Acute Kidney Injury and Lower Extremity Orthopedic Surgery: A Targeted Education on AKI Risk Factors

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Abstract

BACKGROUND: Total knee and total hip replacement surgery is highly effective for relieving pain and improving functionality. Though effective, the surgery is not without risk. Acute kidney injury (AKI) can develop following joint replacement surgery and has been shown to increase morbidity, mortality, hospital costs, and length of stay. There are several risk factors associated with the development of AKI – some of which are modifiable.

METHODS: This quality improvement project implements an educational module with the goal of educating staff on the risk factors for developing AKI and evidence-based recommendations surrounding perioperative management for total joint arthroplasty (TJA). Using Johns Hopkins Nursing Evidence-Based Practice Model, a three-step process called PET: practice question, evidence, and translation will be used to implement a pre-test, educational video, and post-test.

INTERVENTION: Anesthesia providers will be given a pre-test to assess their current knowledge of factors affecting the development of AKI. Immediately following this test, the educational video will be viewed. After watching, a post-test will be administered to the providers to assess if there is an increase in knowledge.

RESULTS: 53 anesthesia providers took this module. The mean pre-test score before the education video was 6.64 points out of the maximum score of 10 points. The mean post-test score after watching the education video was 9.08 points out of 10 points. After conducting a paired two sample t-test the resulting p-value was < 0.00, therefore statistically significant.

CONCLUSIONS: The educational video increased knowledge of risk factors for the development of AKI and evidence-based recommendations.

Keywords: AKI, TJA, quality improvement

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Introduction

Problem

A recent increase of acute kidney injury (AKI) in patients receiving either a total knee arthroplasty (TKA) or total hip arthroplasty (THA) was a major concern of both anesthesia and orthopedic providers at an academic teaching hospital on the east coast. The orthopedic surgery service and anesthesia providers were interested in decreasing the rates of postoperative AKI in their patients, as well as mitigating risk factors that may be contributing to the development of AKI. It is important to decrease the incidence of AKI in the clinical setting due to increased length of stay for patients, which increases financial cost and decreases the number of beds available in the hospital (Medlock et al., 2017). An anesthesia provider knowledge deficit, regarding best practices around avoiding AKI with TKA and THA, was noted by Anesthesia departmental leadership. Furthermore, the lack of standardization of anesthesia care practices was identified as a potential contributing factor in a recent increase in case reports of AKI in TKA and THA in this clinical site department. Variation in anesthesia management practices amongst providers was routinely observed in the care of total joint arthroplasty (TJA) patients. As students, it was observed that many providers were using different methods to medically manage the patient in regard to fluid administration, mean arterial pressure management, and choice of anesthetic. Additionally, dual-antibiotic therapy is ordered by some of the orthopedic surgical staff, and other possibly nephrotoxic medications were being given in an unstandardized manner according to provider preference. All of these factors could play a role in the development of AKI, yet providers did not appear to be educated on best practice recommendations.

Potential barriers to change include the orthopedic surgeon's desire to maintain low mean arterial pressure (MAP) throughout the surgery in order to minimize blood in the field; therefore, making potential kidney-protective strategies such as proper renal perfusion through fluid administration and adequate MAP maintenance difficult. Additional stakeholders include perioperative nursing and ancillary staff, the entire anesthesia workforce, the orthopedic surgical team and service, and postoperative care providers.

Several organizations have proposed classification systems to define and stage acute kidney injury. The two main organizations include the Acute Kidney Injury Network which uses the RIFLE (Risk, Injury, and Failure) classification and the Kidney Disease~~:~~ Improving Global Outcomes (KDIGO) organization which uses a very similar measurement statistic. We chose to define AKI in our population with the RIFLE tool, which stages severity of kidney injury based on serum creatinine (SCr) and urine output (UO), as well as defining two outcome classes of loss of renal function and end stage renal disease (ESRD) (Lopes, 2013).

Available Knowledge

Total joint arthroplasty (TJA), which includes both hip and knee replacements, is a common procedure which is expected to increase in demand due to both an aging population and an increase in overall body mass index in the current population. Age and an increase in body mass index are both risk factors for joint deterioration and need for lower extremity arthroplasty (Kimmel et al., 2014). While the incidence of AKI is low in TJA, poor patient outcomes and hospital costs rise significantly when AKI occurs. The development of AKI is associated with an increase of up to four times the mortality in hospitalized patients (Wang et al., 2012). The current national average of incidence of AKI in total joint replacement is estimated to be around 3.3% (Lands et al., 2018). However, a large review completed by Filippone et al estimates that the average may be as high as 10% if proper, validated tools are used to identify AKI that can often be missed by traditional care (Filippone et al., 2019).

