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# A Case Study Perspective toward Data-driven Process Improvement for Balanced Perioperative Workflow

Jim Ryan
*Auburn University at Montgomery*, jryan@aum.edu

Barbara Doster
*University of Alabama Birmingham Hospital*, bdoster@uabmc.edu

Sandra Daily
*University of Alabama Birmingham Hospital*

Carmen Lewis
*Troy University*, cclewis@troy.edu

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Jim Ryan
Auburn University at Montgomery
jryan@aum.edu

Barbara Doster and Sandra Daily
University of Alabama Birmingham Hospital
bdoster@uabmc.edu

Carmen Lewis
Troy University
cclewis@troy.edu

**Abstract:** Based on a 143-month longitudinal study of an academic medical center, this paper examines operations management practices of continuous improvement, workflow balancing, benchmarking, and process reengineering within a hospital's perioperative operations. Specifically, this paper highlights data-driven efforts within perioperative sub-processes to balance overall patient workflow by eliminating bottlenecks, delays, and inefficiencies. This paper illustrates how dynamic technological activities of analysis, evaluation, and synthesis applied to internal and external organizational data can highlight complex relationships within integrated processes to identify process limitations and potential process capabilities, ultimately yielding balanced workflow and improvement. Study implications and/or limitations are also included.

## INTRODUCTION

The perioperative process yields patient end-state goals: (1) a patient undergoes a surgical procedure; (2) minimal exacerbation of existing disorders; (3) avoidance of new morbidities; and (4) subsequent prompt procedure recovery (Silverman & Rosenbaum, 2009). To these end-state goals, a hospital's perioperative process provides surgical care for inpatients and outpatients during pre-operative, intra-operative, and immediate post-operative periods. Accordingly, the perioperative sub-processes (e.g. pre-operative, intra-operative, and post-operative) are sequential where each activity sequence paces the efficiency and effectiveness of subsequent activities. Furthermore, perioperative sub-processes require continuous parallel replenishment of central sterile supplies and removal of soiled materials. Given the multiple sub-processes and associated dynamics, Fowler et al. (2008) views a hospital's perioperative process as complex and the workflow complexity as a barrier to change and improvement. Nonetheless, integrated hospital information systems (IS) and information technology (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 (Dougherty & Conway, 2008).

The challenge of delivering quality, efficient, and cost-effective services affects all hospital stakeholders. Perioperative workflow tightly couples patient flow, patient safety, patient quality of care, and hospital stakeholders' satisfaction (i.e. patient, physician/surgeon, nurse, perioperative staff, and hospital administration). Consequently, implementing improvements that will result in timely patient flow through the perioperative process is both a challenge and an opportunity for hospital stakeholders, who often have a variety of opinions and perceptions as to where improvement efforts should focus. Furthermore, perioperative improvements ultimately affect not only patient quality of care, but also the operational and financial performance of the hospital. From an operational perspective, a hospital's perioperative process requires multidisciplinary, cross-functional teams to maneuver within complex, fast-paced, and critical situations—the hospital environment (McClusker et al., 2005). Similarly from a hospital's financial perspective, the perioperative process is typically the primary source of hospital admissions, averaging between 55 to 65 percent of overall hospital margins (Peters & Blasco, 2004). Macario et al. (1995) identified 49 percent of total hospital costs as variable with the largest cost category being the perioperative process (e.g. 33 percent). Managing and optimizing a quality, efficient, flexible, and cost-effective perioperative process are critical success factors (CSFs), both operationally and financially, for any hospital. Moreover, increased government and industry regulations require performance and clinical outcome reporting as evidence of organizational quality, efficiency, and effectiveness (PwC, 2012).

This 143-month longitudinal case study covers a clinical scheduling IS (CSIS) implementation, integration, and use within an academic medical center's perioperative process. Empowered individuals driven by integrated internal and external organizational data facilitate the case results. The resulting systematic analysis and subsequent contextual understanding of the perioperative process identified opportunity for improvement. Specifically, the

extension of data mining into the analysis and evaluation process of CSIS' data feedback from particular perioperative sub-processes provides the framework for the discovery and synthesis of redesign and reengineering within perioperative workflow to yield continuous process improvement. This paper investigates the research question of how data-driven continuous improvements can balance perioperative sub-process workflow to improve overall patient flow. Furthermore, investigation of the research question in this paper explains how analysis of perioperative performance metrics (e.g., key performance indicators), evaluation of perioperative sub-process constraints and capabilities, and synthesis of perioperative sub-process redesign implemented to balance perioperative workflow can attain: (1) improved workflow, efficiency, and utilization; (2) tighter process to hospital IS coupling; and (3) patient care accountability and documentation. This study highlights operations management practices of continuous improvement, workflow balancing, best practices, process reengineering, and business process management within a hospital's perioperative process. Measured improvements across intra-operative, pre-operative, post-operative, and central sterile supply also distinguish complex dynamics within the perioperative sub-processes nested in the hospital environment.

The following sections review previous literature on data design and data mining, process redesign, business process management, and perioperative performance metrics. By identifying a holistic model for evaluation, analysis, and synthesis between data and process design, this paper prescribes an a priori environment to support continuous process improvement. Following the literature review, we present our methodology, case study background, as well as the observed effects and analysis discussion of the continuous improvement and workflow balancing efforts. The conclusion addresses study implications and limitations.

## LITERATURE REVIEW

First mover advantage on innovations, adaptation of better management practices, industry competition, and/or government regulations are examples of the many factors that drive process improvement. Traditionally, the hospital environment lacked similar industrial pressures beyond government regulations. However, hospital administration currently face increasing pressure to provide objective evidence of patient outcomes in respect to organizational quality, efficiency, and effectiveness (CMS, 2005; CMS, 2010; PwC, 2012), all while preserving clinical quality standards. Likewise, hospitals in the United States must report and improve clinical outcomes more now due to the American Recovery and Reinvestment Act of 2009, the Joint Commission on Accreditation of Healthcare Organizations (TJC), and the Centers for Medicare & Medicaid Services (CMS). These performance and reporting challenges require leveraging information systems (IS) and technologies (IT) to meet these demands.

Hospital administrators and medical professionals must focus on both the patient quality of care as well as management practices that yield efficiency and cost effectiveness (PwC, 2012). To this end, operations management practices of continuous improvement, best practices, process reengineering, workflow balancing, and business process management (BPM) provide improvement approaches (Jeston & Nelis, 2008; Kaplan & Norton 1996; Tenner & DeToro, 1997). However, such approaches yield significant variations in implementation success.

### Data, Design, and Data Mining

Data is a prerequisite for information, where simple isolated facts give structure through IS design to become information. Early in the IT literature, embedded feedback as a control to avoid management misinformation was proposed in IS design (Ackoff, 1967). Likewise proposed was the selection and supervision of defined data as key performance indicators (KPIs) to assist management in qualifying data needs to monitor CSFs that subsequently manage organizational action (i.e. business processes) through IS feedback (Munroe & Wheeler, 1980; Rockart, 1979; Zani, 1970). Similarly, the perioperative process is becoming increasingly information intensive and doubt exists as to whether perioperative process management is fully understood to meet the increasing hospital environmental demands for value and cost management (Catalano & Fickenscher, 2007). Understanding how IS design and particularly how CSIS design embeds processes into data input and information output is a first step toward understanding data as a resource for heuristic development (Berrisford & Wetherbe, 1979).

