Key Performance Indicators across the Perioperative Process: Holistic Opportunities for Improvement via Business Process Management

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Abstract

This study examines the development and use of multiple scorecard metrics within each stage of the perioperative process as key performance indicators to enable business process management practices across the entire process to target and measure continuous improvement. This paper identifies how dynamic technological activities of analysis, evaluation, and synthesis applied to internal and external organizational data can highlight complex relationships within integrated hospital processes to target opportunities for improvement and ultimately yield improved process capabilities. The identification of existing limitations, potential capabilities, and the subsequent contextual understanding are contributing factors that yield measured improvement. This case study investigates the impact of integrated information systems to identify, qualify, and quantify perioperative improvement based on a 154-month longitudinal study of a large, 1.046 registered-bed teaching hospital. The theoretical and practical implications and/or limitations of this study's results are also discussed with respect to practitioners and researchers alike.

1. Introduction

The current focus of healthcare administration in the United States has shifted toward performance monitoring and improving clinical outcomes to meet regulatory and reimbursement requirements due to the American Recovery and Reinvestment Act of 2009, the Health Information Technology for Economic and Clinical Health Act, the Affordable Care Act, and the Joint Commission on Accreditation of Healthcare Organizations (TJC) / Centers for Medicare & Medicaid Services (CMS) core measures [4]. Meeting these performance and reporting challenges requires leveraging information systems (IS) and technologies (IT) [26]. Consequently, the widespread IS/IT adoption across healthcare also necessitates the need for value realization [14]. To this end, this study investigates how key performance indicators (KPIs) across a hospital's entire perioperative process can identify and ultimately achieve continuous improvement via business process management (BPM).

A hospital's perioperative process is complex [12], involving multiple interconnected sub-processes that provide surgical care for inpatients and outpatients during pre-assessment, pre-operative, intra-operative, and post-operative activities. Furthermore, the perioperative process yields patient end-state goals where: (1) a correct diagnosis for surgical intervention is identified with noted co-morbidities and patient consent; (2) a patient undergoes the surgical procedure; (3) a patient exhibits minimal exacerbation of existing disorders; (4) a patient avoids new morbidities; and (5) a patient experiences prompt procedure recovery [28]. Meeting perioperative patient end-state goals will also avoid hospital-acquired-conditions (HACs) [6] and hospital-acquired-infections connected with negative financial incentives [23, 33]. However, perioperative sub-processes (e.g. pre-assessment, pre-operative, intra-operative, post-operative, and ancillary central sterile supply activities) are sequential, where activity sequence paces the efficiency and effectiveness of subsequent activities which can risk achievement of patient end-state goals. Consequently, the perioperative process is tightly coupled to patient safety, patient quality of care, patient flow, and stakeholders' satisfaction (i.e. patient, physician/surgeon, nurse, perioperative staff, and hospital administration).

This case study identifies complex perioperative dynamics within and across the entire process that are nested in the hospital environment and reflected via sub-process scorecard metrics. This research investigates how traditional business process management (BPM) practices are applicable to explain perioperative complexity and measure continuous process improvement. This study specifically highlights multiple scorecard metrics from each perioperative sub-process (e.g. pre-assessment, pre-operative, intra-operative, post-operative, and ancillary central sterile supply activities) and demonstrates how the metrics are applicable as key performance indicators (KPIs) and how each perioperative sub-process supports specific patient end-

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state goals. The investigation method covers a longitudinal study of an integrated clinical scheduling information system (CSIS) within an academic medical center. The implementation of agile, integrated information systems (IS) and subsequent contextual understanding of perioperative sub-process data prescribed opportunities for measured improvements. Specifically, developing and implementing perioperative sub-process metrics as KPIs, grounded in internal and external best-practices, provides the framework for targeting opportunities and evoking improvement. The combined assessment of sub-process KPIs also provide change dynamics for evaluation and improvement to the overall perioperative process.

The following sections review previous literature on BPM, KPIs, as well as perioperative scorecards and dashboards. Following the literature review, we present our methodology, case study background, observed effects and summary discussion. By identifying a holistic framework for analysis, evaluation, and synthesis of end-to-end process measures with established benchmarks, this paper prescribes an a priori environment to support effective and efficient perioperative sub-process improvement by addressing sub-process root causes rather than process symptoms. The conclusion also addresses study implications and limitations.

2. Literature Review

Integrated information systems (IS) offer continuity through information sharing, synergy, and improvement [18]. Likewise, integrated IS and IT provide measurement and subsequent accountability for healthcare quality and cost, creating a dichotomy (e.g., quality versus cost) that represents the foundation for healthcare improvement [8]. Within the perioperative process, patient end-state goals are the focus of work. However, United States hospitals currently face increasing pressure to provide objective evidence of organizational quality, efficiency, and effectiveness [4, 35]. To this end, a BPM approach [13, 32] borrowed from the manufacturing industry provides a framework to target and measure improvement.