One retrospective analysis found statistically significant increases in length of stay (Abar et al., 2018). The study noted an increase in nearly 4 days of required stay in the hospital, a total of 8 days compared to the control group's approximate length of stay averaging 4.5 days. There was also a very large increase in financial burden of slightly more than $80,000 on average when comparing costs of similar patients who developed AKI versus those who did not.

There are many risk factors for developing AKI—some modifiable and others not. Risk factors identified for AKI post TJA were high body mass index, low baseline hemoglobin and existence of a comorbid condition (Geller et al., 2017). Additional risk factors such as male gender, hypertension, diabetes mellitus, cardiovascular disease, liver disease, pulmonary disease, and pre-exiting chronic kidney diseases have also been identified to increase a patient's risk of developing AKI pre-procedure (Flippone et al., 2019). Pre-operative anemia is a modifiable risk factor that should be assessed before surgery as it is associated with post-operative AKI in many different surgical settings (Flippone, 2019). The goal should be to optimize the patient pre-operatively since this is an elective surgery. As an example, one way to optimize an anemic patient pre-operatively is by administering a pre-operative red blood cell transfusion to increase hemoglobin. This compares to administering the transfusion perioperatively, which has been associated with AKI (Flippone, 2019).

Additionally, studies have found that the type of anesthesia a patient receives can affect the incidence of AKI. Kim et al (2019) conducted a large retrospective review of patients who received TKA and found that patients who received general anesthesia as opposed to spinal anesthesia had significantly higher rates of AKI. Specific drugs have also been linked to AKI diagnosis post TJA surgery. It is recommended by Flippone to stop all renin-angiotensin-aldosterone system inhibitors 1 week pre-operatively and to avoid nonselective and cyclooxygenase-2 selective nonsteroidal anti-inflammatory drugs due to numerous studies showing them as a risk factor that contributes to AKI (Flippone, 2019). Perioperative use of Angiotensin Converting Enzyme Inhibitors has also been associated with increased risk of AKI (Jiang et al, 2017). The addition of a second antibiotic was consistently associated with increased incidence of AKI. Specifically, Jiang (2017), Zhu and Cai (2015), Courtney et. al. (2015) found that vancomycin use was associated with increased incidence of AKI post knee and hip arthroplasty, while Bailey et al. (2014) found that flucloxacillin and gentamicin also showed an increased risk.

Evidence based care protocols, including enhanced recovery after surgery (ERAS), are used to shorten hospital stay, reduce costs to the hospitals, and optimize patient care outcomes. The ERAS protocols recommend limiting intravenous fluid administration and suggest the use of vasoactive medications to increase mean arterial perfusion pressure intraoperatively. At least one ERAS protocol used in orthopedic lower limb arthroplasty recommends the discontinuation of intravenous fluids by midday one day after surgery. This restrictive ERAS protocol included 138 patients who underwent a total joint replacement surgery. In this Restrictive ERAS group at least 9.4% patients suffered AKI, which is above the average rate of 3.3%, therefore prolonging the hospital stay by 2-4.9 days longer and increasing financial cost and decreasing bed availability in the hospital (Medlock et al., 2017). These unexpected adverse patient outcomes are counterproductive to what ERAS protocols are trying to achieve. Instead of using ERAS protocols, using a comprehensive electronic protocol may help decrease AKI rates by identifying pre-operative high-risk patients, controlling medical optimization intraoperatively, and closely monitoring post-operative management (Lands et al., 2018). Lands et al. (2018) found that those who underwent THA and/or TKA at their institution experienced higher hypotension and AKI incidence when compared to the national average. After implementing an electronic protocol, including use of 1g of IV tranexamic acid to decrease blood loss and help with mean arterial pressure (MAP) and close focus on intraoperative and postoperative MAP and fluid balance control, the institution had significantly lower rates of post-operative TJA AKI.

