# A MODEL TO EVALUATE EFFICIENCY IN OPERATING ROOM PROCESSES

by

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## ABSTRACT

In the operating room, efficiency is related to minutes pared from surgical time. The link between operating room efficiency and the composition of surgical teams has been investigated, yet research on the efficiency of surgical nursing staff members and operating room durations is scant. The purpose of this study was to assess the effects of nursing staff arrangements in surgery, with a view to better planning of staff training and structure to achieve savings in time and money. A conceptual framework based on scientific management theory was used to evaluate efficiency in operating room processes as time within and between surgical cases, and projected that nursing staff arrangements including specialization, standardization, and skill mix in surgical processes were key factors in reducing operating room process time. This retrospective, cross-sectional study examined data from electronic records of general surgery cases conducted in 2008 in a large U.S. teaching hospital. The research questions addressed the amount of variation in operating room process efficiency explained by nursing staff arrangement variables after controlling for environmental, patient health status, and case complexity variables. The explanatory statistical model included four independent variables to reflect operating room nursing staff patterns; four control variables to represent environmental conditions, patient health status, and case complexity; and five dependent variables for separate timeframes. Hierarchical regression analysis confirmed that the degree of nursing staff specialization in general surgery explained a significant portion of the variation in process timeframes spanning the surgical procedure, the duration between surgical cases, and the entirety of time within and between

cases. After controlling for environmental, patient health status, and case complexity variables, the independent variable circulator degree of specialization in general surgery made a significant contribution to the model's ability to explain turnover time ($R^2$ change = .028, $F_{inc}(1,292) = 9.83$, $p < 0.05$), also making a unique statistically significant contribution (*B* = -3.37, t = -3.13, $p < 0.05$); and to total operating room process time ($R^2$ change = .009, $F_{inc}(1,292) = 4.98$, $p < 0.05$). Upon controlling for the control variables, the independent variable scrub degree of specialization in general surgery explained a statistically significant portion of the variance in the surgical timeframe spanning incision to dressing end ($R^2$ change = .008, $F_{inc}(1,292) = 4.50$, $p < 0.05$), demonstrating a unique statistically significant contribution to explaining that timeframe (*B* = -14.37, t = -2.12, $p < 0.05$), and explained a statistically significant portion of the variance in turnover time ($R^2$ change = .013, $F_{inc}(1,292) = 4.50$, $p < 0.05$). Scrub degree of specialization also made a significant contribution of 0.8% to the model's ability to explain total process time. Neither professional mix within the roles of the circulator and the scrub, nor consistency of circulator and scrub pairings from case to case, affected operating room process time. Findings that scientific management principles may represent nursing staff arrangements indicate a need for further research to understand the factors that affect the use of perioperative time. One research avenue is to explore the cost-effectiveness of organizing the operating room nursing staff into specialty service teams; another is to evaluate turnover time as an opportunity cost from the perspective of patients, staff, and payers. Use of this model will improve both day-to-day and longer-term planning to optimize use of resources, in particular, nursing labor inputs, that contribute to an efficient and harmonious health care economy.

# CHAPTER I

## INTRODUCTION

American health expenditures continue to rise and are expected to be 19.2% of the U.S. gross domestic product by 2020 (Centers for Medicare & Medicaid Services, 2011). Public policies to improve efficiency in health care focus largely on access and cost, and include establishing patient-centered medical homes; promoting health information technology through the adoption of electronic data enterprise systems; replacing fee-for-service with bundled payments; and addressing health workforce shortages by expanding professional mix through wider use of Advanced Practice Registered Nurses and Physician Assistants (Rosenthal, Beckman, Dauser Forrest, Huang, Landon & Lewis, 2010; Kumar, Ghildayal & Shah, 2011; Guterman, Davis, Schoenbaum & Shih, 2009; American Association of Colleges of Nursing, 2012; Kirch, Henderson & Dill, 2012). Hospitals face particular demands to provide quality care while curbing costs by eliminating wasted materials, effort, and time. With renewed vigor and focus, stakeholders are calling on hospitals to improve efficiency in expensive areas like the operating room (Emanuel, 2012). Key to the success of smooth functioning of the operating room (OR) is the nursing staff who coordinate patient flow and anticipate surgical technique. Through the lens of scientific management theory, this study evaluated characteristics of labor inputs to surgical processes by examining the effects of nursing staff professional mix, specialization, and consistency of assignments on timeframes that bound the OR environment.

## Cost Pressures in U.S. Health Care

Fresh concern about health care spending underpins apprehension about equity in addressing the global burden of illness treatable by surgery. An estimated one of every 25 people around the globe undergo some form of major surgery in an operating room every year (Weiser et al., 2008). In 2006, nearly 46 million surgical procedures occurred in American hospitals; over one-third of these were on patients 65 years and older (DeFrances, Lucas, Buie & Golosinskiy, 2008). With a population that is living longer, the demand for surgical services continues to increase. Worldwide growth in surgery has implications for public health; in the scheme of health care provision, as a greater share of resources are used in the OR, less time, money, and effort is available for other important health care services such as primary care and treatment of chronic diseases.

The pursuit of health in America is very expensive. So enormous have demand and supply become that health care outlays are now nearly one of every five dollars spent in the U.S. By 2010, health care expenditures in the U.S. had grown to ten times those of the $256 billion spent in 1980 (Centers for Medicare & Medicaid Services, 2011). Advances in diagnostic and treatment technology have enhanced the supply of health services available to a population within which expectations for quality care ensures steady demand. At the same time, the availability and affordability of health care remains a dominant concern among Americans (Gallup, 2012). A worrisome economic recession impels an appraisal of options for providing health care that is timely and affordable.

### Approaches to Reducing Health Care Costs

The conundrum of fulfilling demand for health care services while avoiding a spending morass continues to vex policymakers. Efforts to control health care costs have motivated an approach that backs spending reductions and efficiency gains. Emphasis on affordability in health care delivery has been touted by such stakeholders as Dr. Donald Berwick, who said that "we will be partners in the change of care for all Americans, changing it so it is safe care, better care, more patient-centered, timelier, and more effective. I am also convinced we can do that while controlling costs." (Mitka, 2010). With hospital care the largest category of health care spending (American Hospital Association, 2011), cost control in hospitals remains a challenge as facilities need to remain competitive by offering cutting-edge services and honoring physicians' suggestions to carry specialty equipment, thus limiting their ability to cut spending on capital goods. It may also be difficult to reduce the amount of supplies such as bedding, dressings, and surgical supplies because of patient and staff preferences, and contracts with vendors. At the risk of proposing rationing, the denial of services to select groups of patients raises questions about bias and ethics (Orentlicher, 1996).

Cost-cutting that is not possible by eliminating capital goods or non-essential services may be achieved by boosting efficiency: producing more output without increasing inputs. Cutler (2010) outlines three areas in which the health care system may save money, 1) by reducing administrative expenses; 2) providing less care that produces little value; 3) and preventing medical errors through use of checklists, information technology, and attention to hygiene (Cutler, 2010). The second of Cutler's proposals concerns the efficient use of resources in the production of health care. Organizations that are able to raise production without additional inputs are operating efficiently. In re-directing resources to improve productive capacity, efficiencies in health care may be realized.

Faced with the prospect of rationed care and organizational shake-ups, managers may opt to make better use of existing staff resources in order to improve efficiency. Of the inputs to the production of health care services, labor consumes the greatest proportion of costs. More than half of America's $2.6 trillion on health care spending in 2010 went to the wages of health care providers (Kocher & Sahni, 2011). Labor is the largest cost-driver of the growth in hospital spending; from 2004-2009, U.S. hospital labor costs increased steadily by between 5% and 8% (Guerin-Calvert & Israilevich, 2011). Wages and benefits consume nearly 60 cents of each dollar of hospital spending, and nursing staff is the largest category of hospital staffing (American Hospital Association, 2011). The considerable portion of health care costs attributable to labor calls for a fresh look at the efficiency of those who deliver health services, specifically, of nursing staff.

**Operating Rooms and the Health Care Economy**

The OR, moreso than any other area in a hospital, is a convergence of resources uniting people, equipment, coordination, and time. Time saving in the OR is not inconsequential. With reduced time within and between surgical cases, patients spend less time in or waiting for surgery; staff are freed for other productive activities such as patient visits; and hospitals may capitalize on a reputation for efficient surgical services. Yet in health care, efforts to reduce time have chiefly involved purchasing new equipment or adding rooms to accommodate parallel processing; labor has been infrequently the target of initiatives to improve efficiency (Kocher & Sahni, 2011). Changing longstanding labor structures and practices may be an extremely resource-intensive exercise (Taylor, 1911, p. 133). Moreover, mandates such as the Association of periOperative Registered Nurses (AORN) position, one OR registered nurse (RN) for one patient, restrict options for cutting costs by reducing staffing numbers (AORN, 2012). Sweeping changes such as re-structuring nursing services through the hiring of assistive personnel and reducing training opportunities affect recruitment and retention (Buchan, 1999); ineffective use of available resources has also been cited as a cause of recent nursing shortages at the point of care (Buchan & Aiken, 2008). There is another option for improving efficiency in processes, that which involves a review of staffing patterns. Surgical teams may work more efficiently and trim minutes from OR processes simply by aligning staffing patterns to optimize the use of time.

**Problem Statement**

As one of the most expensive areas of American health care, the OR generates large revenues and high costs (Elixhauser & Andrews, 2010). Within the health care labor force, one out of two workers is a nursing care provider (Charting Nursing's Future, 2007). The persistent global nursing shortage stokes unease about access to health care, emphasizing the need to make the most efficient use of professional skill to deliver more needed care. However, little is known about how nursing staff arrangements, including professional mix, individual experience in a surgical service, and circulator-scrub case assignments, affect efficiency in surgical processes.

This study explores the contribution of nursing staff arrangements to OR efficiency, defined as time within and between surgical cases, after controlling for environmental, patient, and case complexity variables. To achieve the research goal of evaluating an explanatory model of efficiency in operating room processes, the following four research questions have been addressed:

**Research Question 1:** What amount of variation in operating room process efficiency is explained by nursing staff professional mix in a surgical case after controlling for environmental, patient health status, and case complexity variables?

**Research Question 2:** What amount of variation in operating room process efficiency is explained by the degree of nursing staff surgical specialization in the general surgery service after controlling for environmental, patient health status, and case complexity variables?

**Research Question 3**: What amount of variation in operating room process efficiency is explained by circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

**Research Question 4**: What amount of variation in operating room process efficiency is explained by nursing staff professional mix, the degree of nursing staff surgical specialization, and circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

## Overview of the Research Study

This study examined data from OR electronic records of surgical cases conducted in 2008 in a large U.S. teaching hospital. In this retrospective, cross-sectional research study, all surgical cases were completed by general surgeons. Cases categorized as general surgery include those of the alimentary tract; breast, skin, and soft tissue; endocrine; oncology; trauma/burn; and solid organ transplantation (The American Board of Surgery, 2012, p.6). Hierarchical regression analysis was used for addressing each research question. The explanatory statistical model included four independent variables to reflect OR nursing staff patterns; four control variables to represent environmental conditions, patient health status, and case complexity; and five dependent variables for separate OR timeframes.

**Organization of the Dissertation**

This dissertation presents background, analysis plan, research findings, and conclusions of a study to assess a model of efficiency in OR processes. The paper is organized as follows. The second chapter provides a review of relevant literature and research, and presents the theoretical basis and conceptual model that direct the study. Key definitions for terms used throughout the paper are also presented in this chapter. In the third chapter, the study design, data source, sample, analysis plan, and data management issues are explained. Conceptual and operational definitions for each of the dependent and independent variables included in the research model are provided. Results of the analysis as they reflect each research question and hypothesis, and the presentation of data, are in Chapter 4. The final chapter, 5, includes a discussion of the study, conclusions from the results, limitations to the study, and recommendations for future work.

**Summary**

In the wake of expectations for nurses and all health care team members to perform together more efficiently, managers seek the right combination of staff to balance professional training, experience, and teamwork. An examination of the effects of professional mix, service specialization, and staffing consistency in surgery will be useful in planning staff training and structure to achieve savings in time and money. This study presents an explanatory model of the effects of OR nursing staff patterns on efficiency in the utilization of surgical time.

# CHAPTER 2

# LITERATURE REVIEW

The pursuit of efficiency has long been an occupation of industrial engineers. In health care as in industry, managers are mindful of metrics and deadlines. With pressure to become more efficient, hospitals must be able to define and measure efficiency. This chapter begins with a review of definitions related to efficiency as an introduction to a study of efficiency in OR processes. The chapter then presents an overview of the theory of scientific management, and continues with a review of scientific management principles as they have been applied in health care research. Turning to definitions and measures of efficiency, the discussion considers research in health care in general, and in ORs in particular. The conceptual model serving as the basis for this research is then presented. At the end of this chapter, the research questions and related hypotheses are discussed.

## Definitions of Efficiency

Efficiency deals with production, and may be considered in terms of the inputs and outputs that constitute the production process. The science of engineering draws on the First Law of Thermodynamics to describe efficiency as the ratio of work or energy output to the work or energy input, up to a maximum of 100 percent (Monteith & Moss, 1977). A related discipline, organizational engineering, focuses on efficiency as minimizing the time required to perform a task or a level of output. In this case, performance measurement considers efficiency as the amount of outcome produced per unit amount of resources allocated to performing a predefined goal and objective within a specific time frame. In business, Stalk (1988) maintained that competitive advantage for a company emerges from the ways in which time in production is managed (Stalk, 1988). The field of economics defines efficiency from three points of view: technical, allocative, and social. Based on the definitions of efficiency by Farrell (1957), technical efficiency is producing the maximum amount of output from a given amount of input or alternatively, producing a given output with minimum input quantities (Farrell, 1957). Technical efficiency is producing the maximum amount of output from a given amount of input or alternatively, producing a given output with minimum input quantities (Lovell, 1993, p. 4). A firm is technically efficient when it produces the maximum output from a given amount of input, or alternatively, produces a given output with minimum input quantities (Hollingsworth, 2008). An analogous definition is that technical efficiency occurs when the maximum output is created from the same number of inputs. Efficiency occurs if, for example, an OR manager is able to place nursing staff whose experience enable surgical cases to proceed more swiftly. With technical inefficiency, a given input bundle fails to produce maximum output. As production units, ORs share common terminology with economic efficiency, definitions which are provided herewith.

**Production Theory:** Economic theory that deems production as a process of obtaining outputs from a combination of factor inputs. Production theory maintains that there can be no outputs without inputs, that is, "there is no such thing as a free lunch".

**Economic Efficiency:** Resource use whereby no additional output may be obtained without additional input, at the lowest cost per unit of production (Coelli & Battese, 2005, p. 5). Two types of efficiency, allocative and technical, contribute to economic efficiency:

*Allocative Efficiency:* Allocative efficiency exists when the same level of inputs are used in the correct proportions with respect to input prices (Coelli & Battese, 2005, p. 5).

*Technical Efficiency:* Technical efficiency exists when the same level of the output cannot be produced with fewer inputs, or when maximum output is produced from a given set of inputs (Coelli & Battese, 2005, p. 3).

**Opportunity Cost:** The cost of foregone advantages resulting from decisions not made and related action not taken.

**Value:** The worth of goods or services. Value in economics is determined by markets and is linked to unlimited desires and wants colliding with scarcity.

**Conceptual Definition of Efficiency in Operating Room Processes**. This research adopts the perspective of technical efficiency: maximizing output given a level of inputs. In the OR, the use of time is key to the efficient production of surgical cases. An aim of efficiency studies is to minimize time waste, or, to maximize time savings. Therefore, this study defines OR process efficiency as maximizing output, in terms of time savings, for a level of inputs.

**Stakeholder Definitions of Efficiency.** It is useful to consider efficiency from the standpoint of various health care stakeholders. The Institute of Medicine (2001) views efficiency as avoiding waste, including waste of equipment, supplies, ideas, and energy Institute of Medicine, 2001). AQA (2009) defines efficiency as a measure of cost of care associated with a specific quality level (AQA, 2009). The Medicare Payment Advisory Commission (MedPAC) views efficiency in terms of value, and as using fewer inputs to get equal or better outcomes ((MedPAC, 2007). The National Quality Forum (2012) broadens the definition of efficiency to include time when considering throughput processes or applying time-driven activity based costing methods (National Quality Forum, 2012). Gilbreth (1915) honed in on hospitals and maintained: “The output of the hospital is “happiness minutes”; the aim of the hospital is to give the largest number of units of happiness to the most people, with the least expenditure of time, money, and effort.—or, in other words, with the least expenditure of energy possible” (Gilbreth, 1915).

**Significance of Efficiency to Nursing.** Nurse leaders in the U.S. find themselves in the middle of a debate about how to curb health care costs. Nurses need to be aware of efficiency, as it affects access to care, and patient and provider satisfaction. Efficiency in practice is also a demonstration of professional competence (Benner, 1984, p. 26), to minimize waste, to maintain a competitive edge given a choice of providers. That nursing staff accounts for the largest proportion of the hospital labor force belies the realities of the persistent nursing shortage. An aging nursing workforce, and changes in accessibility to health care through the Affordable Care Act signal that nursing leaders must make wise choices about staffing assignments, training, and structure. The theme of “working smarter” suggests that managers may maximize efficiency by realigning nursing staff arrangements rather than hiring more workers or promoting longer workdays.

## Scientific Management Theory

The theme of labor efficiency has been sanctioned since the early 1900’s, when Frederick Taylor introduced scientific management theory (SMT) in studying labor inputs to the production process. As a consultant to steel manufacturers, Taylor espoused changes in work processes to promote time efficiency and eliminate waste. Organizational output, Taylor maintained, would not be sustained by increasing either a worker’s task load or his working hours, for it was not the amount of effort expended by an individual, but the organization of work performance that led to leaps in efficiency (Drury, 1918, p. 24).

The process of conducting scientific management research involves time and motion studies of industrial workers. With a stopwatch as a timer, Taylor observed tasks, breaking them into their constituent motions, then analyzed routine movements involved in production (Drucker, 1999). Through these observations, Taylor identified practices that minimized unnecessary motions and enabled each worker to augment his output without increasing his work time. Taylor appreciated that knowledge acquired through extensive experience must be embedded into detailed, documented operations design so as to be useful. A final leg in the process of applying scientific management to industrial operations is to provide incentives for achieving efficiency goals by performing tasks in less time (Taylor, 1911, p. 121). According to Taylor, staff who realized gains in efficiency were to be rewarded with bonuses or paid time off. Thus, through observation of best practices and treats for a job well done, efficiency in labor performance may be sustained and improved.

**Principles of Scientific Management**

Observation, time and motion studies, and incentives as the methods of scientific management are necessary but not sufficient to lasting improvement in work processes. Key to amplifying labor efficiency through scientific management are three principles: professional mix, work specialization, and work flow standardization.

In terms of *professional mix*, Taylor aimed to maximize individual employees' skills through job placement and training that matched those abilities. Managers were encouraged to promote opportunities for each worker to learn to work at his fastest pace and with the utmost efficiency (Taylor, 1911, p.12). With this, finding the right worker for the right job, then placing him on an appropriate functional team, was a way to seal labor efficiency (p. 129). Hamilton, Nickerson, and Owan (2003) investigated the effect of team composition on productivity in garment factories and found that teams whose members were more diverse in abilities were more productive than homogenous teams (Hamilton, Nickerson & Owan, 2003).

*Specialization*, a tenet of optimal labor productivity, can be traced to Adam Smith (1902), who recognized the importance of specialization in augmenting a nation's productive output (Smith, 1902, pp. 43-45). According to Smith, men could be trained as generalists or specialists, with productivity linked to the type of training path that a worker followed (Smith, 1902, pp. 48-49). Allocation of jobs according to specialties, also known as "division of labor", was possible only through focusing on one task at a time. Through division of labor, individuals and teams are apt to perform most efficiently by repeated performance of the same, specialized array of tasks (Hackman & Oldham, 1980, p. 47). Another pioneer in efficiency studies, Frank B. Gilbreth, advocated scientific management's principle of specialization. With so much to know about any type of work, Gilbreth argued, a worker was better off having "100 percent knowledge of one specialty than to have one half percent knowledge of his total knowledge on each of 200 different ways of earning a living" (Gilbreth, 1912, p. 51).

*Standardization* is a third principle of scientific management. For Taylor, standardization of the processes involved in performing a task would lead to efficiency and higher output. For example, if each worker performed on the same team every day, completing particular tasks using the same, repeated motions each time, he would become more efficient in conducting that task. Standardization may also be considered in terms of the stability of staffing by examining the composition of teams. Argote, Insko, Yovetich and Romero (1995) tested task skills on 240 undergraduate students working individually and in teams. As new members were added to existing task teams, the time required for the group to perform tasks increased (Argote, Insko, Yovetich & Romero, 1995). An increase in the number of team members also expands the risk of production breakdowns from poor task coordination among team members (Becker & Murphy, 1992). The addition of new team members may hamper efficiency as handoffs occur and the task flow is disrupted.

In summary, principles of SMT relate to labor efficiency. Scientific management theory emphasizes the advantages of selecting workers who are both specialized and embody the right occupational experience, and of standardizing work processes, in order to achieve efficiencies in terms of time-saving.

**Alternative Theories of Performance Efficiency**

A theory that relates efficient performance to the working patterns of individuals serves as a suitable framework for appraising OR processes. In addition to Frederick Taylor's, the voices of other theorists have shaped approaches to bettering practitioners' work.

Florence Nightingale was dedicated to the belief that experience and observation guided nursing actions. Nursing was not restricted to following prescribed theory, Nightingale maintained, but patient care was most effective when nurses melded observations and experience gleaned from previous actions and patient interactions. That Nightingale's practice occurred amidst squalor, infection, and war-injured soldiers caused her to consider a safe, clean environment as essential to the restoration of health. Nightingale's environmental theory avowed that nurses' actions affect both environmental conditions and patient care, both of which, in turn, affect human health (Zurakowski, 2005, pp. 30-31). Drawing on experience, nurses may become more efficient and effective in performing tasks. It behooved nurses to add to their stock of experiential learning so as to become more competent and resourceful in caregiving. According to Nightingale, efficiency was secondary to providing an optimal and health-restoring environment for the sick.

The field of economics also recognizes the contribution that investments in human capacity building make to organizational efficiency. The theory of human capital (Schultz, 1962; Becker, 1962) views humans as repositories of productive capacity accrued from education and training. Schultz (1962) resounded the theme that human capacity may be a source of economic growth, with experience gained through education in schools and on the job training adding to the stock of human capital. As knowledge is acquired through a variety of mechanisms in workplace settings, efficiency reflects the application of human capacity transferred to task completion. Unlike scientific management, human capital theory focuses on individual educational attainment rather than rearranging work patterns to improve efficiency.

Forays into improving production have emerged from scientific management to incorporate the notion of quality control. W. Edwards Deming echoed Taylor's methods of reviewing work processes through task assessment, adding a component of quality assurance based on statistical analysis. Deming asserted that efficiency in manufacturing demanded that variations in quality be limited. Either systems or individual error may cause variations in quality which led to production losses (Deming, 1975). Management theories that are quality-based, however, may deal with individual workers' motivation for performing as they do. Studying and improviing worker motivation may be difficult to achieve among a team that is dynamic and multidisciplinary as in the OR.

In examining how health care providers may work more efficiently in OR processes, various theories may serve as a framework. A theory that addresses the effects of professional mix, experience, and standardization is apt to capture many of the conditions apparent in day-to-day OR processes. Scientific management theory, with its focus on process, working arrangements, and individual characteristics, is well-suited to applications in the surgical environment. With the aim to evaluate efficiency in surgical processes, this research applied principles of scientific management to OR nursing staff arrangements.

## Scientific Management Principles in Health Care

Research in health care outcomes has examined scientific management principles, namely, professional mix, specialization, and standardization. This section describes some of those studies. Taylor's methods of task analysis and data collection were applied in studies of labor efficiency. So, too, were the principles of scientific management which emphasized skill mix, specialization, and standardization. The translation of the principles of professional mix, specialization, and standardization to OR nursing staff arrangements is presented in Table 1.

Table 1

*Principles of Scientific Management Theory Applied to the Operating Room*

| **Principles of Scientific Management Theory** | **Principles of Scientific Management Theory translated to the OR** |
|---|---|
| Professional mix in job placement: The right person for the right job (Taylor, 1911, pp. 56-57). | Professional mix in job placement: One circulating nurse for every patient; those in the scrub role are expected to have knowledge and experience to manage the sterile field throughout the surgical procedure. |
| Division of labor in work processes: A specialist adopts efficient techniques (Taylor, 1911, p. 123). | Division of labor in work processes: "Where is the usual team?" |
| Standardization in work organization: Organize workers into functional teams (Taylor, 1911, p. 129). | Standardization in work organization: "We do it the same way every time"; a stable team enhances workflow. |

### Professional Mix

Finding the best use of care team members' skills and professional experience is critical to practice in a climate of increasing financial concern (Institute of Medicine, 2011). One of the leading sources of inefficiency in health care is the inappropriate mix of staff (Chisholm & Evans, 2010; World Health Organization, 2010). Workforce imbalances that result in overusing, underusing, or misusing health care personnel compromise population health (Dubois & Singh, 2009). McGhan, Smith, and Adams (1983) studied the performance of pharmacy technicians compared to pharmacists in ambulatory settings, finding that technicians took significantly more time to fill prescriptions than did pharmacists (McGhan, Smith & Adams, 1983).

Among nursing departments, richness of skill mix increases possibilities for finding those with the right skills to perform at the right time (Spitzer & Bolton, 1986, pp. 47-48). Professional mix, reflected in nursing research as skill mix, may be defined as: the ratio of RNs to other nursing personnel; the percent of patient care hours delivered by RNs; or the share of the nursing staff that consists of RNs (Kravitz et al., 2002; Spetz, Donaldson, Aydin & Brown, 2008).

