Chapter 6

Cincinnati Children's Hospital Medical Center: Redesigning Perioperative Flow Using Operations Management Tools to Improve Access and Safety

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Waits, delays, and cancellations have become so common in health care that both patients and providers assume that waiting is an inevitable part of the process.[1] Nevertheless, such symptoms of disrupted patient flow through the health care system result in enormous frustration to patients, families, and staff. Disrupted patient flow has a negative effect on patient satisfaction, staff retention, referrals, and reimbursement, and, most importantly, it has a direct impact on patient safety. Patient congestion has been associated with treatment delays, medical errors, and unsafe practices that can lead to adverse events and poorer outcomes.[2–5] In addition, patients being placed on the wrong care unit or unable to transfer to the appropriate unit are precursor events to safety failures.

Cincinnati Children's Hospital Medical Center

Cincinnati Children's Hospital Medical Center, the only pediatric hospital in the greater Cincinnati area, serves as a primary referral center for an eight-county area in southwestern Ohio, northern Kentucky, and southeastern Indiana. In fiscal year 2008 (July 2007–June 2008), Cincinnati Children's had 27,392 admissions and 93,456 emergency department (ED) visits and performed 6,323 inpatient surgical procedures and 22,845 outpatient surgical procedures during 43,325 surgical hours in 20 rooms. The 25-bed pediatric intensive care unit (ICU) had an average daily census of 17 children in 2006, 20 in 2007, and 21 in 2008.

Identifying the Problem

Like other health care organizations, Cincinnati Children's has had problems with delays in care and poor patient flow through the system. As the hospital has grown and expanded, the number of referrals from across the United States and the world has increased, as has the complexity of the care required. Emergency surgeries were considered unpredictable and were done at the end of the day or forced into slots between scheduled cases. The result was a long list of add-on patients at the conclusion of the regular day and long waiting times for children with urgent needs. Complex cases were often done in the evening or at night, when resources were limited. The competition for available beds in the pediatric ICU sometimes resulted in patients being held in the ED or postanesthesia care unit, causing those locations to back up and causing elective surgeries to be delayed or cancelled. Patients sometimes were placed in beds that were not optimal for their condition. Wide swings in census were difficult to staff, resulting in long hours, fatigue, and reduced morale. Clinicians and families were left frustrated.

Cincinnati Children's has maintained a significant focus on transforming the care delivery system since the late 1990s.[6] In 2001, a new strategic plan aimed at dramatically improving the outcomes, value, and cost of care for children was launched. This plan committed the organization to sustaining breakthrough improvements in clinical outcomes, reducing medical errors, delivering cost-effective care, improving care coordination, and enhancing access to care and timeliness of services delivered. *Improving patient flow* was one of the six original strategic priorities established at a 2002 retreat attended by 100 faculty and organizational leaders.

Preliminary attempts to improve flow, such as increasing the staff in the ED to meet the expected increase in demand during bronchiolitis season, were made at the level of microsystems, the small work units that deliver the care that the patient experiences.[7] However, flow is a series of coordinated, interdependent systems, not the result of isolated independent systems. To truly change the way patients flowed through the care system, Cincinnati Children's chose to look outside health care to operations research methodologies widely used in many other industries, such as banking, insurance, manufacturing, transportation, military, and telecommunications.

The hospital's president and chief executive officer, James Anderson, along with the senior vice president for quality and transformation [U.R.K.], served as the project champions of the efforts to improve perioperative flow. In 2006, two of the authors [F.C.R., U.R.K] met Eugene Litvak, Ph.D. (Program for Management of Variability in Health Care Delivery, Boston University Health Policy Institute, Boston), who, with his colleagues, has studied the effect of variability in patient flow on hospital operations and has described two types of variation in the demand for health care services.[8] There is random—sometimes called natural—variation in the types of diseases or injuries patients present with, their severity of illness, and their arrival patterns. Random variation is beyond the control of the health care system and so cannot be eliminated, but it can be optimally managed. Nonrandom, or artificial, variation is related to the design and management of the way care is delivered or to the behavior of the primary health care providers. It is, thus, potentially controllable. When possible, nonrandom variability should be eliminated.[1] Research has shown that emergency presentations to the operating room (OR) follow a random demand pattern, while the day-to-day variation in elective surgical cases and scheduled requests for an ICU bed are artificial and controllable.[8,9] In addition, the effect of nonrandom, artificial variation on flow far exceeds the effect of natural variation.[8–10] Thus, patient flow can be improved by smoothing the surgical schedule.[1]

In the months preceding the start of this initiative, informal discussions among authors [F.C.R, U.R.K., P.J.C.] and leaders from the departments of surgery and anesthesia confirmed agreement that there were serious problems with patient flow in the OR. However, there was no consensus on the root of the problem. Without data to support opinions, delayed or postponed surgical cases were blamed on slow cleaning of rooms or late patients or surgeons. Because of the multilevel failure points, individual improvements, such as shifting cases or reorganizing the case schedule, that would transform the care in the perioperative area were common, but their lack of interdependent linkage meant that real improvement did not occur.

A New Start

To better serve patients, improve patient safety, and increase the efficiency and reliability of the care delivered,[11] in January 2007 Cincinnati Children's implemented a series of interventions to match demand and capacity to optimize timely, safe, and efficient care as patients flow through and between the Cincinnati Children's ED, perioperative services, or inpatient units, including the pediatric ICU and areas for diagnostic and therapeutic interventions. The specific goals of the interventions were to (1) identify and separate the urgent/emergent case flow from the elective surgical cases and to improve access and throughput and (2) smooth the inflow of elective admissions to the pediatric ICU to make bed occupancy more predictable. A prominent pediatric surgeon [F.C.R.], trained in improvement science, agreed to lead the flow initiative. He was supported by a small steering team, which included authors [E.A., A.M.A., C.A.B., P.J.C., K.R.H., B.L., J.W.M.-D., P.A.Y., U.R.K.] and James Anderson.

Measuring Patient Flow

The first step was to collect baseline data on the current flow through the OR and pediatric ICU. The importance of correct and precise data was recognized early in the project because the flow models were to be constructed on the basis of the case data analysis. Because much of the needed information was not automated, data had to be collected by hand to establish the project. When initial attempts to collect data by individuals without health care training proved to be unreliable, Cincinnati Children's began using in-house employees with previous experience in process improvement. Retrospective data had to be confirmed and new service data validated. This process was time-consuming, and its duration and intensity strained the improvement fabric of the perioperative area.

Outcomes measures were related to delay in the system and included the following:
- Volume of cases
- OR utilization (the percentage of available elective surgical time that rooms were used)
- Timeliness of add-on case (cases that required access to the OR within 24 hours and were not scheduled in advance) access to the OR (percentage of cases started within established goal time frames, measured from the time a case was requested until the time the case began)
- Percentage of days that the OR went over scheduled time
- Daily mean surgical elective cases in pediatric ICU beds
- Daily mean surgical elective cases in cardiac ICU beds (considered diversions)

Clinicians were also surveyed about their experiences with add-on ORs.

Measures are presented in monthly reports and annotated control charts that are provided to the multidisciplinary perioperative clinical system improvement team (*right*), and organizational leadership and are also posted on the hospital's patient safety intranet site.

To improve electronic data collection and direct improvement efforts, Cincinnati Children's retooled the OR scheduling system to ask important flow-related questions, increasing the amount of work required to schedule a case. The additional information added to the scheduling system included prophylactic antibiotic management, case grouping for urgent/emergent add-on cases, ICU bed need and predicted ICU stay, and floor bed need and estimated stay. This information was obtained from individual physician offices and clinics and sent to the same-day surgery center as faxed orders.