Rationale

While completing the literature search on AKI after TJA, it was found that there are not many randomized control trials to reduce AKI rates in this surgical population. Instead, many practice modification recommendations have been made that are centered around existing data. Using the Johns Hopkins Nursing Evidence-Based Practice Model (2017), we used the three-step process called PET: practice question, evidence, and translation. From this we found data on the best practices of AKI with TJA and how to incorporate them into patient care. By providing this knowledge in a pre- and post- test module of learning, the anesthesia providers receiving the educational module will gain better knowledge of the topic. A study performed by Shivaraju et al. (2017) concluded that an educational intervention showed improvement with post-test scores when compared to pre-test scores. About 98.72% of students in this study acknowledged that the pre-tests helped increase focus for didactic material and improved their performance (Shivaraju et al., 2017). Therefore, we will be applying this same educational intervention to the anesthesia provider learners.

Specific Aims

Our primary objective is educating the staff on the many risk factors and impacts of anesthetic management on the development of AKI following THA or TKA. Our goal is for the educational module to translate into a higher level of staff knowledge regarding identification of risk factors for AKI, as well as how to create optimal surgical conditions for patients undergoing THA or TKA. The goal of this project is to improve anesthesia providers knowledge of the risk factors and interventions to decrease AKI in the TJA patient population.

Methods

Context

We plan to develop, implement, and evaluate an educational module to increase anesthesia staff member knowledge of the risk factors and implications of anesthetic interventions on the development of acute kidney injury (AKI) following orthopedic surgery. Primary stakeholders of anesthesia providers and orthopedic surgeons will be introduced to our evidence-based intervention found through an extensive literature search.

Interventions

The team developed a quality improvement project aimed at educating anesthesia staff members on the implications of risk factors and interventions performed during total knee and total hip surgery on the development of AKI. The module is based off of current evidence for best practice. Main topics of education will include risk factors for the development of AKI, interventions known to contribute to AKI, interventions known to protect against the development of AKI, defining postoperative AKI, and the impact of intraoperative hypotension on kidney function.

An email was sent to the anesthesia providers which included the pre-education test to assess their knowledge of factors affecting the development of acute kidney injury and video link to watch immediately following the pre-education test. A link to the post-education test was also provided in the email for staff to take right after watching the educational video. The post-education test will contain the same questions as the pre-education test in order to directly examine if the educational module increased proficiency regarding the topic.

Procedures

The QI project was implemented from August 10, 2020 to September 4, 2020. Pre-test, post-tests, and the educational modules were distributed to staff through QR codes on flyers and multiple email send outs. An email with instructions and links for the module were sent out 3 times to increase educational module results. Pre-tests and post-tests were collected via *Google Forms* and the education module created on *Vimeo* was posted to *YouTube* for easy access for providers. About 2 weeks into implementation, the project leads were allowed back into the hospital. To increase results, the leads administered paper copies of the pre-test, educational video, and post-test, 11 additional results were obtained. Once data collection was complete, and paper copies of the pre-tests and post-tests were input into the *Google Forms* and results were downloaded into an excel file. Due to the personal nature of the participant identifiers, they were replaced with a unique number to link their pre-test and post-test scores anonymously. Then, pre-test and post-tests scores for each participant were compared.

Measures

Provider Knowledge Survey

A survey of 10 questions will measure the providers knowledge pre-educational module and post-education. The questions were formulated from an evidence-based literature search of AKI risk factors with total joint arthroplasty. Practice modifications from existing data were used to create the 10 multiple choice questions for the pre-test and post-test. Each correct answer is worth one-point, wrong answers will be zero points, and the tester receives a score out of ten. See Appendix A for pre-test and post-test questions. The lower the number of points, the less knowledge the provider has on the subject knowledge of AKI post TJA cases. The higher the points the more knowledge the provider has on the subject knowledge. Providers were asked to identify their role in the Anesthesia Team, Anesthesiologist or Certified Registered Nurse Anesthetist (CRNA). They were also asked to submit their email address to their pre-test and post-test as identifiers of each survey submission. The email addresses were used to compare the provider's pre-test and post-test scores.

Data Analysis

Differences on provider knowledge in the pre- and post-test scores will be analyzed using a paired two sample *t* test. It was assumed the samples are representative of the general anesthesia population, and tests were taken individually and following the prompts. All assumptions were met. It was decided by the team that a clinically significant increase in knowledge improvement would be a 15% increase in post-test scores from the pre-test baseline. This was due 15% being a rough estimate of the magnitude of difference between major letter grades in the American grading system. The alpha level used to define a statistically significant finding was 0.05, which represents a 95% confidence interval. Other variables of interest were mean, standard deviation, minimum, and maximum, these are defined in Appendix B. The software that was used to compute the variables and *t*- test was *Microsoft Excel* and *Minitab*.

