervention on RBC transfusions. Lastly, the decision to give blood transfusions postoperatively may not be directly under the control of the anesthesiologist, and often occurs in collaboration with or at the discretion of the surgeon performing the arthroplasty in the postoperative period. Nevertheless, our educational workshops were aligned with other activities promoting evidence-based use of transfusions and may serve to reinforce knowledge in physicians.

Numerous studies have shown an association between TXA use and concomitant decreases in blood transfusion. In one study, a 28-member hospital initiative recommended intraoperative TXA to decrease unnecessary transfusion. For both THA and TKA, decreases were observed during the one-year intervention period and the subsequent year.[19] Each hospital had their transfusion risk compared with other hospitals during quarterly meetings. A standardized protocol to administer TXA in patients undergoing THA

Table 2 Outcomes and balancing measures at hospital sites in the baseline and intervention periods

Variable	Intervention site				Control sites			
	Baseline period ($N = 2298$)	Intervention period ($N = 725$)	Absolute difference, % (95% CI)	P value[a]	Baseline period ($N = 6890$)	Intervention period ($N = 2541$)	Absolute difference, % (95% CI)	P value[a]
Primary outcome								
Intravenous TXA used, *n* (%)								
For hip arthroplasties	615 (67%)	291 (74%)	7 (2.4 to 13.3)	0.005	1,922 (71%)	736 (73%)	2 (-1.1 to 5.5)	0.19
For knee arthroplasties	857 (62%)	275 (82%)	20 (14.4 to 25.5)	$P < 0.001$	2706 (65%)	1090 (71%)	6 (3.6 to 9.0)	$P < 0.001$
Dose of intravenous TXA (g)[b], *n* (%)								
For hip arthroplasties								
0.1–1.0	261 (42%)	139 (48%)	6 (-1.6 to 12.3)	0.13	1,677 (87%)	655 (89%)	2 (-1.1 to 4.5)	0.23
1.1–2.0	332 (54%)	145 (50%)	-4 (-11.1 to 2.8)	0.24	239 (12%)	79 (11%)	-1 (-4.4 to 1.1)	0.23
> 2.0	22 (4%)	7 (2%)	-2 (-3.6 to 1.3)	0.35	6 (0.3%)	2 (0.3%)	0 (-0.4 to 0.5)	0.87
For knee arthroplasties								
0.1–1.0	406 (47%)	89 (32%)	-15 (-21.7 to -8.3)	$P < 0.001$	2201 (81%)	900 (83%)	2 (-1.4 to 4.0)	0.38
1.1–2.0	418 (49%)	174 (63%)	14 (7.7 to 21.2)	$P < 0.001$	499 (18%)	187 (17%)	-1 (-3.1 to 1.4)	0.36
> 2.0	33 (4%)	12 (4%)	0 (-2.1 to 3.2)	0.71	6 (0.2%)	3 (0.3%)	0.1 (-0.3 to 0.4)	0.76
Secondary outcomes								
RBC transfusion received within 72 hr after surgery, *n* (%)								
For hip arthroplasties	48 (5%)	13 (3%)	-2 (-4.4 to 0.6)	0.14	116 (4%)	19 (2%)	-2 (-3.7 to -1.0)	$P < 0.001$
For knee arthroplasties	34 (2%)	2 (0.6%)	-2 (-3.6 to -0.2)	0.03	100 (2%)	18 (1%)	-1 (-2.1 to -0.4)	0.004
≥ 2 units of RBC transfusion received within 72 hr after surgery, *n* (%)								
For hip arthroplasties	35 (4%)	4 (1%)	-3 (-4.8 to -0.8)	0.007	89 (3%)	9 (1%)	-2 (-3.6 to -1.2)	$P < 0.001$
For knee arthroplasties	22 (2%)	0 (0%)	-2 (-2.9 to -0.3)	0.02	63 (2%)	8 (1%)	-1 (-1.6 to -0.3)	0.003
Balancing measures								
Any adverse event after surgery, *n* (%)	20 (1%)	2 (0.3%)	-0.6 (-1.3 to 0.1)	0.10	51 (0.7%)	22 (0.9%)	0.2 (-0.3 to 0.5)	0.54
Myocardial infarction, *n* (%)	2 (0.1%)	0 (0%)	-0.1 (-0.3 to 0.1)	0.42	11 (0.2%)	4 (0.2%)	0 (-0.2 to 0.2)	0.98
Pulmonary embolism, *n* (%)	15 (0.7%)	2 (0.3%)	-0.4 (-1.0 to 0.2)	0.24	31 (0.4%)	15 (0.6%)	0.2 (-0.2 to 0.5)	0.38
Deep vein thrombosis, *n* (%)	4 (0.2%)	0 (0%)	-0.2 (-0.5 to 0.1)	0.26	8 (0.1%)	2 (0.1%)	0 (-0.2 to 0.1)	0.62
Cerebrovascular accident, *n* (%)	0 (0%)	0 (0%)	0.0 (0.0 to 0.0)	0	3 (0.04%)	2 (0.1%)	0 (-0.1 to 0.1)	0.51