In September 2002, Cincinnati Children's moved to a new building, at which point it implemented a system to integrate clinical information that included computerized clinical order entry, clinical documentation, an electronic medication administration record, a data storage repository, and advanced clinical decision support. The medical center is now implementing a new core clinical and financial information system developed by a commercial vendor. Flow measures are being integrated into the information system, and some of them are expected to "go live" in January 2010.

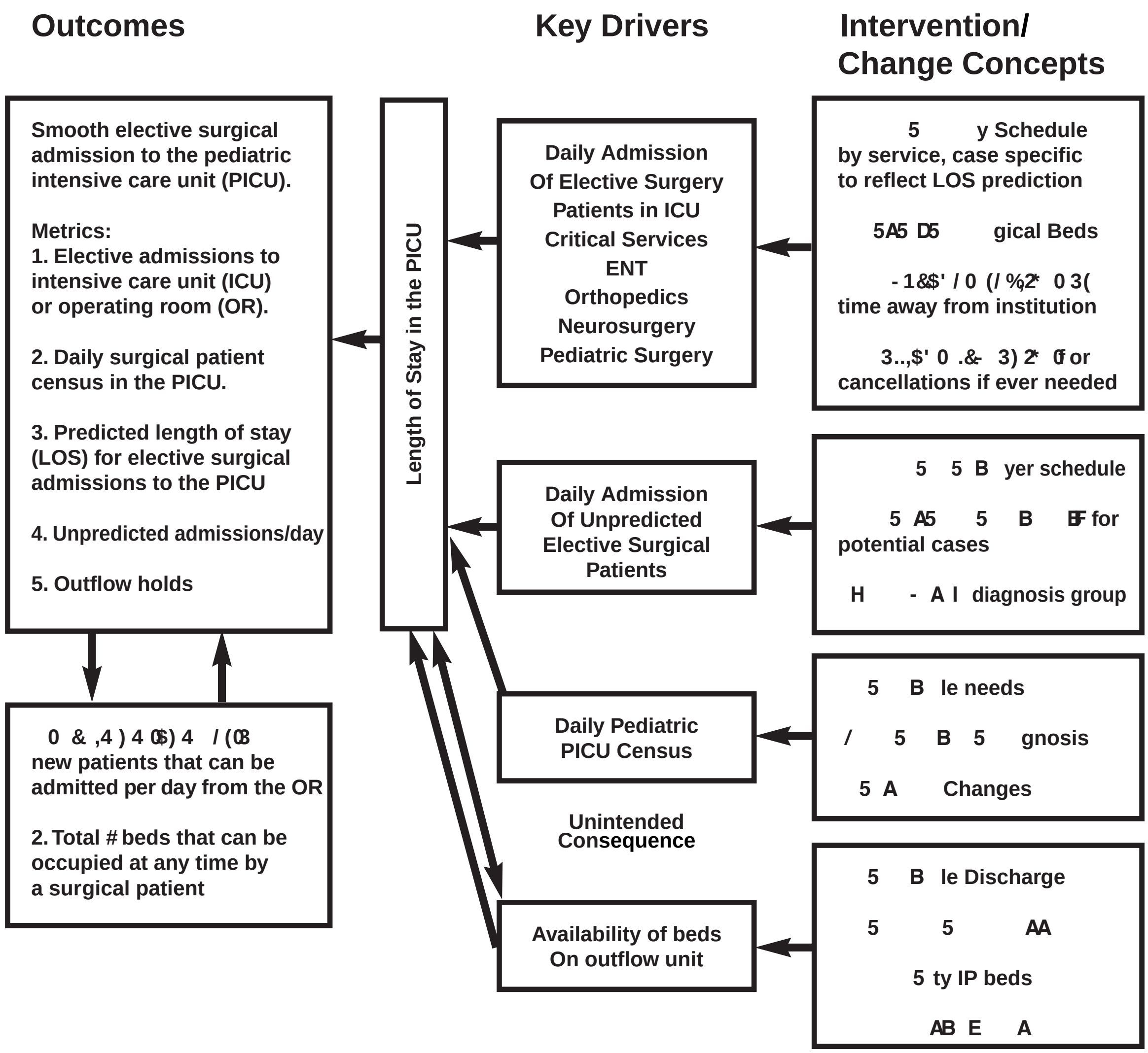
Implementation of Strategies

Planning. The multidisciplinary perioperative clinical system improvement team, formed in January 2005, was composed of key frontline staff from the departments of surgery, anesthesia, perioperative administration, and patient services. A quality improvement consultant and a data analyst from the division of health policy and clinical effectiveness provided support in the application of quality improvement science, data collection, and data analysis. The hospital's chief executive officer served as the team champion and ensured that the team received the help it needed to align the work with organizational priorities, overcome organizational barriers, identify resources, foster energy for change, and share results of activities.

To help build the will for changes to be made, experts from the Program for Management of Variability in Health Care Delivery came to Cincinnati Children's for a day of open sessions with senior leaders and all the surgeons. They made presentations at large- and small-group gatherings and one-on-one meetings. A major concern of the surgeons was that changes would be made to schedules that would result in a loss of patients and revenue; block times (designated times in specific ORs that are assigned or held for surgeons or surgical services for their exclusive use) would be changed, conflicting with established clinical office times; or conflicts would be created with preestablished academic commitments. Access to adequate block time to accomplish elective cases was also a major concern. The surgeons were assured that their time in the OR would not be limited. The goal was clearly articulated to be an improvement in access and care via control of unnatural variation in scheduling and urgent/emergent cases. Model data analysis was supplied by Dr. Litvak and his colleagues, and a close partnership with the program continued throughout the project. Existing Cincinnati Children's system analysts and data managers tracked changes in outcome measures over time. Although Cincinnati Children's did not hire any new employees to complete the project, it did redirect some of the other work that these individuals were responsible for so that they had the time and resources to work on this project.

As reported previously, key driver diagrams were developed to provide a framework of the proposed aim, key factors necessary for improvement, and potential change strategies to improve flow in the pediatric ICU (*see* Figure 6-1, page 100).[12]

Figure 6-1. Operating Room-to-ICU Flow Project: Key Driver Analysis



Key driver diagrams were developed to provide a framework of the proposed aim, key factors necessary for improvement, and potential change strategies to improve flow in the pediatric intensive care unit. LOS, length of stay; ENT, ear, nose, throat; IP, inpatient. The intervention OP Liberty IP beds refers to a plan to add inpatient beds to a large outpatient facility.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

The interventions were steps to define the urgency of need on the basis of medical condition, risk, and rapidity of progression. Historical data were used to identify "streams" (risk groups). These were then assigned real volume and OR case times, which were used in prediction simulations to calculate how many ORs would be needed to accommodate the caseload. The system built and then incorporated the rules for stratifying the cases and running the caseload on a daily basis. The follow-up system was designed to measure the results against the time- and safety-based goals.

Dedication of ORs to Urgent/Emergent Cases. To allow more efficient booking of cases, better reliability of room utilization, and improved schedule predictability, the team decided to separate the stream of elective cases from the stream of emergency add-on cases by dedicating ORs each day for urgent/emergent cases. The first step was to achieve consensus on a definition of urgent and emergent cases. Toward that end, the team established time goals for safe patient access to the OR on the basis of five levels of clinical need:

- A: Acute life-and-death emergencies—into the OR in < 30 minutes
- B: Emergent but not immediately life-threatening—into the OR in < 2 hours
- C: Urgent—into the OR in < 4 hours
- D: Semiurgent—into the OR in < 8 hours
- E: Add-on case to elective schedule—into the OR in < 24 hours

Remaining unscheduled cases that needed access to the OR within 24 hours to 7 days were designated as work-in cases.

