Implementation of a Hip Fracture Care Pathway Using Lean Six Sigma Methodology in a Level I Academic Trauma Center

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Background/Purpose: The application of Lean Six Sigma (LSS) methodology represents a novel trend that is being adopted by academic institutions, private hospitals, and residency curriculums. Such management theory may be most useful in orthopaedic trauma settings; however, orthopaedic trauma literature rarely reports both positive and negative findings associated with LSS. The scope of this study is to illustrate the application of LSS principles in the implementation of a hip fracture integrated care pathway (ICP) designed to reduce the number of patients receiving operative care beyond 48 hours of admission.

Methods: A multidisciplinary team was assembled at a Level I academic trauma center to create a hip fracture ICP with use of LSS principles. From April 2011- April 2012, the multidisciplinary team examined hip fracture care to identify wastes occurring in the process that prolonged time to surgical intervention. By April 2012 several LSS tools including process flow maps, stakeholder and failure analyses, as well as patient focus groups, led to the formation of a standardized hip fracture order set. The ICP was designed to decrease time to surgery to less than 48 hours from April 2012 onward. The implementation of the ICP occurred in a prospectively observational manner. After a year of implementation, IRB approval was obtained to compare pre- and postimplementation metrics. Chart review allowed for direct comparison of pre- (April 2011- April 2012) and postimplementation (April 2012- April 2013) measurements including: time to surgery, percentage of patients operated beyond 48 hours, duration of surgery, complication detection, transfusion rate, length of stay (LOS), hospital cost and charge, 30-day readmissions, and inhospital mortality. Inclusion criteria for both cohorts included patient age >55 and radiographic evidence of hip fracture that indicated surgical intervention. Baseline characteristics were compared for respective cohorts including age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) score, fracture type (intertrochanteric, subtrochanteric, and femoral neck), and instrumentation (percutaneous hip screws, cephalomedullary nails, dynamic hip screws, hemiarthroplasty, and total hip arthroplasty). X^2 results were used for categorical data, and sample *t* tests were used to assess continuous variables. Significance was assigned to *P* values <0.05.

Results: A total of 505 hip fracture patients met inclusion criteria. A total of 221 patients entered the preimplementation cohort, and 284 were incorporated in the postimplementation cohort. Evaluation of baseline characteristics revealed no statistical significance between pre- and postimplementation cohorts with regard to gender, age, BMI, ASA score, fracture type, and instrumentation. The postimplementation cohort demonstrated reduction in time to surgery

that approached significance (preimplementation: 26.11 hours vs postimplementation: 22.75 hours, $P = 0.06$). The percentage of patients that received operative fixation beyond 48 hours significantly decreased (9.50% vs 4.23%, $P = 0.01$). Clinical outcomes were also assessed to elucidate the relationship of LSS application to well-known quality improvement metrics. Significantly more complications were detected in the postimplementation cohort (57.91% vs 77.19%, $P < 0.01$). In conjunction with complication detection, the postimplementation cohort displayed significantly shorter LOS (6.06 vs 5.28 days, $P = 0.02$) and decreased hospital cost by 9.7% ($P = 0.016$). 30-day readmission rate decreased from 22.62% to 17.19% following implementation of ICP ($P = 0.13$). Finally, the postimplementation cohort demonstrated a lower postoperative transfusion rate that approached significance (50.53% vs 58.37%, $P = 0.07$). In turn, this resulted in a 9.7% cost savings per case, and an estimated $1.164 million US in annual cost savings for our institution.

Conclusion: Our findings suggest that using LSS techniques to formulate an ICP at our institution resulted in significantly greater percentage of patients receiving operative care within 48 hours, and lower resource consumption. To our knowledge, this study offers a robust perspective of LSS application with regards to a hip fracture pathway, not elsewhere noted in orthopaedic literature. Future studies regarding LSS application should concentrate on delving into complication prevention, and ultimately how patient perception plays a role in quality of care.