Given that people perform organizational action, people develop IS, people use IS, and people are a component within IS (Silver et al., 1995); understanding the human mind is a requisite in understanding how organizational action via CSIS occur. Ackoff (1988) proposed a hierarchy of the human mind, where each category is an aggregate of the categories below it. Wisdom descends to understanding, knowledge, information, and then data. Other

authors of knowledge management literature share similar hierarchical views of human mind content (Earl, 1994; Davenport & Prusak, 1998; Tuomi, 2000).

Achieving wisdom requires successively upward movement through the other four human mind categories, with each level drawing content from prior levels. Data, information, knowledge, and understanding relate to past events and wisdom deals with the future as it incorporates vision and design.

The IT literature contains volumes of studies to offer opinions on system design. For this study, the intent is to provide a basic understanding of system design activities and substantiate the need for iterative improvement through heuristic development. Blanchard and Fabrycky (2010) recognize system design as a requisite within the systems life cycle where technological activities of analysis, evaluation, and synthesis integrate within iterative applications to minimize systems' risk from entropy, obsolescence, and environmental change.

Under ideal terms, an individual's wisdom recognizes that an IS solution can meet an organizational need. Subsequently, individual understanding and knowledge create the IS design, develop the IS, and implement it to meet the organizational need. This ideal situation is hypothetical, yet it does illustrate that during the design, development, and implementation stages of an IS (i.e. the systems life cycle), understanding, knowledge, and information are decontextualized into detached data and semantic data structures that are accessible by IS' processes. Tuomi (2000) called this set of human mind sequences a reversed hierarchy from the traditional model (e.g. data leads to information, on to knowledge, understanding, and wisdom).

Ackoff (1988) concluded that wisdom might well differentiate the human mind from the IS. Consequently, it is understanding and knowledge of the business process that system stakeholders use to develop information requirements and subsequent data requirements for IS design. Furthermore in reverse logic, it is data within the deployed IS that knowledge workers can use to assist in the organizational action of discovery to develop the knowledge and understanding of how to redesign business processes. Udell (2004) compared data to Play-doh—a tangible substance that can be squeezed, stretched, and explored directly. Witten and Frank (2005) define data mining as the process (i.e. automatic or semiautomatic) of discovering patterns (i.e. structure) within data, where the data already exists within the IS' databases in substantial quantities and the discovered patterns have organizational importance.

## Holistic Model for IS Design and Discovery

Data mining can explore raw data to find organizational and environmental connections (bottom up), or search data to test hypothesis (top down) producing data, information, and insights that add to the organization's knowledge (Chung, 1999). Figure 1 depicts data mining as discovery to use the traditional model of the human mind to churn data, existing within the IS, into information that leads on to knowledge, understanding, and possibly wisdom. Unfortunately, the healthcare industry has not fully embraced data as a resource and utilized data mining as a knowledge discovery tool (Wickramasinghe & Schaffer, 2006; Catalano & Fickenscher, 2007; Delen et al., 2009; Liu & Chen, 2009; Ranjan, 2009).

Figure 1 also depicts a proposed holistic model for IS design and discovery, which demonstrates the logic for mining perioperative data for business process analysis and redesign. The model incorporates the IT literature we have discussed over data as a resource, system design, and data mining. As stakeholders design a new IS, the system designers draw upon the hierarchy (Tuomi, 2000) to embed and encapsulate organizational actions into the new application. Collected data within an implemented IS represents organizational action (i.e. business processes). Captured and stored CSIS data reflects current and past perioperative actions (i.e. perioperative sub-processes and patient workflow) that is available for heuristic development.

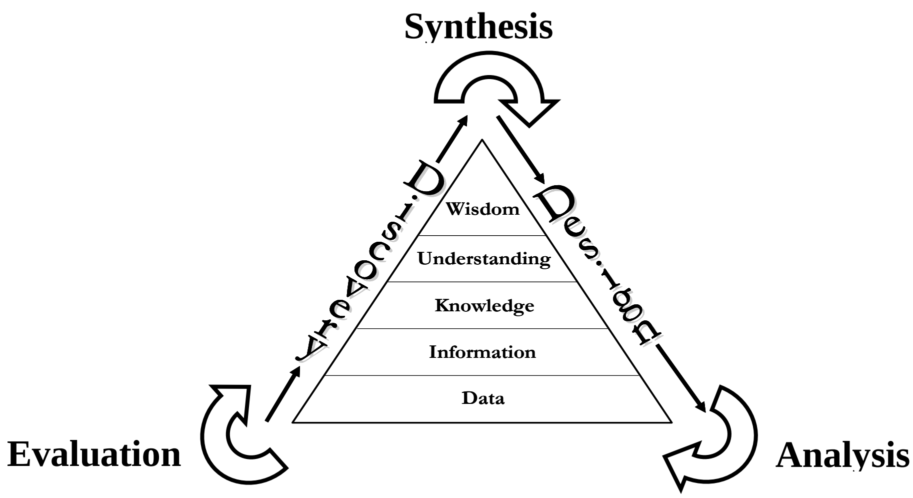



**Figure 1. Holistic IS Design and IS Discovery Model**
Adapted from R. L. Ackoff's (1989, page 3) hierarchy of the human mind

Data mining analyzes associations and data patterns for meaningful structure. Data mining in this study's context yields perioperative knowledge workers analyzing CSIS data for data discovery via online analytical processing (OLAP) and data visualization to identify data associations, clusters, and patterns. Using the reversed hierarchy (Tuomi, 2000), evaluation of the meaningful data pattern structures leads to synthesis (i.e. redesign) of improved or new organizational action. The model in Figure 1 depicts the iterative nature of system design and discovery that is similar to continuous improvement. With respect to this study, the applications of data mining techniques occur within a perioperative data mart (e.g. CSIS data archived to a separate database) for heuristic associations and clusters. OLAP and data visualization of perioperative data occurs via comparisons between capacity constraints and/or industry benchmarks to allow pattern recognition of anomalies, which in turn trigger and justify the synthesis of improvements. Specific anomaly examples are highlighted later under the observed effects section.

## Process Redesign

Specifically, this study examines process redesign approaches over continuous improvement, best practices, and reengineering (Tenner & DeToro, 1997). Continuous process improvement (CPI) is a systematic approach toward understanding the process capability, the customer's needs, and the source of the observed variation. The incremental realization of improvement gains occur through an iterative cycle of analysis, evaluation, and synthesis or plan-do-study-act (Walton, 1986) that minimize the observed variation. CPI encourages bottom-up communication at the day-to-day operations level and requires process data comparisons to control metrics. Tenner & DeToro (1997) views CPI as an organizational response to an acute crisis, a chronic problem, and/or an internal driver. CPI rewards are low (i.e. between 3 to 10 percent) with low risk and cost, easy implementation, and short durations. Within a CPI effort, 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 (Jensen & Nelis, 2008).

An alternative to CPI is best practices, which offers higher rewards (i.e. between 20 to 50 percent) with similar low risk, longer duration, as well as moderate costs and implementation difficulty (Tenner & DeToro, 1979). Camp (1995) differentiates best practices from benchmarking as finding and implementing industry standard practices that lead to superior performance as opposed to benchmarks that are metric standards or key performance indicators (KPIs). Best practice encourages the imitation or adaptation of external industry standards coupled with internal expertise. However, best practices requires more resource allocations versus CPI and a higher degree of understanding about the targeted process, which can lead management to under-estimate the resource requirements necessary for best practice success.