Surgical Chiefs' Classification of Cases as A–E. Individual surgical chiefs for each surgical division were asked to classify all their cases according to the A to E categories. The improvement team then developed an urgency-based list of diagnoses and procedures, stratified according to the established time goals (*see* Table 6-1, below). This list was presented to providers as a guideline only, noting that medical judgment was still required. At the beginning of the initiative, the list was updated almost monthly. More recently, new cases are added as they are defined. In addition, the list is updated at the request of services if they feel that their patient needs have changed.

Determination of Number of ORs for Urgent/Emergent Cases. To balance the elective and emergency workloads, discrete-event simulation models based on queuing theory were used to determine the optimal number of ORs to set aside for urgent/emergent cases. Separate models were created for weekdays (7:00 A.M. to midnight), weekends, and nights (midnight to 7:00 A.M.). The models considered the cases included (A to E), the number of rooms available, the average wait times, the probability that one or more rooms would be available, and the utilization rate. Cases where data were missing were classified as type

Table 6-1. Guidelines for Surgical Case Grouping by Diagnoses/Procedures*

Guideline only: medical judgment required

Acute Life and Death Emergencies

A < 30 Minutes

Airway emergency (upper airway obstruction)
Cardiac surgery postoperative bleeding with tamponade
Cardiorespiratory decompensation (severe)
Liver transplant postoperative emergency
Malrotation with volvulus
Massive bleeding
Mediastinal injury
MuffipleTrauma - unstable or O.R. resuscitation
Neurosurgical condition w/imminent herniation

Emergent, but not immediately life threatening

B < 2 Hours

Acute shunt malfunction
Acute spinal cord corn pression
Bladder rupture
Bowel perforation, traumatic
Cardiac congenital emergencies w/hemodynamic or pulmonary instabilities
Compartment syndrome
Donor harvest
ECMO cannulation
Ectopic pregnancy
Embolization for acute hemorrhage
Esophageal atresia with tracheoesophageal fistula
Gastroschisis/omphalocele
Heart; heart/lung, lung, liver and intestinal transplants
Incarcerated hernias
Intestinal obstruction with suspected vascular compromise
Intussusception-irreducible
Ischemic limb/cold extremity (compromised arterial flow)
Liver/ Multivisceral /SI Transplant (when organ available)
Liver transplant with suspected thrombosis
Newborn bowel obstruction
Open globe
Orbital abscess
Pacemaker insertion for complete heart block
Replant fingers
Replant hand or arm
Spontaneous abortion
Tonsil Bleed
Torsion of testis/ovary
Vascular compromises
Wound Dehiscence

Urgent C < 4 Hours

Abscess with sepsis
Airway (non-urgent diagnostic L&B, flex bronch, non-symptomatic foreign body)
Appendicitis-with sepsis/rapid progression
Biliary obstruction non-drainable
Cardiac ventricular assist device placement
Cerebral angiogram for intracranial hemorrhage
Chest tube placement in patient w/unstable vital signs, increased work of breathing and decreased oxygen saturation
Contaminated Wounds-MultipleTrauma
Diagnostic/therapeutic airway intervention
Hepatic angiogram w/suspected vascular thrombus
Hip Dislocation
Intestinal Obstruction-no suspected vascular compromise
Kidney transplant (ORGAN AVAILABLE)
Liver laparotomy
Massive soft tissue injury
Nephrostomy tube placement in patient w/sepsis
Obstructed kidney (stones) with sepsis
Older child with bowel obstruction
PICC placement where patient has no access but needs fluids/medications urgently
Progressive shunt malfunction
Traumatic dislocation-hip
Unstable neurosurgical condition

Semi-Urgent D < 8 Hours

Abscess drainage
Appendicitis-stable/elective
Caustic ingestion
Chest tube in patient w/stable vital signs
Chronic airway foreign bodies
Closure abdomen - liver transplant
Coarctation repair in newborn
Esophageal foreign body without airway symptoms
GJ tube/NJ tube placement with no other nutrition access
Hematuria with clot retention
I&D abscess without septicemia
Joint aspiration or bone biopsy prior to starting antibiotic therapy
Kidney transplant (ORGAN NOT YET AVAILABLE)
Liver/ Multivisceral /SI Transplant (ORGAN NOT YET AVAILABLE)
Nephrostomy tube placement
Obstructed kidney without sepsis
Open fracture grade III
Septic joint

Add-on case to elective schedule

E < 24 Hours

(Needs to be done that day, but does not require the manipulation of the elective schedule, i.e., pyloromyotomy)
Broviac
Closed reduction
Eyelid/ canalicular lacerations
Facial nerve decompression
Femoral neck fracture
Liver biopsy
Mastoidectomy
Open fracture grade I/II
Open reduction of fracture
PICC placement - has other IV access
Retinopathy of prematurity treatment
Unstable slipped capital femoral epiphysis

*L & B, laryngoscopy and bronchoscopy; OR, operating room; PICC, peripherally inserted central catheter; IV, intravenous; ECMO, extracorporeal membrane oxygenation; SI, small intestinal transplant; GJ, gastrojejunal; NJ, nasojejunal; I & D, incision and drainage.

Source: Cincinnati Children's Hospital Medical Center. Used with permission.

B in the models to be conservative regarding meeting the clinical need.

Selection of Models. Simulation models were selected by matching the appropriate timely access and safety goals, with the recognition that appropriate access for urgent/emergent cases dictated a lower utilization rate in those rooms.

The OR simulation models selected were as follows:

• *A to E Cases, Weekdays, 7:00 A.M. (07:00)–11:59 P.M. (23:59):* The best model recommended that two ORs be set aside for any A to E case (*see* Table 6-2, below). With this scenario, wait times were predicted to be 7 minutes for A cases, 8 minutes for B cases, 9 minutes for C and D cases, and 17 minutes for E cases. The probability that one or more rooms would be available was 83%, and the utilization rate would be 42% for each room. It was estimated that wait times for A cases would exceed the stated limit about 1 time in 112 weekdays (21.4 weeks).

• *A to E Cases, Weekends.* The best model recommended that two ORs be set aside for 7:00 A.M. (07:00)–6:59 P.M. (18:59) on Saturday and Sunday, with an additional trauma/A room on call if needed. With this scenario, average wait times were predicted to be 8 minutes for A and B cases, 9 minutes for C cases, and 12 minutes for D and E cases. The probability of one or more rooms being available would be 87%, and the utilization would be 36% for each room.

• *Weekday Nights.* The best model recommended that one room be set aside for A to D cases, midnight (24:00)–6:59 A.M. (06:59). With this scenario, average wait times were predicted to be 22 minutes for A cases, 24 minutes for B cases, 27 minutes for C cases, and 31 minutes for D cases. E cases were excluded during this time period. The probability that one or more rooms would be available would be 81%, and the utilization rate would be 19%. It was estimated that a room will not be immediately available for an A case once every six months.