CI = confidence interval; RBC = red blood cell; TXA = tranexamic acid

[a] Student's *t* test

[b] When intravenous TXA was used; note that most doses were 1 or 2 g, and all doses at the control sites were rounded to an integer number of grams.

and TKA procedures also produced similar findings.[20] The authors observed an increase in TXA use from 4% pre implementation to 86% post implementation. Despite the large increase in TXA use, program cost saving was observed for THA only; for TKA, the cost savings were negligible.

An Ontario patient blood management program estimated that the cost per transfusion episode (including the cost of RBC unit, increased length of stay, adverse events due to transfusion) is approximately CAD 1,400.[21] Therefore, reductions in blood transfusion arising from TXA utilization can have substantial financial effects. While saving costs for healthcare systems and programs is crucial for the long-term sustainability of care, improving patient care should take precedence. Despite these prior examples, the optimal strategy to increase TXA usage in THA and TKA is unclear.

There are some limitations, which might have affected the outcomes on increasing TXA use. First, the SHC hospital was less than five years old at the start of the study. Recruitment of anesthesiologists from other areas both locally and from many parts of Canada likely contributed to practice variation in TXA use. Many anesthesiologists did not practice exclusively at one site during the study period. The majority (57%) of anesthesiologists performed at least one TJR procedure at the SHC site and one or more TJR procedures at a different site. The proportion of THA and TKA procedures at the intervention site shifted from the baseline to intervention period, while the proportion of THA and TKA at the control sites was stable over the study period. There was also a general increase in the use of TXA in clinical practice over this time. These factors could explain some of the increases in TXA use observed in the intervention sites compared with control sites. Second,