Nursing staff professional mix has been studied extensively, often with hospital-level or unit-level data. Grillo-Peck and Risner (1995) investigated the effects of implementation of a staffing model that decreased skill mix from 80% RN to 60% RN on a hospital neuroscience unit (Grillo-Peck & Risner, 1995). Six months after the introduction of the new model, the number of patient falls declined from a mean of 6.17 to 3, and length of stay was reduced by 0.7 days (Grillo-Peck & Risner, 1995). Aiken, Clarke, Cheung, Sloane, and Silber (2003) found an association between nurses' educational levels and patient mortality rates, with attainment of less than a bachelor's degree (Aiken, Clarke, Cheung, Sloane & Silber, 2003). A conclusion of this study was the need for additional studies on other characteristics of the nursing workforce on the provision and quality of health care. In hospital units other than perioperative services, the skill mix of nursing staff has been associated with patient outcomes. Needleman, Buerhaus, Mattke, Stewart, and Zelevinsky (2002) researched the relation between the mix of nursing personnel and patient outcomes sensitive to levels of nurse staffing (Needleman, Buerhaus, Mattke, Stewart & Zelevinsky, 2002). Using administrative data from 799 hospitals in 11 states, the researchers found that lower rates of adverse outcomes were consistently associated with higher proportion of hours of registered nursing care compared to care given by licensed practical nurses or aides (Needleman, Buerhaus, Mattke, Stewart & Zelevinsky, 2002). In a literature review of 96 studies of RN-to-patient ratios and outcomes, Kane, Shamliyan, Mueller, Duval, and Wilt (2007) found that higher RN staffing was associated with lower odds of hospital-related mortality and adverse patient events (Kane, Shamliyan, Mueller, Duval & Wilt, 2007). In estimating the economic value of higher RN staffing levels, Dall, Chen, Seifert, Maddox, and Hogan (2009) applied patient outcome data related to RN staffing measures to U.S. hospital discharge data from 2005. The authors found that increased RN staffing levels were related to medical cost savings through lower nosocomial complication rates and hospital lengths of stay (Dall, Chen, Seifert, Maddox & Hogan, 2009). Exploring the relationships among nursing staff composition, hospital Magnet status, and patient falls on 5,388 units in 636 hospitals, Lake, Shang, Klaus, and Dunton (2010) considered RN, LPN, and nursing assistant staff hours separately (Lake, Shang, Klaus & Dunton, 2010). They found that more RN hours are associated with less falls in ICUs, whereas LPN and nursing assistant hours are associated with more falls in units other than ICU. The authors suggested that an adjustment of staffing patterns at the unit level may enhance patient safety (Lake et al., 2010).

Results of these studies of professional mix in health care indicate that the composition of the nursing staff is affects patient outcomes. However, few studies of professional mix within the circulator-scrub team in surgery have been conducted. Moreover, few studies have considered the effect of professional mix related to OR nursing staff composition and efficiency.

**Specialization**

Specialization has been viewed according to the range of services provided. In a study of 232 hospitals between 1983 and 1990, a 26.9% increase in the rate of hospital specialization, defined as the limited range of diagnosis-related groups treated, was associated with a 6.9% decrease in cost per admission (Eastaugh, 1992). In a study of 378 colorectal surgery patients, specialization in colorectal surgery was significantly associated with lower overall cancer recurrence rates (Dorrance, Docherty & O'Dwyer, 2000). Specialty surgical teams experienced in particular techniques such as laparoscopy may contribute to OR efficiency by reducing operative times and complications (Kenyon, Lenker, Bax & Swanstrom, 1997). Analyzing hospital services, Schneider et al. (2011) studied the effects of surgeon, patient, and environmental characteristics on predictions of perioperative time. Highly experienced surgeons, having completed more than 1,000 procedures, had a strong influence on operative time, whereas less experience was associated with longer surgical durations (Schneider et al., 2011). The authors acknowledged that the experience of others on the surgical team may affect surgical time. In questioning the role of surgeon volume in health care quality, Dimick, Birkmeyer, and Upchurch (2005) mention patient mortality and identification of high-performance hospitals as outcomes related to provider experience. Time is not included among the quality indicators (Dimick, Birkmeyer & Upchurch, 2005). The effect of surgeon experience is also discussed in the context of the learning curve (Kiran, Kirat, Ozturk, Geisler & Remzi, 2010). The researchers reviewed evidence for laparoscopic colectomy, finding that the time required for surgeons to develop proficiency in laparoscopic procedures accounts for increases in perioperative costs

(Kiran, Kirat, Ozturk, Geisler & Remzi, 2010). Each of these studies focused on the experience of specialist surgeons, and made but cursory references to the effects of other surgical team member characteristics on the use of time.

### Standardization

An early acolyte of scientific management theory was the surgeon William Osler, who noted that standardization and experience in the art of medicine lent to “imperturbability” and “practised familiarity with technique”, building confidence and flexibility in dealing with a variety of challenges (Osler, 1987, pp. 5 and 298). Osler also signaled specialization as having the benefit of providing clarity as well as efficiency in the treatment of particular medical problems (p. 84). Standardization in American hospitals emerged in the form of medical record keeping. In the early 1900s, the American College of Surgeons made strides to improving patient treatment and hospital organization through its hospital standardization movement. Standards required hospitals to keep a record for each patient detailing the course and results of treatments (Reiser, 1991). Massachusetts General Hospital surgeon E.A. Codman seized the potential for standardized patient records to rouse efficiency through organized charting and his framework for patient case reports (Neuhauser, 1990).

Gilbreth applied scientific management principles of standardization to health care through time and motion studies of surgery (Baumgart & Neuhauser, 2009). By analyzing the instrument placement and movements of scrubs, Gilbreth devised standardized surgical set-ups that led to more efficiency in practice (Baumgart & Neuhauser, 2009). The use of standardized, bundled surgical items facilitates the locating and procuring supplies. Kanich and Byrd (1996) note that the use of custom packs reduces opening and set-up time (Kanich & Byrd, 1996).

The importance of "team stability" between surgical cases has been signaled in OR efficiency literature. Bunker (1970), comparing British and American surgical processes, suggested that the British practice of maintaining a unified surgical team in one room throughout the day was a major source of superior efficiency in OR utilization. Pisano, Bohmer, and Edmondson (2001) found that cardiac surgery teams cited similarity in team membership as a key to time efficiency (Pisano, Bohmer & Edmondson, 2001). As teams in 16 hospitals implemented new procedures, a key to maintaining efficient operations was to ensure that team membership was stable and that team members had been consistently trained. Reagans, Argote, and Brooks (2005) studied the frequency of pairs of surgical team members working together in relation to completion time for total joint replacement procedures (Reagans, Argote & Brooks, 2005). Teams where member pairs had worked together took less time to complete procedures (Reagans, Argote & Brooks, 2005). In finding time efficiency through parallel processing, Friedman, Sokal, Chang, and Berger (2006) noted that maintaining the same surgical team membership was important to reducing perioperative times (Friedman, Sokal, Chang & Berger, 2006). Social capital, too, contributes to efficiency in that institutional memory accrues as teams, such as surgical teams, stay together longer. Even upon attaining proficiency, research suggests that the experience of the surgical team members, and familiarity with available infrastructure aids in reducing operative times (Ballantyne et al., 2010).

In addition to increasing coordination demands, the introduction of a new team member requires additional communication. The chance that misleading information is communicated may increase with the introduction of new team members. Communication failures have been signaled as the cause of surgical errors, with handoffs among providers the culprit in 43% of communication breakdowns involved in surgical cases resulting in patient harm (Greenberg et al., 2007). Lingard, Espin, Whyte, Regehr, Baker, Reznick, et al. (2004) tallied failures in 30% of communication exchanges between surgical team members. A third of those miscommunications led to disruptions in the surgical team, and to increased tension and cognitive load (Lingard et al., 2004). Finally, Zarbo and D'Angelo (2007) describe how standardizing the surgical pathology processes including specimen receipt, accessioning, and inspection reduced the number of cases with defects by 55% in one year (Zarbo & D'Angelo, 2007).

### Gaps in Knowledge

The concern about time and efficiency that so consumed operations management pioneers has once again surfaced as hospital managers face emphatic reminders to eliminate wasted time and effort. Principles of scientific management have been the focus of a number of research studies in health care, yet not always in association with efficiency as an outcome. Despite a wealth of studies that consider professional mix, specialization, and standardization in studying health outcomes, few of those studies have focused on time in providing surgical services. In scientific management, the goal is to improve the time efficiency with which workers perform. A study of labor efficiency in surgical processes, using principles of SMT, will provide indications for a fresh look at staffing arrangements of the circulator and scrub role, and their impact on efficiency in the provision of health care services.

## Efficiency Defined and Measured in the Operating Room

Recent emphasis on quality and comparative effectiveness in health services has led to stakeholder consensus about defining and measuring the components of effective care. The measurement of efficiency, however, remains elusive because health-related processes are often complex and involve myriad inputs and ill-defined outputs. In surgical services, surgeons, nursing staff, and anesthesia personnel may differ in their conceptions of efficiency, and their motivation to achieve efficient processes (Arakelian, Gunningberg & Larsson, 2011). Some of the uninterest in measuring efficiency may stem from arguments in that hospitals, especially not-for-profit facilities, are simply not efficient (Newhouse, 1970; Pauly, 1987). Currently, though, a recalcitrant economy and demands for value for money have caused hospitals to behave as cost-minimizing, revenue-optimizing firms.

**Operating Room Efficiency Definitions**

In the surgical setting, definitions of efficiency often focus on time and so are akin to those in industrial engineering, where reductions in time in relation to a given level of inputs translates to efficiency. According to Strum, Vargas, and May (1999), OR efficiency is the value that is maximized when the inefficiency of OR time use has been minimized (Strum, Vargas & May, 1999). Stahl, Rattner, Wiklund, Lester, Beinfeld, and Gazelle (2004) view efficiency as increased patient throughput, or getting patients in and out of a surgical suite (Stahl, Rattner, Wiklund, Lester, Beinfeld & Gazelle, 2004). Another focus of efficiency refers to utilization of surgical suites. Abouleish, Dexter, Whitten, Zavaleta, and Prough (2004) define OR efficiency in terms of overutilization and underutilization of OR time. Underutilized time occurs when neither surgery nor room turnover is occurring during regularly scheduled hours; overutilized time includes surgery occurring after regularly scheduled hours (Abouleish, Dexter, Whitten, Zavaleta & Prough, 2004). McIntosh, Dexter and Epstein (2006) equate inefficiency as the sum of the cost of under-running surgical cases and the cost of over-running surgical cases. The researchers create a definition of inefficiency of use of OR time based on Strum et al, considering the costs and hours of under- and over-utilized OR time (McIntosh, Dexter & Epstein, 2006). Pandit, Stubbbs, and Pandit (2009) define efficiency as work output per cost or effort. However, they measured efficiency by noting that ‘efficiency specifically refers to the notion of a team utilising its scheduled list duration fully, without over-running or cancellation’. The authors developed an equation for efficiency in determining operating room allocation which excluded costs yet included the number of operations completed, along with over-utilized time (Pandit, Stubbbs & Pandit, 2009). In the OR, the concepts of professional mix, experience, staff organization, and time are integral to definitions of efficiency.

**Operating Room Efficiency Measures**

The quest for efficiency in the OR largely focuses on reducing the time that it takes a surgical team to complete tasks. When a surgical team uses time efficiently, more can be used toward caring for patients**.** A particular focus of productivity initiatives is on the components of labor inputs that affect time, and thus costs, in the process of surgery-related activities. Much of an OR’s budget is allocated to staff wages and benefits. Akin to Frederick Taylor’s quest to improve the efficiency of workers in industry, it behooves OR managers to make the best use of this expensive resource. Additionally, national bodies have recognized the effects that both labor and time have on efficiency. The Institute of Medicine recommends that health care teams redesign processes in order to meet patient needs, and singles out wasted time as a source of inefficiency (Institute of Medicine, 2001, p. 62). With time utilization as a mark of efficiency in OR processes, SMT is a useful model for examining the effect of staffing characteristics on surgical outcomes.

**Labor Efficiency in the Operating Room**

Kanich and Byrd (1996) signal human resource management as an aspect of OR efficiency, with nursing staff experience and cross-training in various surgical specialties contributing to flexibility and cost savings (Kanich & Byrd, 1996). Health care teams have been linked to patient outcomes and efficiency in use of resources (Bosch et al., 2009; Lemieux-Charles & McGuire, 2006). In the OR, an immutable staffing practice involves the use of one circulating nurse per patient, as advocated by AORN. In addition to such restrictions on minimum staffing, job descriptions and contract stipulations may limit leeway in reducing human resource costs by eliminating nursing staff. Channeling Frederick Taylor, the champion of scientific management, OR managers seek ways for teams to work smarter in perioperative care.

Numerous factors in the perioperative setting may affect the utilization of time in the OR. Research has examined how OR efficiency is affected by teaching in the OR, bottlenecks in patient transport, status surgical scheduling accuracy, equipment set-up, staff availability, and teamwork. Despite the importance of staffing patterns and characteristics to OR efficiency, research has given scant focus to the relevance of surgical team presence—including professional qualification, individual experience, and team assignments—to surgical processes. McGowan et al. (2007) considered the effects of a multidisciplinary approach to improving OR throughput and efficiency. Strategies targeting communication, bed and discharge planning, internal staffing pool, and environmental services were combined with an incentive program to realize gains in OR cases, and reductions in OR holds and cancellations (McGowan et al., 2007). Accurate scheduling of elective cases has been shown to improve OR efficiency (Wright, Kooperberg, Bonar & Bashein, 1996). Dexter and Traub (2002) also deliberated on scheduling in terms of under-and overutilization; they considered hours of OR staffing, rather than the composition of the surgical team, as factors in the use of OR time (Dexter & Traub, 2002).

Sandberg et al. (2005) found that changing surgical ergonomics and staffing patterns, and adding new technology resulted in less overutilization or more cases being accomplished during allocated work times. Such efforts permitted more cases to be accomplished when procedures were short. However, efficiency gains were insufficient to routinely accomplish longer cases due to limited workday hours. Improvements in throughput were achieved upon adding anesthesia and nursing staff, constructing an integrated OR suite to accommodate pre- and post-operative patient waiting as well as surgeon dictation and computer work between cases, and purchasing mobile tabletops and integrated monitors. The researchers concluded that "improving the effectiveness of surgical/perioperative care is feasible by working smarter without placing an additional burden on an already overworked operating room staff"—inasmuch as the intervention was based on adding new personnel to the OR team (Sandberg et al., 2005).

Other successful approaches to improving OR performance have focused on parallel processing and redesigning staff duties. Overdyk, Harvey, Fishman and Shippey (1998) addressed OR delays by promoting multidisciplinary OR efficiency awareness education flexible OR staffing (Overdyk, Harvey, Fishman & Shippey, 1998). Perioperative delays were reduced largely through nursing staff reassignment to registration and preoperative phases, and bringing the patient into the OR suite before the completion of nursing tasks. Good preoperative communication also contributed to efficiency. Frequent delays included absence of key surgical staff; transport problems; case cancellation; equipment delays; difficult line placement; and lab results. Sokolovic et al. (2002) found that adding more anesthesia personnel to induce anesthesia in patients to follow a case still underway was another means of streamlining OR throughput (Sokolovic et al., 2002).

Finally, Dexter, Epstein, Marcon, and de Matta (2005) reviewed strategies to reduce delays to post anesthesia care units including ensuring that beds are full, adjusting the OR schedule, and requesting nurses to be flexible about working hours (Dexter, Epstein, Marcon & de Matta, 2005). They recommended that ORs review their scheduling practices or request nurses to be flexible in staffing recovery rooms.

Operating room utilization, or the percent of time during a day that patients are in surgical suites, is commonly used as a measure of OR throughput. Another measure of throughput is the number of cases that can be completed during a block of time. When efficiency is measured only by number of cases completed per day, sources of and trends are difficult to identify. Recall that proposed research focuses on surgical team inputs that are transformed as outputs of time utilization in the OR. For this reason, OR utilization both intraoperatively and interoperatively, rather than number of procedures performed, are considered in the research model of nursing staff arrangements as they affect efficiency in OR processes.

## Time in the Operating Room

A key to increasing efficiency in surgery is to reduce waste by targeting the use of time. Hospitals bill for OR services based on the time that individual surgical suites are used; time before, during, or after the completion of surgical cases is not billable. Operating room efficiency is motivated by minimizing non-billable time in order to maximize marginal revenue and provision of care. Because ORs create revenue by charging for time in surgery, time in the OR drives financial cost. Incentives to draw out time in surgery are mitigated by controls such as professional standards for surgical times, hospital benchmarking estimates, and ethical grounds to minimize risks related to anesthesia. In the OR, efficiency is equivalent to saving time both while a patient is in a surgical suite and between surgical cases as a suite is prepared for the case to follow. Efficiency in the OR may be improved by increasing utilization through narrowing gaps and reducing turnover times between cases (Fogg, 2001). Operating Room managers seek to minimize time spent performing surgical procedures and time between cases.

Insofar as time in the OR is translated to financial costs, time also indicates quality. Wait time in perioperative processes affects both patient satisfaction and the productive potential of OR staff to conduct patient visits, provide education, and undertake quality improvement projects. Rossiter and Reynolds (1963) conducted a twelve-week trial in ten clinics to assess ways to reduce the time waited. They defined clinic efficiency in terms of times that patients waited for consultations, and concluded that reduced waiting time is advantageous to physicians and patients. Improved physician-patient relationships, and less pressure on caregivers were noted as advantages. Remarkably, annual savings of 2.6 million working days (not including time saved for those accompanying patients) might be realized from a half-hour reduction in each patient's waiting time (Rossiter & Reynolds, 1963). A hospital's ability to perform more surgeries each year provides additional opportunities for surgical teams to gain prowess through practice, advancing both quality and demand as consumers seek hospitals with better surgical track records.

Measures of health care quality may include surgical performance indicators, such as surgical wound infection and surgical prophylaxis, perioperative mortality, and unplanned returns to the operating room (Thompson, Taber, Lally & Kazandjian, 2004). Additional measures include length of stay and readmission rates (Goodney, Stukel, Lucas, Finlayson & Birkmeyer, 2003). Few studies of OR efficiency have considered OR timeframes to reflect both throughput and quality in surgical services. Previous efficiency studies have relied on outputs such as patient days or the number of procedures performed. What is missing in these studies is consideration of quality-related outputs. In a review of efficiency research related to healthcare, McGlynn (2008) found that common health service inputs included inpatient stays, physician visits, and procedures (McGlynn, 2008). Despite increased awareness about value in health care, few outputs specifically accounted for quality in service provision (McGlynn, 2008).

**Intraoperative Time**

A suite in the OR is utilized whenever a patient is in that room. With the clock as a meter to accrue revenue and secure quality, it behooves ORs to perform surgical activities in the minimum possible time that they can be safely conducted. Weinbroum, Ekstein, and Ezri (2003) conducted a month-long study of OR “time-waste” (time in which the scheduled OR remained unused by the scheduled patient). An evaluation of 102 cases revealed that 15% of the daily scheduled surgery time was wasted. In addition to surgical cancellations and congested recovery rooms, main causes of time wasted were unprepared patients, cleaning time, and unavailable surgeons (Weinbroum, Ekstein & Ezri, 2003).

Kelz et al. (2009) studied 56,920 elective vascular and general surgical procedures with “operation start time” as the independent variable, and its association with morbidity or mortality (Kelz et al;, 2009). Operation start time was moderately associated with mortality, and a strong effect on morbidity, for cases between 9:30 pm and 7:30 am (Kelz et al., 2009).

Bridges and Diamond (1999) estimated the time cost of training surgical residents in the OR, and concluded that virtual surgery modules, additional surgery practice labs, and review of resident selection processes may lead to more efficient resident training (Bridges & Diamond, 1999).

The number of people in a surgical suite may also affect OR process efficiency. An increase in the number of staff involved in a case may help or hinder efficiency, making this input either desirable or undesirable depending on the situation. With more people, it is possible to delegate and accomplish more tasks. Conversely, the addition of individuals to an activity increases the potential for communication failures and time-consuming mistakes. In their study of joint replacement procedures, Reagans, Argote, and Brooks (2005) controlled for the size of the surgical team (Reagans, Argote & Brooks, 2005). Surgical team size was significantly related to an increase in procedure completion time (Reagans, Argote & Brooks, 2005). Cassera, Zheng, Martinec, Dunst, and Swanstrom (2009) analyzed 360 general laparoscopic cases and found a relationship between procedure times and number of nurses taking part in the procedure; holding constant procedure complexity and patient status, an additional team member predicted a procedure time increase of more than 15 minutes (Cassera, Zheng, Martinec, Dunst & Swanstrom, 2009).

Consistency of procedure type between cases is another variable that may affect surgical times. In scheduling cases for surgery on a given day, it is preferable to arrange for procedures of the same type to be conducted in sequential order in the same room. Room set up, instrument preparation, and clean-up, as well as patient preparation, are envisioned to be more efficient when the surgical team does not have to shift gears as they proceed to subsequent cases. Further study of surgical efficiency is needed to address whether scheduling cases by procedure type affects time spent in the perioperative process. Kraus, Buchler, and Herfarth (2005) cite hernia surgery as an example of process flow which employs standardized treatment for similar procedure to maximize efficiency. Exemplifying procedure consistency, surgical teams are organized around similar batches of surgical types, and use similar, structured techniques to complete each case (Kraus, Buchler & Herfarth, 2005).

Graded from 1 (least severe, e.g., in a good preoperative health state) to 6 (most severe, e.g., a candidate for organ procurement) American Society of Anesthesiologists (ASA) physical status classification system (American Society of Anesthesiologists, 2011) has been associated with a number of variables related to perioperative efficiency. In a retrospective review of 224 surgical procedures, Macario, Vitez, Dunn, McDonald, and Brown (1997) found that higher degrees of coexisting illness resulted in longer surgery time. They suggest that a patient's ASA status may predict higher surgical costs stemming from longer case times or more monitoring (Macario, Vitez, Dunn, McDonald & Brown, 1997). Wolthers, Wolf, Stutzer, and Schroder (1996) found an association between ASA physical status and intraoperative blood loss (Wolthers, Wolf, Stutzer & Schroder, 1996). Forrest, Rehder, Cahalan, and Goldsmith (1992) found a number of independent predictors of serious perioperative adverse outcomes in a study of 17, 201 patients undergoing general anesthesia for elective surgery (Forrest, Rehder, Cahalan & Goldsmith, 1992). Among the most significant risks were some history of cardiovascular disease, abdominal and cardiothoracic surgery, and ASA physical status 3 or 4 (Forrest et al, 1992).

Another indicator of the complexity of a surgical procedure is the work relative value unit (RVU) established by the American Medical Association (American Medical Association, 2012). Cases with higher work RVU values are often more complex, requiring more time and effort and therefore may be associated with longer OR durations.

**Interoperative Time**

In addition to intraoperative surgical time, turnover time between surgical cases is used as a measure in orchestrating more productivity in surgical processes. That interoperative time allows the surgical team to make crucial preoperative checks and preparations favoring better outcomes makes it an essential aspect of operating room processes. Activities such as room turnover are necessary for successful operations, yet are sometimes overlooked as a necessary component of perioperative scheduling (Marco & Hart. 2001). Vigoda, Gayer, Tutiven, Mueller, Schefler, & Murray (2008) identified surgical cases with minimal turnover time as a mark of efficiency (Vigoda, Gayer, Tutiven, Mueller, Schefler, & Murray, 2008).

Operating room workflow has been examined in its contribution to turnover time. Baumgart, Zoeller, Denz, Bender, Heinzl, and Badreddin (2007) also noted that turnover time as a perioperative performance measure as they advocated the use of simulations to reduce inefficiency in operating rooms (Baumgart, Zoeller, Denz, Bender, Heinzl & Badreddin, 2007). Cendan and Good (2006) assessed the assigned tasks and workflow of anesthesiologist, circulator, and surgical technician in relation to operating room turnover time. A redesign of the work flow diagram resulted in changes in practice that reduced turnover times significantly (Cendan &Good, 2006). The practice changes involved the addition of a separate nurse to manage the end of a surgical procedure so that the circulator could undertake preoperative preparations. This intervention succeeded in significantly reducing turnover times (Cendan & Good, 2006). Fisher, Lotery, and Henderson (2009) used time-in-motion studies to determine delays in dermatological surgical services. They concluded that paperwork and generic communication time contributed to fewer turnovers, and therefore less revenue, for a practice. Furthermore, they maintained that ‘idle time’’ for an individual staff member correlates with inefficiency (Fisher, Lotery & Henderson, 2009). Marjamaa, Paulus, Hirvensalo, and Kirvela (2009) sought to identify interventions that reduce the non-operative time that would enable more operations to be performed per day. They recommended scenarios including parallel processing, separately staffed induction rooms, and administration of local anesthetics by surgeons during room turnover (Marjamaa, Paulus, Hirvensalo & Kirvela, 2009).

Evidence suggests that minimizing time between short cases may permit more cases of short time to be completed in a single day. Dexter, Coffin, and Tinker (1995) considered the effects of reducing anesthesia-controlled times during and between cases (Dexter, Coffin & Tinker, 1995). They concluded that a separate reduction of either of those times would not significantly affect the number of surgical procedures that could be completed each day. Only where all case times for a surgical suite were less than 76 minutes would a decrease in turnover time allow for the completion of additional scheduled cases. Mazzei (1994) concurred with these findings about turnover time. His 6-month assessment of turnover times for 10 surgical services led to the conclusion that although teamwork is essential to efficiency in ORs, reducing turnover times would not permit sufficient increases in case scheduling to warrant additional staff needed to reduce room clean-up time (Mazzei, 1994). These studies suggest that the effect of reduced turnover time on completion of more surgical cases throughout the course of a day may be limited. Even if more cases cannot be undertaken, the cases that are completed as a result of time reduction are conducted during work hours, thus minimizing costs of overtime and call team pay to hospitals. The added benefit of less wait time allows providers to embark on productive activities outside of the OR, and gives patients and families a reprieve from whiling away minutes in hospital environments.

At the same time, turnovers may be viewed as non-productive because hospitals cannot charge payers for time between surgical cases. Prolonged turnover time bodes ill for patient satisfaction, staff relations, and hospital revenue. Dexter, Abouleish, Epstein, Whitten, and Lubarsky (2003) determined that the use of time between cases is a standard for operating room efficiency. They noted that potential benefits to reducing inter-operative times are both quantitative (e.g., complete more cases and reduce staffing costs) and qualitative (e.g., improve professional satisfaction). The authors argue that as “neither revenue nor direct patient benefit is provided during clean up and set up times, reducing turnover times would seem to benefit both physicians and hospitals” (Dexter, Abouleish, Epstein, Whitten & Lubarsky, 2003). Therefore, turnover time may be seen as an economic “bad”, with its foregone potential viewed as “opportunity cost”. Numerous studies have considered the cost of staffing, time, and utilization in the OR. But because studies often draw on accounting practices to measure costs, opportunity cost as a specified outcome has infrequently been used in estimating effectiveness or productivity in surgery. Chaterjee, Payette, Demas, and Finlayson (2009) compared the efficiency of surgical devices using dollar amounts per minute in surgery when competing devices were used (Chaterjee, Payette, Demas & Finlayson, 2009). In another study, opportunity cost in surgery was defined as the cost of time that may have been devoted to other work but was lost due to inefficiency (Chaterjee, McCarthy, Montagne, Leong & Kerrigan, 2011). Bernet, Moises, and Valdmanis (2011), in studying social access to hospital services, included the cost of patient travel time as an opportunity cost of care (Bernet, Moises & Valdmanis, 2011). Such research indicates that time is a measure of intangible value to patients, families, and society.

Shorter room turnovers are essential to productivity, yet few stakeholders agree on definitions or benchmarks regarding turnover times. Magnum and Cutler (2002) write that short turnover times and wise use of time and personnel during surgical procedures are hallmarks of ORs that are managed proficiently (Magnum & Cutler, 2002). Macario defined turnover time as the period between one patient’s exit from a surgical suite until the entry of the next patient into the same suite. With this, turnover times include cleanup times and setup times, but not delays between cases. Times between cases longer than a defined duration, for example, of one hour, should be considered delays, not turnovers (Macario, 2006). Overdyk, Harvey, Fishman, and

Shippey (1998) defined turnover time as the time between a patient leaving the surgical suite and the next patient entering the suite (Overdyk, Harvey, Fishman & Shippey, 1998).

