Penn Presbyterian Medical Center Hip and Knee Risk Reduction Program Overview

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Introduction

In this overview, we will review the recent effort of Penn Presbyterian Medical Center (PPMC) toward improving the safety of hip and knee arthroplasty patients. The large volume and growing complexity of these cases increases the difficulty in maintaining the safety of patients undergoing elective surgical procedures. We see increasing prevalence of obesity, renal disease, and other medical comorbidities. We also see more patients with more complex orthopaedic problems. Orthopaedic comorbidity at present is addressed simply by the number of revisions. Our focus has been on standardizing pre-hospital and hospital care around best practices and the tools to implement them.

Risk Stratification Tool (RST) Overview: Origin, Development, and New Data

RST Development: Hip Arthroplasty 2007 to 2009

RST development is described in a consecutive hip procedure case-control analysis published in the *Journal of Arthroplasty* by Kamath, *et al.*[1] The study group was comprised of 1,259 consecutive total hip arthroplasty (THA) patients, both primary and revision, who underwent procedures at PPMC between 2007 and 2009. The effort was driven by the recognition of the need to improve morbidity and mortality. Although concern about mortality was the driving factor, the low number of deaths would not have provided statistical significance for stratification of risk variables. Unplanned admission to the surgical intensive care unit (SICU) and rapid responses were selected as proxies for morbidity and mortality. The risk factors that were most predictive for unplanned SICU admission were: 1) age greater than 75 years, with an odds ratio of 2.6; 2) creatinine clearance less than 60 ml/min, with an odds ratio of 6.5; 3) prior myocardial infarction, with an odds ratio of 7.2; 4) BMI greater than 35, with an odds ratio of 2.9; and 5) revision surgery, with an odds ratio of 5.8. If two risk factors were present, the risk of SICU admission was approximately 75%. To maximize sensitivity, two or more risk factors was selected as the threshold for a planned SICU admission, but that threshold meant that only one of three patients would truly need to be in the SICU.

A second guiding principle was the operational benefit of pre-hospital prediction allowing SICU admission planning. Therefore, the risk stratification tool would have to be completed before hospital admission to allow planning for SICU admission.

Kamath, *et al* described the importance of surgical variables which predict the need for SICU admission. Intraoperative use of vasopressors and transfusions during a surgical procedure were both predictive variables. The odds ratio for intraoperative vasopressors was 5.9, and the odds ratio for intraoperative transfusions was 7.1. Although these were important variables recognized in this study, day-of-surgery factors were not included in the original model because the goal was to develop a pre-hospital risk evaluation that could be used to plan care.

Although there were no knee data, we extrapolated the RST to patients undergoing total knee arthroplasty (TKA), with the reasonable expectation of similar risk relationships to hips. Some data were collected starting in November 2011.

RST Early Experience: Hip Arthroplasty November 2011 to April 2012

In 2013, Kamath, *et al* described a post-intervention group of 175 consecutive THA patients who were triaged by the RST.[2] This post-intervention group was compared to the pre-intervention group comprised of 1,259 cases described by Kamath, *et al.*[1] The outcomes of interest were unplanned SICU admissions, rapid responses or codes, major complications, and death. The information contained in this article was based in part on the Clinical Database/ Resource Manager (CDB/RM) maintained by the University HealthSystem Consortium (UHC).

The major complication rate with this small group of RSTed THA patients fell from 12.5%, pre-intervention, to 2.0%, post-intervention. The mortality rate dropped from 4.77 observed-to-expected, pre-intervention, to 1.62, post-intervention. The 11.4% post-intervention rate of total SICU admissions was a modest increase from the historical rate, but the mean SICU length of stay decreased from 2.55 days, pre-intervention, to 1.70 days, post-intervention. After implementation of the triage model, the rate of unplanned SICU admissions dropped

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from 7.1%, pre-intervention, to 2.2%, post-intervention (P=0.013). The complication rate fell significantly from 12.5% to 2%, post-intervention.