Hammer (1990) summarizes process reengineering in his article, "Reengineering Work: Don't automate, obliterate." Reengineering offers more radical redesign when compared to CPI or best practices (Tenner & DeToro, 1979), assuming more risk with greater reward potential. Hammer & Champy (1993, p.32) defined process reengineering as the fundamental rethinking and radical redesign to achieve dramatic improvements in critical measures of performance (e.g. cost, quality, service, and speed). Three key terms in the definition differentiates reengineering from CPI or best practices—fundamental, radical, and dramatic. Reengineering is a project-oriented effort that utilizes top-down improvement, managed by external and internal expertise, to achieve breakthrough improvement. Reengineering a process offers the highest reward potential, with upwards of 1,000 percent. However, the high potential rewards have very high risk, longer durations, as well as very high costs and the highest implementation difficulty (Tenner & DeToro, 1979). A reengineering project requires extensive resource allocations as opposed to CPI or best practices, as well as seeking an order of magnitude improvement by questioning the relevance of every activity and reinventing new ways to accomplish necessary work.

## Business Process Management (BPM)

Specifically, this study uses business process management (BPM) techniques to monitor process KPIs and measure process improvement within perioperative sub-processes. This study uses the BPM definition provided by Jensen and Nelis (2008, 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 process performance improvement that meets organizational objectives. To this end, BPM embraces the concept of CPI aligned to hospital strategy.

As BPM requires alignment to strategic objectives, a balanced scorecard (BSC) approach (Kaplan & Norton, 1996) embraces the ability to quantify organizational control metrics aligned with strategy across perspectives of: (1) financial; (2) customer; (3) process; and (4) learning/growth. Business analytics is the body of knowledge identified with the deployment and use of technology solutions that incorporate BSCs, dashboards, performance management, definition and delivery of business metrics, as well as data visualization and data mining. Business analytics within BPM focus on the effective use of organizational data and information to drive positive business action (Turban et al., 2008). The effective use of business analytics demands knowledge and skills from subject matter experts and knowledge workers. Similarly, Wears and Berg (2005) concur that IS/IT only yield high-quality healthcare when the use patterns are tailored to knowledge workers and their environment. Therefore, BPM success through BSCs and dashboards has a strong dependence on contextual understanding of end-to-end core business processes (Jensen & Nelis, 2008).

## Perioperative Key Performance Indicators (KPIs)

An integral part of CPI is process information before and after intervention. Hence, performance measurement is essential for purposeful BPM. As we previously mentioned, control feedback in IS avoids management misinformation (Ackoff, 1967) and IS feedback as KPIs (Munroe & Wheeler, 1980; Rockart, 1979; Zani, 1970) assists management in monitoring critical success factors (CSFs) for organizational action (e.g. business processes). However, the perioperative process is complex and information intensive (Fowler et al., 2008), so doubt exists as to whether perioperative management can meet increasing demands for cost effectiveness (Catalano & Fickenscher, 2007).

The following scenario illustrates the complexity, dynamic nature, and nested operational, tactical, and strategic relationships among perioperative KPIs. Operating room (OR) schedules are tightly coupled to an individual OR suite, patient, and surgeon. When preoperative tasks are incomplete or surgical supplies are not readily available at time of surgery, the scheduled case is delayed as well as the subsequent scheduled cases in the particular OR suite or for the particular surgeon. Operational and tactical KPIs in managing and optimizing a hospital's perioperative process include: (1) monitoring the percentage of surgical cases that start on-time (OTS), (2) OR turn-around time (TAT) between cases, (3) OR suite utilization (UTIL), and (4) labor hours per patient care hours or units-of-service (UOS) expended in surgical care (Herzer et al., 2008; Kanich & Byrd, 1996; Peters & Blasco, 2004; Tarantino, 2003; Wright et al., 2010). Tarantino (2003) noted how OR TAT and a flexible work environment are CSFs for physician satisfaction, which in turn is a CSF for hospital margin. Poor KPIs on operational and tactical metrics

(i.e., OTS, TAT, UOS, or UTIL) affect strategic CSFs of patient safety, patient quality of care, surgeon/staff/patient satisfaction, and hospital margin (Marjamaa et al., 2008; Peters & Blasco, 2004).

## RESEARCH METHOD

The objective of this study is to investigate how data-driven continuous improvements can balance perioperative sub-process workflow to improve overall patient flow through the analysis of perioperative performance metrics (e.g., key performance indicators), evaluation of perioperative sub-process constraints and capabilities, and synthesis of perioperative sub-process redesign. Furthermore, the continuous improvements to yield balance perioperative workflow can attain: (1) improved workflow, efficiency, and utilization; (2) tighter process to hospital IS coupling; and (3) patient care accountability and documentation. To this end, case research is particularly appropriate (Eisenhardt, 1989; Yin, 2003). An advantage of the positivist approach (Weber, 2004) to case research allows concentrating on specific hospital processes in a natural setting to analyze the associated qualitative problems and environmental complexity. Hence, our study took an in-depth case research approach.

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, having a robotics program encompassing over 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. During the 143-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.

This research spans activities from August 2003 through June 2015, with particular historical data since 1993. Perioperative Services (UHPS) is the University Hospital department that coordinates the perioperative process. Initially, the perspective of this research focused on University Hospital's perioperative process for its 32 general operating room (OR) suites in the main OR campus with Admissions; Surgical Preparations (PRE-OP) having 42 beds; OR Surgery, Endoscopy, and Cystoscopy; Post Anesthesia Care Unit (PACU) having 45 beds, and Central Sterile Supply (CSS). University Hospital administration consolidated all OR management and scheduling within the University Hospital Health System (UHHS) under UHPS in 2008, including cardio-vascular and off-site surgical clinics. In 2011, hospital administration added the Pre-admissions and the preoperative assessment consultation and test (PACT) clinic (Ryan et al., 2012) to UHPS' scope. Currently, UHPS manages 35 general OR suites (GENOR), 6 cardio-vascular OR suites (CVOR), 16 OR suites on the Highlands campus (HHOR), 2 OR suites at Women & Children (WaCOR), and 8 OR suites at the CAL Eye Foundation Hospital (CEFOR). In total, UHPS manages 67 OR suites having a combined FY2014 surgical case volume of 42,741.

## CASE BACKGROUND

UHPS implemented a new CSIS in 2003, after using its prior CSIS for 10 years. The old CSIS and its vendor were not flexible in adapting to new perioperative data collection needs. The old CSIS did not have an online analytical processing (OLAP) capability and the perioperative data mart was multiple Microsoft Access databases. The new CSIS from vendor C supports OLAP tools, a proprietary structured query language, and both operational and managerial data stores (i.e. operational data and a separate perioperative data mart). The new CSIS has flexible routing templates (i.e. from 4 to 36 segments to capture point of care data), customizable over generic and surgeon specific surgical procedures, documented in the CSIS as surgeon preference cards (SPCs). Since the new CSIS implementation in August 2003, University Hospital has maintained over 7,775+ SPCs across the surgical specialty services (SSS) represented in Table 1.

**Table 1. Surgical Specialty Services (SSS) with Surgeon Preference Cards (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 Maxil 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 |
| **Combined Total** | **7,778** |

### November 2004

University Hospital opened a new surgical facility in November 2004, with ORs located over two floors and CSS located on a third. The move expanded UHPS to cover an additional floor and nine additional ORs (i.e., 33% capacity increase). The new facility housed 40 state-of-the-art OR suites, each having new standardized as well as surgical specialty equipment. Within six weeks of occupying the new facility, a scheduling KPI reflected chaos. Surgical case OTS plunged to 18% during December 2004. Within a highly competitive hospital industry, having only 18% OTS was unacceptable, as 82% of scheduled surgeries experienced delays and risked patient care and safety.

In January 2005, UHPS expressed concerns before a quickly convened meeting of c-level executive officers and top representatives of surgeons and anesthesia. The meeting yielded a hybrid-matrix 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 staff). The executive team's charter was to focus on patient care and safety, attack difficult questions, and remove inefficiencies. No issue was off-limits.