In determining acceptable turnover times, Fogg (1998) wrote that AORN is not aware of a standard average for turnover time, with such an estimate meaningless unless all healthcare facilities have the same complements in terms of staffing, facilities, and patient population. However, aggregate and facility-specific reports are useful in assessing performance compared to similar settings as long as terms are well-defined (Fogg, 1998). Others (Epstein and Dexter, 2002) have used one hour as the turnover time limit, with times more than that cut-off considered to be a surgical delay. Dexter, Macario, Qian, and Traub (1999), noting potential difficulties in separating room turnovers including cleaning and setup time, and delays, truncated turnover times longer than one hour to equal one hour (Dexter, Macario, Qian & Traub, 1999). Finally, Abouleish, Hensley, Zornow, and Prough, (2003) used average turnover times by surgical service over a 13-month period and excluded times over 75 minutes. Despite the lack of consensus about reasonable times between surgical cases, the authors affirmed, turnover times remain a target for OR efficiency improvement (Abouleish, Hensley, Zornow & Prough, 2003).

Time savings within and between surgical cases have tangible effects on access and hospital revenue, and intangible results related to opportunity cost. Sufficient reductions in both intra-operative and inter-operative time may allow for more surgical cases to be completed each day, expanding the reach of health care provision. By reducing time in the OR, hospitals may also gain revenue without compromising patient safety or affecting the type, or intensity, of care that surgical patients receive. Time not spent in surgery frees patients, families, and staff to engage in other productive or leisure activities. Research focusing on the people responsible for maximizing time savings in the OR creates possibilities for improving the quantity and quality of surgical care provided.

**Nursing Staff Arrangements in Surgical Processes**

This section opens with an overview of nursing staff arrangements in the OR, and closes with a reflection on the importance of nursing staff arrangements. Appendix A offers a pair of scenarios illustrating potential adverse or supportive effects of nursing staff arrangements during perioperative intervals. Scientific management is reviewed as the theoretical basis for studying efficiency in the OR environment. The conceptual model, based on scientific management theory and applied to the OR environment, is then presented. This chapter ends with a description of research questions hypotheses about the association between nurse staffing arrangements and efficiency in surgical processes.

A surgical case consists of one or more procedures, usually invasive, performed on a patient during one episode in a surgical suite. In the OR, surgical procedures are routinely accomplished through the coordinated efforts of at least one surgeon, one anesthesiologist, one RN circulator (the "circulator"), and one scrub person (the "scrub"). Surgical cases in teaching hospitals often include two additional types of surgical team members, an anesthesia resident or Certified Registered Nurse Anesthetist, and surgical residents or fellows. In some cases, particularly those requiring much specialty instrumentation or time-consuming equipment set-up, additional circulators or scrubs may be used.

Surgical processes involve the efforts of experienced individuals working in teams. Most often, a surgical case involves the work of one surgical service, led by a surgeon specializing in an area of surgery. The anesthesia and nursing staff involved in a given procedure may or may not be specialists as are the surgeons. In a given case, for example, an orthopedic surgeon may work alongside a nurse whose specialty is ophthalmology. In any event, the OR nursing staff are expected to adapt quickly to changing situations.

### Professional Mix within Operating Room Nursing Staff

The OR nursing staff is pivotal in maintaining smooth functioning in the surgical environment. Only an RN may serve as a circulator during a surgical case. Throughout a patient's OR experience, the circulator is responsible for ensuring patient safety through adequate preoperative preparation, and ongoing coordination of the surgical team's activities. Meanwhile, the nursing staff member in the scrub role is expected to have knowledge and experience to manage the sterile field throughout the surgical procedure (AORN, 2010). An RN, a surgical technologist (ST), or a licensed practical nurse may perform the scrub role. In the OR, the work of STs is meant to complement, not replace the work of RNs.

### Specialization within Operating Room Nursing Staff

Nursing staff in the OR may either be hired onto one surgical service team, as specialists, or hired with intent to relieve circulators and scrubs for breaks or off-shift cases, as generalists. Those OR nursing staff on specialty surgical teams are routinely assigned to cases under the purview of their surgical service. Such specialists are viewed as experts in their respective surgical services, and are often called on for advice or information about preparing for and carrying out specialty surgical cases. For those who are hired as "float" or "relief" nursing staff, there remains the expectation that they be versatile, and prepared to step in to cover any type of surgical procedure when required.

### Standardization of Assignments within Operating Room Nursing Staff

Conventional practice regarding OR nursing staff arrangements is for the nursing shift coordinator to assign at the beginning of each shift one circulator and one scrub to work together in a surgical case. Where nursing staff, be they RNs or STs, are not assigned responsibility for a surgical case, those staff are designated to provide breaks, or to be on hand to cover should emergent cases arise. Throughout the duration of the case, relief staff members may rotate into and out of the surgical suite depending on the need for breaks and the events occurring in different portions of surgical timeframes. For example, a surgeon may not remain in the surgical suite during anesthesia induction, and may leave after the dressing is applied to the surgical site. For the nursing staff, however, a circulator and a scrub work in tandem, and a pairing of at least one circulator and one scrub remains in the surgical suite for the entirety of the procedure. From case to case, or even within one case, the circulator and the scrub may be relieved temporarily for breaks, or for the remainder of the shift to hand over patient responsibility. Furthermore, throughout the shift, the circulator-scrub dyad may either remain together in one surgical suite from case to case, or one or both may be assigned to work in another, thus splitting the circulator-scrub dyad.

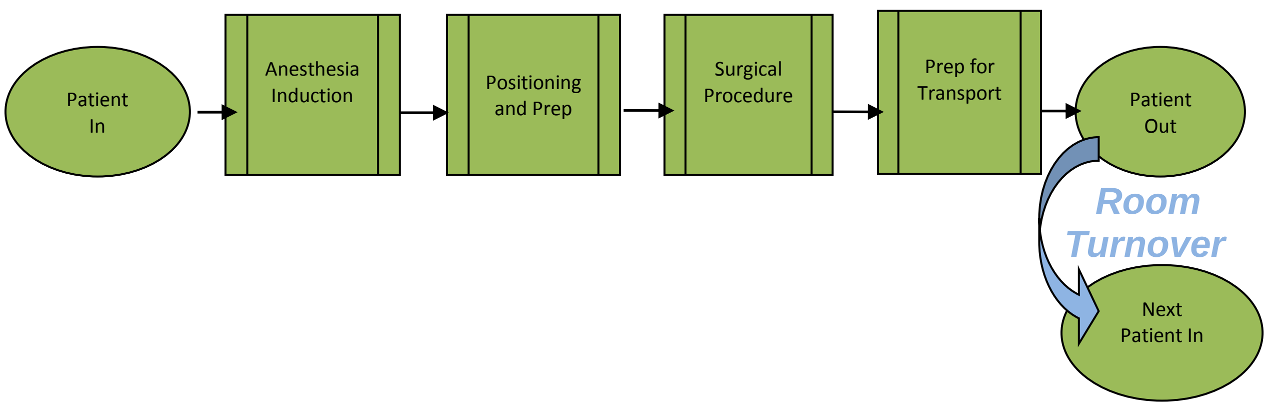
## Themes Related to Nursing Staff Arrangements and OR Efficiency

The principles of scientific management, specifically, of occupational mix, specialization, and standardization, serve as a theoretical framework for a conceptual model of the effects of nursing staff arrangements on efficiency in OR processes. Before describing the conceptual model, key activities occurring throughout sequential surgical cases are reviewed in order.

### Key Activities in OR Processes

Activities that are characteristic of surgical procedures conducted in inpatient ORs are shown in Figure 1, “Key Activities in Operating Room Processes”. Completion of a surgical case consists of more than performing the surgical procedure itself. A patient’s entrance to a surgical suite, administration of anesthetic agents, positioning and prepping of the patient, completion of the surgical procedure, and transport of the patient from the surgical suite are all focal activities within the conduct of a surgical case. Between consecutive surgical cases, the surgical suite is cleaned from the previous case, and prepared for the case to follow. These activities may be grouped according to whether they occur within a surgical case or between surgical cases. Figure 1 shown here illustrates the flow of activities occurring throughout the process of completing surgical cases.

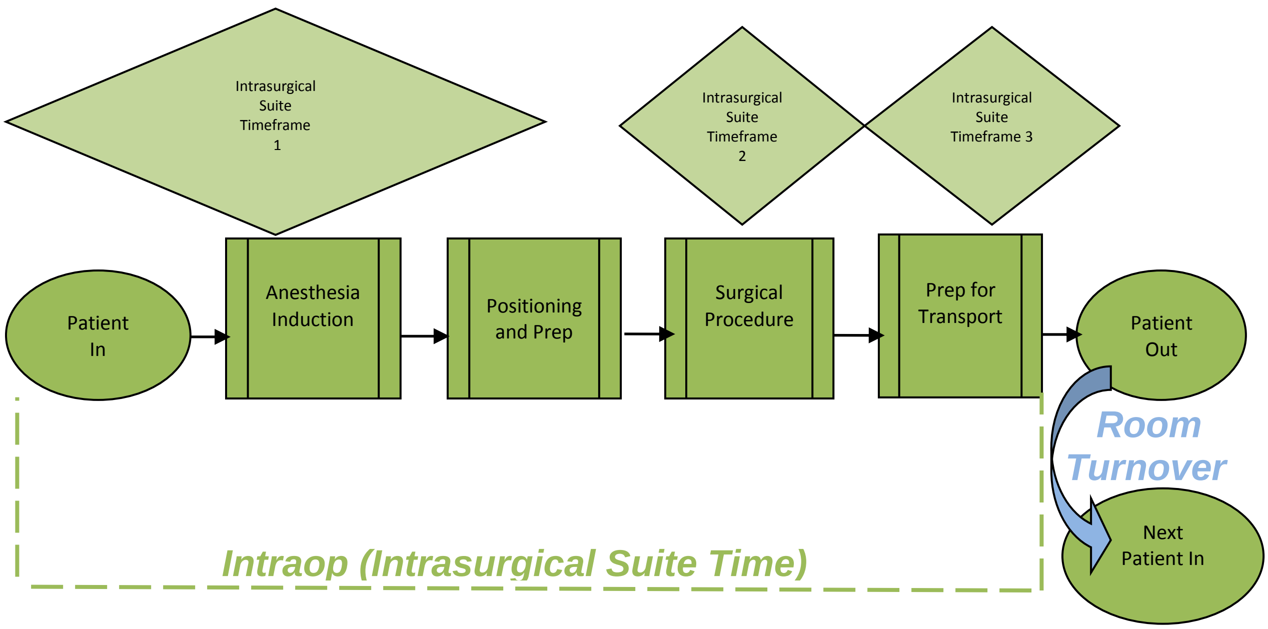
*Figure 1*. Key Activities in Operating Room Processes




**Timeframes in OR Processes**

A common approach to analyzing OR efficiency is to split the surgical process into a series of timeframes occurring within surgical cases (intraoperatively) and between sequential cases (interoperatively). Such a division permits a closer look at the staff roles and tasks involved before, during, and after the surgical procedure itself. In this scheme, the timeframes spanning a patient's entry through exit from a surgical suite constitute *intra*operative events. *Inter*operative events occur in the timeframe between a patient's exit from a surgical suite until the entry of another patient into the same suite for the subsequent surgical case on the same day. Figure 2 illustrates intraoperative and interoperative timeframes in OR processes.

*Figure 2*: Intrasurgical Suite and Intersurgical Suite Timeframes




The first of the intraoperative timeframes is that spanning the period from a patient's entrance into a surgical suite to the making of the surgical incision. Activities such as the preoperative verification with the patient, anesthesia induction, patient positioning and prepping occur in this timeframe. The second intraoperative timeframe spans the period from the surgical incision (or the beginning of the surgical procedure in lieu of an incision) to the application of the surgical dressing (or final washing from the surgical procedure). In this second intraoperative timeframe, the main event is the surgical procedure and activities undertaken by the surgical team to maintain the patient's hemodynamic, temperature, and fluid status. The final stage of the intraoperative period is the interval between the conclusion of the surgical procedure and transport of the patient out of the surgical suite. During this final intraoperative timeframe, the current patient is prepared for transport out of the surgical suite and preparations are begun for the transport of the subsequent patient. The time between surgical cases, represented as the Turnover Time, enables transfer of patient care, room clean-up and instrument decontamination from the previous case. Turnover time is also the stage where equipment and supplies are gathered for the subsequent case, and the patient for that case is interviewed in the preoperative staging area.

### Effects of Nursing Staff Performance on Surgical Procedures

In the surgical environment, working efficiently has become an imperative to maintain flow. Surgical procedures reflect a combination of individual efforts within a complex, adaptive team. Surgical teams are encouraged to minimize time use while maintaining patient safety. Because of mandated provider to patient ratios in inpatient surgery, surgical cases use at least one circulator, one scrub, one anesthesiologist, and one surgeon. These OR staffing practices and time constraints preclude options for staff to work harder by taking on more patients, or work longer by spending unnecessary time on individual surgical cases.

To illustrate the potential effects of OR nursing staff specialization and skill mix on the flow and pace of the surgical process, two scenarios are presented in Appendix A. Both cases involve total hip replacement surgery and describe events occurring as the introduction of new nursing staff, with less orthopedic surgery experience, take part in the surgical process. In sum, mistakes are made and time is squandered when team members lacking experience with t he procedure or service are introduced into the surgical flow.

## Conceptual Model of Nursing Staff Arrangements and OR Processes

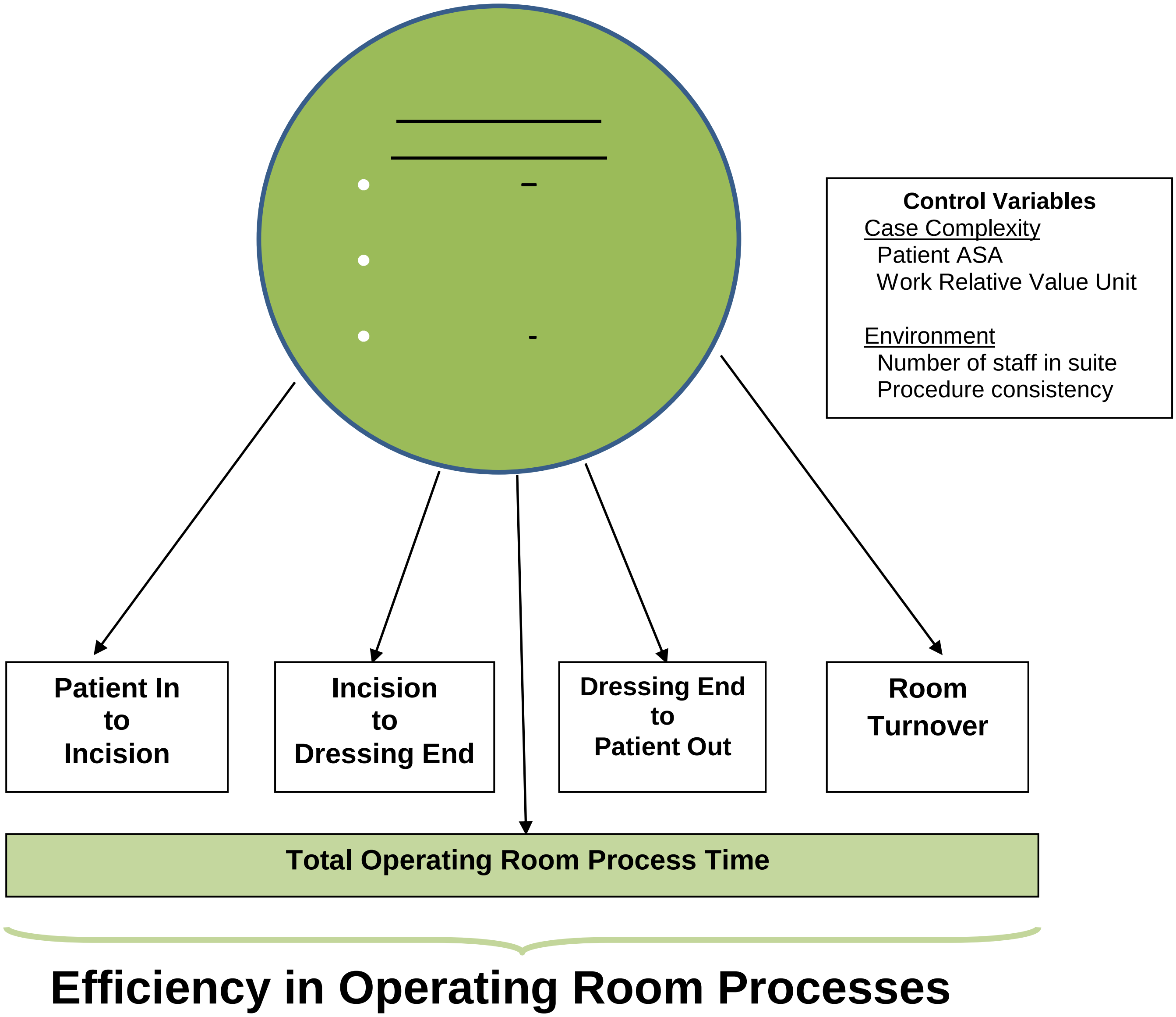
This study has as its basis a conceptual model developed after a review of literature of efficiency in health care, scientific management principles, and nursing staff characteristics that may be related to the use of time in OR processes (Figure 3). In this explanatory model, nursing staff arrangements, and control variables, may have a bearing on five separate timeframes that contain the OR process. These five timeframes reflect levels of OR efficiency and include three intraoperative time intervals, the interoperative time interval, and the combined intraoperative and interoperative time interval. The effect of nursing team staffing throughout the surgical process is illustrated in this conceptual model. At each stage of the perioperative process, the combination of professional training, experience, and partnership represented by the appointment of the circulator and scrub for each case may affect the flow and pace of operations. In this model, elements of nurse staffing arrangements reflect the principles of scientific management theory, and are listed in a circle to signify that nursing is an integral part of the whole of the surgical team. An arrow leads from the nursing staff circle to each of the intraoperative timeframes and to the interoperative timeframe, indicating a potential effect of nursing staff arrangement characteristics on the four time intervals that compose the OR process. Control variables that may affect time efficiency in OR processes, including environmental conditions, patient preoperative health status, and case complexity, are noted in the margin. Essential responsibilities associated with each timeframe are shown in Table 2, “Nursing Staff Responsibilities in OR Processes”.

Table 2

*Nursing Staff Responsibilities in OR Processes*

| Timeframe | Nursing Staff Responsibliities |
|---|---|
| **ISST1, Patient In to Incision** | • Transport patient into OR<br>• Pre-op verification<br>• Anesthesia Induction<br>• Patient Positioning<br>• Skin Prep<br>• Count<br>• Set up equipment |
| **ISST2, Incision to Dressing End** | • Surgical Time out<br>• Monitor equipment<br>• Procure supplies<br>• Anticipate surgical team needs<br>• Document<br>• Call for next patient<br>• Count and coordinate |
| **ISST3, Dressing End to Patient Out** | • Count<br>• Anesthesia recovery<br>• Prepare dressing<br>• Clear instruments and drapes<br>• Communication about case to follow<br>• Transfer patient from OR<br>• Call for room turnover |
| **Turnover Time** | • Clear previous case supplies and instruments<br>• Verify preference card<br>• Gather supplies for next case<br>• Coordinate with surgical team<br>• Interview next patient |

*Figure 3*:  A Conceptual Framework of Nursing Staff Arrangements and Operating Room Process Efficiency



## Research Goal and Questions

A major influence on efficiency, labor patterns, has remained at best unchanged in the scheme of health care delivery over the past two decades. Improvements in health care may be viewed from the standpoint of minimizing time-consuming activities, the effects of replacing labor with capital, and efforts to maximize productivity.

This research assessed the contribution of characteristics of nursing staff labor inputs in effecting reductions in time in the surgical process. A review of data from consecutive surgical cases enables an examination of how nursing staff patterns related to professional mix, specialization in a surgical service, and standardization of nursing staff assignments affect efficiency in surgical processes. Specifically, in order to see the effects of OR nurse staffing arrangements on interoperative (turnover) and intraoperative (surgical) times, cases occurring on the same day, and in the same surgical suite were included in the analysis. Overarching the focus on elements of throughput is the goal of this study: to examine OR efficiency. The research goal is thus stated:

**Research Goal**: To evaluate the contribution of principles of scientific management theory to an explanatory model of efficiency in operating room processes.

Nursing staff labor efficiency may significantly affect health care costs and quality. In the OR, the nursing staff plays a significant role in each surgical procedure. Nurse staffing practices may enable surgical teams to improve performance by contributing to time savings both within, and time between, surgical cases (Catchpole, Mishra, Handa & McCulloch, 2008). Despite the importance of nurse staffing and practice patterns in the surgical setting, few empirical studies have examined the effect of individual staff experience and dyad arrangements on efficiency within OR processes. An evaluation of efficiency in surgical processes must consider variables particular to OR nursing, including professional mix of the circulator and scrub, nursing OR specialization, and circulator-scrub staffing arrangements.

The first research question reflects evidence that nursing staff professional mix affects outcomes (Needleman et al, 2002; Aiken et al, 2003). For this study, professional mix involves the assignment of two nurses, or a nurse and a scrub technologist, to a surgical case. The second research question focuses on individual nursing staff specialty experience as a result of taking part in cases done by a particular surgical service, general surgery. The final research question addresses the issue of standardization by considering the effect of maintaining the same nursing team composition between subsequent surgical cases. For each question, the dependent variable is perioperative time. This study emerges from the following three queries, the answers to which will contribute to achieving the research goal.

**Operating Room Nursing Staff Professional Mix: The Right Person for the Job**

The AORN defines "skill mix" as the "ratio of RNs to STs/LPNs providing direct patient care in the department" (AORN, 2012). The AORN recommends an RN/ST or LPN professional staffing ration of 67:33 (AORN, 2012). Sufficient numbers of competent perioperative RNs must be available for patient and family care. In the circulating role, a registered nurse directs the nursing care of all patients undergoing surgical or other invasive procedures, necessitating a 1:1 perioperative RN:patient ratio. When STs are added to the staffing mix, AORN believes that OR staffing ratios should support the perioperative registered nurse functioning in both the scrub and circulating roles. That is to say, the ratio of RNs to STs should be adequate to allow for two RNs to be paired as a circulator and a scrub in a surgical case. The AORN has adopted the position that staffing resources be maximized "to provide the skill level necessary to promote optimum patient outcomes and efficient patient flow" (AORN, 2012).

In the OR, the nursing staff professional mix involved in a case may involve two RNs, or one RN and one ST. Comparing the professional mix of nursing staff involved in surgical cases provides useful information about staffing arrangements in perioperative areas. This study recognizes the particular skills and training that STs bring to the scrub role, and subscribes to the scientific management view that there is one right type of skilled worker for each job. Few studies of nursing staff mix, however, have targeted OR process efficiency. Thus, the first research question is:

**Research Question 1:** What amount of variation in operating room process efficiency is explained by nursing staff professional mix in a surgical case affect after controlling for environmental, patient health status, and case complexity variables?

**Nursing Staff Experience in Specialty Surgical Services: Specialization**

Surgical services in the U.S. are often organized by specialty although many surgeons function as specialists in one surgical service, nursing staff do not necessarily specialize. The organization of the nursing staff within an OR depends largely on surgical volume and shift worked. Unfamiliarity with equipment routinely used by a surgical service, or lack of preparation to conduct particular tasks such as frozen specimen handling in accordance with a surgical service's protocol, have the potential to impede surgical speed, flow, and precision.

Tasks involved in conducting different surgical procedures are likely to have less variation within a surgical service than between surgical services. For this reason, it may be beneficial to arrange surgical staff according to specialties, as it is more efficient for familiar staff to work together on all types of procedures than for unfamiliar staff to assemble and conduct a specific type of procedure. Greater variation in perioperative practices between than within surgical services raises the issue of nursing staff specialization within surgical service teams as a means of realizing more productivity, with better outcomes, in surgery. Previous research suggests that more exposure to workplace processes, through training and experience, is associated with more efficiency and less time required to complete assignments. Projected to the OR, the experience that individual members of a surgical team gain by taking part in each case enables performance that is both swift and adept. It is plausible that the cumulative time that an individual has participated in a surgical specialty service contributes to efficiency. Previous surgical encounters enable both a circulator and a scrub to ensure patient safety while anticipating the surgical team's needs. More exposure to a particular surgical service affords opportunities to learn both by doing and by observation. In the OR environment, nursing staff who frequently work in one surgical service area are exposed to the equipment, supplies, routines, and idiosyncrasies of that service. Repeated exposure to specific surgical services such as general surgery may improve a scrub's dexterity in assembling tools, and eliminating wasted motions. Previous surgical encounters also form the basis for anticipating surgical team needs such as when to pass certain instruments or pass off items such as oxygen tubing to the circulator.

The amount of time that nursing staff have been involved in a surgical service may aid in speed of procuring and preparing equipment, in anticipating the surgical team's needs, and in communicating effectively. In surgery, it is not uncommon for equipment to be shared within a service and used in other cases within that same service. Methods of patient positioning and prepping, too, may be similar within, but not between, surgical services. Therefore, if a circulator has used a surgical service's positioning devices, or a scrub has set up a service's laparoscopic equipment, those nursing staff are wont to save time when assigned to work in that service.

To date, however, research on the effects of nursing staff specialization in a surgical service on OR efficiency is scant. The second research question, which has separate components for circulator and for scrub specialization, is:

> **Research Question 2:** What amount of variation in operating room process efficiency is explained by the degree of nursing staff surgical specialization in the general surgery service after controlling for environmental, patient health status, and case complexity variables?
>
> > **Research Question 2a:** What amount of variation in operating room process efficiency is explained by the degree of circulator specialization in the general surgery service after controlling for environmental, patient health status, and case complexity variables?
> >
> > **Research Question 2b:** What amount of variation in operating room process efficiency is explained by the degree of scrub specialization in the general surgery service after controlling for environmental, patient health status, and case complexity variables?

### Circulator-Scrub Dyad Consistency: Standardization

The OR nursing staff is uniquely challenged by the expectation that surgical cases will be performed smoothly, safely, and efficiently. In one shift, a circulator or scrub may take part in several different surgical procedures. Efficiency may be hampered by a change of nursing staff between cases if the change affects coordination of the surgical team or the patient 's readiness, or if additional time is required to get the new team member up to speed about the case to follow. For example, turnover time, key activities of which are room cleaning from the previous case and preparation for the case to follow, may be affected by a change of nursing staff between cases. The circulator – scrub dyad from case to case may affect how time is used both within and between surgical cases. Circulators and scrubs who have been paired in the previous case may be better informed about the case to follow, and so may be better able to prepare for that next case. Conversely, changes in nursing staff pairings between cases may enhance productivity if a new team member is rested and ready to "hit the ground running".