• *Weekend Nights.* The best model recommended that one room be set aside for A to D cases, 7:00 P.M. (19:00)–6:59 A.M. (06:59). Average wait times were estimated to be 19 minutes for A cases, 20 minutes for B cases, 22 minutes for C cases, and 24 minutes for D cases. E cases were excluded during this time

Table 6-2. Models for Cases A–E, Weekdays, 7:00 A.M. (07:00)–11:59 P.M. (23:59)

#	Cases Included	# Rooms	Average Waiting Times (minutes)	Probability 1 Or More Rooms Will Be Available	Utilization Rate	Recommendations/Considerations
1	A, B, C, D, "missing" treated as B	1	A: 45 B + missing: 53 C: 72 D: 101	60%	40%	NOT RECOMMENDED 1. Mean wait for A cases would exceed stated limit
2	A, B, C, "missing" treated as B	1	A: 21 B + missing: 24 C: 30	76%	24%	NOT RECOMMENDED 1) Low utilization rate
3	A, B, C (No "missing")	1	A: 17 B: 19 C: 22	81%	19%	NOT RECOMMENDED 1) Low utilization rate 2) Ignores "missing" cases
4	A – E, divided; "missing" treated as D	2 rooms: 1 room for A - C, 1 room for D,E, & missing	A: 18 B: 19 C: 24 D + missing: 70 E: 162	A – C room: 80% D – E room: 43%	A – C room: 20% D – E room: 57%	NOT RECOMMENDED 1) Low utilization rate in A – C room 2) Some cases with missing urgency codes may be more urgent than D
5	A – E together; "missing" treated as B	2 rooms that would take any A – E case	A: 7 B + missing: 8 C + D: 9 E: 17	83%	42%, each room	**RECOMMENDED** 1) Very good waiting times (Wait for A cases would exceed stated limit about 1X/112 weekdays (21.4 weeks)) 2) Treats missing cases conservatively 3) Highest utilization rate 4) Not very sensitive to small increases in case duration or case volume

Source: Cincinnati Children's Hospital Medical Center. Used with permission.

period. With this scenario, the probability that one or more rooms would be available would be 84%, and the utilization rate would be 16%. It was estimated that a room will not be immediately available for an A case once every five years.

Determining Surgeon Availability. Surgeon availability was addressed by individual divisions using different methods. For divisions with frequent add-on cases and urgent needs, such as pediatric general surgery, orthopedics, and otolaryngology, a dedicated surgeon was identified each day or week. Although this surgeon had other responsibilities, his or her primary responsibility was to be available for urgent and emergent cases. Divisions with lesser needs or a small staff component used an on-call system. Although their availability was more limited, the ability to clear other high-frequency add-ons from the schedule in a timely fashion made it more likely that a room would be available when their needs arose.

Testing of Models for the Pediatric ICU. A new prediction pathway for patients in the pediatric ICU was tested on the basis of the surgeons' predicted need for ICU care and length of stay (LOS) obtained from the baseline data. The prediction pathway originally served as a "single-shot" prediction model. That is, on the day the procedure was scheduled, surgeons were asked to make a one-time prediction of how long the patient was expected to be in the ICU. Ongoing interventions include making it available at the bedside as a computer model that can be used to update the predictions daily as a patient's care evolves. It now also stores information on the preferred location for patients after they leave the ICU to assist in demand-capacity matching to the floor beds.

Revision of the Surgical Scheduling System. The surgical scheduling system was revised so that the OR and ICU bed were scheduled simultaneously for surgical cases requiring an ICU bed. In addition, a projected LOS in the pediatric ICU was established when the case was initially scheduled. Posted beds were continuously monitored, and the computerized scheduling system restricted case scheduling if the pediatric ICU elective case limit for that day had been reached.

Morning Huddle. A morning huddle—a daily 6 A.M. (06:00) meeting of the chief of staff, manager of patient services, and representatives from the OR, pediatric ICU, and anesthesia—is held to confirm the plan for that day and anticipate the needs for the next day. Over time, this strategy has broadened to include discharge prediction of outflow units, allowing better proactive demand-capacity matching for patients transferred from the pediatric ICU to patient floors and for opening beds for the predicted incoming surgical patients.

Matching Capacity to Demand. On the basis of the OR models, 85% of all OR time was allocated to physician-specific blocks, two add-on rooms were set aside each day for A–E cases, and one room was set aside for work-in cases needing access in less than seven days (*see* Figure 6-2, page 104). Correct classification was confirmed by the surgical scheduler when the case was scheduled.

When the add-on/work-in room allocations were set, they were integrated with preexisting call schedule requirements (for example, Level 1 trauma room availability, specialty call, allowing a set plan for staffing the entire OR at all hours). The preestablished, agreed-on, safety-directed waiting times for add-on cases clearly identified the need for calling in on-call additional resources to meet the rare, but occasional, increased need. This removed the emotional component from calling in colleagues at night and on weekends because the decision was based on the mathematics of the urgent/emergent add-on system, not individual choice.

Results

Smoothing OR Flow

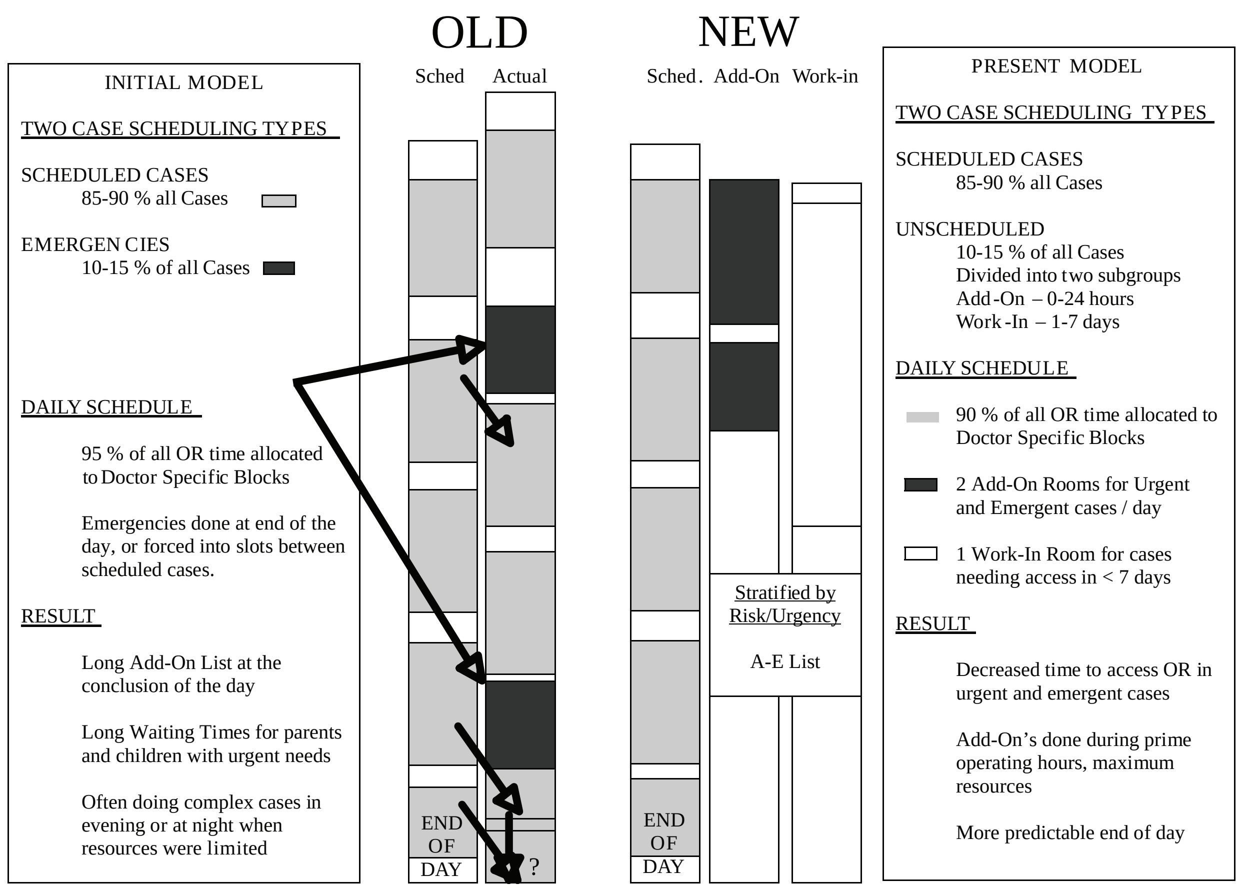
As a result of the redesign, weekday waiting times were decreased by 28%, despite a 24% increase in case volume (*see* Figure 6-3, page 105, which shows wait time for A cases; "Timeliness of add-ons," as listed on page 99). On the weekends, waiting times decreased by 34%, despite a 37% increase in case volume. Overall, growth in case volume was sustained at approximately 7% per year for the next two years ("Volume of cases").