Ethical considerations

Without an intervention directly involving patients at the hospital, ethical considerations are more limited to considerations of privacy of personal data and the considerations of maintaining the standards of the Health Insurance Portability and Accountability Act. Additional considerations could include maintaining confidentiality of the health care providers to be educated. The team applied for exempt category 3 for IRB submission through the University of Pennsylvania, which was approved as exempt status from the hospital's institutional review board. The study qualified as a quality improvement project. No additional ethics consultation was necessary as the perceived risk of ethical compromise was considered to be low. Consideration of potential conflicts of interest also were limited due to no interested parties participating in a research trial or intervention study. Possible difficulty with conflict between release of acute kidney injury statistics could be weighed against the benefit of knowing how the hospital system is performing on metrics which are valuable data points for providing improved patient care.

Results

There were 53 responses to the pre-test and post-test, one response was dropped from the evaluation due to a response to only the pre-test and no post-test. Of the 53 responses, 26 were CRNAs, 9 were Anesthesiologists, and 18 respondents did not fill out their role. The mean pre-test score before watching the education module was 6.64 points out of the maximum score of 10 points. The standard deviation of the pre-test was 1.51. The mean post-test score after watching the education module was 9.08 points out of a maximum score of 10 points. The standard deviation of the post-test score was 1.00 (Table 1). As mentioned in Data Analysis above, it was hypothesized that a clinically significant increase in knowledge improvement would be a 15% increase in post-test scores from the pre-test baseline. In order to normalize that difference of 15% we multiplied it by the mean of the pre-test sample. This resulted in the hypothesized difference for the *t*-test 0.996 (Table 2). In other words, if the resulting 95% confidence interval for the true difference of the means of the population isn't greater than 0.996 then the difference would not have been significant. After conducting a paired two sample *t*-test of the means of the two groups, the resulting *p*-value was 0.00 (Table 2). This *p*-value of less than <0.05 shows that the difference in the means was statistically significant.

Discussion

Summary

This quality improvement project was initiated after a perceived increase in AKI rates at an academic medical center in Philadelphia, Pennsylvania. A literature search was performed to understand current research into risk factors for the development of AKI in lower extremity arthroplasty surgeries. Several consistent themes were identified in the research and an educational module aimed at anesthesia providers was created to increase the knowledge of AKI and TJA. Utilizing the Johns Hopkins Nursing Evidence-Based Practice Model three-step process called PET: practice question, evidence, and translation, an educational module was created. The education portion utilized a pre-test and post-test educational survey of provider knowledge of the risk factors for AKI. An educational module was created utilizing animation software with a scripted educational component based on a literature review. Upon analysis by a paired two sample *t*-test, the group of anesthesia providers showed an increased score in the measurement of their understanding of the risk factors and variables involved in AKI.

Interpretations

After providing the educational video to anesthesia providers on how to mitigate risks of AKI as a post-operative complication after THA and TKA surgery a gain of knowledge was observed. From this new and reinforced knowledge, providers can utilize this information into practice to help decrease the hospital’s AKI rates, therefore improving patient outcomes. This may lead to shorter hospital stays and potentially decrease any loss of profits the hospital may accrue from this complication. Outcomes observed were what we anticipated. Over 50 providers responded to the educational module and there was a statistically significant increase between the pre-test and post-test scores due to the educational module.

Limitations

Our quality improvement project had a few limitations. Our implementation phase was delayed and altered due to the COVID-19 pandemic. Our project was initially planned to be delivered during an in-person meeting with the anesthesia staff; however, weekly meetings were suspended due to the pandemic. Instead, we transitioned our project to be distributed via email with links to our pre- and post-tests and the educational module. The main setback of conducting our project virtually was that we did not have the ability to educate the staff directly. Instead, we had to rely on the staff members checking their email, watching the module, and completing both tests. One respondent only completed the pre-test, rendering their response useless to our project. Despite this limitation, we received an adequate amount of responses. Another limitation to our project was a lack of definitive research regarding AKI in our patient population. Even the best studies we included acknowledge that there is a lack of appropriate data regarding the multifactorial nature of the development of AKI, making it difficult to determine the best way to attenuate this complication.