The perioperative process is typically the primary source of hospital admissions, averaging between 55 to 65 percent of overall hospital margins [25]. Likewise, total hospital supply costs are variable with the largest cost category being the perioperative process (e.g. 33 percent) [20]. Nonetheless, the perioperative process has many core sub-processes nested within the hospital environment that yield overall clinical performance. Furthermore, managing and optimizing quality, efficient, and cost-effective perioperative processes to yield improved clinical outcomes are critical success factors (CSFs), both operationally and financially. To meet these demands, administrators and medical professionals must focus technology-enhanced practices that yield high quality of care and patient safety, coupled with increased efficiency and cost effectiveness. Measured utilization of these practices is not a result from any lack of research as an extensive body of knowledge exists concerning the application of these approaches in healthcare [2, 7, 10, and 30]. However, the literature suggests that such management practices and interventions can yield positive results with significant variations in implementation success.

2.1 Business Process Management (BPM)

Continuous process improvement (CPI) is a systematic approach toward understanding process capability, customer's needs, and sources of observed variation. Tenner and DeToro [29] views CPI as an organizational response to an acute crisis, a chronic problem, and/or an internal driver. CPI encourages bottom-up communication at the day-to-day operations level and requires process data comparisons to control metrics. Incremental improvement gains occur via iterative cycles of analysis, evaluation, and synthesis or plan-do-study-act [32] to minimize observed variation. Doubt can exist as to: whether the incremental improvement addresses symptoms versus causes; whether the improvement effort is sustainable year after year; and/or whether management is in control of the process [13].

This study uses the BPM definition provided by Jeston and Nelis [13, p. 10] as "the achievement of an organization's objectives through the improvement, management, and control of essential business processes." The authors further elaborate that process management and analysis is integral to BPM, where there is no finish line for improvement. Hence, this study views BPM as an organizational commitment to consistent and iterative business process performance improvement that meets organizational objectives. Business analytics is the body of knowledge identified with technology solutions that incorporate performance management, definition and delivery of business metrics, as well as data visualization and data mining [31]. Business analytics within BPM focus on the effective use of organizational data and information to drive positive business action [29]. The effective use of business analytics demands knowledge and skills from subject matter experts and knowledge workers. Similarly, Wears and Berg [35] concur that IS and/or IT only yield high-quality healthcare when the use patterns are tailored to knowledge workers and their environment.

2.2 Key Performance Indicators (KPIs)

Early in the IT literature, Ackoff [1] proposed IS design to include feedback control to avoid management misinformation. Similarly, information before and after intervention is an integral part of CPI, so performance

metrics are essential requirements for CPI and purposeful BPM. KPIs focus on organizational priorities that create long-term value for stakeholders [3]. Consequently, organizations define data metrics as KPIs to assist management in monitoring CSFs for organizational action (i.e. business processes) [22, 27, 39]. However, doubt exists as to whether perioperative management can meet these demands [5], in part due to perioperative process complexity [12].

Operational and tactical KPIs identified in evaluating a hospital's perioperative performance typically focus on intra-operative metrics from the operating room (OR) [7, 15, 25, 30, 37] like: (1) monitoring the percentage of surgical cases that start on-time (OTS), (2) OR turnaround time (TAT) between cases, (3) OR suite utilization (UTIL), and (4) labor hours per patient care hours or units-of-service (UOS) expended. However, OR schedules are tightly coupled to individual OR suites, patients, and surgeons where incomplete perioperative sub-process tasks upstream impact intra-operative KPIs. For example, incomplete pre-assessment or pre-operative tasks as well as unavailable central sterile supply supplies/instruments/devices can delay a scheduled case as well as the subsequent scheduled cases in the particular OR suite or for the particular surgeon. Consequently, intra-operative inefficiencies and delays in turn impact post-operative activities downstream. Within the perioperative sub-processes, symptoms downstream can be more noticeable than actual root causes upstream, which supports having KPIs within all the perioperative sub-processes to gauge performance independently to identify problems and root causes rather than symptoms. Addressing problems and root causes supports continuous improvement.

Perioperative KPIs are often closely associated with multiple hospital CSFs. For example, OR TAT and a flexible work environment are CSFs for physician satisfaction [19, 30, 37], which in turn is a CSF for hospital margin. Conversely, poor operational and tactical KPIs affect strategic CSFs of patient safety, patient quality of care, surgeon/staff/patient satisfaction, and hospital margin [21, 34]. Likewise, inefficient and ineffective reprocessing of instruments/devices within the central sterile supply sub-process yields poor OR TAT KPIs [9]. The BPM approach of this study examines KPIs across the entire perioperative process, specifically highlighting the pre-assessment, pre-operative, intra-operative, post-operative, and ancillary central sterile supply sub-processes.