Overtime hours decreased by an estimated 57% between September 18, 2006, and the first week of January 2007 ("Percent of days that the OR went over scheduled time"). If OR operating costs are estimated at $250/room hour, then these savings are equivalent to $10,750/week, or $559,000 annually.

The true value of redesign for increased efficiency can best be appreciated by contrasting it to the costs of building new resources. Throughput, the total number of case hours during a routine OR day, increased 4.8% ("OR utilization"). This is nearly equivalent to the addition of one more OR, without any of the associated capital or operating costs.

Initial improvements in staffing were achieved as late overtime rooms were no longer necessary. Emergency case volume was accommodated during prime working hours, decreasing the need for complex surgical intervention after hours. Since the initiation of the changes in 2006, overtime hours as a percentage of total hours decreased by 19% during fiscal year 2008 and an additional 15% during fiscal year 2009.

Figure 6-2. Comparison of the Old and New Surgical Scheduling Models



On the basis of the operating room (OR) models, 85% of all OR time was allocated to physician-specific blocks, two add-on rooms were set aside each day for A–E cases, and one room was set aside for work-in cases needing access in less than seven days.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

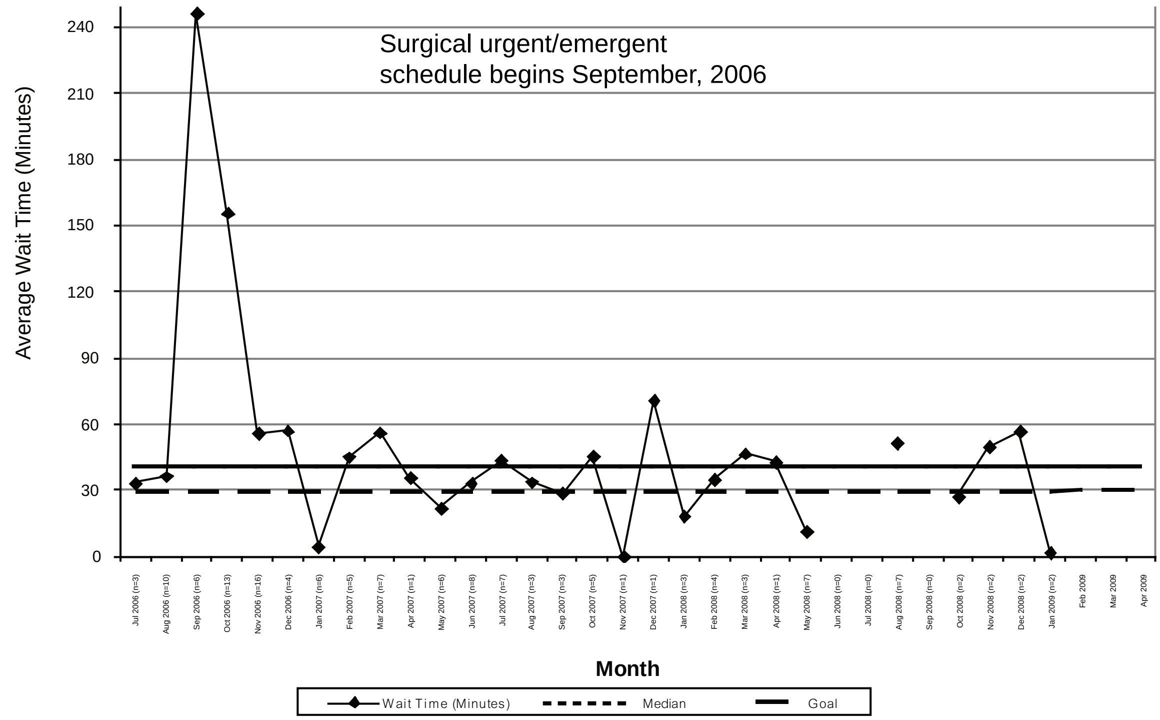
Although not formally measured, staff satisfaction appeared to improve using this model, as the end of the day was more predictable, emergencies were dealt with in a consistent fashion, and timely access improved staff interactions with families.

Smoothing ICU Demand

A second significant area for improvement of unnatural variability was the scheduling of surgical cases requiring a postoperative stay in the pediatric ICU. Because they represented a need for a limited and resource-intense bed, smoothing of inflow and predictable need allowed better access and planning for ICU services. Although elective surgical cases occupied only 20% to 30% of the pediatric ICU beds, they represented a significant and extremely variable portion of daily admissions and discharges, with significant variations in LOS associated with specific procedures (that is ICU bed turnover). The remainder of the admissions represented patients with multiple trauma or other ED cases and pediatric medical patients. These streams were most influenced by natural variation because they were not scheduled admissions.

Initial analysis of the elective pediatric ICU surgical population revealed three distinct groups, segmented by their predicted LOS (*see* Table 6-3, page 105). Because many of these admissions required short-term recovery observation and care after elective surgery, it was not surprising that this first group represented the greatest number of patients (61%), and their mean LOS was 1.27 days. The second, smaller group (28%) represented patients with intermediate LOS, occupying a pediatric ICU bed for an average of 3.72 days. The third group, even though they represented a small population numerically (11%), were long-stay patients. This group, which occupied beds for an average of 9.76 days and also had high variability in occupancy, proved to have the most significant impact on pediatric ICU flow. As can be seen in Figure

Figure 6-3. Add-on Access to Operating Room (OR) Within Accepted Time Frame: Wait Time for A Cases, July 2006–April 2009



As a result of the redesign, weekday waiting times decreased by 28%, despite a 24% increase in case volume.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