In the OR environment, the oft-repeated mantra, "we do it the same way every time", is more than a penchant for routine. Consistency facilitates time management throughout the perioperative period. A surgical team knowledgeable about room and equipment set-up, patient preparation and positioning, the surgical procedure, and plans for patient recovery and transfer eases the surgical flow. Standardization in surgical processes also fosters reliability and safety as all members of the surgical team are equipped to anticipate tasks throughout the perioperative period. The concept of circulator – scrub dyad is appropriate for describing standardization in terms of nurse staffing in the surgical process. Standardization of surgical team functioning through membership stability has been recognized as an important component of OR process efficiency (Bunker, 1970; Pisano, Bohmer & Edmondson, 2001; Friedman, Sokal Chang & Berger, 2006). With sparse evidence about the role of circulator-scrub pairs in surgical processes, the proposed study suggests the third research question:

**Research Question 3**: What amount of variation in operating room process efficiency is explained by circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

**Assessing a model of OR efficiency**

Upon addressing the effects of nursing staff professional mix, specialization, and standardization on OR process efficiency, a final research question remains. The fourth research question addresses the adequacy of a model of OR process efficiency, and evaluates the model which combines independent variables pertaining to nursing staff arrangements, control variables, and each of five dependent variables reflecting OR timeframes. Thus, the fourth research question is:

**Research Question 4**: What amount of variation in operating room process efficiency is explained by difference in nursing staff professional mix, the degree of nursing staff surgical specialization, and circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

## Summary

Efficiency is linked to time saving in OR processes. In the OR, everyone on the surgical team—nursing, anesthesia, and surgeon staff—plays a significant role in a surgical procedure. Nurse staffing practices may enable surgical teams to improve performance by contributing to time savings both within and between surgical cases. In addition, few empirical studies have examined the effect of individual staff experience and dyad arrangements on productivity of OR processes. An evaluation of efficiency in surgical processes must consider variables particular to

OR nursing, including individual experience in surgical specialties, and dyadic staffing arrangements. Scientific management theory holds that organizations may raise labor efficiency through professional mix, specialization, and standardization within individual members of a work team. A particular focus of scientific management is to boost efficiency through improved use of time. Surgical processes are inherently reliant on suitable staffing patterns, specialization, and standardization to accomplish cases. The principles of scientific management may be translated to surgical processes, where efficiency may depend largely on staffing arrangements and their use of time. As ORs strive for efficiency gains, an assessment of OR nurse staffing arrangements reveals feasible approaches to increasing efficiency in surgical processes.

## Summary of Research Questions and Hypotheses

**Research Question 1:** What amount of variation in operating room process efficiency is explained by nursing staff professional mix in a surgical case affect after controlling for environmental, patient health status, and case complexity variables?

**Hypothesis 1:** Similarity in nursing staff professional mix is associated with increased efficiency in surgical processes.

Efficiency nurse-nurse professional mix > Efficiency nurse-scrub technologist professional mix.

**Research Question 2:** What amount of variation in operating room process efficiency is explained by the degree of nursing staff surgical specialization after controlling for environmental, patient health status, and case complexity variables?

**Research Question 2a:** What amount of variation in operating room process efficiency is explained by the degree of circulator specialization in a surgical service after controlling for environmental, patient health status, and case complexity variables?

**Research Question 2b:** What amount of variation in operating room process efficiency is explained by the degree of scrub specialization in a surgical service after controlling for environmental, patient health status, and case complexity variables?

**Hypothesis 2:** Increased nursing staff specialization is associated with increased efficiency in surgical processes.

**Hypothesis 2a:** Increased intraoperative time spent as a circulator in the general surgery service is associated with increased efficiency in surgical processes.

Efficiency circulator with more general surgery specialization > Efficiency generalist circulator

**Hypothesis 2b:** Increased intraoperative time spent as a scrub in the general surgery service is associated with increased efficiency in surgical processes.

Efficiency scrub with more general surgery specialization > Efficiency generalist scrub

**Research Question 3**: What amount of variation in operating room process efficiency is explained by circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

**Hypothesis 3:** Circulator-scrub dyad consistency between subsequent surgical cases is associated with increased efficiency in surgical processes.

> Efficiency of dyad same circulator and same scrub > Efficiency of dyad same circulator and new scrub *or* Efficiency of dyad new circulator and same scrub

and

> Efficiency of dyad same circulator and same scrub > Efficiency of dyad new circulator and new scrub

**Research Question 4**: What amount of variation in operating room process efficiency is explained by difference in nursing staff professional mix, the degree of nursing staff surgical specialization, and circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

**Hypothesis 4:** Nursing staff professional mix, the degree of nursing staff surgical specialization, and circulator-scrub dyad consistency between subsequent surgical cases are associated with increased efficiency in surgical processes.

# CHAPTER 3

# METHODOLOGY

This chapter presents the research design, measures, and analysis plan for this explanatory study of nursing staff arrangements and perioperative timeframes. An overview of the selection of units for data analysis is also provided. The multiple regression equation representing the research model of OR efficiency is presented, and analytical methods using multiple regression to assess the unique contribution to efficiency of nursing staff arrangements, controlling for environmental, and patient health status and case complexity variables, are described.

## Research Design, Data Source, and Sample

This section explains the research design and data sample used for this study. Through secondary data analysis, electronic operative records documented by OR nurses were examined using descriptive and hierarchical regression analyses. Beginning with a description of the study design, this section provides an overview of the methods for selecting units for the data analysis.

### Research Design

This study was a secondary data analysis of sequential surgical cases, employing a cross-sectional cohort design in which the case to follow was of the general surgery service. The unit of analysis in this study is the entirety of the surgical process from the exit of one patient from a surgical suite until the exit of the subsequent patient from the same surgical suite. With this, the unit of analysis is an episode encompassing the total OR process time; each episode includes information from a pairing of two subsequent surgical cases occurring on the same date and in the same suite. Exempt status for this study was obtained from the Institutional Review Board. All data used in this study has remained anonymous.

**Data Source**

The advent of electronic health records has led to a wealth of standardized information about surgical cases. Data for this study was obtained by merging two datasets, each containing information about the variables included in the research model. Operating room data was analyzed from surgical cases recorded in the electronic health record at the inpatient main OR of a large teaching hospital in the Midwest.

**ACS-NSQIP Data Subset: Patient Status and Case Complexity**

The study population (N = 924) includes a random sample of general surgery cases with patient data including preoperative health status and case complexity. General surgery cases are those that are reported as being conducted by the general surgery service of the hospital. This subset of 924 cases was compiled by the hospital as part of its participation in the American College of Surgeon's National Surgical Quality Improvement Plan (ACS-NSQIP) program, which uses surgical data from hospitals throughout the U.S. to improve OR performance and outcomes (Itani, 2009; Campbell et al., 2010). Importantly, the ACS-NSQIP case records include information about patient preoperative health status and case complexity. Operational management data on staffing and surgical times for the study population was obtained from a source data set including 17, 518 surgical cases. All patient data were recorded by the circulating nurse in each case who was an OR registered nurse trained to record information into the hospital's electronic health record system.

## Source Data Set: Time and Staffing

The source data set includes 17,518 surgical cases occurring throughout each 24-hour period from January 1 through December 31, 2008. This source dataset represents cases from a range of surgical services, with weekend and emergency cases. Recorded in the dataset are surgical times, the type of surgery, and methods such as patient positioning and pre-operative skin preparation. Variables essential to this research in the source data set include dates and room numbers for each case; times to mark entrance and exit, incision, and dressing end; and other variables related to the surgical environment such as procedure name and surgical service. Information about staffing patterns, for example, staff identification numbers and roles; and sign-in and sign-out times of entry and exit from the surgical suite, are also included in the source data set. This data set served as a source file for variables used with the study population.

### Sample

*Unit of Analysis.* The sample for this study included only ACS-NSQIP cases that were preceded by another surgical case. The sample used surgical case pairings of one preceding and one subsequent surgical case, occurring in the same surgical suite and on the same day. The unit of analysis thus included the following timeframes:

1. Interoperative time between a preceding case and the ACS-NSQIP case to follow (turnover time)
2. Intraoperative time of the ACS-NSQIP case to follow. Because of the particular responsibilities of different members of the surgical team during this intraoperative timeframe, it has been divided into three segments:
    a. Patient In to Incision
    b. Incision to Dressing End

c. Dressing End to Patient Out

Four timeframes marking time between surgical cases combine to create a fifth timeframe, the total OR process time (please refer to Figure 1). The first timeframe consists of the turnover time spanning the exit of the previous patient to the entrance of the patient in the case to follow. Turnover time lasts from the patient's exit from the suite until the entry of the patient in the subsequent case, or "case to follow". Turnover time may be attributed either to a previous case (since the room turnover involves clean-up from that case) or to a subsequent case (because room turnover involves preparation for and set-up of the case to follow). For this study, turnover time was attributable to the subsequent case. The second, third, and fourth timeframes, Patient In to Incision, Incision to Dressing End, and Dressing End to Patient Out, span the subsequent patient's entry to exit from the surgical suite. In summary, the unit of analysis in this study encompasses the time from one patient's exit from a surgical suite to the time that the patient in the subsequent case leaves that suite, provided that the subsequent patient entered the suite within of 60 minutes (the turnover time cut-off) of the exit of the first patient. The total OR process time therefore includes turnover time, and the three timeframes that comprise the time from the subsequent patient's entry to that patient's exit from the same surgical suite.

*Consideration of Sequential Cases.* ACS-NSQIP case data include information about patient and case complexity that are included among the control variables for this research. Two considerations precluded the use of all 924 cases in the subset of ACS-NSQIP cases. First, this study sought to explain OR process time, controlling for environmental, patient, and case complexity variables, in terms of the unique contribution of nursing staff variables. Included among the five dependent time variables was room turnover time, or that time spanning one patient's exit and the subsequent patient's entrance (within 60 minutes) to an OR suite. The use of turnover times required the use of *sequential* cases. Only cases that are followed by another case in the same surgical suite on the same day have a turnover time. Cases which were the sole case in a surgical suite on any day had no case to follow, and therefore, no turnover time that could be included in the analysis. This study included sequential pairs of cases occurring in the same surgical suite, with subsequent cases no more than one hour apart. For this study, cases occurring more than one hour apart, that is, with a turnover time of more than 60 minutes, are considered as delays in the surgical process, and were excluded from the analysis. As explained in Chapter 2 ("Literature Review"), there is no standard cut-off time for turnover times, but previous research (Dexter et al, 1999; Abouleish, Hensley, Zornow & Prough, 2003) has used either 60 minutes or 75 minutes to delineate room turnovers from delays. For this study, a 60 minute cut-off for turnover times was applied, following the definition of prolonged turnover time in an OR as those at least than 15 minutes beyond the mean for cases with turnover times 90 minutes or less (Dexter, Epstein, Marcon, & Ledolter, 2005; Masursky, Dexter, Isaacson & Nussmeier, 2011). Of the source data set of 17,518 surgical cases, 9,117 cases had a turnover time of 90 minutes or less; the mean turnover time for those cases was 40 minutes ($M = 40$, $SD = 15$). Applying this criterion for prolonged turnover times and adding a margin of 5 minutes, a turnover time of 60 minutes was used for this study. An intervention to reduce turnover times in an otolaryngology OR at the University of Michigan Hospitals sought to reduce turnover times from a mean of 38.4 minutes (Collar et al., 2012). In that study, a multidisciplinary team identified turnover time as a source of inefficiency in the perioperative workflow, and adopted changes that reduced the average turnover time to 29.0 minutes (Collar et al., 2012). Given such evidence that surgical teams consider turnover times averaging slightly more than 38 minutes to be excessive, the cut-off of 60 minutes for turnover time in this study is conservative.

The second consideration that precluded the use of all ACS-NSQIP surgeries is that only cases that are preceded by another case in the same surgical suite on the same day have a nursing staff dyad.  A nursing staff dyad consisted of one circulator and one scrub who were assigned to a room and remained there for a significant portion of the case.  Therefore, cases included in the analysis were always preceded by another case so that the circulator-scrub dyad consistency, as well as the turnover time, may be calculated for inclusion in the research model.

### Methodological Issues Related to the Use of Secondary Data Sets

In secondary data analysis, three types of methodological issues may be of concern, including sampling, measurement, and conditions of data collection (Clarke & Cassette, 2000). The data used in this research was recorded by RNs whose OR training included sessions on managing the electronic OR record and its existing data capture structure.  Those records are routinely audited by the hospital quality department for completeness and accuracy regarding patient information.  Moreover, the data is used for administrative and billing purposes, and includes information that has been provided by surgeons (e.g., type of surgery; case complexity), and has been agreed on by members of the surgical team (e.g., skin prep solution applied; times of patient in, incision, dressing end, and patient out).  Thus, data collection occurred using an existing structure, format, and training.

## Selection of Units for Data Analysis

As previously mentioned, the sample in this research included ACS-NSQIP cases preceded by another case.  Therefore, selection of units for data analysis considered cases occurring on a date and in a room in which an ACS-NSQIP case had taken place.  The process of selecting each unit of analysis described in the following paragraphs is presented in Appendix B, "Steps in Identifying Episodes for Data Analysis"**.** Exclusion criteria are reviewed in the following section.

**Exclusion Criteria**

Cases not occurring on as part of a pairing which included a subsequent ACS-NSQIP case were eliminated from the analysis. From the ACS-NSQIP dataset of 924 surgical cases, 410 cases were eliminated because they were the first case of the day and so would have no preceding case and therefore no turnover time or circulator-scrub dyad. Of the remaining 514 cases, 128 were excluded from the analysis because the TOX was more than 60 minutes; 28 were excluded as they had no staff sign-in times, 20 were eliminated due to no surgical service noted, and 28 were excluded because the case included more than one surgical procedure. Having eliminated a total of 614 of the 924 ACS-NSQIP cases, the remaining units numbered 310 for inclusion in the analytical sample. A total of 63 procedure types were performed among the 310 cases in the sample; procedures are shown in Table 3, "Procedure Types Included in the Analysis".

Table 3

*Procedure Types Included in the Analysis*

| *Total OR Process Time One to Three Hours* | *Frequency* |
|---|---|
| Arterial-venous fistula | 2 |
| Arterial-venous fistula take-down | 1 |
| Breast biopsy | 1 |
| Exam under anesthesia and fistulotomy | 3 |
| Exam under anesthesia | 2 |
| Incision and drainage | 1 |
| Incision and drainage, hip | 1 |
| Incision and drainage lower extremity | 2 |
| Laparoscopic appendectomy | 5 |
| Laparoscopic cholecystectomy | 13 |
| Laparoscopic inguinal hernia repair | 3 |
| Laparoscopic peritoneal window | 1 |
| Laparoscopic Tenckhoff catheter placement | 1 |
| Lumpectomy | 4 |
| Muscle flap | 1 |
| Pancreatic pseudocyst drainage | 1 |
| Parathyroidectomy | 16 |
| Rectal procedure | 1 |
| Tenckhoff catheter insertion | 1 |
| Wire localization breast biopsy | 10 |
| Wide local excision | 8 |
| Wide local excision of melanoma | 3 |
| Wide local excision of melanoma, axillary or inguinal | 8 |

| *Total OR Process Time Three to Five Hours* | *Frequency* |
|---|---|
| Axillary lymph node dissection | 5 |
| Cholecystectomy, open | 2 |
| Colectomy | 15 |
| Diagnostic laparoscopy | 1 |
| Exploratory laparotomy | 9 |

| | |
|---|---|
| Hemicolectomy | 2 |
| Ileostomy or colostomy takedown | 8 |
| Inguinal hernia repair | 3 |
| Inguinal lymph node dissection | 3 |
| Laparoscopic adrenalectomy | 10 |
| Laparoscopic colectomy | 1 |
| Laparoscopic gastric bypass | 5 |
| Laparoscopic incisional hernia repair | 5 |
| Laparoscopic liver resection | 2 |
| Low anterior resection | 4 |
| Neck dissection | 6 |
| Pancreatectomy | 5 |
| Parastomal hernia repair | 1 |
| Puestow procedure | 1 |
| Sigmoid colectomy | 3 |
| Simple or total mastectomy | 4 |
| Small bowel resection | 3 |
| Total gastrectomy | 5 |
| Total thyroidectomy | 65 |
| Umbilical hernia repair | 2 |
| Ventral or incisional hernia repair | 15 |
| Wide local excision of sarcoma | 6 |

| *Total OR Process Time Five to Eight Hours* | *Frequency* |
|---|---|
| Abdominal peritoneal resection | 3 |
| Biliary reconstruction | 1 |
| Choledochojejunostomy | 2 |
| Hepatic lobectomy | 4 |
| Incision and drainage intra-abdominal abscess | 1 |
| Laparoscopic Nissen fundoplication | 2 |
| Laparoscopic splenectomy | 2 |
| Retroperitoneal sarcoma resection | 3 |
| Salpingo-oophorectomy | 1 |
| Total colectomy with ileoanal pull through | 1 |
| Whipple pancreaticoduodenectomy | 5 |
| | |
| Total | 310 |

## Selection of Variables for the Research Model

This section presents the dependent, independent, and control variables as they were considered in the multiple regression analysis. An overview of the analysis plan is then presented. At the end of this section, theoretical and operational definitions of all variables included in the research model are summarized.

### Dependent Variables

Five dependent variables, representing five separate OR timeframes, are considered in this research study: Patient In to Incision, Incision to Dressing End, Dressing End to Patient Out, Turnover Time, and Total OR Process Time. Multiple regression analysis was employed to determine if the addition of information about specific nursing staff arrangements improves the explanatory strength of each of these five timeframes beyond that offered by control variables.

In the OR, time may be characterized by two key intervals related to the conduct of surgical procedures:

> Intrasurgical suite time: that period during which a surgical suite is utilized for the conduct of operative procedures, which will be called "intra-surgical suite time" (ISST),
>
> and
>
> Turnover time: that period between surgical operative procedures undertaken in that surgical suite, which will be called "turnover time" (TOX).

Combined, intrasurgical suite time (ISST) and turnvover time (TOX) comprise the total OR process time spanning the exit of one patient from a surgical suite until the exit of the next patient from that same surgical suite with the case to follow. In this study, time, quantified in seconds of interoperative and intraoperative time, served to measure each of the following five dependent variables.

*Intrasurgical Suite Time (ISST):* For this study, intra-surgical suite time (ISST) is composed of three timeframes: 1) *Patient In to Incision* (the time between the entry of the patient into the surgical suite, and the commencement of the surgical procedure), 2) *Incision to Dressing End* (the timeframe beginning with the commencement of the surgical procedure and ending with the closure of the surgical site), and 3) *Dressing End to Patient out*: (the time between the surgical site closure and the patient's exit from the surgical suite).

The selection of three time intervals in the intraoperative period is based on research (Abouleish, Dexter, Whitten, Zavaleta,, & Prough, 2004; Dexter, Epstein, Marcon, & Ledolter, 2005; Masursky, Dexter, Isaacson & Nussmeier, 2011; Collar et al., 2012) and on practice. Although there is no recognized breakdown of the components of ISST, previous research has considered time before incision, the time covering the surgical procedure, and the timeframe before the patient's exit from the OR as key components of the intraoperative period. Those intervals are consistently noted by the circulator and indicate the start of a new stage in the surgical procedure.

*Intrasurgical Suite Timeframe 1 (ISST1, "Patient in" to "Incision"):* This timeframe is between the entry of the patient into the surgical suite, and the commencement of the surgical procedure. ISST1 reflects a critical perioperative stage during which the surgical team is preparing the patient for the initiation of the surgical procedure. This timeframe involves all members of the surgical team at various points to verify the patient's identity, and to assist with anesthesia induction. During ISST1, errors may occur, for example, positioning a patient wrong side up, or prepping the wrong surgical site. Such mistakes may lead to wasted supplies, effort, and time, not to mention harm to patients and staff. For each case, the time “Patient In” was subtracted from the time, “Incision” to arrive at the first intrasurgical suite timeframe.

*Intrasurgical Suite Timeframe 2 (ISST2, “Incision to Dressing End”):* This timeframe is when the surgical procedure is conducted, commencing with the surgical incision and ending with the closure of the surgical site. During ISST2, the incision is made and the surgical procedure takes place. Time may be wasted during the surgical procedure if supplies are unavailable, equipment malfunctions, or inexperienced surgical team members plod through the procedure. For each case, the time, “Incision” was subtracted from the time, “Dressing End” to calculate the second intrasurgical suite timeframe.

*Intrasurgical Suite Timeframe 3 (ISST3, “Dressing End to Patient Out”):* “Dressing End” to “Patient Out”, which starts with surgical site closure, encompasses the initial recovery from anesthesia and preparation for patient transport from the OR. In this period, delays may be due to unavailable slots in the in the post-anesthesia care unit, or difficulty preparing the patient for transport. For each case, the time in minutes marking “Dressing End” was subtracted from the time, “Patient Out” to calculate the third intrasurgical suite timeframe

*Turnover Time (TOX):* Turnover time is the time between surgical cases. During room turnovers, the surgical suite is cleaned from the previous case, and is prepared with equipment, instruments, and other set-up necessities for the case to follow. Turnover times may be extended if equipment or staff are unavailable, or the surgical team fails to communicate essential information. Turnover times were calculated for all cases with a case immediately following the same surgical suite, on the same date. All times were calculated in SPSS version 18 using case times for each previous and subsequent case in the same surgical suite and on the same date. The time, “previous patient out” was subtracted from the time, “subsequent patient in” for consecutive cases. Thus, a new, continuous variable was created that measured the time, in minutes, spanning a patient's exit from a surgical suite, and the next patient's entrance into that suite. When cases spanned the midnight hour, times were transformed into the number of seconds past midnight in order to avoid negative numbers.

*Total Operating Room Process Time.* The entirety of the OR process, spans the exit of the patient from a previous case to the exit of the patient in the case to follow in the same surgical suite. Total OR process time is a continuous variable, measured in seconds, which is the sum of the intraoperative times (ISST1, ISST2, and ISST3) and the interoperative time (TOX).

**Independent variables**

The aim of this study was to examine surgical nursing staff arrangements and OR duration. It was necessary to identify one circulator and one scrub who served as the primary staff for each episode. This section discusses the primary nursing staff selection process. The discussion then turns to selection and operational definitions of independent variables included in the research model.

*Identification of Primary Nursing Staff.* In order to determine the primary circulator and primary scrub in a case, considerations were made for different possibilities as recorded in the dataset. Primary nursing staff has been identified as a nurse who is assigned to the care of a patient. Convention in the OR is to assign one circulator and one scrub to begin a surgical case, and to remain the primary nursing staff caregivers throughout that case. In addition to those circulator-scrub assignments, nursing staff are assigned to rotate through surgical suites to offer relief so that the assigned, primary staff may have breaks. Thus, nursing staff for one surgical case consists of the primary circulator and scrub, and additional nursing staff who sign in to provide breaks.

No official definition of primary nursing in the OR exists, so for this study sign-in and sign-out times were used for determining primary nursing staff for each case. Those nursing staff who were signed in at the beginning of a surgical case, and signed out at the time of the patient's exit from the suite, were designated as the primary nursing staff. In cases with only one staff signed in as scrub, and one staff signed in as circulator, those two staff were designated as the primary nursing staff. In cases with more than two staff signed in as either or both the circulator and the scrub, the staff member who had stayed in the case for the longest percentage of time was included in the analysis as primary nursing staff. Finally, in cases where two staff members were signed in and signed out for the same times, the staff member who had worked the most time throughout the year of the study was included for analysis. Nursing staff may have signed in to a previous case after the "Patient In" time, but were not primary nursing staff. Those nursing staff may have been signed in at the beginning of the subsequent case. In those instances, those nursing staff were considered to be relief staff, not a primary staff member, and therefore not part of a circulator-scrub dyad.

**Nursing Staff Arrangement Variables**

*Nursing Staff Professional Mix.* The professional training among those on the OR nursing team is the first of three types of nursing staff variables in this study that may affect OR efficiency. In the OR, there are two possible types of professional pairings for the circulator and scrub role in each surgical case. The circulator is always an RN. The scrub role in this study may be performed by either an RN or an ST. For each case, professional skill mix within a circulator-scrub pairing is either one RN with another RN, or one RN with one ST. Thus, nursing staff professional mix is a dichotomous rather than a percentage or numeric variable:

Nursing staff professional mix = 1 if the circulator is an RN and the scrub is also an RN.

Nursing staff professional mix = 0 if the circulator is an RN and the scrub is an ST.

*Circulator/Scrub Degree of Specialization.* The extent to which a circulator and a scrub have experience working in a type of surgical service, or are specialized, may also affect OR efficiency. The researcher defined specialization for the primary circulator and scrub involved in each unit of analysis according to the percent of time each was signed in to surgical cases throughout the study period. Specifically, the percent of total time each circulator and scrub spent signed in to cases assigned to the service defined "degree of specialization". For each nursing staff member, total time signed in *to all cases* was calculated as the sum of *all* case sign in and sign out times during the study period. Next, for each nursing staff member, total time signed in to all general surgery cases was calculated as the sum of *general surgery* case sign in and sign out times during the study period. Total general surgery service sign-in time was divided into the total sign-in time. The resulting value was multiplied by 100 to arrive at a value of "Degree of Specialization" signifying the percentage of time each nursing staff member spent in general surgery cases.

"Degree of specialization" is a continuous variable, calculated separately for each primary circulator and scrub:

Degree of specialization = total time signed in to general surgery cases / total time signed in to all cases over the course of one year, 2008.

*Circulator-Scrub Dyad Consistency.* Circulator-scrub dyad consistency as an expression of standardization within nursing staff organization considers whether nursing staff in a prior surgical case remained together into the next case. To evaluate the effect of standardization within nursing staff from case to case, a variable to signify circulator-scrub dyads was created. For each case, the sign-in and sign-out times of all nursing staff involved in the case were examined, and one primary nursing staff circulator and scrub were identified. With this, a circulator-scrub dyad was considered to remain intact if the following applied:

--both the circulator and the scrub were the primary nursing staff in a case; and

--the same circulator and scrub were signed in at the beginning of the case to follow in the same surgical suite; and

-- the same circulator and scrub were signed in to the case to follow at least until the time of incision.

Similarly, a circulator-scrub dyad was broken if the following applied:

--both the circulator and the scrub were the primary nursing staff in a case; and

--either that primary circulator or that primary scrub were not signed in at the beginning of the case to follow in the same surgical suite; or

-- either that same circulator or that scrub were not signed in to the case to follow at least until the time of incision.

Circulator-scrub dyad consistency is a dichotomous variable:

Dyad consistency = 1 if both the primary circulator and the primary scrub remained in the case to follow.

Dyad consistency = 0 if neither the primary circulator nor the primary scrub remained in the case to follow, or if only one of the pair or primary circulator-primary scrub remained in the case to follow.

## Control Variables

Variables that may affect OR time use were statistically controlled for, thereby addressing each of the four research questions. Variability in OR process efficiency can be explained by a number of variables that represent environmental conditions in the OR, and by patient health status, and the complexity of the surgical case. The following variables served as control variables in the multiple regression analysis: number of staff in the surgical suite, the procedure type in a sequence of two surgical cases, patient preoperative health status, and work relative value unit.

### Environmental conditions

Environmental conditions inherent in the organization of surgical services may explain variability in OR process efficiency. Variables representing environmental conditions are number of staff in the surgical suite and consistency of procedure type in subsequent cases.