2.3 Perioperative Scorecards and Dashboards

The terms scorecard and dashboard are frequently used synonymously to describe a visual display mechanism that conveys performance information at a glance [3]. Dashboards and scorecards are comprised almost entirely of KPIs, which collectively embody the corporate strategy tailored to each individual in the organization by role and level [10]. Using scorecards and dashboards for purposes such as strategic, tactical, and day-to-day operations, coupled with internal and external best-practice benchmarks, provide the framework for targeting opportunities and measuring improvement to the perioperative process. Drawing a distinction between the two, dashboards monitor process performance via charts or tables while scorecards focus on target or goal attainment using graphics [3, 36].

The KPI data presented in scorecards or dashboards provides the opportunity to monitor performance for process improvement or gather data for timely information in support of decision making. KPI data granularity within the scorecard or dashboard must be high enough to support drill down capabilities for knowledge discovery via online analytical processing or data mining to support analysis, evaluation, and synthesis activities associated with possible decisions [17]. Overall, scorecards and dashboards can play a pivotal role in converting data and information into actionable knowledge [3, 10, 36]

3. Research Methodology

The objective of this study is to examine KPIs across the entire perioperative process for use in traditional BPM practices that provides a framework to target and measure improvement as well as maintain perioperative patient end-state goals. To this end, case research is particularly appropriate [11, 34]. Paré [24] recommended using a positivist case study methodology to build and test theories in IS research. A positivist approach in case research allows focus and analysis of the associated qualitative problems and environmental complexity [38]. Hence, our study took an in-depth positivist approach to case research.

Our research site (e.g. University Hospital) is an academic medical center, licensed for 1,046 beds and located in the southeastern United States. University Hospital is a Level 1 Trauma Center, with a robotics program across eight surgical specialties as well as a Women's/Infant facility. University Hospital's recognition includes Magnet since 2002 and a Top 100 Hospital by U.S. News and World Report since 2005. Concentrating on one research site facilitated the research investigation and allowed collection of longitudinal data. This research spans activities from August 2003 through May 2016, with particular historical data since 1993. During the 154-month study, we conducted field research and collected data via multiple sources including interviews, field surveys, site observations, field notes, archival records, and document reviews.

4. Case Background

University Hospital Perioperative Services (UHPS) is the University Hospital department designated to coordinate and manage perioperative patient care across pre-admissions via the pre-operative assessment consultation and treatment (PACT) clinic, admissions, surgical preparations (PRE-OP), central sterile supply (CSS), OR surgery and endoscopy, and post anesthesia care units (PACU). The workflow through CSS reprocesses all reusable surgical instruments/devices and moves supplies to pre-assessment, pre-operative, intra-operative, and post-operative activities. The following sections highlight tools, events, and outcomes that have shaped the UHPS BPM approach.

4.1 CSIS Implementation

UHPS implemented a new, agile CSIS in 2003, after using its prior CSIS for 10 years. The new CSIS supports OLAP tools, a proprietary structured query language, and both operational and managerial data stores (e.g. an operational data store and a separate perioperative data mart). Flexible routing templates or surgical preference cards (SPCs) allow standardization of surgical care supplies-instruments-devices or SPC customization for specific surgeon's procedures. Since the CSIS implementation, over 7,750 generic and custom SPC configurations facilitate the surgical specialty services (SSS) represented in Table-1. Similarly, the agile CSIS data mart serves as the central repository for perioperative process data used to report KPIs with a business intelligence layer to support data visualization.

Table 1 – Current CSIS SPCs

Surgical Specialty Service	SPCs
BURN – Trauma burns	26
CARDIO –Cardiovascular & Thoracic	946
ENT – Ear, Nose, & Throat	1,030
GI – Gastro-intestinal	460
GYN – Obstetrics, oncology, incontinence	611
NEURO – Neurological	763
ORAL - Oral Maxilla Facial	236
ORTHO – Orthopedic, joint/device	1,208
PLAS – Plastic surgery	681
SURG ONC – Surgical oncology	329
TX – Transplants (liver, renal)	194
TRAUMA – Trauma, MASH	203
URO – Urology	533
VASCULAR – arteries & blood vessels	558

4.2 November 2004

University Hospital built a new diagnostic and surgical facility (e.g. North Pavilion) that opened in November 2004. UHPS relocated CSS onto one floor (e.g. 3rd) with Pre-OP, ORs, and PACU on each of the two floors above CSS (e.g. 5th and 7th). The North Pavilion campus expanded UHPS to cover an additional floor and nine ORs (i.e., 33% capacity increase) to provide 40 state-of-the-art OR suites, each having new standard as well as surgical specialty equipment. Within six weeks of occupancy, an intra-operative KPI reflected chaos. Surgical case OTS plunged to 18% during December 2004. Having only 18% OTS is unacceptable in a highly competitive hospital industry, as 82% of scheduled surgeries experience delays and risk patient care and safety.

In January 2005, UHPS expressed concerns before a quickly convened meeting of c-level officers and top nursing, surgeons, and anesthesia representatives. The meeting yielded a hybrid management structure and governance in the formation of a multidisciplinary executive team, chartered and empowered to evoke change. The executive team consisted of perioperative stakeholders (i.e., surgeons, anesthesiologists, nurses, and UHPS). The executive team's charter was to focus on patient care and safety, attack difficult questions, and remove inefficiencies. No issue was off-limits.