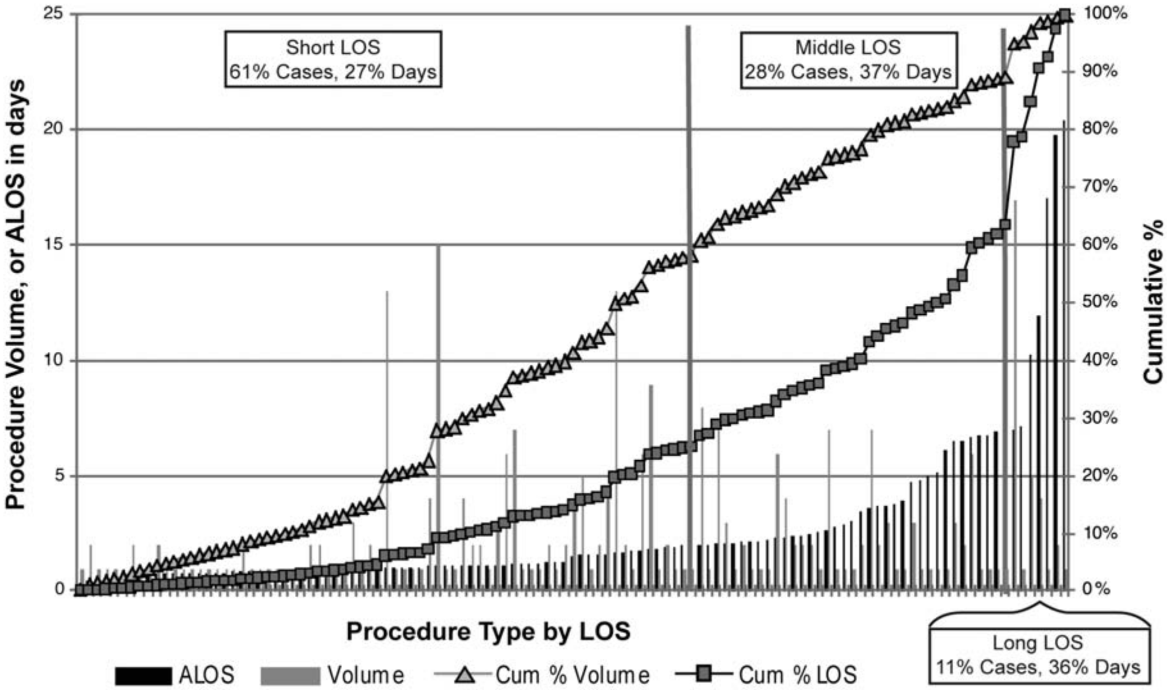
Table 6-3. Case Statistics by Category

Category	Total ICU Days	Case Counts	Average Length of Stay
Short	224.47	177 (61%)	1.27 (27%)
Medium	304.74	82 (28%)	3.72 (37%)
Long	302.56	31 (11%)	9.76 (36%)
Total	831.78	290	2.87

Source: Cincinnati Children's Hospital Medical Center. Used with permission.

6-4 (page 106), the long-stay patients had a greater bed occupancy impact than did the much more numerous short-stay patients. On the basis of an analysis of these groups, a numeric cap was defined to force spread and smoothing at the time of scheduling (*see* Figure 6-5, page 107). This capping model was initially established at five cases per day but has changed as pediatric ICU capacity has varied. Analysis of the long-stay cases showed them, in majority, to be related to complex airway reconstructions. The impact of these long-stay cases on pediatric ICU bed turnover was smoothed by an internal monitor in otolaryngology scheduling, where projected LOS was used to limit the number of occupied pediatric ICU beds for elective airway reconstructions to three on any given day. This spaced the elective long cases, decreasing their prolonged impact on pediatric ICU when excessive numbers were done in clusters. It is important to note that case volume and projected growth were anticipated and accommodated in these

Figure 6-4. Distribution of Procedure Volumes and Pediatric ICU (PICU) Average Length of Stay (ALOS)



These data, collected during a four-month period, indicate that the long-stay patients had a greater bed occupancy impact than the much more numerous short-stay patients. Each data point represents a separate patient on the x axis reviewed from the database of ICU admissions. Cum, cumulative.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

smoothing predictions. As a consequence, there has been no limitation of overall access and no cap on overall case volume. In fact, a 7% growth in operative volume has occurred throughout this time.

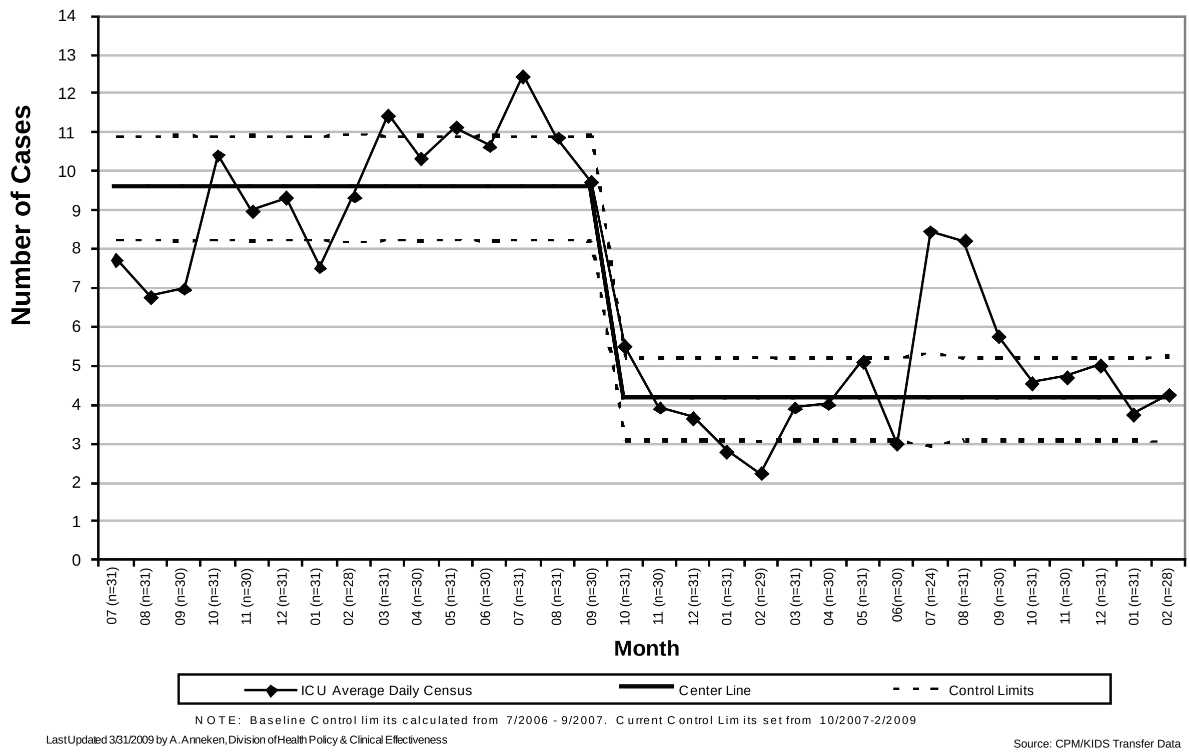
A benefit of elective case smoothing has been a decrease in the need to divert overflow cases into other ICU beds, primarily the cardiac pediatric ICU. Although this method is still used on occasion to accommodate demand, it is now uncommon (*see* Figure 6-6, page 108). In addition, the postanesthesia care unit was often used as a substitute overflow pediatric ICU. Because this unit does not have staff with the same level of experience as the pediatric ICU and the nurse–patient ratios are not as high, its interchangeability with the pediatric ICU was limited. Since decreasing the variation in scheduling, use of the postanesthesia care unit has been unnecessary, ensuring that all patients are in suitable ICU environments.

Before implementing these operations management strategies, cases were cancelled when ICU resources were not available for postoperative management. The policy at Cincinnati Children's is to never begin a case requiring ICU care if this resource is not predictably available. In the absence of the smoothing efforts, periodic high-volume influxes of elective patients, especially long-stay patients, would have a significant and long-standing impact on the availability of beds. Case cancellations have occurred a total of 10 times on 5 separate days in the past 2 years. When a rare cancellation is necessary, the service affected is rotated, and every effort is made to ensure that the case is rescheduled and completed within 24 hours.

Comments from Clinicians

After implementation, partners at the Management Variability Program asked clinicians a series of questions about setting aside ORs for add-on cases. A representative selection of their comments, which were almost uniformly positive, is shown in Table 6-4 (*see* page 109). The respondents felt that the changes had improved satisfaction for parents, their colleagues, and other OR professionals.