*Number of staff in the surgical suite.* Number of staff signed in to a case is included among control variables in order to assess whether more staff affects efficiency. Staff number is defined as: the number *of non-duplicate* anesthesia, surgical, and nursing staff sign-ins recorded in the operating room record spanning the time between “patient in” and “patient out” for an individual surgical case. Number of staff in the surgical suite is a continuous variable.

*Procedure consistency:* Much as the variable “dyad consistency” may be a form of standardizing practice, maintaining the consistency of the type of surgical procedure in a surgical suite may also represent standardization according to scientific management principles. Consistency of procedure sequence was computed by reviewing procedure types of previous and subsequent cases within the sample, and is a dichotomous variable with inconsistent procedure sequence as the referent.

**Patient status and Case Complexity**

*Patient ASA Physical Status*. From the American Society of Anesthesiologists' classification system, ASA status grades a patient's physical status before surgery, and allows comparisons of patient condition and the operative procedure (Saklad, 1941). ASA status was obtained from preoperative histories taken by anesthesia staff. Preoperative patient status is a dichotomous variable, with ASA of less than 3 as referent.

*Work Relative Value Unit (RVU)*. For each case, the work RVU was noted in the dataset. Work RVU, a proxy for the complexity of each type of surgical procedure, is a continuous variable. A summary of conceptual and operational definitions of all variables included in the research model is presented in Tables 4, 5, and 6.

Table 4

*Conceptual and Operational Definitions of Dependent Variables*

| **Dependent Variables** | | |
|---|---|---|
| **Variable** | **Conceptual Definition** | **Operational Definition** |
| ***Intrasurgical Suite Timeframe 1 (ISST1)*** | ISST1 is the timeframe between the entry of the patient into the surgical suite, and the commencement of the surgical procedure. ISST1 spans the timeframe "Patient in to Incision" and reflects a critical perioperative stage during which the surgical team is preparing the patient for the initiation of the surgical procedure. | For each case, the time "Patient In" was subtracted from the time, "Incision" to arrive at the first intrasurgical suite timeframe, "Patient In to Incision". ISST1 is measured in seconds. |
| ***Intrasurgical Suite Timeframe 2 (ISST2)*** | ISST2 is the timeframe beginning with the commencement of the surgical procedure and ending with the closure of the surgical site. ISST2 spans the timeframe "Incision to Dressing end", during which the surgical procedure is conducted. | For each case, the time, "Incision" was subtracted from the time, "Dressing End" to calculate the second intrasurgical suite timeframe, "Incision to Dressing End". ISST2 is measured in seconds. |
| ***Intrasurgical Suite Timeframe 3 (ISST3)*** | ISST3 is the timeframe between the surgical site closure and the patient's exit from the surgical suite. ISST3 spans the timeframe "Dressing End to Patient Out", encompassing the initial recovery from anesthesia and preparation for patient transport from the OR. | For each case, the time, "Dressing End" was subtracted from the time, "Patient Out" to calculate the third intrasurgical suite timeframe, "Dressing End to Patient Out". ISST3 is measured in seconds. |
| ***Turnover Time (TOX)*** | Turnover time marks the timeframe spanning the exit of the patient of the previous case until the entrance of the patient of the subsequent case in the same surgical suite within a period of 60 minutes. | Turnover times were calculated for all cases with a case to follow in the same surgical suite, on the same date. Turnover times were calculated in SPSS version 18 using case times for each previous and subsequent case in the same surgical suite and on the same date. The time, "previous patient out" was subtracted from the time, "subsequent patient in" to arrive at the turnover time between consecutive cases in the same surgical suite. TOX is measured in seconds. |

| | | |
|---|---|---|
| ***Total OR Process Time*** | The time spanning the exit of a patient of the previous case through the exit of the patient of the subsequent case occurring in the same surgical suite and within a turnover time of 60 (90) minutes. | Total OR Process Time is the sum of ISST1 + ISST2+ ISST3 + TOX.  Total OR Process Time is measured in seconds. |

Table 5

*Conceptual and Operational Definitions of Control Variables*

| **Control Variables** | | |
|---|---|---|
| **Variable** | **Conceptual Definition** | **Operational Definition** |
| ***Number of staff in suite*** | Staff number is defined as: the number *of non-duplicate* nursing, anesthesia, and surgical staff sign-ins recorded in the operating room record spanning the time between "patient in" and "patient out" for an individual surgical case. | Number of staff in the surgical suite is a continuous variable. |
| ***Consistency of procedure type between cases*** | In scheduling cases for surgery on a given day, it is preferable to arrange for procedures of the same type to be conducted in sequential order in the same room. The type of surgical procedure in a surgical suite represents standardization according to scientific management principles. | Consistency of procedure sequence was computed by reviewing procedure types of previous subsequent cases within the sample. This is a dichotomous variable with inconsistent procedure sequence as the referent. |
| ***Patient ASA*:** American Society of Anesthesiologists (ASA) physical status. | ASA status grades a patient's physical status before surgery, and allows comparisons of patient condition and the operative procedure (Saklad, 1941). | Preoperative patient status was obtained for this dataset from preoperative histories taken by anesthesia staff and is a dichotomous variable, with ASA of 1 and 2 as referent. |
| ***Work Relative Value Unit (Work RVU)*** | Work RVU, a proxy for the complexity of each type of surgical procedure, is established by a committee within the American Medical Association. Work RVUs are published in the book of *Current Procedural Terminology* (American Medical Association, 2008). | Work RVU was obtained from the dataset as established by the primary surgeon for each case. This is a continuous variable, ranging from 0 to 50, and with each value having two decimal points. |

Table 6

*Conceptual and Operational Definitions of Independent Variables*

| Independent Variables | | |
|---|---|---|
| **Variable** | **Conceptual Definition** | **Operational Definition** |
| ***Circulator-Scrub dyad consistency*** (Research Question 1) | Dyad consistency as an expression of standardization within nursing staff organization considers whether nursing staff in a prior surgical case remained together into the next case. In order to evaluate the effect of maintaining standardization within nursing staff from case to case, a variable to signify circulator-scrub pairings, or *dyads*, was created. | For each case, the signin and signout times of all nursing staff involved in the case were examined, and one primary nursing staff circulator and scrub were identified.<br><br>A circulator-scrub dyad was considered to remain intact if the following applied:<br>--the circulator and the scrub were the primary nursing staff in a case; and<br>--the same circulator and scrub were signed in at the beginning of the case to follow in the same surgical suite; and<br>--the same circulator and scrub were signed in to the case to follow at least until the time of incision.<br><br>A circulator-scrub dyad was broken if the following applied:<br>--the circulator and the scrub were the primary nursing staff in a case; and<br>--the primary circulator or that primary scrub were not signed in at the beginning of the case to follow in the same surgical suite; *or*<br>--the primary circulator or the primary scrub were not signed in to the case to follow at least until the time of incision<br><br>Dyad consistency is a dichotomous variable:<br>Dyad consistency = 1 if both the primary circulator and the primary scrub remained in a case to follow. |

| | | |
|---|---|---|
| | | Dyad consistency = 0 if neither the primary circulator nor the primary scrub remained in a case to follow,<br>*or*<br>if only one of the primary pair or circulator-scrub remained in a case to follow. |
| ***Nursing staff professional mix*** (Research Question 2) | The designation of primary nursing staff was used for determining whether each nursing staff dyad was a combination of an RN with an RN, or an RN with an ST. Because the circulator for each case can only be an RN, only the profession of the primary scrub role for each case was reviewed. | Nursing staff skill mix is a dichotomous variable:<br>Nursing staff skill mix = 1 if the circulator is an RN and the scrub is also an RN.<br>Nursing staff skill mix = 0 if the circulator is an RN and the scrub is an ST, not an RN. |
| ***Circulator/scrub degree of specialization*** (Research Question 3) | The researcher defined specialists according to the percent of total time signed in throughout the study period that was spent signed in to cases assigned to the general surgery service. | For each nursing staff member, total time signed in *to all cases* was calculated as the sum of *all* case sign in and sign out times during the study period. Next, for each nursing staff member, total time signed in to all general surgery cases was calculated as the sum of *general surgery* case sign in and sign out times during the study period. Total general surgery service sign-in time was divided into the total sign-in time. The resulting value was multiplied by 100 to arrive at a value of "Degree of Specialization" signifying the percentage of time each nursing staff member spent in general surgery cases.<br>Degree of specialization is a continuous variable, calculated as a separate variable for circulators and for scrubs:<br>Degree of specialization =<br>total time signed in to general surgery cases / total time signed in to all cases. |

## Analysis Plan

In order to achieve the goal of evaluating an explanatory model of efficiency in OR processes**,** multiple regression analysis using sequential introduction of variables was used to examine the relationship between nursing staff arrangements and time efficiency in OR processes. Multiple regression analysis is an appropriate means of capturing the influences of both control and independent variables on perioperative timeframes. First, the dependent variables are continuous values and are normally distributed; second, there are multiple possible predictors of the use of time throughout the surgical process; third, predictors include continuous and dichotomous variables (Pallant, 2010, p. 151).

Schmueli (2010) distinguishes between explanatory models, which are based on theoretically-formulated causal structures and set out to explain phenomena, and predictive models, which are less formally specified and aim to generate accurate predictions (Schmueli, 2010). The explanatory context involves a search for factors that effect a response, whereas the predictive context seeks the combination of predictors that optimizes an outcome through associations between variables (Schmueli, 2010).

For explanatory research models, a form of multiple regression that uses blockwise introduction of variables is an appropriate means of capturing the influences of both control and independent variables on perioperative timeframes. Multiple regression that introduces variables in blocks is also called hierarchical regression. Through hierarchical regression analysis, blockwise introduction allows variables that are likely to affect the dependent variable to be controlled for, and to identify the independent and unique effect of independent variables, thereby serving as a means of testing hypotheses (Cohen & Cohen, 1983, p. 99). In this statistical approach, all predictors are entered as blocks in an order of entry that is based on theory (Pedhazur, 1997). Blockwise introduction of sets of variables also permits the researcher to evaluate each independent variable, or each block of independent variables, in terms of its unique effect on the variability the dependent variables (Tabachnick & Fidell, 2007, p. 138).

In hierarchical regression analysis, variables are entered in blocks; each block may contain one or more variables. Through hierarchical regression, the researcher may enter independent variables into the equation in an order based on theoretical or logical considerations (Tabachnik & Fidell, 2007, p. 138; Schafer, 1991). That control variables may offer more theoretical evidence for their effect on dependent variables than do other independent variables is another consideration determining the order of entry of variables into the model in hierarchical analysis (Schafer, 1991; Cohen & Cohen, 1983, pp. 99 and 136).

Hierarchical regression analysis is used for studying the effect of an independent variable on a dependent variable after controlling for other variables (Pedhazur, 1997. pp. 177-178). The set of control variables and independent variables in the model account for some proportion of the variance in the dependent variable; this proportion of the variance is the coefficient of determination, $R^2$. In hierarchical regression analysis, the $R^2$ change indicates a change in the explanatory power of the model as variables are added to the model. A statistically significant change in $R^2$ indicates that addition of the new variable improved the model fit. Of particular interest is the proportion of variance, accounted for at a subsequent stage, above and beyond that accounted for by the variables entered in previous stages (Wampold & Freund, 1987). This incremental proportion of variance is the change in $R^2$, and an $F$ statistic ($F_{\text{inc}}$) is used to determine the significance of a change in $R^2$ from the $R^2$ for the blocks entered previously. With hierarchical regression analysis, a researcher may pinpoint the incremental variance in the dependent variable that is accounted for by newly-added independent variables (Petrocelli, 2003). This change in variance, over and above that explained by variables entered at earlier steps in the model, permits a unique examination of the effects of independent variables added at a subsequent stage to the analytical model (Hoyt, Imel & Chan, 2008).

In this study of OR process efficiency are four control variables, each of which offers a theoretical basis for its effect on perioperative time. The research hypotheses accommodate the effects of independent variables representing nursing staff arrangements on OR process duration. Therefore, for this research, an analytical model such as hierarchical regression analysis, which first controls for environmental, patient, and case complexity variables, then assesses the added and unique contribution of independent variables to the model, is apposite.

The utility of multiple regression analysis using blockwise introduction is evident in light of the research questions addressed in this study. Each research question concerns one aspect of OR nursing staff arrangements. These nursing staff arrangements are represented as three categories: professional skill mix, degree of specialization in general surgery, and circulator-scrub dyads. Through hierarchical regression, it is possible to demonstrate the explanatory power of each of those categories of independent variables, separate from each other and from control variables, on OR efficiency, by using blockwise introduction. In this research, the four control variables were entered as the first block in the hierarchical regression analysis. Then, nursing staff arrangements, as they corresponded to their respective research questions, were entered in the second block. Such an order of entry permitted evaluation of the unique contribution of particular nursing staff arrangements to each OR process timeframe while controlling for the control variables.

With five dependent variables representing five separate timeframes as OR time efficiency, five multiple regression analyses were conducted for each of the four research questions. Hence, hierarchical regression analysis was employed to determine if the addition of information about specific nursing staff arrangements improved the explanatory power regarding each of the five dependent variable timeframes beyond that offered by control variables.

The analysis plan is outlined here:

Research Question 1: What amount of variation in operating room process efficiency is explained by difference in nursing staff professional mix after controlling for environmental, patient health status, and case complexity variables?

Block 1: Four control variables (number of staff signed in to surgical case, procedure type consistency, patient ASA status, and work RVU).

Block 2: One independent variable, "Circulator-Scrub professional mix".

Research Question 2: What amount of variation in operating room process efficiency is explained by the degree of nursing staff surgical specialization after controlling for environmental, patient health status, and case complexity variables?

Block 1: Four control variables (number of staff signed in to surgical case, procedure type consistency, patient ASA status, and work RVU).

Block 2: Two independent variables, "Circulator degree of specialization" and "Scrub degree of specialization", entered separately.

Research Question 3: What amount of variation in operating room process efficiency is explained by circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

Block 1: Four control variables (number of staff signed in to surgical case, procedure type consistency, patient ASA status, and work RVU).

Block 2: One independent variable, "Circulator-Scrub dyad consistency".

Research Question 4: What amount of variation in operating room process efficiency is explained by difference in nursing staff professional mix, the degree of nursing staff surgical specialization, and circulator-scrub dyad consistency between subsequent surgical cases after controlling for environmental, patient health status, and case complexity variables?

Block 1: Four control variables (number of staff signed in to surgical case, procedure type consistency, patient ASA status, and work RVU).

Block 2: All four nursing staff arrangement independent variables (Circulator-Scrub professional mix, Circulator degree of specialization, Scrub degree of specialization, and Circulator-Scrub dyad consistency).

## Multiple Regression Model

Multiple regression analysis using blockwise introduction of variables, was used for assessing the relationship between OR process timeframes and predictor variables for nursing staff arrangements, environmental conditions, patient preoperative health status, and surgical procedure complexity. This model is specified as:

$$y(\text{perioperative timeframe}) = \alpha + \beta_1 (\text{nursing staff professional mix}) + \beta_2 (\text{circulator degree of specialization}) + \beta_3 (\text{scrub degree of specialization}) + \beta_4 (\text{circulator-scrub dyad consistency}) + \beta_5 (\text{number of staff in suite}) + \beta_6 (\text{procedure consistency}) + \beta_7 (\text{patient ASA}) + \beta_8 (\text{work RVU}) + \varepsilon$$

Means and standard deviations were calculated for continuous variables (ISST1, ISST2, ISST3, TOX, Total OR Process time, degree of specialization, number of staff in room, and work RVU), and frequencies and percentages were used for dichotomous variables (nursing staff professional mix, circulator-scrub dyad consistency, procedure consistency, and patient preoperative health status). Variables were assessed for non-violation of the assumptions of multiple regression by checking for normality, non-multicolinearity, homoscedasticity, and outliers. All statistical analyses were performed using SPSS software (version 18, SPSS Inc., Chicago, IL).

## Summary

This retrospective cross-sectional study used secondary data analysis to address research questions pertaining to OR nursing staffing patterns and OR efficiency. Hierarchical regression analysis was employed to evaluate the effects of OR nursing staff professional mix, specialization, and standardization on interoperative and intraoperative timeframes after controlling for environmental, patient health status, and case complexity variables.

# CHAPTER 4

# RESULTS

This dissertation sought to explain the effect of nursing staff arrangements on efficiency in OR processes. In this chapter, results of the analyses described in Chapter 3 (Methodology) are presented. The chapter begins with an overview of the descriptive statistics for all variables. Next, results of the tests for non-violation of multiple linear regression assumptions are presented. Results of the tests of hypotheses of nursing staff arrangements, environmental conditions, patient preoperative status, and case complexity on OR process efficiency are then discussed. Finally, a summary of results of the effect of nursing staff arrangements on OR process efficiency is provided.

## Descriptive Statistics Summary

From the 2008 dataset of OR electronic health records of surgical cases, 310 episodes of previous-subsequent case pairings met the main criteria for this research: 1) Turnover time of one hour or less, and 2) subsequent surgical cases available from the 924 ACS-NSQIP cases conducted by a general surgery service. Descriptive statistics for dependent variables are shown in Table 7.

### Dependent Variables

The first intraoperative timeframe, ISST1: For the timeframe marked by patient entry into a surgical suite and the surgical incision, time ranged from 14 minutes to 90 minutes, and averaged slightly over half an hour (*M* = 32 minutes, *SD* = 10 minutes). The second intraoperative timeframe, ISST2: Surgical procedure time from incision to dressing end, with a mean of about two hours, lasted a minimum of eight minutes and a maximum of nine hours (*M* = 124 minutes, *SD* = 82 minutes). This range reflects the time variations in the different surgical procedure types in the sample. The third intraoperative timeframe, ISST3: Dressing end to patient out time displayed the lowest level of variation, with a low of one minute (rapid transit from the OR) and a high of 72 minutes (*M* = 11 minutes, *SD* = 9 minutes). Interoperative time between cases, TOX: Turnover time between cases was on average 37 minutes long, with times ranging from 19 minutes to 60 minutes (*M* = 37 minutes, *SD* = 9 minutes). The sum of intraoperative and interoperative times, Total OR Process Time: Combined, the interoperative and intraoperative time for each case had a mean of nearly three and one half hours. The highest total process time was longer than ten hours; the lowest was just over one hour (*M* = 207 minutes, *SD* = 91 minutes).

Table 7

*Descriptive Statistics for Dependent Variables*

| Dependent Variable | *N* | *Mean* | *SD* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| ISST1 | 308 | 00:32 | 00:09 | 00:14 | 01:01 |
| ISST2 | 305 | 01:59 | 01:10 | 00:08 | 05:58 |
| ISST3 | 307 | 00:10 | 00:06 | 00:00 | 00:54 |
| Turnover Time | 310 | 00:37 | 00:10 | 00:01 | 01:00 |
| Total OR Process Time | 300 | 03:19 | 01:18 | 01:02 | 07:21 |

## Independent Variables

Descriptive statistics for independent variables are shown in Table 8. In Table 9, an overview of dichotomous independent variable frequencies, with percentages, for the sample of 310 surgical cases is displayed.

Circulator degree of specialization in general surgery cases averaged near 60% (*M* = 59.73%, *SD* = 30.38), and the scrub degree of specialization averaged slightly higher, at 66% (*M* = 66%, *SD* = 31.03). Thus, among the circulators and scrubs who were the primary nursing staff in the cases included in the analysis, spent more than half the total time signed in to all cases.

Dyad consistency, whereby both the primary circulator and the primary scrub remained together throughout a preceding case and into the subsequent case, was high, with 80% of circulator-scrub dyads remaining together within the units of analysis.

For professional mix, nearly three out of five cases in this study were conducted by a circulator-scrub dyad having an RN in the scrub role as well as in the circulator role.

Table 8

*Descriptive Statistics for Independent Variables*

| Variable | *N* | *Mean* | *SD* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| Circulator Specialization | 310 | 59.73 | 30.38 | 1.20 | 100.00 |
| Scrub Specialization | 310 | 66.00 | 31.03 | 2.14 | 100.00 |

Table 9

*Frequencies for Independent Variables*

| Variable | Frequency | Percent |
|---|---|---|
| Dyad Not Continued. | 61 | 19.7 |
| Dyad Continued | 249 | 80.3 |
| RN-RN Skill Mix | 179 | 57.7 |
| RN-ST Skill Mix | 131 | 42.3 |

**Control Variables**

Descriptive statistics for control variables are shown in Table 10. In Table 11, an overview of dichotomous dependent variable frequencies is provided. Surgical cases had an average of 9 staff signed in, including circulator, scrub, anesthetist, and surgeon roles ($M$ = 8.9, $SD$ = 1.54). This case sign-in tally was not broken down by professional designation or team role. About two-fifths of the units of analysis in this study consisted of a previous-subsequent case pairing wherein both cases were the same procedure type. In this research, the preoperative health status of most (66%) of the patients undergoing surgery was less than 3, suggesting that the majority of patients were not critically ill. Work relative value averaged about 18 for the surgical cases in this study. Given the range of general surgery cases in the analysis, this figure may indicate that case complexity was, overall, on the low end of the spectrum.

Table 10

*Descriptive Statistics for Control Variables*

| Variable | *N* | *Mean* | *SD* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| Number of Staff | 305 | 8.90 | 1.54 | 6 | 13 |
| Case RVU | 303 | 16.79 | 7.74 | 0 | 49.05 |

Table 11

*Frequencies for Control Variables*

| Variable | Frequency | Percent |
|---|---|---|
| Procedure Consistency | 121 | 39.4 |
| Procedure Inconsistency | 186 | 60.6 |
| Patient ASA less than 3 | 203 | 65.7 |
| Patient ASA greater than 3 | 106 | 34.3 |

## Non-violation of Multiple Linear Regression Assumptions

The following results were verified to ensure that there were no violations of the assumptions of multicollinearity, normality, or outlying values. Diagnostic tests were conducted to check the assumptions inherent in multiple regression. These assumptions include non-violation of multicolliinearity, normality of distribution, and outliers (Polit, 1996, pp. 282-284).

*Multicollinearity*. Assessment for non-violation of multiple regression assumptions indicated low levels of mulitcollinearity as evidenced by low Variance Inflation Factor (VIF) values. VIF is a measure of collinearity among independent and control variables. Ranging from 0 to 10, higher VIF values indicate a stronger relationship between variables. The VIF for all independent variables was low (less than 1.4), indicating that the variability of each was not explained to a high degree by any of the other independent variables and could be included in the analysis. Inspection of the VIF values served as a double-check of correlations between variables. Table 12 presents the results of correlations between control and independent variables and total OR process time.

Table 12

*Correlations between Control and Independent Variables and Total Operating Room Process Time (N = 306)*

| Variable | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|
| •TotalOR Time | 1.00 | | | | | | | | |
| •Patient ASA | .24*** | 1.00 | | | | | | | |
| •Work RVU | .55*** | .15** | 1.00 | | | | | | |
| •Number of staff | .56*** | .16** | .35* | 1.00 | | | | | |
| •Procedure consistency | -.18 | -.07 | -.02 | -.06 | 1.00 | | | | |
| •RN with RN | .04** | .05 | .08 | .06 | -.06 | 1.00 | | | |
| •Circulator specialization | -.03 | .02 | .16* | -.02 | .01 | .19** | 1.00 | | |
| •Scrub specialization | -.01 | .03 | .14* | .06 | 01 | .25*** | .42 | 1.00 | |
| •Dyad consistency | -.06 | .03 | -.02 | -.10* | -.06 | .12 | .17** | .28 | 1.00 |

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

*Normality of distribution* was tested by creating normal probability-probability (P-P) plots of the regression standardized residual for each of the regression analyses. For three of the dependent variables (ISST1, ISST2, and Total OR Process Time), the P-P plot revealed a linear distribution of the data along the reference line. The P-P plots for ISST3, "Dressing End to Patient Out", and turnover time revealed some lack of symmetry of points as they were distributed around the diagonal. A scatterplot of the standardized residuals for each analysis showed a rectangular distribution of points, with several outliers. All outliers were noted for further examination to identify outlying cases. Inspection of histograms of the residuals for dependent variables revealed that each was skewed slightly to the right. However, no log transformation of the dependent variables was necessary to correct for any deviation from linear distribution. This decision was based on the consideration that "seconds", the measure of time for the regression coefficients in this study, are universally acknowledged as a meaningful measure of time. Log transformation would have rendered interpretation of the regression coefficients (unstandardized betas) meaningless as they would have become the exponential of log-transformed results.

*Outliers* were visualized on boxplots of each of the variables. The following outliers, identified through inspection of the boxplots, were excluded from the analysis by means of deletion of those values from the relevant units of analysis:

Turnover Time: One case was recorded as having a TOX of one minute. This value was excluded from the analysis.

Case RVU: Five cases had relative value units of over 50, and those values were excluded.

Number of staff in room: Three cases with 15, and two cases with 14 people signed in to the case were removed from the analysis.

## Results of Hierarchical Regression Analysis

To test the hypothesis that total OR process time is a function of nursing staff professional mix, controlling for number of staff signed in, procedure consistency, patient ASA, and work RVU, hierarchical regression analysis was employed. This analytical method was used in accordance with the explanatory nature of the research model, and the aim of controlling for control variables which had theoretical links to OR efficiency.

Each research hypothesis considered five separate dependent variables representing different OR timeframes, yielding 25 hierarchical regression analyses. For each hypothesis test, the hierarchical regression analysis began with the entry of all four control variables as a block according to theoretical support for their effect on OR process time. The explanatory power of the control variables, $R^2$, was then used for determining whether additional variance in each of the dependent variables was explained by the independent variables added to the model as a second block. In this manner, hierarchical regression analysis permitted controlling for the control variables. Each of the control variables from the first block was retained for further analysis (Victora, Huttly, Fuchs & Olinto, 1997). The second block included the independent variables for nursing staff arrangements, which were also the variables tested in each of the research hypotheses. Tables 13 through 37 display the unstandardized regression coefficients (*B*), the standardized regression coefficients ($\beta$), and $R$ and $R^2$ resulting after entry of each model in the separate analyses. The following paragraphs summarize results of hierarchical regression analysis employed to test the research hypotheses. Tables corresponding to the results for each analysis are presented after the narrative summary of each result.

**Research Question 1: Nursing Staff Professional Mix and OR Process Time**

To test the hypothesis that total OR process time is a function of nursing staff professional mix in a case, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, RN with RN professional mix in the second model. The regression coefficient of interest in this analysis is the unstandardized beta, *B*, measured in seconds. With this, the betas represent the amount of change in seconds due to a one unit change in the control and independent variables.

**Intrasurgical Suite Time 1 ("Patient In to Incision"):** After addition of the first model, all control variables accounted for 9.8% of the variance in the dependent variable, ISST1 ($F(4,293) = 8.0$, $p < 0.001$). When added as the second block, the measure of nursing staff professional mix, RN as scrub and RN as circulator, did not explain a statistically significant additional portion of the variance in ISST1 ($R^2$ change = .001, $F_{inc}(1,292)=.35$, $p = .56$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 84.64$, t = 3.57, $p < 0.001$); and patient ASA status ($B = 143.89$, t = 1.98, $p < 0.05$). Therefore, the addition of one staff member signed in to a case increased "Patient In to Incision" time by about 85 seconds; compared to cases having a patient with an ASA status of 1 or 2, cases having a patient with ASA status 3 experienced an increase in ISST 1 by more than 2 minutes. The independent variable "professional mix" (RN with RN) did not make a unique statistically significant contribution to explaining ISST 1 ($B$ = 40.63, t = .59, $p$ = .556).