4.3 Perioperative Process Improvements

University Hospital's executive team launched a process improvement effort in 2005 to address the perioperative crisis. This CPI effort resulted in the executive team enlisting numerous task forces to address specific problems and opportunities, which became the foundation for their current BPM approach.

Table 2 — Perioperative Improvements

Perioperative Process Improvement	Yr.
Implemented the current CSIS	2003
Relocated CSS and ORs to North Pavilion	2004
Changed governance—initiated CPI	***2005***
Initiated OR heuristic scheduling rules	2006
Addressed hospital-wide patient flow (EMR, patient tracking, CPoE, etc.)	2007
Established performance reporting (strategic, tactical, and operational)	2008
Developed PACT Clinic	2011
RFID phased implementation (intra-operative activities)	2012
Redesigned supply workflow (CSS-to-Intra-operative-to-CSS)	2013
Unit-of-service CSIS charge via EMRs	2014
CSS instrument reprocessing & tracking	2015
Real-time perioperative KPIs & dashboards	2016

Since 2005, UHPS has focused data-driven analysis of KPIs to gauge process variance, identify improvement opportunities from variances, and improve end-to-end workflow. Using this systematic BPM

approach, improvement efforts have targeted various activities and areas within the perioperative process and sub-processes as identified in Table 2 above.

In 2009, UHPS expanded its management beyond the initial 32 general ORs (GENOR) and 8 cardio-vascular OR suites (CVOR) within the North Pavilion campus to the other campuses of University Hospital Health System (UHHS) OR facilities including 16 OR suites at the Highland campus (HHOR) and 8 endoscopy labs at the TK Clinic campus. In 2011, UHPS also assumed management of the new pre-operative assessment, consultation, and treatment (PACT) clinic to screen pre-operative patient flow into UHHS ORs. Two additional general ORs have been equipped since 2013 at the North Pavilion campus to bring UHPS management to 58 ORs and 11 endoscopy labs.

5. Observed Effects

The identification and definition of perioperative KPIs has been an iterative evolution since 2005. Consistently, the focus was data-driven improvements, with process control measures collected through the CSIS and benchmarked to external industry standards or prior months' metrics. While reviewing what could have been done better early in the CPI efforts, UHPS recognized the need to involve more perioperative stakeholders in improvement efforts and not just end-result to-do lists. Consequently, the executive team launched an initiative in 2008 to begin performance reporting for CMS and TJC. The perioperative BPM effort established balanced scorecard measures [16] (e.g. quality of process, satisfaction of customer, or financial) and a means to disseminate the process feedback to perioperative stakeholders at strategic, tactical, and operational levels. The BPM approach was expanded in FY2010 to reinforce UHHS strategy across all core hospital processes.

In FY 2016, the BPM task force was charged to create actionable information in support of operational, tactical, and strategic initiatives across the perioperative process. The task force expanded perioperative KPIs beyond intra-operative performance into all the sub-processes. The following sections detail the resulting KPIs as well as an intra-operative performance dashboard and KPI data visualization examples.

5.1 Pre-assessment KPIs

Pre-operative integrated evaluations communicate and document practitioner-patient awareness to avoid conflicts and identify potential OR specific risks [28]. As a result, the PACT clinic manages pre-admission patient flow into UHHS ORs where all surgical patients receive a scheduled PACT evaluation prior to their surgical procedure. When a patient arrives in the PACT clinic, the surgeon documents a focused surgical assessment of the patient with confirmed surgical consent. The surgeon may also order testing (i.e. Stress, EKG, Imaging/X-ray, and/or Lab) as well as a cardiac/medical consultation as needed. Documentation of existing HACs or HAIs prior to the patient's admission also disassociates UHHS with potential negative financial incentives [23, 33] for the pre-existing HACs or HAIs.

During the PACT evaluation, a PRE-OP nurse also verifies CSIS inclusion of pre-assessment patient documentation across the following categories: 1) surgery consent; 2) medication reconciliation; 3) medical history / physical exam (H&P); 4) surgical procedure history; 5) patient allergies; 6) problem listing; 7) pre-surgical physician orders; and 8) scheduled procedure / patient education. Table 3 details the current UHHS recommended pre-assessment KPIs and denotes the balanced scorecard (e.g. BSC) metric classification of F-financial, Q-quality of process, or S-satisfaction of customer.

Table 3 – Pre-assessment Sub-process KPIs

Pre-assessment KPIs	BSC	Best Practice
% of Patients Seen	Q	100%
% of Patient Walk-ins	F	5% or less
% of No Shows	F	1% or less
Missing Documentation	Q	0
PACT Length of Stay (LOS)	S	45 min.

