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Using Data To Drive Emergency Department Design: A Metasynthesis

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Abstract

Objective: There has been an uptick in the field of emergency department (ED) operations research and data gathering, both published and unpublished. This new information has implications for ED design. The specialty suffers from an inability to have these innovations reach frontline practitioners, let alone design professionals and architects. This paper is an attempt to synthesize for design professionals the growing data regarding ED operations.

Methods: The following sources were used to capture and summarize the research and data collections available regarding ED operations: the Emergency Department Benchmarking Alliance database; a literature search using both PubMed and Google Scholar search engines; and data presented at conferences and proceedings.

Results: Critical information that affects ED design strategies is summarized, organized, and presented. Data suggest an optimal size for ED functional units. The now-recognized arrival and census curves for the ED suggest a department that expands and contracts in response to changing census. Operational improvements have been clearly identified and are grouped into three categories: input, throughput, and outflow. Applications of this information are suggested.

Conclusion: The sentinel premise of this meta-synthesis is that data derived from improvement work in the area of ED operations has applications for ED design. EDs can optimize their functioning by marrying good processes and operations to good design. This review paper is an attempt to bring this new information to the attention of the multidisciplinary team of architects, designers, and clinicians.

Key Words: *Emergency department, emergency department operations, triage, throughput, design, efficiency, quality, safety*

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Aim of This Paper

The universe of emergency department (ED) operations has seen an uptick in innovations in the past two decades (Beach, Haley, Adams, & Zwemer, 2003; Bertoty, Kuszajewski, & Marsh, 2007; Chan, Killeen, Kelly, & Guss, 2005; Choi, Wong, & Lau, 2006; Gorelick, Yen, & Yun, 2005; Richards, Navarro, & Derlet, 2000; Spaite et al., 2002; Thompson, Yarnold, Williams, & Adams, 1996; Welch, 2010a; Wiler et al., 2010). These innovations have important implications for the way EDs are designed and how operations

and processes are married to design. This paper is an attempt to synthesize for design professionals the growing data, published and unpublished, regarding ED operations and to suggest applications for ED design.

Background

From 1995 to 2005 the number of ED visits increased nearly 20% to 115.3 million, even though the number of hospitals decreased by nearly 10% (Nawar, Niska, & Xu, 2007). The American Hospital Association (2005) reports that 69% of urban EDs are over capacity, resulting in crowded conditions and ambulance diversions. In 2005 the Joint Commission implemented a new leadership standard regarding the management of patient flow, which mandated that hospitals "...develop and implement plans to identify and mitigate impediments to efficient patient flow throughout the hospital" (Joint Commission, 2005).

The valuable effect on patient outcomes of streamlining ED operations has been emphasized by the Agency for Healthcare Research and Quality (AHRQ), the Institute for Healthcare Improvement, and the Institute of Medicine. Research demonstrating the impact of ED efficiency on subsequent outcomes for a number of clinical entities has been accumulating (Bernstein et al., 2009; Fee, Weber, Maak, & Bacchetti, 2007; Joint Commission, 2002; Magid et al., 2009; Pines & Hollander, 2008; Richardson, 2006; Sprivulis, Da Silva, Jacobs, Frazer, & Jelinek, 2006).

Changing demographics affect the way EDs operate. As patients age, the complexity of their acute health care needs increases (Sprivulis, 2004). As the Baby Boomers reach their senior years, they will hit the ED like a tidal wave. The sheer amount of information, diagnostic and therapeutic tasks, and personnel involved in caring for these complex patients will make it necessary to change space, processes, and operations in the ED.

The most common complaint about visits to the ED is the perception that everything takes too much time (Press Ganey Associates, 2009). From the patient's perspective, an ED visit is a series of seemingly random queues without clear communication about what the patient is waiting for, what the next step in the process will be, and how long that step will take. The waiting has no value to the patient. Emergency care providers often offer the excuse that patient demands are "unpredictable" and that the sickest patients must be treated first. Although both of these statements are founded in truth, the demands on the ED are much more predictable than practitioners are often willing to admit.

Most hospitals are capable of providing timely care for the sickest patients without delaying service for low-acuity patients. The key is using data-driven process improvements to expedite care.

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service for low-acuity patients. The key is using data-driven process improvements to expedite care.