Important Lean Six Sigma Principles

LSS Term	Description	Application in ICP Setting
DMAIC	An acronym for the following parameters: define, measure, analyze, improve, control.	Identification of key stake holders within the hip fracture ICP pathway and their contributions.
Failure Analysis	The process of determining cause of failure, and putting measures in place to prevent such occurrence.	Stakeholder analysis helped detect specific areas of process failure. Physician-to-physician peer evaluation of inability to perform surgery within 48 hours admission also aided in decreasing failure.
Standard Work	A concept whereby each work activity is precisely described and includes specifying cycle time, task sequence, and other steps involved within the process.	Each key stakeholder assessed their input into the process. i.e. anesthesia-preoperative pain management; emergency room physician-activate hip fracture order set and consult both orthopaedic and medicine teams.
Continuous Flow	One service moves from one process to the next. Where a unit of product flows from process to process. In effect, the batch quantity is one. A specific type of continuous flow is single-piece flow.	Our application of single piece continuous flow is modeled in our process flow map figure.
Value	The net difference between customer-perceived benefits and burdens; it is sometimes expressed as a ratio of benefits to burdens or a ratio of worth to cost.	For our implementation, the customer was considered to be the patient. During benchmark sessions, they described time as a value. A cost-analysis occurred with regard to time-to-surgery.
Lean Six Sigma	A fact based, data driven philosophy of improvement that values defect prevention over defect detection. It drives customer satisfaction and bottom line results by reducing variation, waste, and cycle time, while promoting standardization of flow.	The analysis method chosen by our comanagement team to help evaluate and create an integrated care pathway.
Lean	A comprehensive approach complemented by a collection of tools and techniques that focus on reducing cycle time, standardizing work, and reducing waste.	The application of Lean philosophy is evident in the DMAIC cycle described in discussion. Furthermore, successful reduction of cycle-time and value-stream mapping allowed for Lean implementation.
Kaizen	A term that means gradual unending improvement by doing small things better and setting and achieving increasingly higher standards. Kaizen is typically implemented as a small, intensive event or project over a relatively short duration, such as a week.	Kaizen meetings occurred amidst the ICP team. Furthermore, physician-to-physician interaction offered methods to enhance team morale and reinvest efforts toward decreasing time-to-surgery.

See pages 49 - 106 for financial disclosure information.

Baseline Characteristics of Hip Fracture Patients

Characteristics	Pre-Implementation	Post-Implementation	p-value
Gender (n, %)			
Female	164	217	.617
Male	57	67	
Age (mean, SD)	80.98 (10.21)	82.19 (9.99)	.182
BMI (mean, SD)	24.52 (6.91)	24.20 (5.09)	.568
ASA Score			
1			
2	28	35	.800
3	134	180	
4	59	69	
Fracture Type			
Femoral Neck	116	134	.443
Inter-trochanteric	96	140	
Sub-trochanteric	9	10	
Instrumentation			
Cephalomedullary nails	85	131	.305
Dynamic hip screws	31	33	
Hemi-arthroplasty	70	74	
Percutaneous hip screws	30	43	
Total hip arthroplasty	5	3	

Value Stream Map of Integrated Care Pathway

Clinical Outcomes of Pre- and Post-implementation of Hip Fracture Integrated Care Pathway

Outcomes	Pre-Implementation	Post-Implementation	p-value
Time-to-Surgery (mean, standard deviation [SD])	26.11 (24.74)	22.75 (15.27)	.061
% of Patients Operated Beyond 48 Hours	9.50%	4.23%	.01
Duration of Surgery (hrs. [SD])	1.16 (.559)	1.05 (.494)	.028
Detection of Complication	57.91%	77.19%	<.001
Transfusion Rate	58.37%	50.53%	.07
Length of Stay (LOS) (avg. days)	6.06	5.28	.023
Hospital Charge (USD)	Reference	-2.7%	.515
Hospital Cost (USD)	Reference	-9.7%	.016
30-Day Readmissions	22.62%	17.19%	.126
In-Hospital Mortality	1.8%	2.8%	.464