Table 13

*Summary of Hierarchical Regression Analysis of Nursing Professional Mix and Intrasurgical Suite Time 1*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | |
| Number of staff | | 85.08 | .21 | .000 | 84.64 | .21 | .000 |
| Procedure consistency | | -85.13 | -.07 | .221 | -83.04 | -.07 | .234 |
| Patient ASA 3 | | 145.21 | .11 | .047 | 143.89 | .11 | .049 |
| Work RVU | | 6.94 | .09 | .141 | 6.77 | .09 | .152 |
| Independent Variable | | | | | | | |
| RN with RN | | | | | 40.63 | .03 | .556 |
| Complete Model | | | | | | | |
| | $R$ | .313 | | | .315 | | |
| | $R^2$ | .098 | | | .099 | | |
| | $R^2$ change | .098 | | | .001 | | |
| | | $F_{inc}(4,293) = 8.0$ | | | $F_{inc}(1,292) = .347$ | | |
| | | $p < 0.001$ | | | $p = .556$ | | |

**Intrasurgical Suite Time 2 ("Incision to Dressing End")**: After addition of the first model, it was found that 47.9% of the variance in the dependent variable, ISST2, was accounted for by all control variables as they were added in the first block ($F(4,293) = 67.30$, $p < 0.001$). When added as the second block, the measure of nursing staff professional mix, RN as scrub and RN as circulator, did not explain a statistically significant portion of the variance in ISST2 ($R^2$ change = 0.00, $F_{inc}(1,292) = .25$, $p = .615$). In the final model, three of the control variables were statistically significant, number of staff signed in ($B = 1237.93$, t = 8.50, $p < 0.001$); procedure consistency ($B = -1150.67$, t = -2.68, $p < 0.05$); and work RVU ($B = 268.02$, t = 9.22, $p < 0.001$). The independent variable professional mix did not make a unique statistically significant contribution to explaining ISST 2 ($B = -214.60$, t = -.51, $p = .615$).

Table 14

*Summary of Hierarchical Regression Analysis of Nursing Professional Mix and Intrasurgical Suite Time 2*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 1235.57 | .38 | .000 | 1237.93 | .38 | .000 |
| Procedure consistency | -1139.63 | .11 | .008 | -1150.67 | -.11 | .008 |
| Patient ASA 3 | 823.86 | .08 | .067 | 830.85 | .08 | .065 |
| Work RVU | 267.14 | .42 | .000 | 268.02 | .42 | .000 |
| Independent Variable | | | | | | |
| RN with RN | | | | 214.60 | -.02 | .615 |
| Complete Model | | | | | | |
| $R$ | .692 | | | .692 | | |
| $R^2$ | .479 | | | .479 | | |
| $R^2$ change | .479 | | | .000 | | |
| | $F_{inc}(4,293) = 67.30$, $p < 0.001$ | | | $F_{inc}(1,292) = .254$, $p = .615$ | | |

**Intrasurgical Suite Time 3 ("Dressing End to Patient Out"):** After addition of the first model, it was found that 3.5% of the variance in the dependent variable, ISST3, was accounted for by all control variables as they were added in the first block ($F(4,293) = 2.63$, $p < 0.05$). Added as the second model, the measure of nursing staff professional mix, RN as scrub and RN as circulator, did not account for a statistically significant increase in the variance in ISST3 ($R^2$ change = .005, $F_{inc}(1,292) = 1.37$). In the final, overall model, one of the control variables was statistically significant, patient ASA status ($B = 143.54$, t = 2.15, $p < 0.05$). The independent variable professional mix did not make a unique statistically significant contribution to explaining ISST 3 ($B = -74.30$, t = 1.17, $p = .242$).

Table 15

*Summary of Hierarchical Regression Analysis of Nursing Professional Mix and Intrasurgical Suite Time 3*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 2.02 | .01 | .926 | 2.84 | .01 | .897 |
| Procedure consistency | -47.12 | -.04 | .462 | -50.94 | -.05 | .426 |
| Patient ASA 3 | 141.12 | .12 | .036 | 143.54 | .13 | .033 |
| Work RVU | 7.68 | .11 | .077 | 7.98 | .11 | .066 |
| Independent Variable | | | | | | |
| RN with RN | | | | -74.30 | -.07 | .242 |
| Complete Model | | | | | | |
| $R$ | .186 | | | .198 | | |
| $R^2$ | .035 | | | .039 | | |
| $R^2$ change | .035 | | | .005 | | |
| | $F_{inc}$ (4,293) = 2.63<br>$p < 0.05$ | | | $F_{inc}$ (1,292) = 1.37<br>$p = .242$ | | |

**Turnover Time:** The first model, including all four control variables, contributed to 12.6% of the variance in the dependent variable, turnover time ($F(4,293) = 10.57$, $p < 0.001$). When added as the second block, the measure of nursing staff professional mix was close to explaining a statistically significant portion of the variance in TOX ($R^2$ change = .01, $F_{inc}(1,292) = 3.04$, $p = .082$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 79.08$, t = 3.46, $p = .001$); and procedure consistency ($B = -284.62$, t = -4.27, $p < 0.001$). The independent variable professional mix did not make a unique statistically significant contribution to explaining TOX ($B = -115.06$ , t = -1.74, $p = .082$).

Table 16.

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Intrasurgical Suite Time 1*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | *B* | *β* | *p* | *B* | *β* | *p* |
| Control Variables | | | | | | |
| Number of staff | **85.08** | .214 | .000 | **84.0** | .21 | .000 |
| Procedure consistency | -85.13 | -.068 | .221 | -85.12 | -.07 | .222 |
| Patient ASA 3 | **145.21** | .113 | .047 | **145.48** | .11 | .047 |
| Work RVU | 6.94 | .088 | .141 | 7.47 | .10 | .121 |
| Independent Variable | | | | | | |
| Circulator specialization | | | | -.64 | -.03 | .573 |
| Complete Model | | | | | | |
| $R$ | | .314 | | | .315 | |
| $R^2$ | | .098 | | | .099 | |
| $R^2$ change | | .098 | | | .001 | |
| | F = (4, 293) = 7.997<br>$p < .05$ | | | F(1, 292) = .557<br>$p = .578$ | | |

**Total OR Process Time:** After addition of the first model, it was found that 49.0% of the variance in the dependent variable, total OR process time, was accounted for by all control variables as they were added in the first block ($F(4,293) = 70.52$, $p < 0.001$). When added as the second block, the measure of nursing staff professional mix, RN as scrub and RN as circulator, did not explain a statistically significant additional portion of the variance in total OR process time ($R^2$ change = .001, $F_{inc}(1,292) = .53$, $p = .466$). In the final model, all of the control variables were statistically significant: number of staff signed in, ($B = 1414.38$, t = 8.85, $p < 0.001$); procedure consistency ($B = -1565.70$, t = -3.34, $p = .001$) and patient ASA 3 ($B = 1195.25$, t = 2.44, $p = .015$), and work RVU ($B = 280.89$, t = 8.88, $p < 0.05$). The independent variable professional mix did not make a unique statistically significant contribution to explaining total OR time ($B = -339.26$, t = -.73, $p = .466$).

Table 17

*Summary of Hierarchical Regression Analysis of Nursing Professional Mix and Total Operating Room Process Time*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | |
| Number of staff | | 1410.66 | .40 | .000 | 1414.38 | .40 | .000 |
| Procedure consistency | | -1548.30 | -.14 | .001 | -1565.75 | -.14 | .001 |
| Patient ASA 3 | | 1193.71 | .10 | .015 | 1204.76 | .11 | .015 |
| Work RVU | | 281.08 | .40 | .000 | 282.47 | .40 | .000 |
| Independent Variable | | | | | | | |
| RN with RN | | | | | -339.26 | -.03 | .466 |
| Complete Model | | | | | | | |
| | $R$ | .700 | | | .701 | | |
| | $R^2$ | .490 | | | .491 | | |
| | $R^2$ change | .490 | | | .001 | | |
| | | $F_{inc}$ (4, 293) = 70.52, $p$ <0 .001 | | | $F_{inc}$ (1, 292) =.533, $p$ = .466 | | |

### Summary of Results for Research Question 1

To test the hypothesis that total OR process time is a function of nursing staff professional mix in a case, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, RN with RN professional mix in the second model. Addition of the control variables in the first model revealed that all of the control variables were statistically significant with total OR process time. Higher number of staff signed, patient ASA status of 3, compared to lower patient ASA, and higher work RVU were each associated with longer OR process times, whereas procedure consistency between cases was associated with lower OR process times. When added as the second block, the measure of nursing staff professional mix, RN as scrub and RN as circulator, did not explain additional variance in any of the OR process times, as evidenced by $R^2$ change values that were not statistically significant. Moreover, the independent variable RN with RN did not make a unique statistically significant contribution to explaining any of the OR process times. Therefore, the null hypothesis for Research Question 1 was not rejected, with findings that there was no reduction in OR times when the professional mix in a surgical case consisted of an RN scrub with the circulator.

**Research Question 2a: Circulator Degree of Specialization and OR Process Time**

To test the hypothesis that total OR process time is a function of circulator degree of specialization in general surgery, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, circulator degree of specialization, in the second model. The regression coefficient of interest in this analysis is the unstandardized beta, *B*, measured in seconds. With this, the betas represent the amount of change in seconds due to a one unit change in the control and independent variables.

**Intrasurgical Suite Time 1 ("Patient In to Incision"):** After addition of the first model, it was found that 9.8% of the variance in the dependent variable, ISST1, was accounted for by all control variables as they were added in the first block ($F(4,293) = 7.96$, $p < 0.001$). When added as the second block, the measure of circulator specialization in general surgery, did not explain a statistically significant portion of the variance in ISST1 ($R^2$ change = .001, $F_{inc}(1,292) = .319$, $p = .573$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 83.98$, t = 3.53, $p < 0.001$); and patient ASA status ($B = 145.48$, t = 2.00, $p < 0.05$). The independent variable circulator specialization in general surgery did not make a statistically significant contribution to explaining ISST 1 ($B = -.64$, t = -.57, $p = .573$).

Table 18

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Intrasurgical Suite Time 1*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 85.08 | .21 | .000 | 83.98 | .21 | .000 |
| Procedure consistency | -85.13 | -.07 | .221 | -85.12 | -.07 | .222 |
| Patient ASA 3 | 145.21 | .11 | .047 | 145.48 | .11 | .047 |
| Work RVU | 6.94 | .09 | .141 | 7.43 | .10 | .121 |
| Independent Variable | | | | | | |
| Circulator specialization | | | | -.64 | -.03 | .573 |
| Complete Model | | | | | | |
| $R$ | .313 | | | .315 | | |
| $R^2$ | .098 | | | .099 | | |
| $R^2$ change | .098 | | | .001 | | |
| | $F_{inc} = (4, 293) = 7.96$<br>$p < 0.001$ | | | $F_{inc}$ $(1, 292) = .319$<br>$p = .573$ | | |

**Intrasurgical Suite Time 2 ("Incision to Dressing End"):** After addition of the first model, it was found that 47.9% of the variance in the dependent variable, ISST2, was accounted for by all control variables as they were added in the first block ($F(4,293) = 67.30$, $p < 0.001$). When added as the second block, the measure of nursing staff specialization, circulator specialization in general surgery, did not explain a statistically significant portion of the variance in ISST2 at the set *p*-value, $p < 0.05$, but did meet criteria of statistical significance for $p < 0.10$ ($R^2$ change = .005, $F_{inc}(1,292) = 2.81$, $p = .095$). In the final model, three of the control variables were statistically significant, number of staff signed in ($B = 1215.45$, t = 8.31, $p < 0.001$); procedure consistency ($B = -1139.38$, t = -2.67, $p < 0.05$); and work RVU ($B = 266.04$, t = 9.40, $p < 0.001$). The independent variable circulator specialization in general surgery did not make a unique statistically significant contribution to explaining ISST 2 ($B = -11.71$. t = -1.68, $p = .095$).

Table 19

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Intrasurgical Suite Time 2*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 1235.57 | .38 | .000 | 1215.45 | .38 | .000 |
| Procedure consistency | -1139.63 | -.11 | .009 | -1139.38 | -.11 | .008 |
| Patient ASA 3 | 823.86 | .08 | .067 | 828.65 | .08 | .065 |
| Work RVU | 267.14 | .42 | .000 | 276.04 | .43 | .000 |
| Independent Variable | | | | | | |
| Circulator specialization | | | | -11.71 | -.07 | .095 |
| Complete Model | | | | | | |
| $R$ | .692 | | | .696 | | |
| $R^2$ | .479 | | | .484 | | |
| $R^2$ change | .479 | | | .005 | | |
| | $F_{inc}$ (4, 293) = 67.30<br>$p < 0.001$ | | | $F_{inc}$ (1, 292) = 2.81<br>$p = .095$ | | |

**Intrasurgical Suite Time 3 ("Dressing End to Patient Out"):** After addition of the first model, it was found that 3.5% of the variance in the dependent variable, ISST3, was accounted for by all control variables as they were added in the first block ($F(4,293) = 2.63$, $p < 0.05$). When added as the second block, the measure of nursing staff specialization, circulator degree of specialization in general surgery, did not explain a statistically significant portion of the variance in ISST3 ($R^2$ change = .008, $F_{inc}(1,292) = 2.30$, $p = .130$). In the final model, two of the control variables were statistically significant, patient ASA status ($B = 141.77$, t = 2.12, $p < 0.05$); and work RVU ($B = 8.88$, t = 2.03, $p < 0.05$). The independent variable circulator specialization did not make a unique statistically significant contribution to explaining ISST 3 ($B = -1.58$, t = -1.52, $p = .130$).

Table 20

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Intrasurgical Suite Time 3*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 2.02 | .01 | .926 | -.70 | -.03 | .975 |
| Procedure consistency | -47.12 | -.04 | .462 | -47.09 | -.04 | .461 |
| Patient ASA 3 | 141.12 | .12 | .036 | 141.77 | .12 | .035 |
| Work RVU | 7.68 | .11 | .077 | 8.88 | .13 | .044 |
| Independent Variable | | | | | | |
| Circulator specialization | | | | -1.58 | -.09 | .130 |
| Complete Model | | | | | | |
| $R$ | .186 | | | .205 | | |
| $R^2$ | .035 | | | .042 | | |
| $R^2$ change | .035 | | | .007 | | |
| | $F_{inc}$ (4,293) = 2.63<br>$p$ < 005 | | | $F_{inc}$ (1,292) = 2.30<br>$p$ = .130 | | |

**Turnover Time:** After addition of the first model, it was found that 12.6% of the variance in the dependent variable, TOX, was accounted for by all control variables as they were added in the first block ($F(4,293) = 10.57$, $p < 0.001$). After entry of the measure of nursing staff specialization, circulator specialization in general surgery in model 2, the total variance explained by the model was 15.4% ($F(1,292) = 10.67$, $p < 0.01$). Circulator specialization explained an additional 2.8% of the variance in TOX, after controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU ($R^2$ change = .028, $F_{inc}(1,292) = 9.83$, $p < 0.05$). The addition of the independent variable, circulator degree of specialization, thus made a significant contribution of 2.8% to the model's ability to explain TOX. In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 72.03$, t = 3.199, $p < 0.05$); and procedure consistency ($B = -278.63$, t = -4.24, $p < 0.001$). The independent variable circulator degree of specialization made a unique statistically significant contribution to explaining TOX ($B = -3.37$, t = -3.13, $p < 0.05$). Holding constant the control variables in the model, TOX was reduced by about 3 and a half seconds with a one percent increase in circulator degree of specialization.

Table 21

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Turnover Time*

| Variables | | Model 1 | $B$ | $\beta$ | $p$ | Model 2 | $B$ | $\beta$ | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| Control Variables | | | | | | | | | |
| Number of staff | | | 77.82 | .20 | .001 | | 72.03 | .19 | .002 |
| Procedure consistency | | | -278.70 | -.23 | .000 | | -278.63 | -.23 | .000 |
| Patient ASA 3 | | | 129.95 | .10 | .064 | | 131.33 | .11 | .057 |
| Work RVU | | | 2.77 | .04 | .539 | | 5.34 | .07 | .239 |
| Independent Variable | | | | | | | | | |
| Circulator specialization | | | | | | | -3.34 | -.17 | .002 |
| Complete Model | | | | | | | | | |
| | $R$ | .355 | | | | .393 | | | |
| | $R^2$ | .126 | | | | .154 | | | |
| | $R^2$ change | 126 | | | | .028 | | | |
| | | | $F_{inc}$ (4,293) = 10.57, $p$ < 0.001 | | | | $F_{inc}$ (1,292) =9.83, $p$ < 0.01 | | |

**Total OR Process Time:** After addition of the first model, it was found that 49.0% of the variance in the dependent variable, total OR process time, was accounted for by all control variables as they were added in the first block ($F(4,293) = 70.52$, $p < 0.001$). After entry of the measure of nursing staff specialization, circulator specialization in general surgery in model 2, the total variance explained by the model was 49.0% ($F(1,292) = 58.17$, $p < 0.01$). An additional 0.9 percent of the variance in total OR process time was accounted for by the addition of the second block (circulator specialization in general surgery) ($R^2$ change = .009, $F_{inc}(1,292) = 4.98$, $p < 0.05$). In the final model, all of the control variables were statistically significant, number of staff signed in ($B = 1381.54$, t = 8.68, $p < 0.001$); procedure consistency ($B = -1547.94$, t = -3.33, $p < 0.05$), patient ASA status ($B = 1200.00$, t = 2.47, $p < 0.05$); and work RVU ($B = 293.96$, t = 9.20, $p < 0.001$). The independent variable circulator specialization in general surgery made a unique statistically significant contribution to explaining total OR time ($B = -16.94$, t = -2.23, $p < 0.05$). A one percent increase in circulator degree of specialization in general surgery led to a near 17-second decline in total OR process time.

Table 22

*Summary of Hierarchical Regression Analysis of Circulator Degree of Specialization and Total Operating Room Process Time*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 1410.66 | .40 | .000 | 1381.54 | .39 | .000 |
| Procedure consistency | -1548.30 | -.14 | .001 | -1547.94 | -.14 | .001 |
| Patient ASA 3 | 1193.71 | .10 | .015 | 1200.55 | .10 | .014 |
| Work RVU | 281.08 | .40 | .000 | 293.96 | .42 | .000 |
| Independent Variable | | | | | | |
| Circulator specialization | | | | -16.94 | -.094 | .026 |
| Complete Model | | | | | | |
| $R$ | .700 | | | .706 | | |
| $R^2$ | .490 | | | .499 | | |
| $R^2$ change | .490 | | | .009 | | |
| | $F_{inc}$ (1, 292) = 70.52<br>$p < 0.001$ | | | $F_{inc}$ (1, 292) = 4.98<br>$p < 0.05$ | | |

**Summary of Results for Research Question 2a**

To test the hypothesis that total OR process time is a function of the circulator's degree of specialization in general surgery, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, circulator degree of specialization, in the second model. Addition of the control variables in the first model revealed that all of the control variables were statistically significant with total OR process time. Higher number of staff signed, patient ASA status of 3, compared to lower patient ASA, and higher work RVU were each associated with longer OR process times, whereas procedure consistency between cases was associated with lower OR process times. When added as the second block, the measure of circulator specialization in general surgery explained the variance in TOX and in total OR process time, as evidenced by $R^2$ change values that were statistically significant. Moreover, the independent variable circulator degree of specialization in general surgery made a unique statistically significant contribution to explaining both TOX and total OR process time, with higher degree of specialization related to lower times. Having found circulator degree of specialization statistically significant for variance in OR process time, the null hypothesis for Research Question 2a was rejected.

**Research Question 2b: Scrub Degree of Specialization and OR Process Time**

To test the hypothesis that total OR process time is a function of scrub degree of specialization in general surgery, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, scrub degree of specialization, in the second model. The regression coefficient of interest in this analysis is the unstandardized beta, *B*, measured in seconds. With this, the betas represent the amount of change in seconds due to a one unit change in the control and independent variables.

**Intrasurgical Suite Time 1 ("Patient In to Incision"):** After addition of the first model, it was found that 9.8% of the variance in the dependent variable, ISST1, was accounted for by all control variables as they were added in the first block ($F(4,293) = 7.96$, $p < 0.001$). When added as the second block, the measure of scrub specialization in general surgery, did not explain a statistically significant portion of the variance in ISST1 ($R^2$ change = .000, $F_{inc}(1,292)$ =.10, $p = .755$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 85.05$, t = 3.58, $p < 0.001$); and patient ASA status ($B = 144.96$, t = 1.99, $p < 0.05$). The independent variable scrub specialization in general surgery did not make a unique statistically significant contribution to explaining ISST 1 ($B = .35$, t = .31, $p = .755$).

Table 23

*Summary of Hierarchical Regression Analysis of Scrub Degree of Specialization and Intrasurgical Suite Time 1*

| Variables | | | Model 1 | | | | Model 2 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $B$ | $\beta$ | | | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | | | |
| Number of staff | | | 85.08 | .21 | .000 | | 85.05 | .21 | .000 |
| Procedure consistency | | | -85.08 | -.07 | .221 | | -85.42 | -.07 | .220 |
| Patient ASA 3 | | | 145.21 | .11 | .047 | | 144.96 | .11 | .047 |
| Work RVU | | | 6.94 | .09 | .141 | | 6.74 | .09 | .156 |
| Independent Variable | | | | | | | | | |
| Scrub specialization | | | | | | | .35 | .02 | .755 |
| Complete Model | | | | | | | | | |
| | $R$ | .313 | | | | .313 | | | |
| | $R^2$ | 098 | | | | .098 | | | |
| | $R^2$ change | 098 | | | | .000 | | | |
| | | | $F_{inc}$ (4,293) = 7.96<br>$p$ < 0.001 | | | | $F_{inc}$ (1, 292) = .10<br>$p$ = .755 | | |

**Intrasurgical Suite Time 2 ("Incision to Dressing End"):** After addition of the first model, it was found that 47.9% of the variance in the dependent variable, ISST2, was accounted for by all control variables as they were added in the first block ($F(4,293) = 67.30$, $p < 0.001$). After entry of the measure of nursing staff specialization, scrub specialization in general surgery in model 2, the total variance explained by the model was 48.7.0% ($F(1,292) = 55.38$, $p < 0.01$). When added as the second block, the measure of nursing staff specialization mix, scrub specialization in general surgery, explained a statistically significant portion of the variance in incision to dressing end time after controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU ($R^2$ change = .008, $F_{inc}(1,292) = 4.50$, $p < 0.05$). In the final model, three of the control variables were statistically significant, number of staff signed in ($B = 1237.07$, t = 8.51, $p < 0.01$); procedure consistency ($B = 1127.58$, t = 2.65, $p < 0.05$); and work RVU ($B = 275.26$, t = 9.48, $p < 0.001$). The independent variable scrub specialization in general surgery made a unique statistically significant contribution to explaining ISST 2 ($B = -14.37$, t = -2.12, $p < 0.05$). These results indicate that, controlling for other variables, time between incision and dressing end was reduced by 14.37 seconds as the scrub degree of specialization in general surgery increased by one percent. In this study, increasing a scrub's degree of specialization by 50% (e.g., from 500 hours to 750 hours for 1,000 hours signed in) would contribute to a reduction in the duration of the surgical procedure by (50 x 14.37 seconds =) 719 seconds, or nearly 12 minutes.

Table 24

*Summary of Hierarchical Regression Analysis of Scrub Degree of Specialization and Intrasurgical Suite Time 2*

| Variables | | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | | |
| Number of staff | | | 1235.57 | .38 | .000 | 1237.07 | .38 | .000 |
| Procedure consistency | | | 1139.63 | .11 | .008 | -1127.58 | .11 | .009 |
| Patient ASA 3 | | | 823.86 | .08 | .067 | 834.42 | .08 | .062 |
| Work RVU | | | 267.14 | .42 | .000 | 275.26 | .43 | .000 |
| Independent Variable | | | | | | | | |
| Scrub specialization | | | | | | -14.37 | -.09 | .035 |
| Complete Model | | | | | | | | |
| | $R$ | .692 | | | .698 | | | |
| | $R^2$ | .479 | | | .487 | | | |
| | $R^2$ change | .479 | | | .008 | | | |
| | | | $F_{inc}$ (4,293) = 67.30<br>$p < 0.001$ | | | $F_{inc}$ (1,292) = 4.50<br>$p < 0.05$ | | |

**Intrasurgical Suite Time 3 ("Dressing End to Patient Out"):** After addition of the first model, it was found that 3.4% of the variance in the dependent variable, ISST3, was accounted for by all control variables as they were added in the first block ($F(4,293) = 2.63$, $p < 0.05$). When added as the second block, the measure of nursing staff specialization, scrub degree of specialization in general surgery, did not explain a statistically significant portion of the variance in ISST3 ($R^2$ change = .003, $F_{inc}(1,292) = .81$, $p = .368$). In the final model, one of the control variables was statistically significant, patient ASA status ($B = 141.80$, t = 2.12, $p < 0.05$). The independent variable scrub specialization did not make a unique statistically significant contribution to explaining ISST 3 ($B = -.92$, t = -.90, $p = .368$).

Table 25

*Summary of Hierarchical Regression Analysis of Scrub Degree of Specialization and Intrasurgical Suite Time 3*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | |
| Number of staff | | 2.02 | .01 | .926 | 2.12 | .01 | .923 |
| Procedure consistency | | -47.12 | -.04 | .462 | -46.35 | -.04 | .469 |
| Patient ASA 3 | | 141.12 | .12 | .036 | 141.80 | .12 | .035 |
| Work RVU | | 7.68 | .11 | .077 | 8.20 | .12 | .061 |
| Independent Variable | | | | | | | |
| Scrub specialization | | | | | -.92 | -.05 | .368 |
| Complete Model | | | | | | | |
| | $R$ | .186 | | | .193 | | |
| | $R^2$ | .035 | | | .037 | | |
| | $R^2$ change | .035 | | | .003 | | |
| | | $F_{inc}$ (4, 293) = 2.63<br>$p < 0.05$ | | | $F_{inc}$ (1, 292) = 0.81<br>$p = .368$ | | |

**Turnover Time:** After addition of the first model, it was found that 12.6% of the variance in the dependent variable, TOX, was accounted for by all control variables as they were added in the first block ($F(4,293) = 10.57$, $p < 0.001$). After entry of the measure of nursing staff specialization, scrub specialization in general surgery in model 2, the total variance explained by the model was 13.9% ($F(1,292) = 9.45$, $p < 0.01$). When added as the second block, the measure of nursing staff specialization, scrub specialization in general surgery, after controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU explained a statistically significant portion of the variance in TOX ($R^2$ change = .013, $F_{inc}(1,292) = 4.50$, $p < 0.05$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 78.05$, t = 3.45, $p < 0.05$); and procedure consistency ($B = -276.82$, t = 4.17, $p < 0.001$). The independent variable scrub degree of specialization made a unique statistically significant contribution to explaining TOX variation ($B = -2.24$, t = -2.12, $p < 0.05$).