The pre-assessment sub-process assists with a patient's end-state goal of (1) identifying a correct diagnosis for surgical intervention with noted co-morbidities and patient consent. The five pre-assessment sub-process KPIs are quantitative metrics derived from the CSIS operational data store per the following calculations. *% of Patients Seen* is the number of PACT patients divided by the number of scheduled out-patient and same-day-surgery cases that should yield 100%. *% of Patient Walk-ins* is the number of PACT walk-ins divided by the number of PACT visits where the metric should be 5% or less. *% of No Shows* is the number of no show appointments divided by the total appointment slots and the target is 1% or less. *Missing Documentation* is a ratio of the total missing documents per category (e.g. 8 categories) divided by the number of PACT evaluations where the target is none. *PACT LOS* is the average elapsed minutes for a patient's PACT evaluation and the target is 45 minutes.

5.2 Pre-operative KPIs

During pre-operative activities, PRE-OP nurses prepare patients for their surgical procedures per surgeon/anesthesiologist orders and provide acute patient care after initial administration of anesthesia. The pre-operative sub-process assists patient's end-state goals of (1) identifying a correct diagnosis for surgical intervention with noted co-morbidities and patient

consent, (3) patient exhibits minimal exacerbation of existing disorders, and (4) patient avoids new morbidities. Table 4 details the current UHHS recommended pre-operative KPIs and denotes the BSC metric classification of F-financial, Q-quality of process, or S-satisfaction of customer.

Table 4 – Pre-operative Sub-process KPIs

Pre-operative KPIs	BSC	Best Practice
Patient-Arrival-to-Admission	Q	2 to 3 hours
% Patients w/o PACT Eval	F	5% or <
PRE-OP Delays (By reason)	Q	5 min. or <
PRE-OP Length of Stay (LOS)	S	35 min.

The four pre-operative sub-process KPIs are quantitative derivations from the CSIS per the following calculations. *Patient-Arrival-to-Admission* is the patient UHHS arrival time prior to PRE-OP entry and the target timeframe is 2 to 3 hours. *% Patients w/o PACT Eval* is the number patients not seen in PACT divided by the number of PRE-OP patients and the target is 5% or less. *PRE-OP Delays* are delay minutes tallied by reason and the average minutes per reason is targeted to be five minutes or less. *PRE-OP LOS* is the elapsed minutes a patient stays in PRE-OP prior to moving to an OR suite and the target average is 35 minutes per patient.

5.3 Intra-operative KPIs

When a patient arrives in an OR suite, an OR nurse begins documenting all people, time, and activities encountered while the patient is in the OR, as required by TJC and CMS, as well as all medication, blood, tissue, and supply usage via the CSIS surgical case. Other CSIS intra-operative documentation includes quality issues for patient longitudinal outcomes, retained object counts, and robotic usage. The final intra-operative CSIS documentation occurs after the patient's surgical case completion when OR staff document the UOS spent on the OR suite clean up and setup of the next scheduled surgical patient. The intra-operative sub-process assists UHHS in meeting a patient's end-state goals of (2) a patient undergoes the surgical procedure; (3) a patient exhibits minimal exacerbation of existing disorders; and (4) a patient avoids new morbidities.

Table 5 details the current UHHS recommended intra-operative KPIs documented via the CSIS during a patient's surgical or endoscopy procedure and denotes the BSC metric classification of F-financial, Q-quality of process, or S-satisfaction of customer. The fifteen intra-operative KPIs are derived from the CSIS operational data store per the following calculations. *Prime Time Room Utilization* (e.g. UTIL) is the sum of the time duration to perform each surgical procedure (i.e. "OR In" to "OR Out"), plus the total turnaround time, divided by the prime time available to GENOR and CVOR (i.e. 7AM-5PM Mondays to Fridays except 8AM-5PM on Tuesdays) or to HHOR (i.e. 7AM-3PM Mondays to Fridays except 8AM-3PM on Tuesdays) suites, with OR availability decreasing on holidays and weekends. The best practice target for Prime Time Room Utilization is 80%. *Modified Block Utilization* is the sum of the time duration to perform each surgical procedure (i.e. preparation of the patient in the OR, anesthesia induction, and emergence) plus the total turnover time, divided by the modified block time scheduled where the target is 75 to 80%. *Block Run-Over Utilization* is the sum of the time duration of surgical procedure performed in 2 hour increments after the assigned prime time block for GENOR and CVOR (i.e., 5PM – 7 PM and 7 PM – 9 PM) or HHOR (i.e., 3 PM – 5 PM and 5 PM – 7 PM)] divided by the hours available based on scheduled ORs during those time increments. The Block Run-Over Utilization target is none, with an exception for emergency surgeries.