University Hospital's executive team launched a process improvement effort in 2005 to address the perioperative crisis through soft innovations (Ryan et al., 2008). As a result, the executive team enlisted numerous task forces to address specific problems and/or opportunities, which was the foundation for their BPM approach. All initiatives were data-driven from the existing integrated hospital IS. Supporting data identified problem areas, strengths to highlight, and direction for improvement. Each identified problem area presented a new goal proposal and strategy for implementation.

## OBSERVED EFFECTS OF PERIOPERATIVE CPI

Since 2005, UHPS has focused on data-driven, systematic analysis of perioperative KPIs to gauge process variance and improve end-to-end workflow balance. Perioperative KPI feedback occurs at strategic, tactical, and operational levels via balanced scorecards and dashboards, aligned to hospital strategy (Ryan et al., 2014b). Using this BPM approach, perioperative CPI efforts have documented OR scheduling (Ryan et al., 2011a); hospital-wide electronic medical record (EMR) integration (Ryan et al., 2011b); preoperative patient evaluations (Ryan et al., 2012); radio-frequency identification (Ryan et al., 2013); CSS/OR supply workflow (Ryan et al., 2014a); unit-of-service charge capture via EMRs in the CSIS (Ryan et al., 2015); and instrument/device reprocessing and tracking (Ryan et al., 2015). Table 2 depicts 14 of the UHPS initiated CPI efforts as well as the specific associated sub-process workflow and implementation year from 2003 to 2015.

Due to the perioperative CPI efforts in Table 2, a balanced workflow exists upstream and downstream of the ORs, yielding improved patient flow throughout the perioperative process via Pre-admissions; Admissions; Surgical Preparations (PRE-OP); Central Sterile Supply (CSS); OR Surgery, Endoscopy, and Cystoscopy; as well as Post Anesthesia Care Units (PACU and PACU Phase-II). Surgical patients move through the perioperative workflow via events: (1) A clinic visit resulting in surgery scheduling, (2) PACT Clinic evaluation, (3) day of surgery admission, (4) PRE-OP, (5) Intra-operative, Endoscopy, or Cystoscopy procedure, (6) PACU, (7) PACU Phase-II, and (8) discharge or movement to a medical bed. The following sections highlight particular CPI efforts from Table 2 that reduced or eliminated bottlenecks, delays, and inefficiencies within a specific sub-process workflow. These particular CPI efforts on Table 2 have a green tone. Also noted on Table 2 with a red tone is the perioperative process governance change which facilitated and chartered all the CPI efforts.

**Table 2. Perioperative Continuous Process Improvement Timeline**

| Perioperative CPI Effort | Sub-process Workflow | Year |
|---|---|---|
| Implemented Clinical Scheduling IS (CSIS) | OR Surgery, ENDO, CYSTO, CSS | 2003 |
| Relocated ORs to NP Building | All | 2004 |
| Changed governance and initiated CPI efforts | All | 2005 |
| Heuristic/Modified Block Scheduling | OR Surgery, CSS | 2006 |
| Hospital-wide EMR Integration via Project IMPACT | PRE-OP, OR Surgery, PACU. CSS | 2007 |
| Established perioperative performance dashboards | All | 2008 |
| PACU Nursing Record | PACU | 2010 |
| Preoperative Assessment Consultation and Test (PACT) | Pre-admissions, PRE-OP | 2011 |
| Radio-frequency Identification Phased Implementation | OR Surgery | 2012 |
| Redesigned CSS / OR Supply Workflow | CSS, OR Surgery, ENDO, CYSTO | 2013 |
| PRE-OP and PACU Phase-II Nursing Records \| EMRs | PRE-OP, PACU Phase-II | 2014 |
| ICU/After-Hours PACU Overflow Record \| EMR | PACU | 2014 |
| Completed UOS CSIS charge capture via EMRs | PRE-OP, PACU, PACU Phase-II | 2014 |
| Redesigned Instrument/Device Reprocessing and Tracking | CSS, OR Surgery, ENDO, CYSTO | 2015 |

## Heuristic/Modified Block Scheduling

In November 2004, University Hospital allocated OR suites by SSS (i.e. for SSS listing refer to Table 1)—scheduling blocks of time for an OR suite between 7 a.m. to 4:30 p.m., regardless of the SSS caseload. Scheduling OR suites by SSS assigned blocks did not reflect actual SSS cases occurring within the scheduling blocks (i.e. the scheduling method did not reflect the OR data collected by the CSIS). The inefficient practice of block scheduling OR suites was directly attributable to University Hospital reaching 100 percent of OR capacity in December 2004, even though the new facility had increased existing OR capacity by 33 percent.

The actual OR hours used by SSS cases (i.e. specific SSS caseload) from the data mart were analyzed against OR hours allocated to each SSS block assignment. The resulting data patterns showed the need to re-design the OR scheduling process. Hence, UHPS discontinued straight SSS block scheduling. Given that physician satisfaction is linked to OR block scheduling by SSS (Peters & Blasco, 2004), block assignments were kept for outside-of-two-weeks planning purposes. However, review of SSS block hour assignments for OR suites occur every three months to reflect the actual SSS caseload history and to reflect individual SSS patient population, similar to marketing segmentation among demographic groups. The perioperative scheduling heuristic review process routinely modifies the block scheduling release rules by analyzing actual SSS caseload versus respective SSS block schedule. SSS with wide variability in scheduling are given consideration and a reduction in the number of early release blocks of OR suites.

| Scheduling Window | OR cases scheduled (%) | Cumulative OR Cases Scheduled |
|---|---|---|
| Beyond 14 days | 15.4% | 100.0% |
| 7 to 14 days | 14.2% | 84.6% |
| 1 to 7 days | 34.6% | 70.4% |
| 24 to 72 hours | 18.1% | 53.9% |
| Within 24 hours | 33.1% | 35.8 % |
| Day-of-surgery | 2.7% | 2.7% |

**Table 3. Heuristic / Modified Block Release Rules OR Scheduling Windows**

Current OR heuristic rules release unscheduled hours of any SSS OR suite block time within: (1) 7 days out to any SSS for robotic rooms, (2) 72 hours out to a surgeon within the same SSS, and (3) 48 hours out to any SSS. Furthermore, any SSS averaging more than 6% of unused OR suite hours per day-of-surgery are penalized during the next OR scheduling heuristic review. Table 3 lists the resulting scheduling windows of OR suite time and the corresponding percentage of OR cases scheduled in each window. Overall, 29.6% of the surgical cases performed were scheduled outside a week and only 2.7% of the cases were scheduled the day-of-surgery (e.g. emergency cases). Over two-thirds of surgical patients were able to schedule their surgical

procedure during the week of their surgery, which indicates the success of the heuristic/modified block release rules for scheduling flexibility.

## Hospital-wide EMR Integration via Project IMPACT

Project IMPACT, encompassed 11 task forces covering surgeon's orders (CPoE), clinical documentation, electronic medical records (EMRs), pharmacy, physician workflow, critical care, knowledge and content, technical metrics, communications, and testing / training / transition. The hospital-wide integration effort extended the CSIS across the perioperative sub-processes into ancillary hospital processes as well as perioperative tracking information on surgical patients (e.g. outpatient and in-patient) from Admissions through PACU discharge, including the in-patient's location after PACU discharge.