Figure 6–5. Xbar Chart of Change in Daily Mean Surgical Elective Cases in Pediatric ICU Beds, July 2006–February 2009



The xbar chart shows variability around the mean, so that the decrease, as shown, is equivalent to decreased variability of the process. The numeric cap was used to limit the peaks, which effectively smooths flow by spreading the cases to other, less-filled, days. This mechanism is in place as the case is booked, so a case cannot be booked on a day when the cap on elective cases is reached, and another day must be picked. Emergencies are still done as needed.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

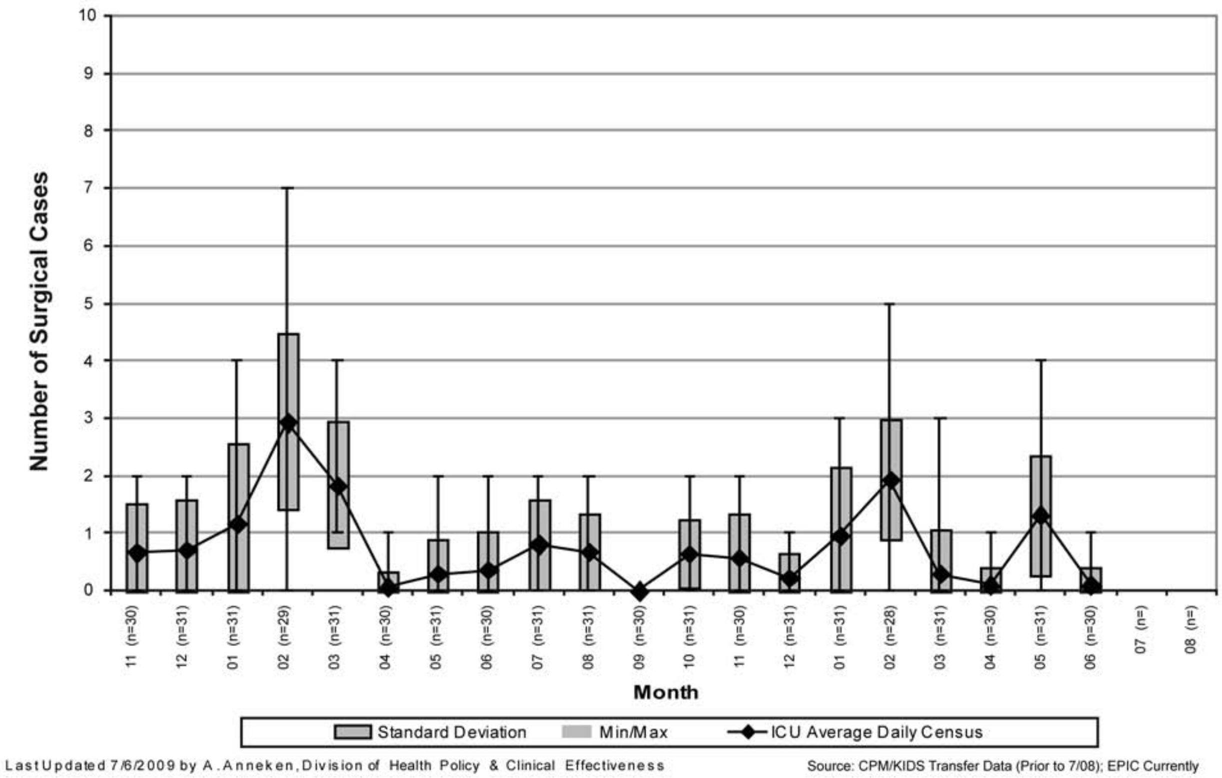
Discussion

Efforts at Cincinnati Children's highlight the contrasting approaches of building more resources (ICU beds, ORs) versus using operations management techniques to improve flow, with a strategy to grow programs and expand volume. Establishing improvement as the core business strategy is important to inspire and sustain improvement efforts throughout the organization.[13–15] In the past, most organizations responded to overcrowding, diversions, and delays with expensive rebuilding programs, creating more resources rather than improving utilization of existing resources. In this economically sensitive time, a strategy of building for success is doomed to failure. A more successful approach is to build resources and strategies to maximize their utilization and efficiency.

A health care system is not a machine; rather, it functions as a complex adaptive system.[16–18] It is complex because of the many interconnections between its many parts (for example, ORs, ICUs, ED, laboratories, nurses, physicians, specialists, health plans, accreditors, regulators). It is adaptive in that it is composed of people who can change their behavior. Like ecosystems, complex adaptive systems evolve, adapt, and respond. However, the way individuals in a complex adaptive system act and how that action changes the context for others is not always predictable or linear.[17–19]

Addressing flow is a difficult task because there are so many participants, with different perspectives and priorities. Flow streams need to be carefully identified, quantified, and managed. Flow decisions are important to good patient care and cannot occur by accident. Flow is a complex interaction between many

Figure 6-6. Daily Mean Surgical Elective Cases in the Cardiac ICU, November 2007–June 2009



Cardiac ICU stays are considered diversions; patients should be placed in the pediatric ICU.

Source: *Cincinnati Children's Hospital Medical Center. Used with permission.*

different factors in complex environments. The majority of unpredictable factors in flow are determined by the care providers. The use of appropriate operations management techniques allows health care providers to supply improved patient care, timely access to limited services, and patient-centered intervention using available resources by decreasing artificial, often provider-directed, variability.

The keys to improving flow at Cincinnati Children's included outstanding data and sound mathematical models to optimize patient care. The models allowed experimentation with the system variables "outside" the system. Clinicians were actively involved in project planning and the classification of cases according to the A–E categories. Ensuring surgeons that their time in the OR would not be limited was important to gain their support. The revised surgical scheduling system linked the surgical case to the need for an ICU bed, allowing for improved planning and flow in the pediatric ICU. The morning huddle allowed the varied participants to be aware of the daily status and to anticipate the needs for the next day. Throughout the entire project, Cincinnati Children's was supported by strong leadership committed to solve day-to-day issues as they arose and keep the organization focused on the long-term goals.

This project also resulted in a culture change in the surgical provider environment, improving mutual accountability, open communication, and team mentality. In the old system, access was primarily driven by the chronology of case booking—a first-come, first-served system. Although case urgency was considered, the time of case booking was the primary determinant in most instances. This system fostered the surgeon behavior of working urgent cases into the middle of the elective OR schedule, displacing elective cases into the later day and, often, the evening. Patient satisfaction and operative day prediction for staffing were compromised. In contrast, in the urgency-based add-on system, access is urgency directed and time-goal driven. This has improved not only timely access for all patients but has also decreased ED delays awaiting OR access and ensured urgent access to the most significantly endangered patients (classification A).