Conclusion

In summary, this quality improvement project demonstrated the ability to educate anesthesia staff members on the risk factors for the development of AKI and the evidence-based recommendations to decrease the occurrence of this complication. Our educational module was successful in educating staff based on the significant increase in post-test scores compared to pre-test scores. The development of acute kidney injury in the perioperative setting increases morbidity and mortality, hospital costs, and length of stay. The best protocol regarding hemodynamics, fluid balance, and medication administration regarding the prevention of acute kidney injury in orthopedic surgery patients remains to be identified. More adequately designed, well powered research trials on the prevention of AKI are necessary.

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Table 1

Test Results and Descriptive Statistics

Average Score	6.64	9.08
Standard Deviation	1.51	1.00
Median	7.00	9.00

Table 2

Hypothesis Testing

	Pre-Test (n=53)	***Post-Test (n=53)***
Mean	6.64	9.08
Standard Deviation	1.51	1.00
Pearson Correlation	0.03	
Hypothesized Mean Difference	0.996	
t Stat	-14.02	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.67	

Appendix A

Pre- and Post-Test Questionnaire

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1. Risk factors for the development of postoperative AKI include all of the following EXCEPT:
    a. Older age
    b. Higher BMI
    c. Pre-operative renal insufficiency
    d. Female gender
2. In total joint replacement patients, each year increase of age is associated with a __ higher risk of acute kidney injury
    a. 10%
    b. 7%
    c. 2%
    d. 20%
3. The RIFLE criteria use which of the following values to define AKI?
    a. Glomerular filtration rate, serum creatinine, and urine output
    b. Post-operative serum creatinine and blood loss
    c. Urine output and BUN level
    d. Creatinine clearance and mean arterial pressure
4. Which of the following is NOT an **independent** risk factor for the development of AKI?
    a. Decreased blood pressure
    b. Significant blood loss
    c. Decreased urine output
    d. Administration of nephrotoxic agent
5. Perioperatively, the administration of _______ has been shown to decrease blood loss and hypotension
    a. At least 2 liters intravenous crystalloid
    b. 1 unit packed red blood cells
    c. Tranexamic acid
    d. Hexastarch
6. Intraoperatively, a mean arterial pressure (MAP) of less than ___ mmHg for ___ minutes is linked to an increase in AKI. **Select 2.**
    a. 60, 20
    b. 60, 10
    c. 55, 10
    d. 55, 5
7. Which comorbidities are risk factors for the development of AKI? **Select 2**
    a. Traumatic brain injury
    b. Cardiovascular disease
    c. Thyroid dysfunction
    d. Diabetes mellitus

Appendix A

Pre- and Post-Test Questionnaire

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8. True or false: Dual antibiotic therapy with vancomycin and cefazolin compared to cefazolin alone has been shown to increased rates of AKI
    a. True
    b. False
9. Which of the following has been linked to increased rates of AKI in the perioperative setting?
    a. Vancomycin
    b. Renin-angiotensin-aldosterone system inhibitors (ACE/ARBs)
    c. Aminoglycosides
    d. All of the above
10. True or False: Both nonselective and cyclooxygenase-2 selective nonsteroidal anti-inflammatory drugs can be given safely to joint replacement patients <u>at risk</u> for AKI
    a. True
    b. False

Appendix B

Test Results

Participant	Pre - Score	Post -Score
1	6	10
2	8	9
3	5	10
4	8	10
5	9	7
6	6	8
7	6	10
8	6	7
9	6	10
10	9	10
11	6	10
12	8	9
13	8	10
14	6	10
15	5	10
16	7	9
17	9	9
18	9	9
19	6	10
20	8	10
21	8	9
22	8	10
23	8	9
24	5	10
25	5	9
26	8	9
27	7	9
28	7	10
29	5	10
30	7	9
31	4	9
32	4	9
33	7	10
34	4	8

Table 1

Test Results and Descriptive Statistics

35	8	8
36	8	8
37	5	6
38	8	10
39	6	8
40	5	9
41	6	9
42	7	8
43	6	8
44	5	9
45	3	9
46	8	8
47	9	10
48	5	8
49	8	7
50	6	10
51	7	10
52	7	9
53	7	10