**Figure 2. CSIS Patient Status Boards in PACU**

**Figure 3. Family Link Boards in OR Waiting Rooms**

Beyond the enterprise application integration and software coding efforts, the most visible interface into the dissemination of perioperative process information across Admissions, PRE-OP, and PACU were electronic patient status boards. The deployed boards were in each functional area and the perioperative patient information adhered to HIPAA (e.g. Health Insurance Portability and Accountability Act of 1996) compliant formats. Figure 2 depicts Clinical IS departmental views of the electronic boards in PACU.

Additional flat panel displays on wall mounted information boards in each OR waiting room also provided patient tracking status for patient's family members or friends. Clinical staff give documentation to all patient family members, which explains the information boards and how to track your patient. Extending the clinical scheduling IS integration across the hospital gives all stakeholders access to the CSIS modules and tracking of surgical patients. The coded patient information boards in each OR waiting room also ensures patient privacy and HIPAA compliance. Figure 3 depicts patient information boards in one of the OR waiting rooms.

## Preoperative Assessment Consultation and Test (PACT) Clinic

Project IMPACT integrated EMRs from Admissions through PACU in 2007, but omitted parts of the preoperative evaluation documentation such as external medical records (MRs), preoperative assessment consultation (PAC), patient medical history (PMH), surgical history (SH), and former medication history (FMH). Figure 4 represents University Hospital's preoperative patient evaluation flow as of FY2010. Inefficient processes and decision points (see gray areas on Figure 5) delayed scheduled surgical case starts while PRE-OP staff obtained incomplete information. CSIS data reflected incomplete patient information delays for over one out of six surgical cases. As a result, UHPS launched a PACT Clinic task force to reengineer preoperative patient evaluations. Task force members visited four leading academic medical centers in the United States, as well as the two internal University Hospital sites, to gather a transparent and bottom-up view of different perspectives to preoperative evaluation processes. The external sites were located in: (1) Baltimore, MD; (2) Boston, MA; (3) Rochester, MN; and (4) Cleveland, OH.

Essential elements of the preoperative patient flow reengineering required EMR inclusion of all pertinent external records with the initial University Hospital referral as the preoperative evaluation appointment is made simultaneously with the initial surgeon appointment. Patient screening and standardized co-morbidity risk stratification occurs by telephone, the Internet, or by the surgical clinic making the referral. The best practices identified during the site visits afforded University Hospital the opportunity to reengineer their preoperative patient evaluation into a preoperative assessment, consultation, and treatment (PACT) clinic. A "clinic without walls' in that the PACT clinic exists only within the CSIS and evaluations can occur anywhere within University Hospital.

Figure 5 reflects the reengineered PACT Clinic workflow. All surgical patients receive a PACT Clinic evaluation prior to their scheduled procedures. During the same surgeon appointment, a comprehensive preoperative evaluation is performed and recorded via the PACT Clinic ambulatory EMR to include: a complete preoperative history and physical exam (H&P), confirmed informed consent and signed release on surgical procedure (ROS), optimized medications, and patient education. Prompt cardiac/diagnostic testing or cardiac/medical consultations may also occur during the PACT and surgical appointment.

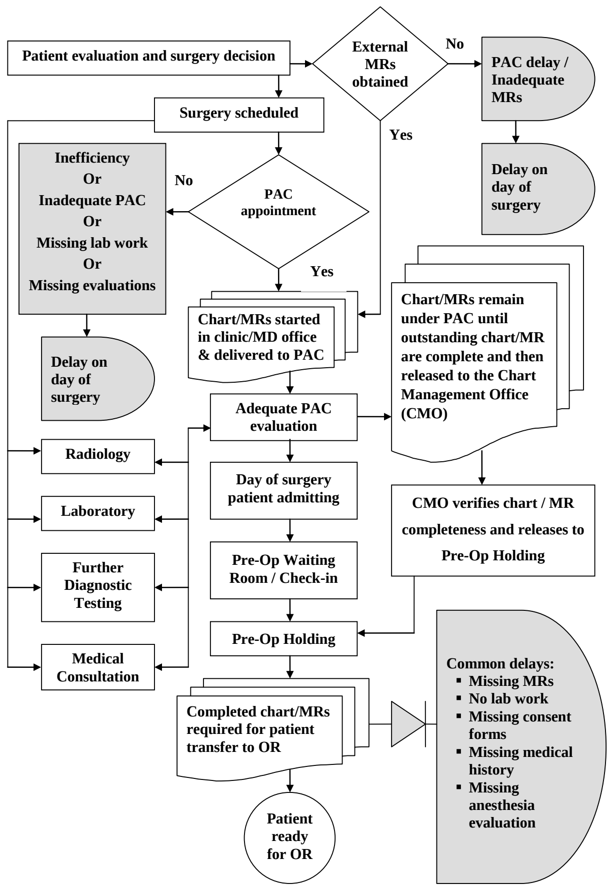



**Figure 4. Preoperative Patient Evaluation FY2010**

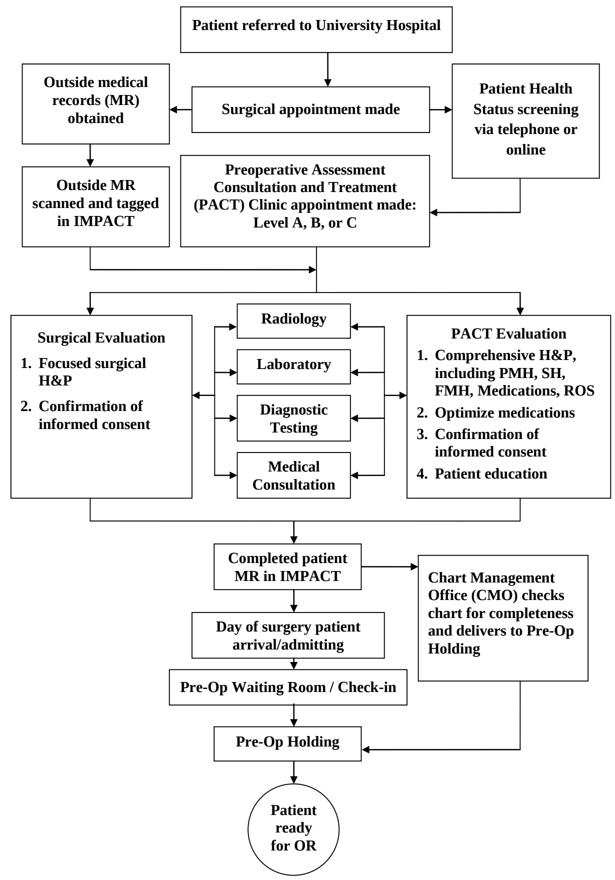



**Figure 5. Reengineered Patient Evaluations PACT**

## Redesigned CSS / OR Supply Workflow

Within the perioperative process, CSS pushes supply/instrument inventory to all ORs via three channels: 1) Case carts stocked specifically for a scheduled surgical case according to a specific SPC pick list (i.e. standardized supply/instrument bill of material); 2) standard supplies moved to an OR Core holding area on each OR floor; and/or 3) a specific requisition from OR staff. As early as 2006, UHPS noted multiple inventory receipts within the perpetual inventory for every inventory usage across particular perioperative supplies. In 2010, the executive team launched an initiative to assess the status of perioperative supply/instrument inventory and workflow due to increasing inventory values and slowing inventory turns metrics. The processes reviewed included: (1) inventory/Par level management, (2) replenishment processes, and (3) technology. The sub-process CSIS data reviewed identified inventory reduction as well as improvement opportunities to sustain reduced perioperative supply/instrument costs. The analysis of the assessment yielded the following themes:

- Scheduling inaccuracy due to lack of SPC maintenance and SPC inaccuracies.
- Work duplication in CSS case cart picking due to lack of trust in case scheduling and SPC.
- Charge capture issues where items left off the SPC may not get charged.