Table 26

*Summary of Hierarchical Regression Analysis of Scrub Degree of Specialization and Turnover Time*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 77.82 | .20 | .001 | 78.05 | .20 | .001 |
| Procedure consistency | -278.70 | -.23 | .000 | -276.82 | -.23 | .000 |
| Patient ASA 3 | 129.95 | .10 | .064 | 131.60 | .11 | .059 |
| Work RVU | 2.77 | .04 | .539 | 4.00 | .05 | .373 |
| Independent Variable | | | | | | |
| Scrub specialization | | | | -2.24 | -.12 | .035 |
| Complete Model | | | | | | |
| $R$ | .355 | | | .373 | | |
| $R^2$ | .126 | | | .139 | | |
| $R^2$ change | .126 | | | .013 | | |
| | $F_{inc}$ (4, 293) = 10.57<br>$p < 0.001$ | | | $F_{inc}$ (1, 292) = 4.50<br>$p < 0.05$ | | |

**Total OR Process Time:** After addition of the first model, it was found that 49.0% of the variance in the dependent variable, total OR process time, was accounted for by all control variables as they were added in the first block ($F(4,293) = 70.52$ $p < 0.001$). After entry of the measure of nursing staff specialization, scrub specialization in general surgery in model 2, the total variance explained by the model was 49.9% ($F(1,292) = 58.06$, $p < 0.01$). When added as the second block, the measure of nursing staff specialization mix, scrub specialization in general surgery, after controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU explained a statistically significant portion of the variance in total OR process time ($R^2$ change = .008, $F_{\text{inc}}(1,292) = 4.70$, $p < 0.05$). The addition of the independent variable, scrub degree of specialization, made a significant contribution of 0.8% to the model's ability to explain total OR process time. In the final model, all of the control variables were statistically significant, number of staff signed in ($B = 1412.33$, t = 8.90, $p < 0.001$); procedure consistency, ($B = -1534.87$, t = -3.30, $p < 0.05$); patient ASA status ($B = 1205.49$, t = 2.48, $p < 0.05$); and work RVU ($B = 290.12$, t = 9.15, $p < 0.001$). The independent variable scrub degree of specialization in general surgery made a unique statistically significant contribution to explaining total OR time ($B = -16.02$, t = -2.17, $p < 0.001$).

Table 27

*Summary of Hierarchical Regression Analysis of Scrub Degree of Specialization and Total Operating Room Process Time*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 1410.66 | .40 | .000 | 1412.33 | .40 | .000 |
| Procedure consistency | -1548.30 | -.14 | .001 | -1534.87 | -.14 | .001 |
| Patient ASA 3 | 1193.71 | .10 | .015 | 1205.49 | .11 | .014 |
| Work RVU | 281.08 | .40 | .000 | 290.12 | .41 | .000 |
| Independent Variable | | | | | | |
| Scrub specialization | | | | -16.02 | .09 | .031 |
| Complete Model | | | | | | |
| $R$ | .700 | | | .706 | | |
| $R^2$ | .490 | | | .499 | | |
| $R^2$ change | .490 | | | .008 | | |
| | $F_{inc}$ (4, 293) = 70.52<br>$p$ < 0.001 | | | $F_{inc}$ (1, 292) = 4.70<br>$p$ < 0.05 | | |

### Summary of Results for Research Question 2b

To test the hypothesis that total OR process time is a function of the scrub's degree of specialization in general surgery, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, scrub degree of specialization, in the second model. Addition of the control variables in the first model revealed that all of the control variables were statistically significantly associated with total OR process time. Higher number of staff signed, patient ASA status of 3, compared to lower patient ASA, and higher work RVU were each associated with longer OR process times, whereas procedure consistency between cases was associated with lower OR process times. When added as the second block, the measure of scrub specialization in general surgery explained the variance in ISST2, TOX, and total OR process time, as evidenced by $R^2$ change values that were statistically significant. Moreover, the independent variable scrub specialization in general surgery made a unique statistically significant contribution to explaining ISST2 (Incision to Dressing End time), turnover time, and total OR process time, with higher degree of specialization related to lower times. Having found scrub degree of specialization statistically significant for variance in OR process time, the null hypothesis for Research Question 2b was rejected.

## Research Question 3: Circulators-Scrub Dyad Consistency and OR Process Time

To test the hypothesis that total OR process time is a function of circulator-scrub dyad consistency, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, circulator-scrub dyad consistency, in the second model. The regression coefficient of interest in this analysis is the unstandardized beta, *B*, measured in seconds. With this, the betas represent the amount of change in seconds due to a one unit change in the control and independent variables.

**Intrasurgical Suite Time 1 ("Patient In to Incision"):** After addition of the first model, it was found that 9.8% of the variance in the dependent variable, ISST1, was accounted for by all control variables as they were added in the first block ($F(4,293) = 7.96$, $p < .05$). When added as the second block, the measure of nursing staff standardization in surgery, circulator-scrub dyad consistency, did not explain a statistically significant portion of the variance in ISST1 ($R^2$ change = .000, $F_{inc}(1,292) = .001$, $p = .978$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 85.08$, t = 3.59, $p < 0.001$); and patient ASA status ($B = 145.21$, t = 2.00, $p < 0.05$). The independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining ISST 1 ($B = -2.41$, t = -.03, $p = .978$).

Table 28

*Summary of Hierarchical Regression Analysis of Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 1*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | |
| Number of staff | | 85.08 | .21 | .000 | 85.01 | .21 | .000 |
| Procedure consistency | | -85.13 | -.07 | .221 | -85.25 | -.07 | .222 |
| Patient ASA 3 | | 145.21 | .11 | .047 | 145.31 | .11 | .047 |
| Work RVU | | 6.94 | .09 | .141 | 6.94 | .09 | .141 |
| Independent Variable | | | | | | | |
| Dyad continued | | | | | -2.41 | .00 | .978 |
| Complete Model | | | | | | | |
| $R$ | .313 | | | | .313 | | |
| $R^2$ | .098 | | | | .000 | | |
| $R^2$ change | 098 | | | | .000 | | |
| | | $F_{inc}$ (4,293) = 7.96, $p < .0001$ | | | $F_{inc}$ (1,292) = .001, $p$ = .978 | | |

**Intrasurgical Suite Time 2 ("Incision to Dressing End"):** After addition of the first model, it was found that 47.9% of the variance in the dependent variable, ISST2, was accounted for by all control variables as they were added in the first block ($F(4,293) = 68.30$, $p < 0.001$). When added as the second block, the measure of nursing staff standardization in surgery, circulator-scrub dyad consistency, did not explain a statistically significant portion of the variance in ISST2 ($R^2$ change = .000, $F_{inc}(1,292) = .211$, $p = .646$). In the final model, three of the control variables were statistically significant, number of staff signed in ($B = 1228.17$, t = 8.34, $p < 0.001$); procedure consistency ($B = -1151.38$, t = -2.68, $p < 0.05$); and work RVU ($B = 267.29$, t = 9.21, $p < 0.001$). The independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining ISST 2 ($B = -243.49$, t = -.46, $p = .646$).

Table 29

*Summary of Hierarchical Regression Analysis of Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 2*

| Variables | | Model 1 | | | | Model 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | | |
| Number of staff | | 1235.57 | .38 | .000 | | 1228.17 | .38 | .000 |
| Procedure consistency | | -1139.63 | -.11 | .008 | | -1151.38 | -.11 | .008 |
| Patient ASA 3 | | 823.86 | .08 | .067 | | 833.30 | .08 | .065 |
| Work RVU | | 267.14 | .42 | .000 | | 267.29 | .42 | .000 |
| Independent Variable | | | | | | | | |
| Dyad continued | | | | | | -243.49 | -.02 | .646 |
| Complete Model | | | | | | | | |
| $R$ | .692 | | | | .692 | | | |
| $R^2$ | .479 | | | | .479 | | | |
| $R^2$ change | .479 | | | | .000 | | | |
| | | $F_{inc}$ (4,293) = 67.30<br>$p < 0.001$ | | | | $F_{inc}$ (1,292) = 0.21<br>$p = .646$ | | |

**Intrasurgical Suite Time 3 ("Dressing End to Patient Out"):** After addition of the first model, it was found that 3.5% of the variance in the dependent variable, ISST3, was accounted for by all control variables as they were added in the first block ($F(4,293) = 2.63$, $p < 0.05$). When added as the second block, the measure of nursing staff standardization in surgery circulator-scrub dyad consistency added nothing to explain a statistically significant portion of the variance in ISST3 ($R^2$ change = .000, $F_{inc}(1,292) = .02$, $p = .887$). In the final model, one of the control variables was statistically significant, patient ASA 3 ($B = 141.12$, t = 2.11, $p < 0.05$). The independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining ISST 3 ($B = -11.25$, t = 1.142, $p = .887$).

Table 30

*Summary of Hierarchical Regression Analysis of Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 3*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | *B* | $\beta$ | *p* | *B* | $\beta$ | *p* |
| Control Variables | | | | | | | |
| Number of staff | | 2.02 | .01 | .926 | 1.68 | .01 | .939 |
| Procedure consistency | | -47.12 | -.04 | .462 | -47.66 | -.04 | .458 |
| Patient ASA 3 | | 141.12 | .12 | .035 | 141.56 | .12 | .036 |
| Work RVU | | 7.68 | .11 | .077 | 7.69 | .11 | .077 |
| Independent Variable | | | | | | | |
| Dyad continued | | | | | -11.25 | -.01 | .887 |
| Complete Model | | | | | | | |
| | $R$ | .186 | | | .186 | | |
| | $R^2$ | .035 | | | .035 | | |
| | $R^2$ change | .035 | | | .000 | | |
| | | $F_{inc}$ (4,293) = 2.625<br>$p < 0.05$ | | | $F_{inc}$ (1,292) = .020<br>$p < .887$ | | |

**Turnover Time:** After addition of the first model, it was found that 12.6% of the variance in the dependent variable, TOX, was accounted for by all control variables as they were added in the first block ($F(4,293) = 10.57$, $p < 0.001$). When added as the second block, the measure of nursing staff standardization in surgery circulator-scrub dyad consistency did not explain a statistically significant portion of the variance in TOX ($R^2$ change = .003, $F_{inc}(1,292) = 1.15$, $p = .285$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 75.13$, t = 3.28, $p < 0.05$); and procedure consistency ($B = -282.96$, t = -4.23, $p < 0.001$). The independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining TOX ($B = -88.33$, t = -1.07, $p = .285$).

Table 31

*Summary of Hierarchical Regression Analysis of Circulator-Scrub Dyad Consistency and Turnover Time*

| Variables | | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | | |
| Number of staff | | 77.81 | .20 | .001 | | 75.13 | .19 | .001 |
| Procedure consistency | | -278.70 | -.23 | .000 | | -282.96 | -.23 | .000 |
| Patient ASA 3 | | 129.95 | .10 | .064 | | 133.38 | .11 | .057 |
| Work RVU | | 2.77 | .04 | .539 | | 2.83 | .04 | .531 |
| Independent Variables | | | | | | | | |
| Dyad continued | | | | | -88.33 | -.06 | .285 | |
| Complete Model | | | | | | | | |
| $R$ | .355 | | | | .360 | | | |
| $R^2$ | .126 | | | | .129 | | | |
| $R^2$ change | .126 | | | | .003 | | | |
| | | $F_{inc}$ (4,293) =10.57 $p < 0.001$ | | | | $F_{inc}$ (1,292) = 1.15 $p$ = .285 | | |

**Total OR Process Time:** After addition of the first model, it was found that 49.0% of the variance in the dependent variable, total OR process time, was accounted for by all control variables as they were added in the first block ($F(4,293) = 70.52$, $p < 0.001$). When added as the second block, the measure of nursing staff standardization in surgery, circulator-scrub dyad consistency, did not explain a statistically significant portion of the variance in total OR process time ($R^2$ change = .001, $F_{inc}(1,292) = .32$, $p = .576$). In the final model, all four of the control variables were statistically significant, number of staff signed in ($B = 1400.82$, t = 8.71, $p < 0.001$); procedure consistency ($B = 1563.93$, t = -3.32, $p < 0.05$); patient ASA status ($B = 1205.27$, t = 2.46, $p < 0.05$). and work RVU ($B = 261.27$, t = 8.88, $p < 0.001$). The independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining total OR time ($B = -373.78$, t = -.56, $p = .576$).

Table 32

*Summary of Hierarchical Regression Analysis of Circulator-Scrub Dyad Consistency and Total Operating Room Process Time*

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| | | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | | |
| Number of staff | | 1410.66 | .40 | .000 | 1400.82 | .39 | .000 |
| Procedure consistency | | -1548.30 | -.14 | .001 | -1563.93 | -.14 | .001 |
| Patient ASA 3 | | 1193.71 | .10 | .015 | 1206.27 | .11 | .015 |
| Work RVU | | 281.08 | .40 | .000 | 281.27 | .40 | .000 |
| Independent Variables | | | | | | | |
| Dyad continued | | | | | -323.78 | -.02 | .576 |
| Complete Model | | | | | | | |
| | $R$ | .700 | | | .701 | | |
| | $R^2$ | .490 | | | .491 | | |
| | $R^2$ change | .490 | $F_{inc}$ (4,293) =70.515<br>$p < 0.001$ | | .001 | $F_{inc}$ (1,292) = 0.313<br>$p$ = .576 | |

### Summary of Results for Research Question 3

To test the hypothesis that total OR process time is a function of circulator-scrub dyad consistency in a case, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the nursing staff variable, circulator-scrub dyad consistency in the second model. Addition of the control variables in the first model revealed that all of the control variables were statistically significant with total OR process time. Higher number of staff signed, patient ASA status of 3, compared to lower patient ASA, and higher work RVU were each associated with longer OR process times, whereas procedure consistency between cases was associated with lower OR process times. When added as the second block, the measure of circulator-scrub dyad consistency did not explain the variance in any of the OR process times, as evidenced by $R^2$ change values that were not statistically significant. Moreover, the independent variable circulator-scrub dyad consistency did not make a unique statistically significant contribution to explaining any of the OR process times. Therefore, the null hypothesis was not rejected for Research Question 3, and there was no reduction in OR times by continuing the circulator-scrub dyad from case to case.

**Research Question 4: Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and OR Process Time**

To test the hypothesis that total OR process time is a function of nursing staff professional mix, degree of specialization in general surgery, and circulator-scrub dyad consistency, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by the block of all four nursing staff variables in the second model. The regression coefficient of interest in this analysis is the unstandardized beta, *B*, measured in seconds. With this, the betas represent the amount of change in seconds due to a one unit change in the control and independent variables.

**Intrasurgical Suite Time 1 ("Patient In to Incision"):** After addition of the first model, it was found that 9.8% of the variance in the dependent variable, ISST1, was accounted for by all control variables as they were added in the first block ($F(4,293) = 7.96$, $p < 0.001$). When added as the second block, the four nursing staff measures (professional mix, circulator specialization in general surgery, scrub specialization in general surgery, and circulator-scrub dyad consistency) did not explain a statistically significant portion of the variance in ISST1 ($R^2$ change = .003, $F_{inc}(4,289) = .26$, $p = .904$). In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 82.53$, t = 3.43, $p < 0.05$); and patient ASA status ($B = 144.13$, t = 1.97, $p = 0.05$). None of the independent variables made a unique statistically significant contribution to explaining ISST 1, RN with RN ($B = 43.18$, t = .602,

$p$ = .548); circulator degree of specialization, ($B$ = -1.00, t = -.80, $p$ = .424), scrub degree of specialization ($B$ = .614, t = .483, $p$ = .630); or circulator-scrub dyad consistency, ($B$ = -9.39, t = -.104, $p$ = .917).

Table 33

*Summary of Hierarchical Regression Analysis of Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 1*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 85.08 | .21 | .000 | 82.53 | .21 | .001 |
| Procedure consistency | -85.13 | -.07 | .221 | -83.86 | -.07 | .232 |
| Patient ASA 3 | 145.21 | .11 | .047 | 144.13 | .11 | .050 |
| Work RVU | 6.94 | .09 | .141 | 7.19 | .09 | .136 |
| Independent Variables | | | | | | |
| RN with RN | | | | 43.19 | .04 | .548 |
| Circulator specialization | | | | -1.00 | -.05 | .424 |
| Scrub specialization | | | | 0 .61 | .03 | .630 |
| Dyad continued | | | | -9.39 | -.01 | -.917 |
| Complete Model | | | | | | |
| $R$ | .313 | | | .318 | | |
| $R^2$ | .098 | | | .101 | | |
| $R^2$ change | .098 | | | .003 | | |
| | $F_{inc}$ (4,293) = 7.96 | | | | | $F_{inc}$ (4,289) = 0.260 |
| | $p < 0.001$ | | | | | $p = .904$ |

**Intrasurgical Suite Time 2 ("Incision to Dressing End"):** After addition of the first model, it was found that 47.9% of the variance in the dependent variable, ISST2, was accounted for by all control variables as they were added in the first block ($F(4,293) = 67.30$, $p < 0.001$). When added as the second block, the measure of nursing staff specialization, circulator specialization in general surgery, did not explain a statistically significant portion of the variance in ISST2 ($R^2$ change = .009, $F_{inc}(4,289) = 1.33$, $p = .260$). In the final model, three of the control variables were statistically significant, number of staff signed in ($B = 12227.94$, t = 8.32, $p < 0.001$); procedure consistency ($B = -1122.13$, t = -2.61, $p < 0.05$); and work RVU ($B = 279.07$, t = 9.47, $p < 0.05$). None of the independent variables made a unique statistically significant contribution to explaining ISST 2, RN with RN ($B = 34.35$, t = .08, $p = .938$); circulator degree of specialization, ($B = -6.94$, t = -.901, $p = .369$), scrub degree of specialization ($B = -12.14$, t = -1.56, $p = .120$), and circulator-scrub dyad consistency, ($B = 112,03$, t = .203, $p = .840$).

Table 34

*Summary of Hierarchical Regression Analysis of Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 2*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | *B* | $\beta$ | *p* | *B* | $\beta$ | *p* |
| Control Variables | | | | | | |
| Number of staff | 1235.57 | .38 | .000 | 1227.94 | .38 | .000 |
| Procedure consistency | -1139.63 | -.11 | .008 | 1122.13 | -.11 | .009 |
| Patient ASA 3 | 823.86 | .08 | .067 | 830.16 | .08 | .067 |
| Work RVU | 267.14 | .42 | .000 | 279.07 | .44 | .000 |
| Independent Variables | | | | | | |
| RN with RN | | | | 24.35 | .00 | .938 |
| Circulator specialization | | | | -6.94 | -.04 | .369 |
| Scrub specialization | | | | -12.14 | -.08 | .120 |
| Dyad continued | | | | 112.03 | .01 | .840 |
| Complete Model | | | | | | |
| *R* | .692 | | | .699 | | |
| *R* | .479 | | | .488 | | |
| $R^2$ change | .479 | | | .009 | | |
| | $F_{inc}$ (4,293) =67.30 | | | | $F_{inc}$ (4,289) = 1.33 | |
| | $p < 0.001$ | | | | $p = .260$ | |

**Intrasurgical Suite Time 3 ("Dressing End to Patient Out"):** After addition of the first model, it was found that 3.5% of the variance in the dependent variable, ISST3, was accounted for by all control variables as they were added in the first block ($F(4,293) = 2.63$, $p < 0.05$). When added as the second block, the four nursing staff measures did not explain a statistically significant portion of the variance in ISST3 ($R^2$ change = .01, $F_{inc}(4,289) = .799$, $p = .526$). In the final model, two of the control variables, patient ASA status ($B = 142.95$, t = 2.13, $p < 0.05$), and work RVU ($B = 9.066$, t = 2.05, $p < 0.05$) were statistically significant. None of the independent variables made a unique statistically significant contribution to explaining ISST 3, RN with RN ($B = -58.09$, t = -.883, $p = .378$); circulator degree of specialization, ($B = -1.36$, t = -1.18, $p = .239$), scrub degree of specialization ($B = -.22$, t = -.189, $p = .850$), and circulator-scrub dyad consistency, ($B = 20.28$, t = .245, $p = .807$).

Table 35

*Summary of Hierarchical Regression Analysis of Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and Intrasurgical Suite Time 3*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | *B* | $\beta$ | *p* | *B* | $\beta$ | *p* |
| Control Variables | | | | | | |
| Number of staff | 2.02 | .01 | .926 | 0.96 | .00 | .966 |
| Procedure consistency | -47.12 | -.04 | .462 | -48.92 | -.04 | .447 |
| Patient ASA 3 | 141.12 | .12 | .036 | 142.95 | .13 | .034 |
| Work RVU | 7.68 | .11 | .077 | 9.10 | .13 | .041 |
| Independent Variables | | | | | | |
| RN with RN | | | | -58.09 | -.05 | .378 |
| Circulator specialization | | | | -1.36 | -.08 | .239 |
| Scrub specialization | | | | -.22 | -.01 | .850 |
| Dyad continued | | | | 20.28 | .02 | .807 |
| Complete Model | | | | | | |
| $R$ | .186 | | | .213 | | |
| $R^2$ | .035 | | | .045 | | |
| $R^2$ change | .035 | | | .011 | | |
| | $F_{inc}$ (4,293) =2.625 | | | $F_{inc}$ (4,289) = .799 | | |
| | $p < 0.05$ | | | $p$ = .526 | | |

**Turnover Time:** After addition of all four control variables in the first model, it was found that 12.6% of the variance in the dependent variable, TOX, was accounted for by those variables ($F(4{,}293) = 10.57$, $p < 0.001$). After entry of the four measures of nursing staff specialization, scrub specialization in general surgery in model 2, the total variance explained by the model was 16.1% ($F(4{,}289) = 6.91$, $p < 0.001$). When added as the second block, the measures of nursing staff specialization mix, circulator specialization in general surgery, scrub specialization in general surgery, and circulator-scrub dyad consistency, after controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU explained a statistically significant portion of the variance in total OR process time ($R^2$ change = .034, $F_{inc}$ $(4{,}289) = 2.97$, $p < 0.05$). The addition of the four independent variables made a significant contribution of 3.4% to the model's ability to explain turnover time. In the final model, two of the control variables were statistically significant, number of staff signed in ($B = 73.15$, t = 3.22, $p < 0.05$); and procedure consistency ($B = -282.82$, t = -4.28, $p < 0.001$). The nursing staff variable circulator degree of specialization was the independent variable that made a unique statistically significant contribution to explaining TOX ($B = -2.78$, t = -2.34, $p < 0.05$).

Table 36

*Summary of Hierarchical Regression Analysis of Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and Turnover Time*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 77.82 | .20 | .001 | 73.15 | .19 | .001 |
| Procedure consistency | -278.70 | -.23 | .000 | -282.82 | -.23 | .000 |
| Patient ASA 3 | 129.95 | .10 | .064 | 134.90 | .11 | .052 |
| Work RVU | 2.77 | .04 | .539 | 5.62 | .07 | .217 |
| Independent Variables | | | | | | |
| RN with RN | | | | -70.87 | -.06 | .296 |
| Circulator specialization | | | | -2.78 | -.14 | .020 |
| Scrub specialization | | | | -0.76 | -.04 | .527 |
| Dyad continued | | | | -24.30 | -.02 | .776 |
| Complete Model | | | | | | |
| $R$ | .355 | | | .401 | | |
| $R^2$ | .126 | | | .161 | | |
| $R^2$ change | .126 | | | .034 | | |
| | $F_{inc}$ (4,293) =10.57 $p < 0.001$ | | | $F_{inc}$ (4,289) = 2.97 $p < 0.05$ | | |

**Total OR Process Time:** After addition of the first model, it was found that 49.0% of the variance in the dependent variable, total OR process time, was accounted for by all control variables as they were added in the first block ($F(4,293) = 70.52$, $p < 0.001$). When added as the second block, the measure of nursing staff arrangements did not explain a statistically significant portion of the variance in total OR process time ($R^2$ change = .012, $F_{inc}(4,289) = 1.72$, $p = .146$). In the final model, all of the control variables were statistically significant, number of staff signed in ($B = 1394.11$, t = 8.68, $p < 0.001$); procedure consistency ($B = -1536.24$. t = -3.29, $p < 0.05$); patient ASA status ($B = 1204.79$, t = 2.47, $p < 0.05$); and work RVU ($B = 296.90$, t = 9.25, $p < 0.001$). The independent variables for nursing staff arrangements made no unique statistically significant contribution to explaining total OR time, RN with RN professional mix ($B = -45.46$, t = -.09, $p = .928$); circulator degree of specialization, ($B = -12.26$, t = -1.46, $p = .145$); scrub degree of specialization ($B = -11.30$, t = -1.33, $p = .184$), and circulator-scrub dyad consistency ($B = 94.44$, t = .157, $p = .876$).

Table 37

*Summary of Hierarchical Regression Analysis of Nursing Staff Professional Mix, Circulator Degree of Specialization, Scrub Degree of Specialization and Circulator-Scrub Dyad Consistency and Total Operating Room Process Time*

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | $B$ | $\beta$ | $p$ | $B$ | $\beta$ | $p$ |
| Control Variables | | | | | | |
| Number of staff | 1410.66 | .40 | .000 | 1394.11 | .39 | .000 |
| Procedure consistency | -1548.30 | -.14 | .001 | -1536.24 | -.14 | .001 |
| Patient ASA 3 | 1193.71 | .10 | .015 | 1204.79 | .11 | .014 |
| Work RVU | 281.08 | .40 | .000 | 296.90 | .42 | .000 |
| Independent Variables | | | | | | |
| RN with RN | | | | -43.46 | 0.00 | .928 |
| Circulator specialization | | | | -12.26 | -.07 | .145 |
| Scrub specialization | | | | -11.30 | -.06 | .184 |
| Dyad continued | | | | 94.44 | .01 | .876 |
| Complete Model | | | | | | |
| $R$ | .700 | | | .709 | | |
| $R^2$ | .490 | | | .502 | | |
| $R^2$ change | .490 | | | .012 | | |
| | $F_{inc}$ (4,293) =70.52, $p < 0.001$ | | | $F_{inc}$ (4,289) = 1.72, $p = .146$ | | |

### Summary of Results for Research Question 4

To test the hypothesis that total OR process time is a function of the nursing staff arrangements including RN with RN, circulator specialization, scrub specialization, and circulator-scrub dyad consistency, controlling for number of staff signed in to a surgical case; procedure consistency; patient ASA; and work RVU; hierarchical multiple regression analysis was employed. According to the theoretical basis for expected effects of control variables on perioperative timeframes, the four control variables were entered as a block in the first model, followed by all of the nursing staff variables in the second model. Addition of the control variables in the first model revealed that all of the control variables were statistically significant with total OR process time. Higher number of staff signed, patient ASA status of 3, compared to lower patient ASA, and higher work RVU were each associated with longer OR process times, whereas procedure consistency between cases was associated with lower OR process times. When added as the second block, the measures of nursing staff professional mix, circulator and scrub degrees of specialization in general surgery, and circulator-scrub dyad consistency did not explain variance in four of the OR process times, as evidenced by $R^2$ change values that were statistically significant. However, the independent variable circulator degree of specialization explained the variance in turnover time (TOX). Moreover, circulator degree of specialization made a unique statistically significant contribution to explaining TOX, with higher degree of specialization related to lower times. Having found circulator degree of specialization statistically significant for variance in TOX among the OR process times, the null hypothesis for Research Question 4 was rejected.