Table 5 – Intra-operative Sub-process KPIs

Intra-operative KPIs	BSC	Best Practice
Prime Time Room Utilization	F	80%
Modified Block Utilization	F	75% - 80%
Block Run-Over Utilization	F	None
First Case of the Day On-time Starts	S	90% +/- 5 min. 95% in 15 min.
Subsequent On-time Starts	S	80% in 15 min.
OR Turnaround Time	F	25-30 min.
In Room to Cut Time	Q	20 – 30 min.
Close to Out of Room Time	Q	12-17 min.
Surgeon RVU Gap	F	30 - 40%
Accurate Case Duration Est.	Q	80%
Day of Surgery Cancel Rate	F	< 2%
Day of Surgery Add-ons	Q	< 10 %
% of Cases with Delays	S	< 5%
Average Minutes per Delay	S	5 – 15 min.
Total Minutes Lost to Delays	F	None

First Case of the Day On-time Starts is the percentage of first cases scheduled as of 6 AM day of surgery with an in-room start time (wheels in) that is either early or not more than 5 minutes after the scheduled start time with a cut off time of 7:30 AM Mondays to Fridays except 8:30 AM on Tuesdays. The target for First Case of the Day On-time Starts is 90% +/- 5 minutes and 95% within 15 minutes. *Subsequent On-time Starts* (e.g. OTS) is the percentage of "Prime Time" non-first cases where patient-in-room start time is within 15 minutes of the estimated scheduled procedure start time and the best practice target is 80% within 15 minutes. *OR Turnaround Time* (e.g. TAT) is the minutes

elapsed between the prior patient exiting the room and the succeeding patient entering the room, with the best practice target of 25 to 30 minutes.

In Room to Cut Time is the elapsed minutes from when a patient enters the room (i.e. wheels in) till the patient's cut-procedure-start time, where the target is 20 to 30 minutes. *Close to Out of Room Time* is the elapsed minutes between the patient's close-procedure-stop time till the patient leaves the OR (i.e. wheels out), where the target is 12 to 17 minutes. *Surgeon RVU Gap* is the minutes elapsed between the prior patient-closed-procedure-stop time and the surgeon's succeeding patient's cut-procedure-start, divided by the prior case time (e.g. cut-procedure-starts to close-procedure-stop). The best practice for Surgeon RVU Gap is 30 to 40%.

Accurate Case Duration Est. is the percentage of cases where patient-in-room duration (e.g. wheels-in to wheels-out) is within 15 minutes of the estimated in-room duration (i.e. total scheduled surgical time), where the best practice target is 80%. *Day of Surgery Cancel Rate* is a percentage of scheduled cases cancelled after 7PM on the day prior for any reason, divided by the number of scheduled cases for the day of surgery, where the target is less than 2%. *Day of Surgery Add-ons* is a percentage of cases scheduled after 7PM on the day prior, divided by the number of scheduled cases for the day, where the target is less than 10%.

% of Cases with Delays is a percentage of case delays to cases performed by a surgical specialty service (e.g. SSS), where the best practice target is less than 5%. *Average Minutes per Delay* is the elapsed minutes associated with a particular SSS delays divided by the number of delays for a SSS, where the target is 5 to 15 minutes. *Total Minutes Lost to Delays* is the number of elapsed minutes associated with delays for a particular SSS, where the best practice target is none.

5.4 Post-operative KPIs

PACU nurses receive surgical patients from the OR and continue acute care per surgeon's orders until patient recovery. As surgical patients recover from anesthesia, the need for acute care lessens and patients move to PACU Phase-II ambulatory patient care via the CSIS. The post-operative sub-process assists in meeting a patient's end-state goals of (3) a patient exhibits minimal exacerbation of existing disorders; (4) a patient avoids new morbidities; and (5) a patient experiences prompt procedure recovery. Table 6 details the current UHHS recommended post-operative KPIs documented via the CSIS during a patient's PACU visit and denotes the BSC metric classification of F-financial, Q-quality of process, or S-satisfaction of customer.

The five post-operative sub-process KPIs are derived per the following calculations. *Bed-Assigned to Ready-to-Move* is for inpatients (e.g. IP) only and represents the average minutes between the two times, where the target is 15 minutes. *Ready-to-Move to Occupy-Bed* is for inpatients only and represents the average minutes between the two times, where the target is 15 minutes. *Ready-to-Sign-Out to Sign-Out* is for both inpatients and outpatients (e.g. OP), representing the average minutes between the two times and the target for both is 5 minutes. *# of Patient Holds in PACU* is the number of patient holds in PACU by Patient Type and average elapsed minutes, where the target is none. *PACU LOS* is the average minutes from patient arrival in PACU to discharge from PACU, where the target is 60 minutes for inpatients and 45 minutes for outpatients.