- Abundance of unused supply/instrument returns to CSS after case completion produce CSS inefficiencies.
- Breakdown in the supply workflow process effects overall inventory management.

Perioperative inventory turns had slowed to 3.7 against an industry average of 9, which represented 3.2 months supply. These KPIs reflected a breakdown in the supply/instrument workflow process. However, responsible actors (e.g. nurses and UHPS staff) interact among the OR case carts, OR Core inventory locations, and CSS. The BPM efforts among CSS and OR perioperative actors yielded a CSS/OR instruments/supplies workflow redesign to ensure effective instrument/supply inventory management. Likewise, a major task force recommendation was for scheduled surgical cases to have specific and required inventory information that includes accurate location, procedure, specific equipment, and supply needs from consistently updated SPCs.

A review of each of the SPCs yielded the removal of 1,937 SPCs, which reduced the SPC total by 20 percent (e.g. down to 7,778 from 9,315 SPCs) and scrubbed the SPC routings to ensure accuracy. Table 1 lists the frequency counts of current SPCs by SSS. The perpetual maintenance of SPCs, redesigning the perioperative supply workflow, decreasing closing suture and hand-held instrument inventories to industry standards, and managing perioperative inventory turns to 10 turns per 18 months targeted opportunities and evoked changes to the perioperative instruments/supplies inventory in excess of $6.6M over two years.

## Completed UOS CSIS charge capture via Nursing Records | EMRs

UHPS developed and configured unique CSIS nursing records as EMRs to manage patient care documentation across the perioperative workflow. UOS standards reflect perioperative staff labor hours associated with particular patient care activity units—one hour of patient care time, an Endoscopy procedure, or a sterilized instrument load. UOS metrics reflect patient care hours in each workflow segment. Table 4 lists the current CSIS nursing record documentation via EMR, the fiscal year of the UOS charge capture implementation, UOS standard labor hours, and UOS unit.

**Table 4. CSIS Nursing Record Documentation via EMR with UOS Standards**

| CSIS Documentation via EMR | FY Start | UOS Standard | UOS Unit |
|---|---|---|---|
| Ancillary Services Record - Family | 2007 | -- | -- |
| Preop Nursing Assessment | 2012 | 1.93 | Time |
| Endo Preop Nursing Record | 2014 | -- | Procedure |
| Endo Sedation Nursing Record | 2014 | 2.1 | Time |
| Regional Block Nursing Record | 2014 | 2.21 | Time |
| CSS | 2003 | 3.52 | Sterilized Loads |
| OR Nursing Record - CVOR | 2007 | 9.04 | Time |
| OR Nursing Record - Cardiac Perfusion | 2012 | 4.22 | Time |
| OR Nursing Record - GENOR | 2003 | 7.45 | Time |
| OR Nursing Record - ENDO | 2014 | 6.92 | Procedure |
| Ancillary Services Record – Room Cleanup | 2005 | -- | Time |
| PACU Nursing Record | 2010 | 2.71 | Time |
| ICU/After Hours PACU Overflow Record | 2014 | 2.71 | Time |
| PACU Phase-II Nursing Record | 2014 | 1.93 | Time |

Prior to the implementation of each real-time UOS charge capture via EMR documentation, perioperative staff manually batch-keyed UOS charges. As of March 2014, all CSIS nursing documentation via EMRs capture UOS charge data (e.g., UOS standard multiplied by UOS units) using the appropriate UOS standards and units. UHPS use the granularity in the aggregated UOS charge data for perioperative sub-process OLAP to offer contextual understanding to analyze sub-process variances, target improvement areas, and justify resource allocations. CSIS nursing records with UOS standards differentiate staffing labor hours for different levels of patient care (e.g. acute versus ambulatory).

Within PACU, the Phase-II and ICU nursing records also facilitate PACU workflow balancing and bed/resource utilization. Within PRE-OP and PACU, a finite number of acute care beds are valued resources, when compared to ambulatory care beds. The PACU Phase II Nursing Record allows ambulatory nursing documentation via the CSIS in any University Hospital ambulatory bed. Hence, PACU Phase II patients are transferable to PRE-OP or floor beds when PACU beds are in critical supply. Moreover, the ICU Overflow record identifies ICU bed capacity issues to avoid unplanned ICU discharges (Utzolino et al., 2010).

CSIS nursing records without UOS standards facilitate information and data collection on patient family/advocate, Endoscopy patient status, or surgical case OR suite TAT. All OR Nursing Record EMRs also provide documentation for OR suite OTS and UTIL measures.

## DISCUSSION OF PERIOPERATIVE CPI FOR BALANCED WORKFLOW

Figures 6 and 7 depict the resulting patient flow and integrated IS across University Hospital Health System (UHHS) per the CPI efforts described in table 2 of the observed effects section. As depicted in Figure 6, patient admissions are either medical or surgical. Surgical patient admissions occur via three venues: 1) diagnostic office visits to physicians within the TK Clinic, 2) non-UHHS physician referrals to the PACT clinic, or 3) patients seeking treatment through the Emergency Department. All surgical patients receive a PACT Clinic evaluation prior to their scheduled procedures. The PACT Clinic exists virtually in the CSIS, so the TK Clinic allocated physical space to facilitate PACT evaluations.

All IS depicted in Figure 7 are integrated with either bi-directional data exchange or uni-directional for limited exchange. The seven IS clustered around the CSIS are modules that directly support and extend the CSIS suite, where the Clinical Charting IS houses CPOE and EMRs. The HIPAA compliant Web services and biomedical device interface bus (BDIB) integrate ancillary IS, clinical data sensors, and bio-medical equipment. The institutional intranet serves as a single entry secured portal to extend each IS according to particular user-IS rights and privileges negotiated via user authentication.

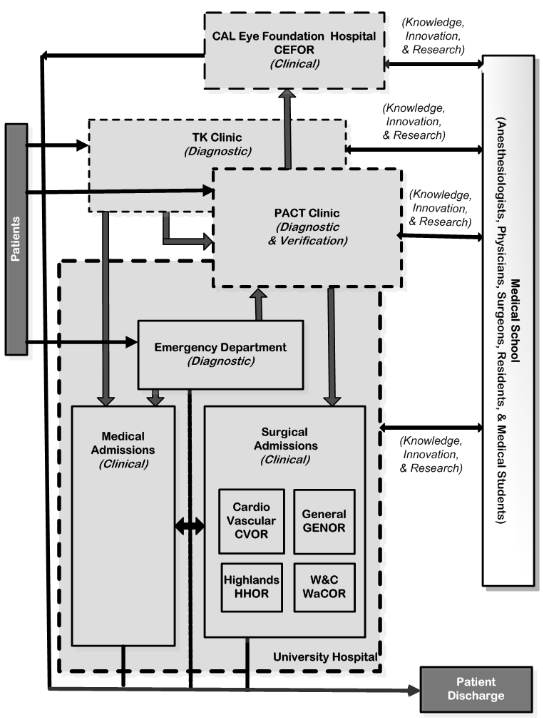



**Figure 6. UHHS Patient Flow**

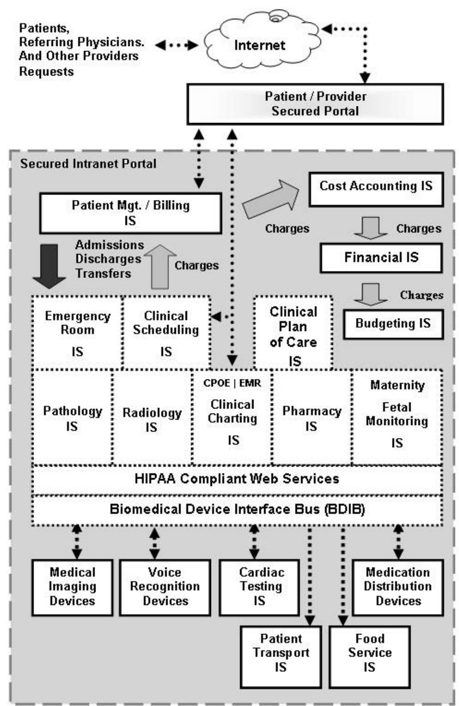



**Figure 7. UHHS Integrated IS**

### Balanced Workflow Results Achieved

Figure 8 depicts CPI efforts to achieve perioperative workflow balancing across sub-processes of pre-operative, intra-operative, post-operative, and CSS. The five CPI efforts described in the observed effects section removed inefficiencies and delays in particular perioperative sub-processes to support balanced patient flow through the perioperative process as well as information flow as depicted in Figure 7. The following discussion explains the holistic impact of the workflow balancing efforts.