## Summary

As an explanatory study, this research used scientific management theory to explain, in part, the utilization of time in OR processes. Four hypotheses, based on scientific management's principles of professional mix, specialization, and standardization, were tested by applying hierarchical multiple regression models to OR data. Hierarchical regression analysis employed blockwise introduction of variables in separate models to evaluate the estimated relationship between nursing staff arrangements and control variables, and OR process efficiency. In this study, nursing staff arrangements were expected to explain OR times after controlling for environmental, patient status, and case complexity variables. Therefore, according to the theoretical support for their effect on OR process time, all control variables were entered in the first block (Model 1), and independent variables for nursing staff arrangements were entered in the next block (Model 2). The explanatory power of the control variables was then used for determining whether additional variance in each of the dependent variables was explained by the independent variables added to the model as a second block. Of the independent variables, circulator degree of specialization revealed a statistically significant relationship with turnover time and total OR process time, and scrub degree of specialization with ISST2 (Incision to Dressing End), turnover time, and total OR process time. Therefore, the results of this study failed to reject the null hypotheses for three of the research questions was rejected, based on the following findings:

- A greater degree of circulator specialization in general surgery explained variation in OR process times for RQ 2a (reduction in turnover time and total OR process time), and RQ4 (turnover time).

- A greater degree of scrub specialization in general surgery explained variation in OR process times for RQ 2b (reduction in Incision to Dressing End time, turnover time and total OR process time).

# CHAPTER 5

## DISCUSSION

Links between operating room efficiency and surgical teams have been investigated, yet research on the efficiency of surgical nursing staff members is scant. Specifically, little is known about the effects of nursing staff arrangements in surgery; such knowledge will be useful in planning staff training and structure to achieve savings in time and money. This study assessed efficiency in operating room processes that are affected by surgical nursing staff arrangements including specialization, standardization, and skill mix in surgical processes. Within the theoretical framework of scientific management, an explanatory model considered operating room nursing staff arrangements and their effect on time variation in surgical processes. In a cross-sectional cohort design, operating room data from electronic health records was analyzed using multiple regression analysis to reveal associations between individual experience working within various surgical services, skill mix, and consistency of nursing staff pairings between surgical cases. Other environmental, patient, and case variables that may explain differences in operating room efficiency were included as controls in the model. Of the nursing staff variables, specialization in general surgery explained a significant portion of the variance in OR timeframes.

The purpose of this study was to evaluate an explanatory model of efficiency in OR processes. Hierarchical regression analysis revealed that circulator and scrub degree of specialization in general surgery explained variation in turnover times, surgical procedure times, and total OR process times. After controlling for environmental, patient health status, and case complexity variables, the independent variable circulator degree of specialization in general surgery made a significant contribution of to the model's ability to explain turnover time ($R^2$ change = .028, $F_{\text{inc}}(1,292) = 9.83$, $p < 0.05$)—making a unique statistically significant contribution to turnover time variation ($B = -3.37$, t = -3.13, $p < 0.05$)—and total operating room process time ($R^2$ change = .009, $F_{\text{inc}}(1,292) = 4.98$, $p < 0.05$). Upon controlling for the control variables, scrub degree of specialization in general surgery explained a statistically significant portion of the variance in the surgical timeframe spanning incision to dressing end ($R^2$ change = .008, $F_{\text{inc}}$ (1,292) = 4.50, $p < 0.05$), demonstrating a unique statistically significant contribution to explaining that timeframe ($B = -14.37$, t = -2.12, $p < 0.05$), and explained a statistically significant portion of the variance in turnover time ($R^2$ change = .013, $F_{\text{inc}}$ (1,292) = 4.50, $p < 0.05$). Scrub degree of specialization also made a significant contribution of 0.8% to the model's ability to explain total process time. No statistically significant association existed between the consistency of dyad pairings in subsequent surgical cases, or of the nursing skill mix within a circulator and scrub pairing.

This research study proposed a model focusing on three characteristics of OR nursing staff arrangements as they relate to the use of time in the perioperative period. These three characteristics—professional mix, specialization, and standardization—are inherent in OR work processes and reflect the themes of efficiency proposed by scientific management. Operating room nursing staff patterns, on which there has been little research, were examined for their effect on surgical process timeframes, controlling for environmental, patient, and case complexity variables. This chapter reviews the results of the study in light of implications for nursing practice and health policy. Limitations are discussed, and directions for future research are suggested.

## Design, Sample, and Measures

### Design

In this study, a retrospective, cross-sectional cohort design was employed to conduct a secondary data analysis of sequential surgical cases. The unit of analysis in this study encompassed the surgical process from the exit of one patient from a surgical suite through the time of exit of the subsequent patient from the same surgical suite. This unit of analysis considered the total OR process time. That the study was retrospective and included information in OR records permitted access to a variety of time, staffing, and patient variables. This retrospective design was appropriate to a study of turnover times between surgical cases; had the design been prospective, consent for study participation for many of the patients would had to have been obtained when they were in the preoperative holding area. As such, the obtaining of consent between cases would have extended the turnover time.

### Sample

**T**he sample for this study included surgical cases paired as one preceding and one subsequent surgical case, occurring on the same day in the same suite. This pairing of surgical cases was essential to examining the dependent variable turnover time, and the independent variable of nursing staff standardization, “circulator-scrub dyad consistency”. Pairings of previous-subsequent surgical cases are commonly used for analyzing TOX in OR settings. In order to consider patient preoperative health status and case complexity information, each subsequent case was part of the ACS-NSQIP dataset.

## Measures

All measures for the models evaluated in this study were obtained from the electronic OR record for each unit of analysis. The use of electronic data from surgical cases facilitated the use of sign-in and sign-out times. If manually collected, obtaining those times would be prohibitively resource-intensive. In studies where extensive data manipulation has occurred, the quality of the data needs to be thoroughly explored. Threats to reliability and validity were minimized as all records were completed using a standardized form, and all data was recorded by trained OR nurses. Furthermore, this data was kept for the hospital's administrative and billing purposes. Where new measures were created from the existing data (e.g., the turnover time value for each case), calculations were verified twice, using SPSS and Excel, in order to identify and correct errors. Use of electronic health record data provided an efficient means of data analysis for this study. Further studies involving OR nursing staff arrangements would be facilitated by the inclusion of a data field to note the primary nursing staff in each surgical case.

## Evaluation of the Research Model

Findings for each research question are reviewed in light of differences in OR process times.

### Research Question 1: Nursing Staff Professional Mix

Hierarchical regression analysis revealed that the combination of an RN as circulator with an RN as scrub in a surgical case did not explain a statistically significant portion of the variance in OR process time. In other words, case duration was not explained by whether an RN or an ST was in the scrub role. Although independent effects of professional mix on OR times were not statistically significant, RN-RN professional mix resulted in less time for all OR timeframes except for "Patient In to Incision", since the sign of the betas was negative. That variance in OR time was not explained by professional mix, yet demonstrated a (statistically non-significant) trend toward less times in cases with an RN circulator-RN scrub pairing suggests potential for further defining professional mix in the OR.

### Research Question 2: Nursing Staff Specialization

Results of hierarchical regression analysis in this study indicate that differences in OR process time may be explained by the degree of specialization of the circulator and the scrub in a surgical case. Scientific management theory maintains that specialists, organized into specialty teams, work more efficiently than do non-specialists. When defined according to the percent of overall time signed in to general surgery cases, cases in which the primary nursing staff had a higher degree of specialization were, on average, speedier than cases in which the primary nursing staff had a lower degree of specialization.

*Circulator Degree of Specialization.* A one percent increase in circulator degree of specialization trimmed about three and a half seconds from turnover time, and 17 seconds from total OR process time.

*Scrub Degree of Specialization.* A one percent increase in scrub degree of specialization, controlling for other variables, was linked to a reduction in time between incision and dressing end by 14.37 seconds. Scrub degree of specialization made a unique statistically significant contribution to explaining total both reductions in turnover time and total OR process time (by 2.24 seconds and 16 seconds, respectively) for a one percent increase in scrub degree of specialization.

These results indicate that increased specialization in a surgical service among circulators and scrubs makes a difference in OR times as it has implications for staffing arrangements. Circulators who are more specialized (by virtue of having spent a greater proportion of their time signed in to general surgery cases) should be assigned to particular services, where they may realize time savings in turnover and total OR time. Scrubs who are more specialized should be assigned to particular procedures, no matter which surgical service is responsible, since reductions in "incision to dressing end" (e.g., surgical procedure) time occurred with more specialized scrubs.

### Research Question 3: Nursing Staff Standardization

In this study, statistical analysis did not suggest that circulator-scrub dyad consistency between surgical cases explained variations in any of the OR timeframes. Among the units of analysis, more than 80% demonstrated dyad consistency, where the circulator and scrub from the previous case remained together into the subsequent case. This research did not distinguish between cases where a circulator and scrub who remained into the subsequent case maintained their roles, or changed roles. It is possible that a change of focus such as that afforded by exchanging circulator and scrub roles affects the pace and duration of surgery.

### Research Question 4: Nursing Staff Professional Mix, Specialization, and Standardization

Results of hierarchical regression analysis in this study indicate that circulator degree of specialization explained a portion of the variance in turnover time, controlling for other variables. Circulator degree of specialization was the only independent variable to make a unique, statistically significant to reducing turnover time between cases.

## Implications for Health Care Policy

This study translated scientific management principles to the practice of OR nursing. With statistically significant results about specialization (of nursing staff) and standardization (of surgical procedure types), the model of efficiency in the OR was able to translate some principles of scientific management theory to daily surgical processes. A shortage of bedside nurses and a surfeit of demand for surgery argue better use of the talents of individuals and teams in the OR. As an alternative to reducing services or raising costs to improve the health care balance sheet, we should re-examine health care labor as a means of improving affordability and accessibility. Findings from this study reveal a new area of research that has the potential to affect OR staffing, scheduling, costs, and patient experiences.

This study's results indicate that nursing staff degree of specialization, with other variables controlled for, explains differences in OR process time. Therefore, where case volume is sufficient to include various surgical service specialties, benefits may be realized in terms of faster interoperative and intraoperative times from organizing OR nursing staff by specialty surgical service teams. Organizing OR nursing staff into specialty teams may lead to gains in OR process efficiency, but these may be at the expense of staff satisfaction. For some, the allure of the OR is the potential to take part in—and become competent in—a variety of surgical services. Nursing staff may prefer to not be categorized by surgical service team membership and labeled as "a plastics nurse" or "an ortho scrub". Alternatively, nursing staff may prefer to function almost exclusively with the same team members, becoming proficient in one surgical specialty. Recruitment and retention of OR nursing staff may be affected by mismatches between staffing arrangements (specialty teams or no specialty teams) and individual preferences for specializing.

In the OR, nursing staff arrangements characteristically retain a 1:1 ratio circulator-scrub ratio for each surgical case. Routine in the OR is for the circulator and the scrub first assigned to the case to be considered the primary nursing staff. However, there remains no official definition of primary OR nursing staff. The model developed in this study addressed gaps in nursing research by offering operational definitions for primary nursing staff, professional mix, experience, and case assignments of the circulating nurse and the scrub role. Continued explication of such definitions will be useful in recruiting OR nursing staff, determining daily staffing assignments, and reviewing the effect of staffing patterns on OR processes and patient care during surgery.

The move to identifying whether nursing staff characteristics explain differences in efficiency in OR processes has implications for incentives. Extant practices in some surgical settings reward anesthesiologists and surgeons for efficiency in terms of time savings. Results from this study indicate that the experience of the scrub and of the circulator explain some of the interoperative and intraoperative times in the surgical process. For example, the presence of a specialized scrub may significantly reduce the surgical procedure time. The principles of scientific management suggest that incentives, in the form of bonuses or time off, be offered in order to encourage efficiency in completing assignments. Nursing staff, as an integral part of the surgical team, may also be considered as candidates for incentives based on reducing time in the production of surgery.

This study found an association between higher numbers of staff in surgical cases, and longer OR duration. Surgical teams may look to ways to minimize staff handoffs during cases. Congestion may reduce efficiency by making it more difficult for staff to accomplish tasks, or by using up time as additional staff members are involved in teaching activities. Interruptions, studied extensively in hospital units other than the OR, do affect surgical processes. Initiatives designed to reduce the number of staff in ORs may have additional benefits of reducing potential for infection, and improving teamwork among staff.

Consistency of procedure types from case to case may be thought of as a form of standardization. Applying principles of scientific management to health care, managers may find that standardization implies more than simply doing things the same way every time. The manner in which surgical procedures are scheduled, and patients grouped, may be improved by considering standardization by procedure type. Scheduling surgical cases by similar procedure type will streamline both the preoperative patient preparation process and the flow of surgery, thereby increasing potential to increase access to surgical procedures to more people.

## Limitations

This section illuminates some of the limitations to this study, including the sample, measurement, and generalizability.

### Sample

A major limitation to the study was the inclusion of a variety of surgical procedures within the sample. Heterogeneity of procedure types included in the analysis may have influenced associations between independent and dependent variables. Moreover, exclusion of cases having no turnover time limited analytical power. Future studies may evaluate a more homogenous set of procedure types.

The experience and specialization of other members of the surgical team, notably, the attending surgeon and anesthetist, and the residents, was not included in the analyses. Experience of all of those around the OR table, not only the nursing staff, may affect the flow and pace, and therefore, the time, of a surgical procedure. Evaluation of the experience of all surgical team members should be included in follow-up studies.

Another omission from the model was patient variables such as body mass index, previous surgery, and adhesions. All of those variables may affect the time needed to complete various segments of the total OR process. However, as the control variables already accounted for a significant percentage of variation in dependent variables, it is questionable whether additional control variables would have added important information.

**Measurement**

A possible limitation to this study was that the calculation of specialization and its reliance on sign-in times as a proxy for garnering experience. Though this is based on actual data, it may not have accounted for such factors as non-productive time (e.g., waiting for a patient to be transported to the OR).

The calculation of the variable, "degree of specialization", for the primary circulator and scrub was a potential limitation of this research. For example, nursing staff who took part in only one surgical case during the study period were considered to have 100 percent specialization in a surgical service. Such limited experience may not accurately reflect whether one is a specialist.

Additional noise or error may be related to sign-ins and calculations applied in this study. Productive time, too, was not differentiated from non-productive time. The full extent of these effects is currently unknown and will be the focus of future studies.

The determination of dyads posed a challenge. When there were cases in which the primary staff from a previous case either 1) was signed in for only the first portion of the subsequent case, or 2) was signed into the subsequent case only after incision. A standard definition of, and indicators for, does not exist for primary nursing staff (circulators and scrubs) in the OR. Therefore, the definition that the researcher applied here, though applied consistently, may not have accurately reflected designation of primary nursing staff.

### Generalizability

Data for this study was from one hospital and included adults who sought care at this facility for general surgery. With a limited patient population, as well as a restricted range of nursing staff members, the results of the study may be limited to similar inpatient surgical settings.

## Future Research

The wealth of information from electronic health records, and the dearth of evidence about OR nursing staff arrangements, provide ample opportunity for further studies in perioperative processes. The surgical team functions within a complex, dynamic, and highly technical environment in a rhythm that is only sometimes predictable. This study is unique in its application of the principles of scientific management theory to staffing arrangements in the OR. Findings that scientific management principles may represent nursing staff arrangements indicate the need for further research to understand the factors that affect the use of time both within and between surgical cases.

The degree of specialization in the general surgery service explained, in part, variation in OR process times. This finding raises numerous possibilities for future research. One research avenue is to explore the cost-effectiveness of organizing the OR nursing staff into specialty service teams. Another possibility is to separate, for RNs, their degree of specialization according to percent of time spent in the scrub role versus time spent in the circulator role. Future research may examine whether such an exchange of roles within a dyad has an effect on OR process time. Nursing staff may be either energized by a change of roles (and speed up the pace) or may be distracted by a role swap (and slow down their routines). Insights to differences in role-related performance would improve decision-making regarding staffing assignments and OR nursing staff training.

In surgery, the scrub role may be assumed by either an RN or an ST; the circulator is always an RN. That STs are included among the nursing staff signifies the need to refine definitions of nursing staff professional or skill mix in the OR. Previous research (e.g, Needleman, Buerhaus, Mattke, Stewart & Zelevinsky, 2002; Kane, Shamliyan, Mueller, Duval & Wilt, 2007) suggests that hospitals with a higher percentage of RNs on the nursing staff have lower rates of patient adverse events such as falls and infections. This study defined professional mix according to the unit of analysis, which included the time from a previous patient's exit from a suite to the time of exit of the next patient from that suite. Hence, the professional mix was a dichotomous variable (defined as RN with RN, or RN with ST) rather than a percentage of RNs among the entire OR nursing staff. Future research may examine the application of traditional definitions of skill mix (e.g., the percent of RNs among the OR nursing staff) to the OR setting. Findings reported here confirm that existing definitions applied to unit level staffing are not appropriate for the OR environment. Therefore, appropriate OR staffing measures are due to be developed.

A novel concept was the identification of circulator-scrub dyad consistency to characterize OR nursing staff arrangements. Because this concept of circulator-scrub dyads has not previously been defined, future research may aim to provide a more precise definition of circulator-scrub dyads between subsequent surgical cases.

The opportunity cost of time is undervalued in health care (Krueger, 2009). That the model considered turnover time to be an indicator of wasted opportunity is a reminder of the value of waiting time. As a type of "intangible invaluable", time such as that spent waiting for room turnovers in the OR is an asset that could otherwise be used for productive activity. Studies of efficiency in health care delivery processes do not routinely include opportunity cost of time waiting (Needleman, Buerhaus, Stewart, Zelevinsky & Mattke, 2006). The results of this study demonstrate that waiting time may be reduced, and variations in turnover time are partly explained by the nursing staff assigned to a case. Future research may assess the extent to which patients and providers value shorter turnover times, and evaluate the value of turnover time as an opportunity cost from the perspective of families, staff, and payers.

Nursing staff is a considerable portion of the health care labor force. Scientific management theory suggests that the organization of labor within an organization, in terms of professional mix, specialization, and standardization, affects time efficiency in production. Similarly, nursing staff arrangements in the perioperative environment were shown in this study to affect efficiency in the delivery of surgical services. In sum, SMT is valuable for studying the OR staffing environment. Future studies will further develop the presented models and validate these findings.

# APPENDICES

# APPENDIX A

## APPENDIX A

### Effects of Nursing Staff Arrangements on the Total OR Process

To illustrate the potential effects of OR nursing staff specialization and skill mix on the flow and pace of the surgical process, two scenarios are presented. Both cases involve total hip replacement surgery and describe events occurring as nursing staff with different levels of orthopedic surgery experience take part in the surgical process.

> <u>Case 1:</u> In the first case of the day, a circulator and a scrub, each of whom has spent more than half of their working time in orthopedic surgery cases, are assigned to work together in a hip replacement procedure. Although the circulator has worked in fewer hip replacement cases than has the scrub, she is familiar with the pace and routine of joint replacement surgery. Before the patient enters the surgical suite, the circulator arranges to have appropriate equipment and devices available for positioning, prepping, and surgical set-up. The circulator ensures that additional X-ray gowns are on hand, suction canisters are plentiful, and a variety of saw blades are in the room. The scrub reminds the circulator that a fluoroscopy table must be placed before the patient is brought into the room, and the circulator calls the nursing assistant to exchange the standard OR table for a fluoroscopy table. Next, the circulator calls the OR x-ray technicians as a reminder to set up the fluoroscopy machine. The nursing assistants, busy elsewhere, don't respond, and the circulator forgets to call them a second time. The scrub makes preparations for using bone cement, and coordinates with the circulator to ensure that hip prostheses are available and intact in their sterile packages. The circulator notices a tiny tear in one package,

and is quickly able to locate a replacement in the orthopedics section of the sterile supply room. Just before the patient is brought into the room, the circulator puts the beanbag on the OR table, and recognizes that it is not the fluoroscopy table required for the surgery. The circulator contacts the nursing assistant again, and they position the fluoroscopy table in for surgery. When the patient is brought into the room, he is transferred to the fluoroscopy table, and anesthesia induction proceeds. After induction, the circulator enlists the assistance of two surgical residents to position the patient on a beanbag pillow. Because the circulator knows that the orthopods routinely use four sterile U-drapes and chloraprep for the surgical prep, she puts those items on the prep table for the resident. The circulator hands the anesthesia resident an x-ray gown, then counts instruments, sharps, and sponges with the scrub. When the orthopedic surgeon enters the room, the circulator verifies that all supplies are available, including several sizes of hip prostheses. During the surgical procedure, the surgeon requests the femoral head prosthesis and bone cement be placed on the sterile field. The circulator shows the package to the scrub, who verifies the size and expiration date. The prosthesis is then placed onto the sterile field, and the circulator works with the scrub to set up the bone cement mixer and evacuator. As the surgeons begin to close the surgical site, the circulator calls the nursing coordinator to call for pre-operative preparation of the next patient scheduled for that OR suite. The surgeon gives the circulator a retractor that will need to re-sterilize one of the instruments for use in the case to follow. The circulator puts the retractor in the autoclave, which is set to run for 20 minutes.

Case 2: In the subsequent case in the same room, a new circulator comes in to replace the previous circulator. The new circulator has spent less than ten percent of her time in orthopedic surgery and is paired with the scrub from the previous case. She was delayed in coming to the room, so did not receive a circulator hand-off report. To prepare for this second case, the incoming circulator gathers two pillows for positioning, x-ray gowns for the surgeon and surgical resident, and all suture items on the surgeon preference card. The scrub comments that they are likely to go through a lot of sponges and irrigation fluid during the procedure. The scrub then reminds the circulator that a fluoroscopy table must be placed before the patient is brought into the room, and the circulator d the circulator calls the nursing assistant to exchange the standard OR table for a fluoroscopy table. The nursing assistant, busy elsewhere, does not respond, and the circulator forgets to call her a second time. The scrub makes preparations for using bone cement, and coordinates with the circulator to ensure that hip prostheses are available and intact in their sterile packages. The circulator notices a tiny tear in one package, and spends several minutes looking for a replacement in the orthopedics section of the sterile supply room. Just before the patient is brought into the room, the circulator puts the pillows on the OR table, and fails to notice that it is not the preferred table for hip surgery. When the patient is brought into the room, he is transferred to the standard OR table, which cannot accommodate the fluoroscopy machine. Fortuitously, just before anesthesia induction proceeds, the scrub notices the table and a fluoroscopy table is brought to the room. The patient, dismayed and confused about an uncomfortable and awkward transfer to another OR table, is assisted onto the fluoroscopy table with some ado.

After induction, the circulator enlists the assistance of two surgical residents to position the patient on a beanbag pillow. The circulator puts the generic scrub pack onto the prep table, and the surgical resident requests U-drapes and chloraprep. The scrub tries to direct the circulator to where the drapes are kept in the room, and the circulator find only three drapes. She puts the three drapes on the prep table for the resident, who promptly requests a fourth. The circulator wonders aloud why the resident can't simply make do with three drapes, and returns to the sterile supply room where she spends two minutes searching for a U-drape. The scrub reminds the circulator that they need to count, and they proceed to count instruments, sharps, and sponges. When the orthopedic surgeon enters the room, the circulator verifies that all supplies are available, including several sizes of hip prostheses. Shortly after incision, the surgeon asks for the x-ray technician to take a picture. The circulator calls the x-ray technicians, who reply that there will be a 20-minute wait. While the surgeons are waiting for fluoroscopy, the anesthesia resident asks for an x-ray gown, and the circulator leaves the room to track one down. During her absence, the suction canister stops working because it is full and there is no overflow canister. The surgeons request more sponges, and the scrub realizes that he has only one sponge. Normally, a circulator will notice when sponges are getting low and will add more to the sterile field. The surgeon then asks for the retractor that was put in the autoclave. The circulator returns to the room to find a tense, annoyed surgical team waiting for sponges, the retractor, and x-ray. She hands the scrub a pack of five sponges but fails to note the added sponges to the count sheet because the surgeon is asking for his retractor. The circulator searches in vain for the retractor until the scrub finally mentions that it might be in the autoclave. After the retractor is retrieved from the autoclave, the surgical team waits several minutes for it to cool off. At this point, the scrub tech is relieved by a nurse who usually works in other surgical services. When the surgeon requests the femoral head prosthesis and bone cement be placed on the sterile field. The circulator, noticing that the scrub is busy passing instruments, tosses one of the prostheses onto the sterile field. The scrub nurse assesses the prosthesis, and asks the surgical resident if it's the correct size. The surgeon, peering over, sees that it is the wrong size and promptly informs the nurses that they have just wasted an extremely expensive item. The circulator apologizes, stating that she doesn't work in orthopedics very often. As the surgeons begin to close the surgical site, the circulator is busy recounting sponges to identify how five additional sponges are on the field. As the patient is leaving the OR, the coordinator remembers to call the nursing coordinator to call for pre-operative preparation of the next patient scheduled for that OR suite.

# APPENDIX B

**APPENDIX B**

**Steps in Identifying Episodes for Data Analysis**

Step 1: Using the staffing source data set, create a variable to combine dates and corresponding surgical suites for all cases.

Step 2: Identify date-suite variables for NSQIP cases, occurring on 127 dates and in 23 suites

→ 533 NSQIP date-suite combinations

Step 3: Identify all cases having one of the 533 NSQIP date-suite combinations

→ 1,443 cases

Step 4: Eliminate single cases: Cases (N = 62) that are the only case in a suite on a day have no prior or subsequent case.

→ 1,381 cases remain

Step 5: Identify cases that are part of a preceding-subsequent case pairing characterized by the following:

1. NSQIP case following a NSQIP case
2. NSQIP case following a non-NSQIP case

Step 6: Eliminate cases without a NSQIP case pairing such as that described in Step 5: Only cases that are ACS-NSQIP cases to follow are included in the analysis.

→ 514 cases remain

Step 7: Identify single NSQIP cases with a turnover time between 0 and 60 minutes. "Turnover time" is the difference between the "time in" of a subsequent case the "time out" of its preceding case.

→ 386 cases remain.

Step 8: Eliminate cases with missing staff sign-in times (N = 28): Staff sign-in times are needed to calculate nursing staff variables.

→ 358 cases remain.

Step 9:  Eliminate cases with missing surgical service (N = 20):  Surgical service information is needed to verify that all cases are performed by the general surgery service.

→ 338 cases remain.

Step 10:  Eliminate cases with a second procedure listed (N = 28):  Attribution of perioperative times within the general surgery service requires that no cases with multiple procedures are included in the sample (e.g., the service performing a second procedure is not noted in the OR record).

→ 310 cases remain as episodes in the analytical sample.

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