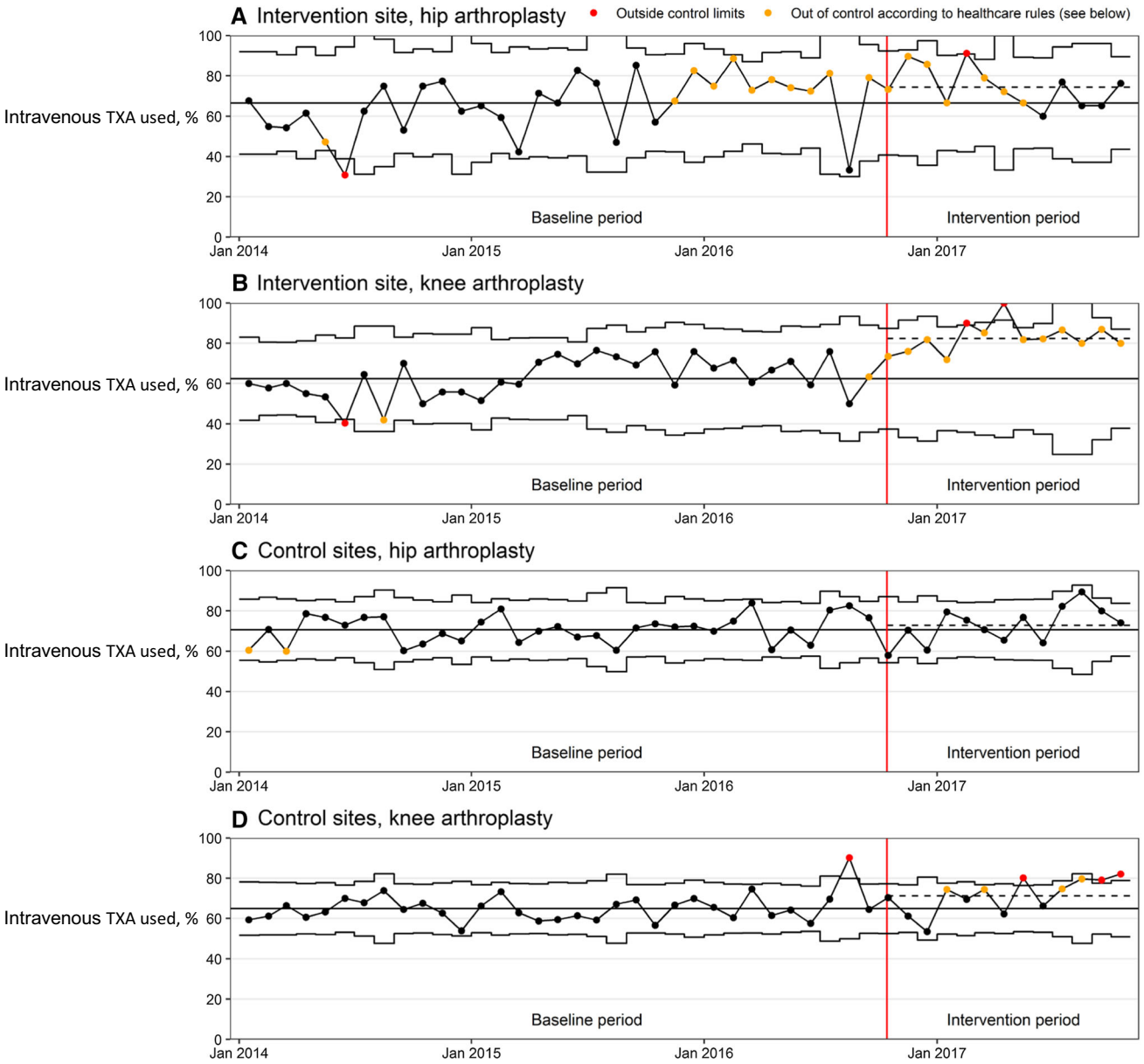

Fig. 2 Statistical process control charts for monthly use of tranexamic acid (TXA) during the baseline and intervention periods. Solid centre line is the mean percentage in the baseline period and the upper/lower lines are control limits, calculated using the formula for p-charts (± 3 standard deviations [SDs]). Dashed line is the mean percentage in the intervention period. Vertical red line is the first feedback session (14 October 2016). The orange out of control points are highlighted according to the healthcare rules: 2 of 3 consecutive points above or below two SDs of the centre line, 8 points in a row above or below the centre line, 6 points in a row increasing or decreasing, or 15 points in a row within one SD of the centre line. Hip arthroplasty at the intervention (A) and control (C) sites, and knee arthroplasty at the intervention (B) and control (D) sites.

some perioperative measures were not collected at control sites or were inconsistently collected in some cases. The type of anesthesia used during TJR is a strong predictor of transfusion. In a five-year surgical quality improvement program, it was observed that patients who undergo TJR with general anesthesia are more likely to have a transfusion (odds ratio [OR], 1.53; 95% CI 1.46 to 1.60) than patients who undergo spinal anesthesia are.[22] A strong predictor for blood transfusion during TJR is preoperative hemoglobin levels. For close to 65% of patients, this information was missing, which restrained analyses and comparisons with specific transfusion triggers established by best-evidence guidelines. In a retrospective analysis, an increase in hemoglobin levels by 1 $mg{\cdot}dL^{-1}$ can decrease risk of transfusion by 40% (OR, 0.62; 95% CI 0.53 to 0.76).[23] Nevertheless, additional patient factors such as