Table 6 – Post-operative Sub-process KPIs

Post-operative KPIs	BSC	Best Practice
Bed-Assigned to Ready-to-Move	Q	15 min. for IP
Ready-to-Move to Occupy-Bed	Q	15 min. for IP
Ready-to-Sign-Out to Sign-Out	Q	5 min. for both
# of Patient Holds in PACU	F	None
PACU Length of Stay (LOS)	S	60 min. - IP 45 min. - OP

5.5 Central Sterile Supply KPIs

The workflow through Central Sterile Supply (CSS) moves supplies/instruments/devices to ORs and reprocesses reusable surgical instruments/devices on all three OR campuses via separate CSS facilities. Prior to a patient's arrival in each OR, CSS delivers a prepared case cart (i.e. up to 8-hours in advance) containing supplies and instruments for the patient's specific surgical procedure per the CSIS SPC pick list and reprocesses used and un-used case cart contents after the surgical case completion. The CSS sub-process assists the patient's end-state goals of (3) a patient exhibits minimal exacerbation of existing disorders and (4) a patient avoids new morbidities. Likewise, CSS KPIs assists UHHS to avoid HACs and HAIs with perioperative patients and associated potential negative financial incentives [23, 33]. Table 7 details the current UHHS recommended KPIs documented during the CSS sub-process and denotes the BSC metric classification of F-financial, Q-quality of process, or S-satisfaction of customer.

Table 7 – CSS Sub-process KPIs

Central Sterile Supply KPIs	BSC	Best Practice
IUSS Usage Rate	Q	< 2%
Damaged Tray Rate	Q	None
PM Plan Adherence Rate	Q	100%
Instrument Trays > 25 Lbs.	F	None
Vendor Tray Mgt. NC Rate	S	None
SPC Update Review	F	100%

The six CSS KPIs are quantitative and derived per the following calculations. *Immediate Use Steam Sterilization (e.g. IUSS) Usage Rate* is the number of IUSS processed divided by the number of surgical procedures, where the target is less than 2%. *Damaged Tray Rate* is the incident total of all trays not meeting surgeon and staff expectations including tracking of wet trays, divided by the total trays processed, where the target is none. *Preventive Maintenance (e.g. PM) Plan Adherence Rate* is the percentage of trays receiving the PM review per the contracted number of sets to be reviewed, where the target is 100%. I*nstrument Trays > 25 Lbs.* is the number of tray sets, including vendor trays, exceeding the 25 pound weight limit, where the target is none. *Vendor Tray Management Non-Compliance (e.g. NC) Rate* is the number of incidents that the vendor tray management process was not met, where the target is none. *Surgeon Preference Card (e.g. SPC) Update Review* is the number of surgical preference cards signed off by the SSS surgeons every 6 months divided by the number of SSS SPCs, where the target is 100%.

5.6 Intra-operative Performance Dashboard

Before FY2016, UHPS tallied perioperative BSC measures into electronic dashboards and pushed the results out to stakeholders. As of FY2016, dashboards are pulled on-demand by stakeholders and Figure 1 below depicts a dashboard query of January 2016 intra-operative scheduling metrics. For a given time period and a location, OR room, or SSS, the dashboard query will visualize intra-operative scheduling KPIs of *First Case of the Day On-time Starts* and *Subsequent On-time Starts*. Complete cases have been UHPS verified and the *Add-on Case* gauge reflects the criticality of 25% add-on case volume to resource capacities.

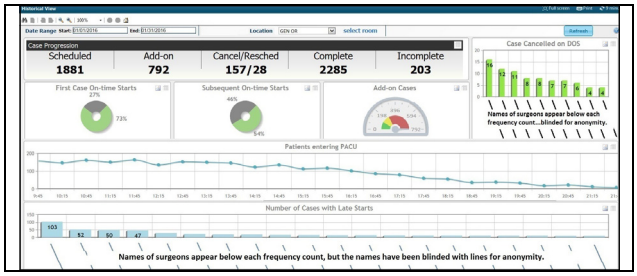

Figure 1 – Intra-operative Performance Dashboard

Case Cancelled on DOS is a Pareto chart identifying surgeons who have the most cases cancelled on days specific surgeries were scheduled to occur. The *Patients entering PACU* graph depicts cumulative peak volume times of OR patients entering post-anesthesia care over a 24-hour frequency. Lastly, the *Number of Cases with Late Starts* is a Pareto chart identifying surgeons with the highest frequency of surgical cases that did not start on-time.