RST Two-Year Experience: Hip and Knee Arthroplasty January 2012 to December 2013

Two years of consecutive hip and knee arthroplasty patients, both primary and revision, were stratified prospectively by the RST. Although developed for hip patients, RST was applied to knee patients as well, with the expectation of a similar risk relationship but without specific knee data. These two years of data from primary and revision cases for hip and knee replacements illustrate outcomes specific to the Penn Presbyterian Medical Center when stratified for perioperative risk.

The control group is composed of patients who had hip or knee arthroplasty in 2010 and 2011. There were eight deaths in 2,308 patients. The full study group consisted of 2,853 patients who had hip or knee arthroplasty in 2012 and 2013. The study group included 2,294 patients who were RSTed and 559 patients who were not RSTed owing to urgent admissions or insufficient data. There were no deaths among 2,294 RSTed during the index admission. There was one death for an RSTed patient during readmission for sepsis and liver failure. Of the 559 patients who were not RSTed, there was one death in the urgent group and one death in the insufficient data group. The combined complete group had a mortality rate of 0.11% (3/2,853 deaths), whereas mortality in the control group was 0.35% (8/2,308 deaths), for a Fisher exact two-tailed statistic of p = 0.072 comparing both groups.

UHC data, shown in Table 1, include 15 months of consecutive patients before RST and 24 months after implementation of RST but includes RSTed and urgent patients. The combined Mortality Index dropped from 1.42 to 0.51 after intervention. A Mortality Index of 1.00 indicates that observed mortality equals expected mortality based on UHC criteria. Raw mortality rate dropped from 0.22% to 0.08%, and there were no early deaths after RST was initiated.

Further Development: Penn Arthroplasty Risk Score (PARS) Data

Courtney, *et al*[5] evaluated a recent consecutive subset of patients for care requiring SICU stay. The currently used RST demonstrated moderate specificity, which prompted the consideration of unnecessary SICU admissions. A consecutive series of 295 patients was evaluated for need for critical care intervention. The PARS was developed to include intraoperative risk factors and to improve the specificity of the RST. Based on this retrospective data, PARS was prospectively validated over a consecutive series of 738 patients. The study found that while 176 patients were in the ICU (24%), only 50 patients (6.7%) required critical care intervention. Weighted risk factors in this model included estimated blood loss (EBL) greater than 1000mL, intraoperative vasopressors, COPD, CHF, BMI greater than 35, and revision hip arthroplasty.

Although we expected a RST positive predictive value (PPV) of about 0.3, we found the RST PPV to be 0.22. Evaluation of PARS data shows that a model with higher PPV could be based on the operative events of transfusions and blood loss risk factors for SICU care with a subset of RST variables of heart and pulmonary disease. Both the PARS data and the original RST data[1] show that EBL and intraoperative pressor use are strong predictors for the need for SICU care. PARS data tighten the prediction of need for the SICU by including intraoperative blood loss and vasopressor treatment.

This PARS stratification could only be completed postoperatively, whereas pre-hospital planning for SICU admission was the central theme of RST. Pre-hospital planning probably has value beyond reserving the SICU bed, but even with the planning supported by RST, there are occasions when an SICU bed is not available. The SICU decision is then based on resources such as prolonged PACU monitoring, observations, and discussion among the anesthesia, orthopaedic, and SICU teams. We have the sense that a pre-hospital planning component is valuable and that day of surgery variables and clinical judgment must be part of appropriate triage to SICU or floor care.

Table 1. Information about all consecutive THAs and TKAs before and after implementation of RST. LOS: length of stay. ICU cases included both planned and unplanned ICU admissions. Mortality Index: ratio of PPMC mortality rate to UHC expected mortality rate; less than 1.0 is favorable.