ED operations research is often slow to reach the front lines. To date there is no journal for ED operations and there is frequently a significant delay between operational innovation and widespread frontline acceptance (Welch, 2010a). Every day, emergency physicians, nurses, and staff innovate to improve ED processes. The 4,500 EDs in the United States are living laboratories, and each one is trying to solve logistical and operational challenges (typically constrained by physical space limitations). When ingenious local solutions are achieved, timely and widespread dissemination of these ideas fails to occur; mechanisms for the diffusion of innovation are lacking. The specialty suffers from an inability to have these innovations reach front-line practitioners let alone design professionals and architects. The result is a knowledge-action gap in ED operational innovation.

The sentinel premise of this metasynthesis is that data from improvement work in the area of ED operations have applications for ED design.

EDs can optimize their functioning by marrying good processes to good design.

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Measures of ED Performance

A number of metrics appear in the emergency medicine literature and are used by healthcare leaders as markers for quality and performance (Welch, 2010a; Welch et al., 2011). The time interval metrics are better understood when referring to this chart, which depicts the time stamps/time intervals of a typical ED stay (Figure 1). In addition, a number of measures reported as percentages or rates have been used to capture elements of performance in the ED.

Time Metrics (Time Intervals)

- **Arrival-to-provider time** (a.k.a. "door-to-doc time"): Arrival time to provider contact time.
- **ED length of stay (LOS):** Arrival time to departure time.

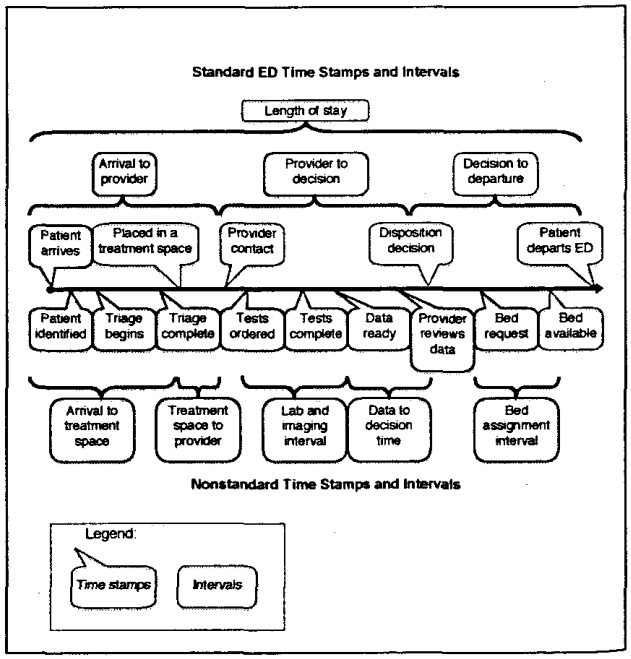

Figure 1. Timeline of Emergency Department time stamps and intervals.

Table 1. ED Performance as a Function of Size

	Under20k (*n* = 64)	20K to 40K (*n* = 146)	40K to 60K (*n* = 92)	60K to 80K (*n* = 35)	Over 80K EDs (*n* = 22)	*p*-value
Performance Metrics						
Left before treatment complete (%)	1.37	2.10	2.82	3.34	3.59	< 0.0001**
Door-to-physician time (in minutes)	24	27.5	30.5	36.5	36.5	0.0012*
Median ED LOS for admitted patients (in minutes)	207	246	306.5	312.0	347.5	< 0.0001*
Median ED overall LOS (in minutes)	125	148.5	174.0	183.0	203.0	< 0.0001*

*Wilcoxon rank sum test
**ANOVA

Proportion Metrics

- **Left without being seen (LWBS):** All patients who leave the ED before being seen by a provider.
- **Left before treatment complete (LBTC):** All patients who leave the ED before formal disposition is made.
- **Complaint ratio:** All spontaneous written, phone call, or spoken expressions of concern brought to the attention of ED management or hospital staff. By convention, complaint ratios are tracked as complaints per 1,000 ED visits.

Patient Satisfaction

- **Patient and staff satisfaction surveys:** Although typically done using local survey instruments, Press Ganey or other professional patient survey companies may administer these. They are usually reported as percentiles.