5.7 KPI Data Visualization

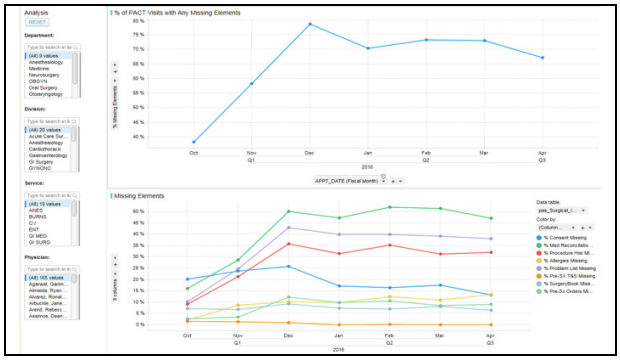

Figure 2 – PACT Missing Document KPIs

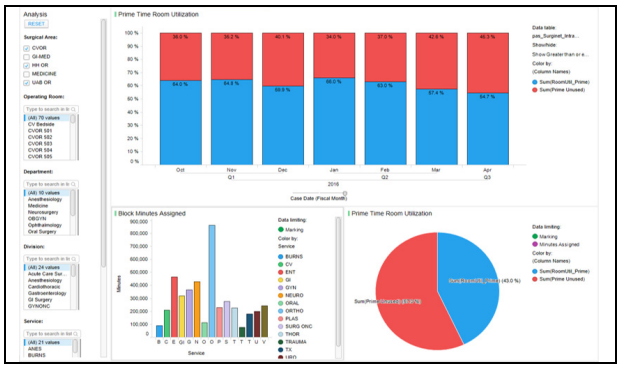

Figure 3 – Prime Time Utilization KPI

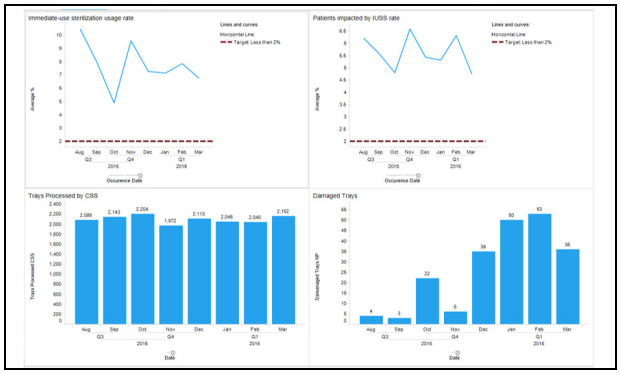

Figure 4 – Central Sterile Supply KPIs

Figures 2, 3, and 4 are examples of data visualization for pre-assessment, intra-operative, and central sterile supply sub-process KPIs. KPI filters are depicted on the left side of each figure. Figure 2 takes each of the 8 KPI categories of PACT *Missing Documents* required for complete documentation and uses line graphs to illustrate the magnitude of the top three missing document frequency counts above 30% on medical reconciliation, problem lists, and surgical procedure history versus the bottom five that were 15% or less for April 2016.

Figure 3 takes the *Prime Time Utilization* KPI and displays it as a stacked bar graph and a pie chart, along with a bar chart of modified block minutes assigned to each SSS. Lastly, Figure 4 displays *IUSS* KPIs via line graphs and *Tray Set* KPIs via bar charts. All of the perioperative sub-process KPI data residing in the CSIS data mart can be visualized like these examples.

6. Brief Summary and Discussion

The 35 perioperative KPIs represent distinct perioperative sub-process perspectives from which UHHS can gauge, visualize, and measure localized performance while providing the opportunity to drill down to potential problem root causes within a given sub-process rather than identifying and addressing associated symptoms downstream. In regards to a balanced scorecard approach [16], 13 of the KPIs reflect financial perspectives (e.g. 37.1%), 14 reflect quality of the process (e.g. 40%), and 8 reflect satisfaction of the customer (e.g. 22.9%). Similarly, all 35 KPIs provide a learning perspective by dividing the perioperative process into sub-processes for evaluation as to how each supports specific patient end-state goals. Furthermore, the perioperative process complexity [12] breakdown into component sub-processes demonstrates a proven approach to understanding complexity by reducing the perspective of the phenomenon into smaller more manageable and comprehendible units (e.g. sub-processes). Hence, the BPM taskforce's charge to create actionable information to support initiatives at the operational, tactical, and strategic levels requires a periodic iterative review of KPIs due to anticipated improved understanding of specific sub-process relationships and the need to revise existing KPIs to better reflect the improved understanding. To this end, periodic KPI reviews and revisions provide continuous process improvement opportunities for the perioperative sub-processes and overall process.

7. Conclusion

This study highlights multiple scorecard metrics from each perioperative sub-process (e.g. pre-assessment, pre-operative, intra-operative, post-operative, and ancillary central sterile supply activities), demonstrates how the metrics are applicable as KPIs, and defines how each perioperative sub-process supports specific patient end-state goals. Empowered individuals, integrated IS, and a holistic framework for analysis, evaluation, and synthesis of end-to-end process measures prescribed an a priori environment for replication and use. Moreover, BPM practices were adaptable to explain overall perioperative complexity and improvement efforts by focusing on the sub-processes. The cycle of analysis, evaluation, and synthesis also reinforced communication and stimulated individual as well as collective organizational learning.

Our case study contributes to the healthcare IT literature by examining how continuous process improvement is applicable to BPM practices of establishing KPIs as well as the management of the perioperative process nested within the hospital environment. This paper also fills a gap in the literature by identifying sub-process KPIs to help explain perioperative complexity and how process metrics as data are both a performance measure and management tool.

This study was limited to a single case, where future research should broaden the focus to address this issue along with others that the authors may have inadvertently overlooked. The case examples presented in this study can serve as momentum for the BPM and KPI creation and use in healthcare methodology, comprehension, and extension. The study's results should be viewed as exploratory and in need of further confirmation. Researchers may choose to further or expand the investigation, while practitioners may apply the findings to create their own version of BPM and KPI use within the hospital environment.

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