	Pre-RST	Post-RST		
	All THA/TKA 10/2010 – 12/2011	All THA/TKA 1/2012 – 12/2013	THA 1/2012 – 12/2013	TKA 1/2012 – 12/2013
Cases	1,386	2,664	972	1,692
Mean LOS	3.79	3.61	3.84	3.47
LOS Index	1.01	1.00	1.08	0.95
ICU Cases	8.4%	21.4%	23.0%	20.4%
Mean ICU Days	1.70	1.52	1.67	1.42
Deaths	0.22%	0.08%	0.00%	0.12%
Mortality Index	1.42	0.51	0.00	0.80
Early Deaths	0.14%	0.00%	0.00%	0.00%

A blended model would maintain sensitivity and increase specificity. A modified RST including preoperative weighted PARS variables maintains the pre-admission planning value based on new data. The first step would be modified risk stratification with more predictive weighting of patient comorbities and would improve the RST PPV. The second step would be postoperative stratification which would further improve PPV by a final adjustment based on EBL and pressor treatment. Patients with borderline RST scores would be included or excluded from SICU admission in a final postoperative stratification based on PARS values.

Based on this new analysis, the newly proposed risk stratification is more predictive due to weighting of the variables that have been used in the prior risk stratification tool. It has become clear that the prediction for SICU admission of patients who require SICU interventions is stronger using the two variables of intraoperative blood loss and intraoperative vasopressors. Patients who were triaged to the floor but who have blood loss greater than a liter and who required intraoperative use of vasopressors should be managed in the SICU. Patients who are stratified to the SICU based on age, weight, and revision but who have a low blood loss and no use of intraoperative vasopressors may be sent safely to the floor. This second phase postoperative evaluation further increases the sensitivity, specificity, and PPV beyond pre-hospital risk stratification while maintaining strong negative predictive value (NPV, Table 2).

Limitations of RST

An important limitation identified is the infrequent occurrence of certain diseases such as hemophilia, liver disease, complications in transplant patients, and pulmonary embolism. We noted especially that for two of the three deaths during the RST period, the patients had severe liver disease directly contributing to their demise. There were 18 cirrhosis patients in the 14 months of data we collected. Death is too rare to allow statistical significance. In addition, some diseases or patient types may be clinically important but also are too rare to show statistical significance, such as transplant patients, cancer survivors, hemophiliacs, and adults with congenital heart disease.

Orthopaedic disease burden is poorly evaluated at present. We evaluated hip and knee revision arthroplasty and found that hip revision alone is predictive. Because there is great variability in complexity among revisions, we do not have the tools to further risk stratify revisions. A simple hip cup or

Table 2. Sensitivies and specificities of the RST and Post-op PARS.

RST			
	Needed ICU Care		
	Yes	**No**	**Total**
Sent to ICU	36	126	162
Sent to Floor	14	562	576
Total	50	688	738
Sensitivity	0.720		
Specificity	0.816		
PPV	0.222		
NPV	0.975		

Post-op PARS			
	Needed ICU Care		
	Yes	**No**	**Total**
Score ≥ 3	36	52	88
Score < 3	14	636	650
Total	50	688	738
Sensitivity	0.720		
Specificity	0.924		
PPV	0.409		
NPV	0.978		

stem revision has lower risk than a revision for major bone loss. Thus, a good metric for orthopaedic disease burden is needed.

Other Safety Initiatives During the RST Period

Other changes contributed to improved safety outcomes during the past two years. Although we have standardized venous thromboembolism prophylaxis, the RST process allows us to tailor prophylaxis for higher-risk patients. The MP3 preemptive pain protocol has increased the use of non-narcotic analgesics, lowered the use of narcotics overall, and allowed us to limit PCA use while maintaining or improving pain control. The RST process leads to better recognition of and care for patients at risk of delirium, alcohol withdrawal, and sleep apnea. The Hawthorne effect may be important by increasing safety discussion and awareness. Active ongoing discussions among the teams are inherently valuable to improve safe care.

Summary

These efforts have been recognized by UPHS Risk Reduction Initiatives, Joint Commission, and the IBC. We feel that preoperative risk stratification has improved safety for hip and knee arthroplasty patients but at the cost of a 20% rate of ICU admission. We are now evaluating the PARS data to develop an improved stratification model which keeps the high negative predictive value of RST with improved positive predictive value. We look forward to evaluating the new model which lowers the rate of "unnecessary" SICU admissions while maintaining safety.

References

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