Size (Annual Volume) Matters

Unpublished but credible data from the Emergency Department Benchmarking Alliance (EDBA) suggests that the size (which, in ED operations, typically refers to annual volume) correlates with performance on metrics. EDBA is a consortium of 486 performance-driven American EDs. It has been collecting performance and operational data on EDs for 7 years through its annual mandatory data survey. Data from the EDBA reveal that performance on metrics is volume dependent—the smaller, lower-volume EDs are operationally more efficient and perform better on metrics, suggesting that there may be an optimal size for functional units in the ED (see Table 1) (Augustine, 2011a). These performance data are in keeping with a 2010 Canadian study that also found that lower-volume departments functioned more efficiently (Hutten-Czapski, 2010).

In addition, EDBA data suggest that a new ED be built with the assumption that approximately 1,500 patients a year could be treated in each patient treatment room, in keeping with recom-

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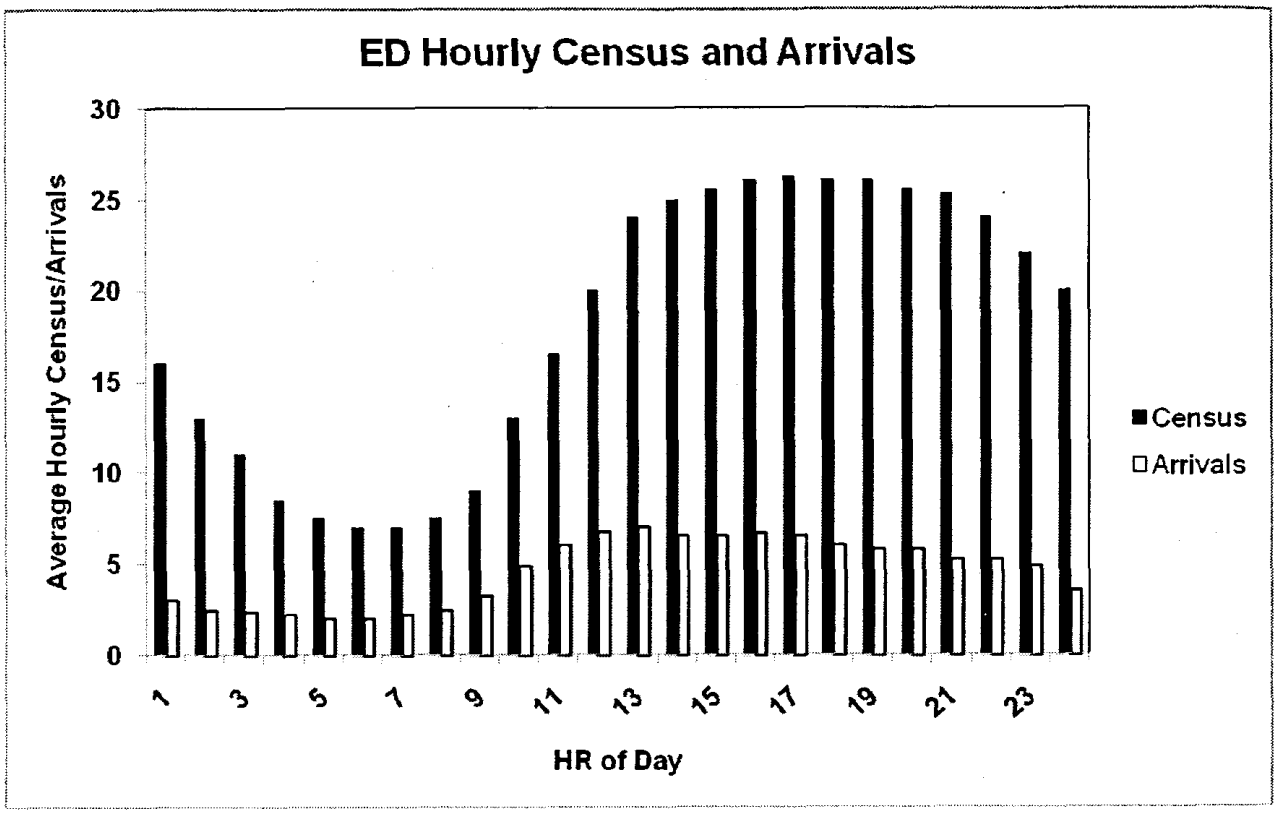

Figure 2. Census and arrival curve of the Emergency Department.

mendations put forth by Huddy (2006).