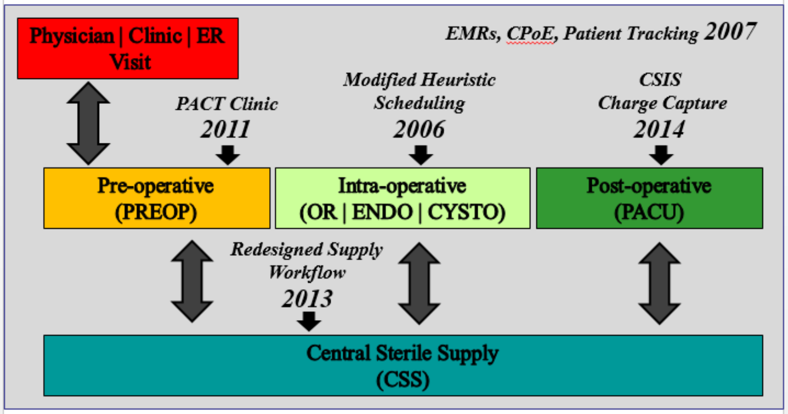



**Figure 8. Particular CPI efforts to balance patient flow through perioperative sub-processes**

UHPS is the primary source of admissions to University Hospital and the state of UHPS in early 2005 prohibited streamlining hospital-wide patient flow without first streamlining patient flow through the ORs (e.g. intra-operative). Likewise, the modified block scheduling via heuristic release rules improved the perioperative process planning where OR scheduling yielded a tighter coupling between projected versus actual surgical cases. The structural, process, procedural, and cultural changes achieved in UHPS intra-operative sub-processes over FY2005 and FY2006 allowed the executive committee to move forward in early 2007 to extend the CSIS across University Hospital and address hospital-wide patient flow.

Extending the CSIS across the entire perioperative process in FY2007 through Project Impact provided the basis for perioperative data collection and subsequent CPI efforts. However, Project IMPACT omitted many of the preoperative evaluation activities. The FCOTS KPI for FY2010 was 55.8 percent versus a target of 70 percent. Upon closer analysis of the surgical case delays, 17.5 percent of surgical delays (e.g. more than one out of six cases) were preventable through improved preoperative patient evaluation and improved electronic integration of preoperative documentation and communication. Hence, UHPS identified the need to address the chronic problems in preoperative patient evaluations through a process reengineering effort to yield the Preoperative Assessment, Consultation, and Test (PACT) Clinic to evaluate all surgical patients prior to day-of-surgery.

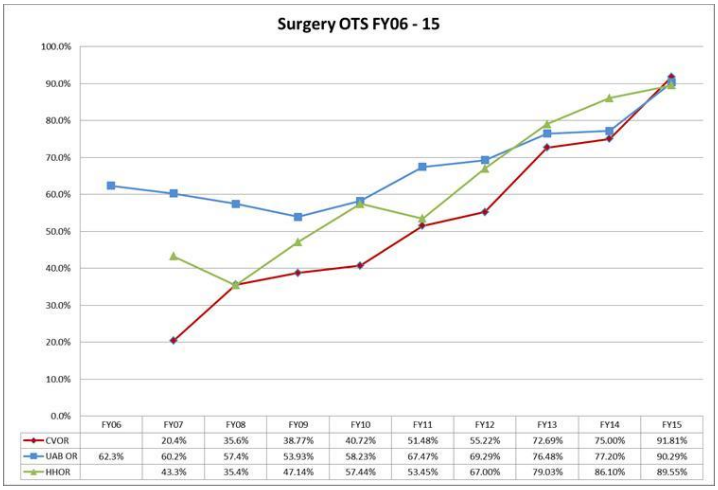
In May 2011, UHPS identified perioperative supply inventory levels of $15.5M, where inventory turns had slowed to 3.7 versus an industry average of 9, yielding 3.2 months supply. These KPIs reflected a breakdown in the CSS/OR workflow sub-processes. However, responsible actors (e.g. nurses and UHPS staff) interacting within and among the CSS and intra-operative sub-processes yielded a process redesign effort for an effective solution to improved instrument/supply inventory management and workflow.

Nursing documentation as EMRs with UOS standards differentiate staffing labor hours for different levels of patient care in PRE-OP and PACU. Within PACU, the Phase-II and ICU nursing records facilitate PACU workflow and bed/resource utilization, allowing more critical patients additional surgical recovery time. Moreover, the ICU Overflow record identifies ICU capacity issues to avoid unplanned ICU discharges, while allowing critical patients time to recover in both PACU and ICU. Also Nursing EMRs without UOS standards facilitate information collection on patient family/advocate, Endoscopy patient status, or surgical case OR suite TAT. Similarly, all OR Nursing Record EMRs provide documentation for OR suite OTS and UTIL measures (e.g. KPIs).

## Data Visualization of Balanced Perioperative Workflow

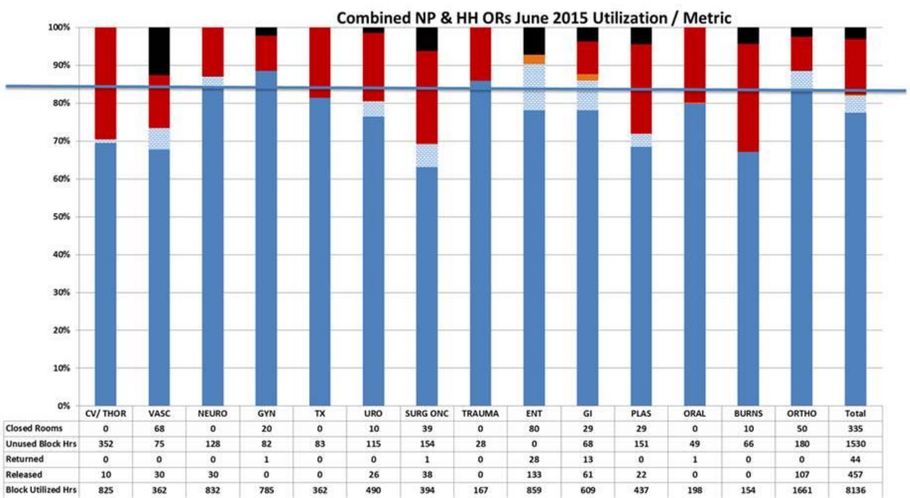
Figures 9, 10, and 11 depict aggregated surgical case (e.g. patient) data for perioperative process performance on OTS, UTIL/OTS/TAT, and UOS, respectively. Figure 10 depicts the yearly OTS averages for GENOR, CVOR, and HHOR surgical cases since FY2006 (i.e. UHHS fiscal year begins in October). The chart helps visualization of aggregate workflow performance improvement in providing efficient perioperative patient care while limiting unnecessary patient safety risk. From a BPM approach, these charts also help visualize where perioperative teams

and task forces should target CPI efforts. Since the full implementation of the PACT Clinic during FY2012, over 70% of surgical cases in GENOR, CVOR, and HHOR started on time. Prior to FY2013, the OTS 70% target was elusive, in part to incomplete PREOP documentation, which PACT Clinic evaluations eliminated (Ryan et al., 2012).