Table 6-4. Comments from Clinicians*

1. Did you experience any improvement (or other changes) in your work due to the recent creation of specific rooms for add-on cases? If yes, what kind of improvement?
"This is the best thing for ortho since I have been here. With the additional add-on rooms and our new first available surgeon policy, we almost always get our add-ons done in the early AM, which makes our families very happy. The weekends are unbelievably good. We get our case done early, and patients don't have to wait NPO until the evenings to have their surgery. This has made call much less stressful for my surgeons and myself. The OR is now happy to let us do our add-on cases on weekends, and the hostility has been virtually eliminated." — *Orthopedic surgeon, division director*

"Improved access, less waiting time on weekends and on the weekdays." — *Pediatric surgeon, attending*

"I have only had two opportunities to appreciate the impact of this change. In one instance, no add-on room was available, and both patients had to wait 4 hours until an OR was available. In the other instance, a room was available within 30 minutes." — *Pediatric surgeon, attending*

"I feel there is an improvement in our time and efficiency when assigning staff. We assign add-on staff the day before, instead of 'pulling' staff from rooms. Knowing that we are opening 2 rooms in the morning is easier and more predictable." — OR nurse

2. Is it easier to schedule add-on cases now, compared to the old system? If yes, what specifically is easier?
"Yes. Less delay, less haggling to get cases done." — *General/thoracic surgeon, attending*

"I believe that we are better able to serve the add-on patients now. There are not as many days when there are 12 add-ons at 6:15 in the morning." — *OR nurse*

3. Have your add-on patients been able to have their surgeries more quickly than before the changes? If yes, how do you think it influences the quality of care?
"Definitely. I think emergency cases now happen in an urgent manner — rather than waiting hours for an OR." — *General/thoracic surgeon, attending*

"Add-on patients have been able to get surgery earlier in the day than before. There are fewer complaints about being hungry all day." — *Orthopedic surgeon, attending*

"The family satisfaction with their experience is better than it used to be." — ENT surgeon, attending

4. Do you think that the change has influenced parents' satisfaction with their child's care (e.g., as a result of a decreased waiting time for surgery)?
"We have not had anywhere near the patient complaints or physician complaints. Physician and family satisfaction has skyrocketed. Ask our ortho nurse specialist how much time she had to spend comforting patients and families during the prior all-day waiting process." — *Orthopedic surgeon, division director*

"Yes — more efficient OR means patients get to surgery in a more timely fashion." — *General/thoracic surgeon, attending*

"As a general rule, I believe the new system is satisfying most families and patients." — *OR nurse*

5. What impact have these changes had on your or your colleagues' level of satisfaction with OR operations?
"Less stress, delay, frustration." — *General/thoracic surgeon, attending*

"More operations during the day — instead of night time — seems well received so far." — *Orthopedic surgeon, attending*

(continued on page 110)

Source: Cincinnati Children's Hospital Medical Center. Used with permission.

Table 6-4. *(continued from page 109)*

"Getting the add-on list done during the day has been nice." — *ENT surgeon, attending*

"The sometimes extreme pressure we felt from dissatisfied surgeons and/or families has seemed to greatly decrease. We have more options now. Earlier, there was nowhere to go with cases!" — *OR nurse*

6. What do you think has been the impact of these changes on other OR professionals (i.e., nurses, anesthesiologists)?

"Anesthesia team more willing to do cases knowing we have guidelines — not dependent on surgeon availability or convenience (seems to have been major gripe)." — *Orthopedic surgeon, attending*

"As a general observation, nursing staff 'on call' are not staying as late due to add-ons remaining at change of shift." — *OR nurse*

7. Are there any other comments you would like to make about the creation of the add-on rooms?

"Let's fine-tune it—but overall a big step in the right direction." — *Orthopedic surgeon, attending*

"Don't stop here." — *ENT surgeon, attending*

"Life just seems to be significantly more peaceful at the front desk since the creation of the add-on rooms. This says to me that for the most part, we have surgeons, families, and other staff who are more content. There are always 'those days' that are not good, but they seem fewer and fewer as time goes on." — *OR nurse*

* NPO, nothing by mouth; OR, operating room; ENT, ear, nose, and throat.

Although this redesigned system required cooperation and availability of the surgeons, it has also given them and their patients better utilization and access, thus increasing their buy-in. The operative schedule has become more reliable for anesthesia and nursing, which allows them to anticipate and more often meet end-of-the day predictions. For patients and families, because the surgical schedule is more likely to be followed, they have less anxiety, and their stay is more predictable.

As a consequence of smoothing elective surgical cases, in the ICU Cincinnati Children's observed a near elimination of placement of ICU patients into long-term recovery room beds because of lack of ICU availability (inappropriate holds), a decreased need for diversion of postoperative patients to a secondary unit for care because of ICU bed unavailability (inappropriate diversions), a near elimination of cancelled elective surgical cases because of a lack of postoperative ICU beds, and a planned increase in operative volume without the need to construct additional ICU beds.

Efforts at inflow case smoothing can only be successful when predictable ICU outflow to the correct inpatient unit is available. To match the upcoming transfer bed requirements from the pediatric ICU with preferred outflow inpatient units, Cincinnati Children's implemented a system to predict future pediatric ICU transfer and receiving inpatient floor bed availability. An internally built pediatric ICU discharge and floor discharge prediction computer model allows the use of demand-capacity matching to improve this step. Predicted pediatric ICU discharges for the next day are used to construct a bed plan that reserves needed bed resources when specific inpatient care units are needed, such as airway management, postcardiac surgery, and transplantation. Expansion of this system for demand-capacity matching on a hospitalwide basis is currently under way.

Except for the collection of baseline data, development and implementation of this model was not resource intense. Cincinnati Children's assembled an initial team to structure the urgent/emergent stream separation and construct the necessary case lists (Table 6-1). Postanalysis implementation and ongoing management have been absorbed into the daily work of the perioperative leadership and staff. Since this project began, two system analysts have received training in simulation modeling to support future work.

Modern OR construction cost is rarely less than $800,000 and can regularly reach $2 million.[13] Building more complex facilities, as are needed for cardiac surgery, transplants, and neurosurgery, may double this cost. The business case for better utilization is apparent. This is further strengthened in an urban, land-locked facility such as Cincinnati Children's, where available physical space for future ORs is very limited. Since 2006, when the redesign of perioperative flow management was initiated to the end of fiscal year 2009 (June 2008), revenues (total dollars) have increased by 34%; overtime dollars as a percentage of total dollars has decreased by 26% (by 6% in 2007–2008, 20% in 2008–2009), and overtime hours as a percentage of total hours have decreased by 31% (10.2% and 20.6%). Improvements in efficiency have boosted our capacity by the equivalent of a $100 million, 100-bed expansion and increased income from treatment of patients by even more.[20]

Before undertaking this initiative, Cincinnati Children's did not appreciate the complexity of the perioperative system, or the potential for improvement. Staff felt that they were just hostages to the emergency nature of the work and, so, that was their life. However, the result has been a more proactive improvement of care for patients and better staff satisfaction. Surgeon schedule flexibility has been the greatest barrier to change, stressing the system and limiting its growth. The additional responsibilities of surgeons can conflict with the need for availability. Also, services with a limited number of providers do not always have someone free to do an urgent case immediately. However, they still benefit from the system, which "cleans up" the other add-on cases so that the more infrequent users do not come into a very full schedule when they need access or when a small service provider needs access. Everyone benefits from the common good.

Identifying the surgical case mix was critical to understanding urgency equation and needs. The need for complete and accurate data when building this model cannot be overstressed. Correct allocation of resources and acceptable postimplementation use are based on correct predictions of need. These predictions cannot be accurately made if the data constructing the model are inaccurate or incomplete. Good data result in good models, and good models encourage acceptance of change.

The next steps at Cincinnati Children's are all in the inpatient area, matching capacity to demand to maximize bed usage, and in the elective schedule, identifying opportunities to further smooth the elective case mix to allow inpatient capacity to meet demand match without decreasing caseloads. The goal is a redistribution of case volume, not a restriction of case volume.

Better and timely access when care is needed is always better than waiting and compromising. Smoothing care streams has allowed patients to be placed on the most appropriate unit so they can receive the specialty nursing care they need. The concentration of similar patients on a unit also allows optimization of evidence-based care plans. The results at Cincinnati Children's show that better care and safer care do not necessarily mean care that is more expensive. It just requires a better use of resources.

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