The Breathing Emergency Department

It is well recognized that the workload in an ED is not level throughout the day. The ED goes through a 24-hour cycle that is predictable regardless of volume (Welch, Jones, & Allen, 2007). The census in an ED, regardless of size, is typically three to four times as great at 4 p.m. as the census at 4 a.m. (Figure 2). This means that the ED space and operations must be able to flex up and down to meet this extreme variation in census and arrivals throughout the day.

Applications to Design

The EDBA data showing that lower-volume EDs are more efficient could suggest an optimal size for functional units in an ED, even if the overall department must have many more beds. Knowing from EDBA data that EDs seeing 20,000 or fewer annual visits are the most efficient (according to standard performance metrics) and that departments can anticipate 1,500 visits per bed per year, the performance-driven ED might have no more than 13 beds in a functional unit. To be sure, these relationships are not fully understood, but they do suggest that economies of scale are not seen in EDs; in that world, bigger is not necessarily better. The data are not definitive in terms of functional unit size, but they suggest a place to start.

It may be that the higher-volume ED is simply trying to manage so many patients and tasks and

so much information that systems and processes break down. Therefore, designing smaller functional units within a larger department may be a design strategy whose time has come. A functional unit requires a place for physicians and nurses to work, a place for the health unit clerk, space for the management of lab specimens, a portal for the tube system, a medication room, a space for imaging study results (a viewing area for hard copies to be reviewed—or more commonly in 2011, a digital radiography station), and both clean and dirty utility rooms.

Should functional units be equivalent and act as multiple smaller EDs or should they be chief complaint or acuity differentiated? The uncontestable amount of research around the efficacy of the fast track would suggest that patient segmentation based on acuity and creating functional units or zones for patients with similar acuities may be superior to creating zones that are small ED equivalents (Cooke, Wilson, & Pearson, 2002; Hampers, Cha, Gutglass, Binns, & Krug, 1999; Handel et al., 2011; O'Brien, Williams, Blondell, & Jelinek, 2006; Oredsson et al, 2011). Although the definitive data on this have not been gathered, higher-volume EDs are gravitating toward increasing patient segmentation and differentiation of the functional zones (discussed in more detail later).

In response to increasing volume, EDs are being built with increasing numbers of beds. However, often little attention is paid to how workflow will be adapted to the larger footprint. But combine the idea that the ED footprint should change in a 24-hour cycle with the concept of smaller operating zones and a new notion is born:

***The cyclical daily opening and closing of functional units according to patient arrivals creates the* Breathing ED.**

The cyclical opening and closing of functional units according to patient arrivals creates the *Breathing ED*. The University of Iowa, a 52,000-volume ED and Level I trauma and teaching hospital in Iowa City, Iowa (which was redesigned in conjunction with Lean applications to its ED processes), the Coxhealth ED in Springfield, Missouri, and the University of Kentucky Chandler ED in Lexington, Kentucky, also a Level I trauma center and teaching hospital that has 55,000 visits annually (and is part of the Pebble Project), are recent examples of EDs designed to be Breathing EDs (Dickson, Singh, Cheung, Wyatt, & Nugent, 2009).

As the daily surge of patient arrivals begins, the ED opens up new functional care units. The department is designed to accommodate the flow model used by the department and in accordance with the community's needs. For instance, the fast-track lower-acuity unit is seldom open for 24 hours a day, even in high-volume EDs. The University of Iowa operates its pediatric ED and fast track out of the same functional unit and space from late morning until midnight and then closes the area down. Contrarily, departments