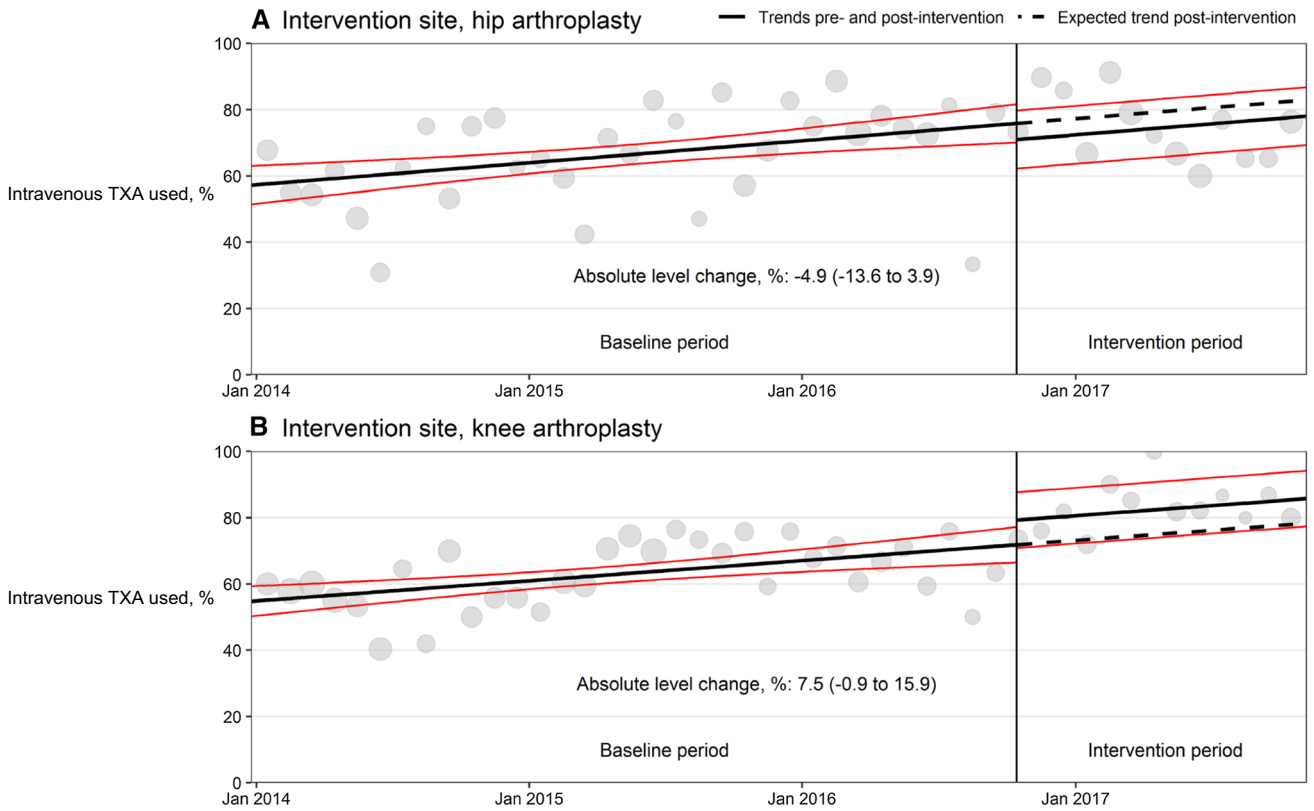

Fig. 3 Interrupted time series analysis for the effect of group-facilitated feedback session (GFFS) intervention on tranexamic acid (TXA) use. Trends for utilization of TXA at the intervention site for hip arthroplasty (A) and knee arthroplasty (B). Red lines represent 95% CI of the trend in the baseline and intervention periods. Dashed line in the intervention period is the trend observed in the baseline period and is the expected trend if no intervention occurred. Spheres represent monthly measures of TXA use.

symptom presentation in the postoperative period might influence the decision to provide a blood transfusion, independent of hemoglobin levels. We did not stratify patients according to present comorbidities or disease history. There is a lack of strong evidence to support TXA use in patients who might be at higher risk for a thromboembolic event such as a recent history of myocardial infarction, stroke, or stent placement.[24] In higher risk patients, topical use of TXA might be preferred and this decision might have contributed to an overall increase in TXA use. It is possible that decisions on TXA use considered these factors as a greater concern in some patients, which led to lower than anticipated intravenous TXA use during the intervention. Variation in TXA use in THA procedures was primarily attributed to patient factors and minor influence of the practitioner (anesthesiologist or surgeon) on the likelihood of receiving TXA.[25] While ITS analysis is useful to account for secular trends, there must be a sufficient number of data points observed in the pre- and post-intervention periods to estimate the slope and regression coefficients.[26] The small effect size observed in this study for TXA use in THA at the intervention site could have been affected by a shorter intervention period. Additional follow-up time would provide more data points for the ITS analysis to ascertain if TXA use changed. Moreover, ITS analysis cannot make inferences about individual-level outcomes, such as a patient's likelihood of receiving TXA, since within-person measurements (measures in the same individual) are required.[26]

Several strengths highlight the effectiveness of our intervention. The CAFF model used at the two feedback sessions emphasized collaborative, team-based social learning to understand and contextualize the data, reflect, discuss, and plan for change. Support for the use of audit and feedback is clear.[27] Studies should now discern how to make audit and feedback more effective, such as the inclusion of local physician champions for the intervention, socialization of learning, and impact of facilitation used within the CAFF model, rather than simply asking if audit and feedback is suitable for quality improvement interventions. Adverse events and rates of transfusion within 72 hr were captured and despite recent changes in practice patterns to same-day or accelerated discharge,[28] this should not limit the generalizability of this study's findings to other facilities or jurisdictions. Meta-analyses have shown that TXA interventions can reduce transfusion

rates,[7] yet the sustainability of these effects can be variable. Harnessing the power of multidisciplinary teams to lead change has been effective in other modalities of medical education such as surgical rounds[29] and could lead to more long-term practice improvement.

Conclusion

Audit and group feedback can be used to address practice variation such as TXA use in arthroplasty procedures. Important aspects of audit and group feedback that may support practice change include facilitation in a multidisciplinary environment and opportunities to reflect on data and discuss barriers and facilitators to change. Future studies can look further into the optimization of TXA administration to improve surgical outcomes for patients undergoing TKA and THA procedures and implementing audit and feedback methods to physician practice improvement in additional aspects in anesthesia care.

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