| | FY06 | FY07 | FY08 | FY09 | FY10 | FY11 | FY12 | FY13 | FY14 | FY15 |
|---|---|---|---|---|---|---|---|---|---|---|
| CVOR | | 20.4% | 35.6% | 38.77% | 40.72% | 51.48% | 55.22% | 72.69% | 75.00% | 91.81% |
| UAB OR | 62.3% | 60.2% | 57.4% | 53.93% | 58.23% | 67.47% | 69.29% | 76.48% | 77.20% | 90.29% |
| HHOR | | 43.3% | 35.4% | 47.14% | 57.44% | 53.45% | 67.00% | 79.03% | 86.10% | 89.55% |

**Figure 9. Surgical OTS FY 2006 to FY 2015**




| | CV/ THOR | VASC | NEURO | GYN | TX | URO | SURG ONC | TRAUMA | ENT | GI | PLAS | ORAL | BURNS | ORTHO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Closed Rooms | 0 | 68 | 0 | 20 | 0 | 10 | 39 | 0 | 80 | 29 | 29 | 0 | 10 | 50 | 335 |
| Unused Block Hrs | 352 | 75 | 128 | 82 | 83 | 115 | 154 | 28 | 0 | 68 | 151 | 49 | 66 | 180 | 1530 |
| Returned | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 28 | 13 | 0 | 1 | 0 | 0 | 44 |
| Released | 10 | 30 | 30 | 0 | 0 | 26 | 38 | 0 | 133 | 61 | 22 | 0 | 0 | 107 | 457 |
| Block Utilized Hrs | 825 | 362 | 832 | 785 | 362 | 490 | 394 | 167 | 859 | 609 | 437 | 198 | 154 | 1661 | 8136 |

**Figure 10. OTS/UTIL/TAT by SSS (June 2015)**

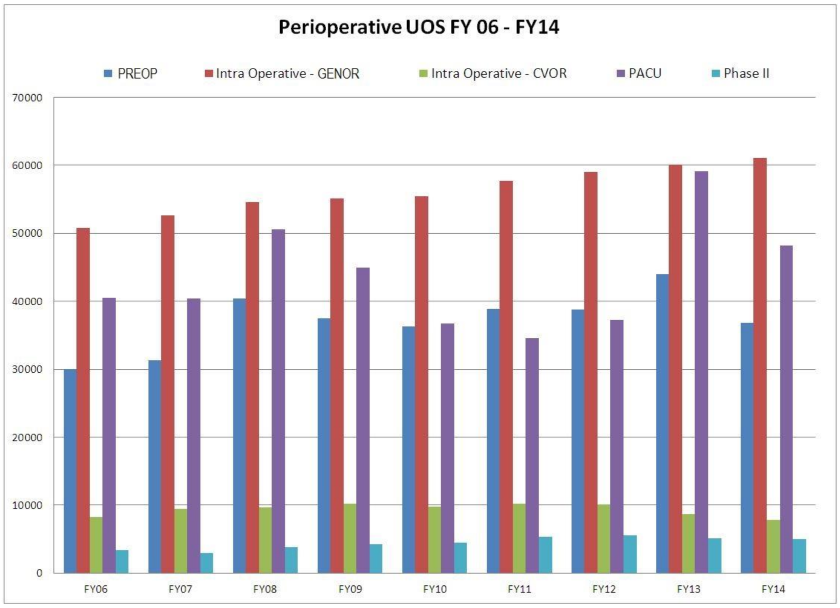



**Figure 11. Perioperative UOS FY2006 to FY 2014**

Figure-10 details UTIL, OTS, TAT, and modified- block released time (Ryan et al., 2011a; Peters & Blasco, 2004) by SSS for June 2015. The chart demonstrates granularity and dimensionality of aggregated patient data used in the systematic analysis of process performance. UHPS uses the detailed dimensionality of KPI data to identify specific performance results as well as target specific improvement opportunity.

Aggregated UOS data offers similar analysis capabilities for contextual understanding of patient care workflow dynamics and complexity. Figure-11 reports the UOS patient hours for GENOR and CVOR workflow since FY2006. In Figure-12, the FY2013 spike in PACU hours, up 12K hours (i.e., 32% increase) from FY2012, is attributable to ICU overflow patient care in PACU (i.e., extended-stay PACU patients waiting for an ICU bed or ICU patients over-nighting in PACU). UHPS use PACU beds to relieve Trauma-ICU and Surgical-ICU patient workflow congestion, moving PACU Phase-II patient care to PREOP beds. In December 2013 (e.g., FY2014), UHPS implemented Phase-II and ICU Overflow nursing records in PACU via the CSIS to document the workflow flexibility and capture UOS charges. As a result, FY2014 hours reflect the virtual PACU flexibility and tightened the CSIS-to-PACU workflow coupling.

### Goal Setting and Process Improvement Aligned to the Hospital Strategic Plan

Reach for Excellence (RFE) goals coordinate and align individual department and employee actions to the UHHS strategic mission and vision of becoming the preferred academic medical center of the 21st century. RFE goals are revised each year as quantitative targets, designed to measure objective outcomes. RFE goals must be aggressive and realistic, where fewer, rather than more, is better. RFE goals change focus as AMC21 progress advances. Consequently, each year UHHS administration reviews opportunities for improvement and identifies the most important outcomes needed. As a result, many perioperative KPIs and CPI efforts become RFE goals. As such, UHPS stakeholders focus on RFE process outcomes aligned to AMC21 strategy yielding aligned stakeholder action across departments and employees alike—a very powerful process management tool.

## CONCLUSION

Empowered individuals (e.g. nurses, surgeons, anesthesiologists, and perioperative staff), integrated IS, and a holistic model for evaluation, analysis, and synthesis of process data allows UHPS to take control and continuously improve the perioperative sub-processes to balance patient workflow. The perioperative KPIs provide feedback control loops to reflect the perioperative workflow balance as well as identify inefficiencies, delays, and areas for

improvement. The RFE goal layer affords UHPS opportunities for process improvement aligned to AMC21 vision. The balanced perioperative workflow improved efficiency, effectiveness, and utilization of .perioperative sub-process dynamics within pre-operative, intra-operative, post-operative, and central sterile supply (CSS) activities. Through the CPI efforts, the balanced workflow reflects tighter sub-process to hospital IS coupling as well as patient care accountability and documentation.

Enlisting CPI efforts at strategic, tactical, and day-to-day operations levels further educates hospital stakeholders on the benefits of integrated IS for process measurement, control, and improvement. The cycle of analysis, evaluation, and synthesis reinforces communication and stimulates individual as well as collective organizational learning.

Our case study contributes to the healthcare IT literature by examining how data mining, business analytics, process redesign, and process management are applicable to the hospital environment. This study prescribes an a priori framework to foster their occurrence. This paper also fills a gap in the literature by describing how hospital process data is both a performance measure and a management tool. Furthermore, this study highlighted the complexity and dynamics with the perioperative process.

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 healthcare CPI and balanced workflow 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 CPI for balanced perioperative workflow.

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