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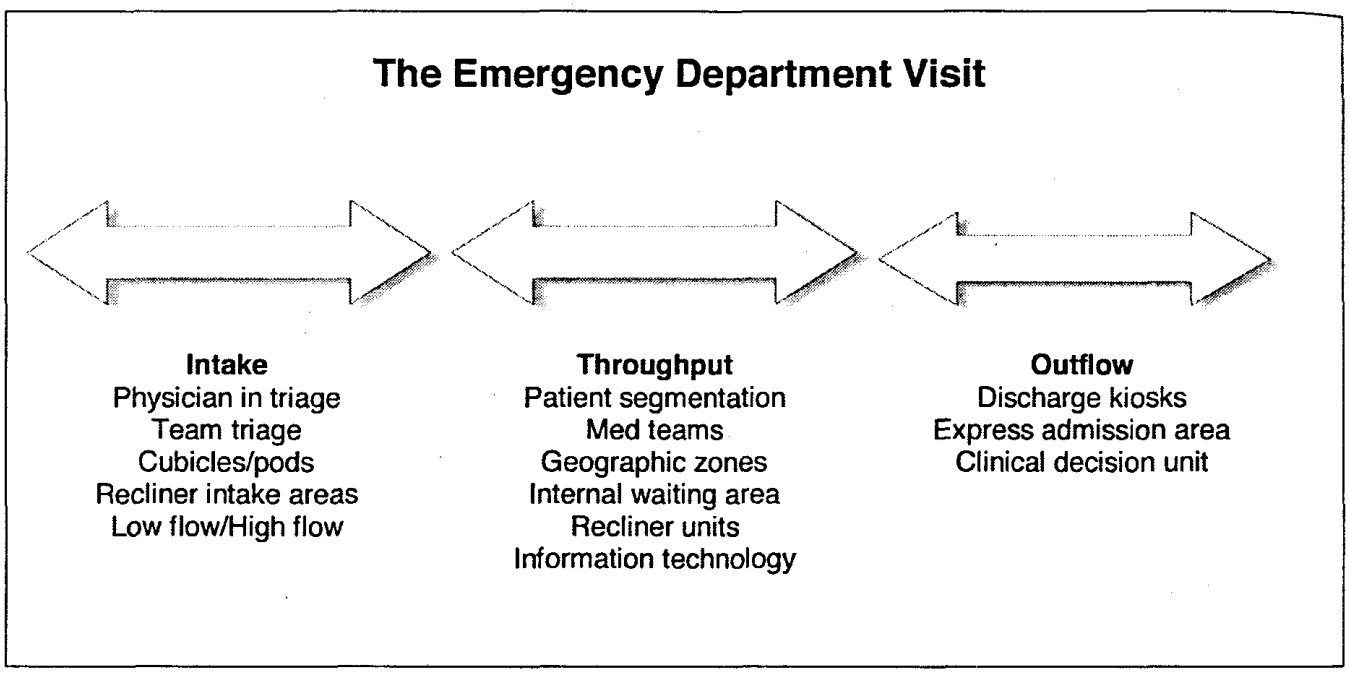

Figure 3. Emergency Department operational innovations.

serving high numbers of seniors often maintain one functional unit for longer periods of observation. Most clinical decision and observation units are open 24 hours and part of the "core" that is always open and staffed.

Operational Research

This review uses the intake-throughput-outflow model to organize and present the innovations being tested around the country (Figure 3). Most of the operational research done in emergency medicine has focused on patient intake (also known as the *front end*) because improvements in the intake process can have a dramatic and immediate impact on patient satisfaction, door-to-physician times, and LWBS (Welch & Davidson, 2010). There is added impetus to focus on the *front end* because the Centers for Medicare & Medicaid Services (CMS) has announced that two of the five operational metrics it is expecting to incorporate into its value-based purchase model of payment are arrival-to-provider time and LWBS, markers for intake performance (National Quality Forum, 2008).

Improvements at Intake

A first step in decreasing waiting times is to create an ED intake process that assesses patients efficiently and sends them to the appropriate area within the department.

Physician in Triage

One of the most common areas of operational innovation, both published and unpublished, involves moving away from the traditional nurse triage model that has dominated intake into the ED for more than 30 years. Recent research has shown that traditional nurse triage, as currently practiced, fails to treat the sickest patients according to recommended time frame guidelines and

creates a bottleneck in the beginning of the ED visit (Weber, McAlpine, & Grimes, 2011; Welch & Davidson, 2011).

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Newer intake models now put a physician, either alone or as part of a team, at the front of the ED visit—at intake. The literature shows that a physician assessment is more reliable than assessments by providers with less training (Dent, Weiland, Vallender, & Oettel, 2007; Kosowsky, Shindel, Liu, Hamilton, & Pancioli, 2001; Levine et al., 2006; Rocker et al., 2004; Rodriguez, Wang, & Pearl, 1997; Sinuff et al., 2006). Using an experienced physician in triage allows many patients to be sent home with little or no testing (Sen et al., 2011; Terris, Leman, O'Connor, & Wood, 2004). It reduces the arrival-to-provider time, the overall LOS, and the LWBS rate and increases both patient and staff satisfaction with the process (Choi, Wong, & Lau, 2006; Holroyd et al., 2007; Partovi, Nelson, Bryan, & Walsh, 2001; Rogers, Ross, & Spooner, 2004; Travers & Lee, 2006). There are many variations of the physician-in-triage model. Typically a lone physician in triage will do an abbreviated assessment and send the patient to the appropriate area in the department for further diagnostic or therapeutic interventions, or for discharge processing.

Team Triage

More detailed intake assessments are performed using a team triage model (Chan et al., 2005; Mayer, 2005; McD Taylor, Bennett, & Cameron, 2004; Richardson, Braitberg, & Yeoh, 2004; Subash, Dunn, McNicholl, & Marlow, 2004). In this model, the team might consist of a combination of the following: physician, nurse, midlevel provider, laboratory technician, ED technician, and scribe. In this model, more diagnostic and therapeutic work is performed during the intake encounter.

Pods and Zones

Some centers have begun reporting the implementation of changes to the physical space to accommodate new intake models through case reports. Though not yet published in peer-reviewed journals, the data from these reports are compelling. At Arrowhead Regional Medical Center in Colton, California, the ED volume more than doubled from 50,000 visits to 110,000 visits in 5 years. The LWBS rate had risen to an astounding 20%, and arrival-to-provider time was a dangerous 4 hours. In desperation the staff trialed a physician-in-triage model made possible by bringing in furniture modules that created small cubicles in which physicians can see patients.

Their experience revealed that 50% of patients could be discharged right from the cubicle. This opened up beds and resulted in an unexpected

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reduction in nurse staffing. Their LWBS rate dropped to 1% and their arrival-to-provider time was reduced to 31 minutes (Welch & Davidson, 2010). At Methodist Sacramento Hospital, in Sacramento, California, the ED was grossly under-bedded seeing 42,000 annual visits in a 19-bed ED. The staff took a different approach to the space and layout to allow a physician and nurse to be present at intake.

The staff created a six-bed *triage pod,* occupied by contiguous stretchers with curtains. This operational model articulated a goal that patients spend less than 15 minutes in the triage pod before being moved elsewhere in the department. The physician traverses the pod and after a quick assessment transfers the patient to one of three areas: the waiting room, the main ED, or a monitored higher-acuity ED bed.

Although the department shrank from 19 to 13 beds, with new processes in place they believe they have smarter bed utilization. Methodist has seen their LWBS rates drop from 5% to 1% (Augustine, 2011a). In Gaston Memorial Hospital in Gastonia, North Carolina, $800 was spent to create a *care initiation area* (also called the CIA) with a physician and team in triage. By changing the space and the process, this 80,000-visit ED saw its LWBS rates fall from 12% to 1.3%, and its Press Ganey patient satisfaction scores rose to the 99th percentile (Besson, 2009).

Recliner Intake

In another case study in Carolinas Medical Center in Charlotte, North Carolina, the ED team redesigned its intake area, putting recliners and supplies within reach of the physician and team. Like Arrowhead, they found that the physician could discharge 45.5% of patients from triage. This is an effective way to off-load the main department when it is over capacity. This Level I trauma center, which sees an annual ED volume of 115,000 visits, has seen improvement in arrival-to-provider time, decreased LWBS rates, and an overall decrease in LOS in these trials (Welch & Savitz, 2011).

Low-Flow/High-Flow

Another new intake model as yet unpublished but presented at an AHRQ-sponsored summit involves the use of two distinct processes for intake, depending on the census in the department and the rate of arrivals. Thomas Jefferson University in Philadephia, Pennsylvania, a busy urban teaching hospital with an annual volume of 85,000, dubbed this model the *low-flow/high-flow* process model. When the ED is at a low census with open beds, the process is the same as that employed in most traditionally run EDs. Patients are triaged in the traditional manner, and each patient occupies a room after triage. As the ED reaches capacity, the department shifts into the high-flow process. In this model, a processing area is opened and a team using protocol-guided treatment plans begins the intake process and patient workups there. The first pilot of the new low-flow/high-flow model showed a decreased LOS from 653 minutes to 158 minutes. Exit surveys of patients involved in the pilot showed extremely high patient satisfaction scores: 4.5 on a scale of 5 for extreme satisfaction (Welch & Savitz, 2011).

Applications to Design

First, the design of the intake area will depend on the process the clinicians intend to use. For very rapid physician assessments, a pod design or a bay with multiple treatment spaces that feeds other ED areas may be appropriate. Data about annual volume, admission rates, acuity, and the age of the patient populations served would inform decisions about intake models. Recliners could replace either chairs or stretchers for the first leg of the ED journey.

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For a more comprehensive intake, physicians are most effective if they have a team of personnel to assist them. In many of the new models, the intake area could also be a site for initiating orders, drawing blood, and starting intravenous lines. This means the intake space may need to be bigger with room for supplies and clinical work areas. The intake model and the design of the intake space must be integrated into the patient flow scheme for the entire department.

Whichever model is chosen, it is important to understand other critical factors that will influence the design of intake spaces. Foremost is the pressure to identify cardiac patients rapidly by quickly performing an electrocardiogram (EKG) on any patient who might be presenting with acute coronary syndrome. The recognition of atypical presentations of acute coronary syndrome patients has led to the new practice of performing an EKG on any patient with symptoms "between the nose and the navel."

Many older triage rooms are not big enough for a patient to recline for an EKG and to accommodate an EKG machine at the bedside, nor do they have curtains to allow the privacy required for an EKG. Whether the multidisciplinary team selects a model employing multiple curtained intake bays married to a rapid initial intake process, or separate intake rooms married to a comprehensive team intake process, private space will be necesssary for EKG evaluations. This might mean an EKG alcove with curtains next to the triage pod or some other design innovation to meet this particular need.

There will be new pressures to have patients seen by a physician sooner because arrival-to-provider times will be reportable to CMS. With this as an incentive, an adequate number of intake spaces will be an imperative. Remembering the arrival curve already mentioned, patients arrive in surges during the afternoon and evening shifts. Knowing the census of an ED can help designers plan their designs for an appropriate number of intake spaces.

The low-flow/high-flow model from Thomas Jefferson University presents another idea for consideration in ED design. Medium- and low-volume

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EDs struggle with extreme swings in census that can sometimes show 100% variation or more from one day to the next. A design that can accommodate these extreme variations in census and arrivals with coordinated operational changes allows the ultimate in flexibility. This means that an ED might look like a traditional department at low-flow times with the immediate bedding of patients, in-room triage, and bedside registration, sometimes called *pull to full*, described in a North Carolina ED (Colucciello, 2009). Later in the day, when the predictable surge of patients arrives and census exceeds capacity, an intake area with a physician-led triage team opens up. This kind of adaptability and flexibility in design and operations is cutting edge and not seen in most current ED designs.

Improvements in Throughput

Although there is not as much in the literature about operational improvements in the ED throughput domain, there are trends worth noting and considering for integration into design.

Patient Segmentation

As EDs have experienced gains in annual census, the practice of patient segmentation has grown. The earliest example of patient segmentation (also called *streaming*) was the development of the *fast track,* an area in an ED dedicated to the care of patients with lower-acuity conditions, typically minor accidents and injuries. The evidence supporting efficacy, efficiency, and improved performance when a fast track is introduced is now exhaustive and irrefutable (Darrab et al., 2006; Ieraci, Digiusto, Sonntag, Dann, & Fox, 2008; Kwa & Blake, 2008; Nash, Nguyen, & Tillman, 2009; Rodi, Grau, & Orsini, 2006; Sanchez, Smally, Grant, & Jacobs, 2006; Simon et al., 1996).

At Mary Washington Hospital in Fredericksburg, Virginia, Dr. Jody Crane has taken patient segmentation even further. Published in a trade paper and not a peer-reviewed journal, Dr. Crane has used Lean processes to improve patient flow in his 100,000-visit ED. By creating even more tracks dedicated to the treatment of patients of varying acuity and clinical needs, he has reduced LWBS, decreased LOS, and improved patient satisfaction (Welch, 2008). At Banner Health System in Phoenix and Mesa, Arizona, a similar "quick look" at patients and then patient segmentation have been employed in a new intake model. All of the tools and a detailed description of this innovation can be found on the Internet (Banner Health, 2011). Banner calls this process "D2D SPF" (Door to Doc Split Patient Flow).

Less sick patients are not undressed or bedded; instead they are treated as though they were in a clinic setting. The sickest patients are seen in an expedient manner and treatment is begun. Banner implemented this new process across eight different EDs with varying volumes and saw reductions in the LWBS rates of 30% to 60% across the board. This concept of patient segmentation allows for less acute patients to be moved out of beds after initial examination. Such accelerated bed turnover, much like table turns in a restaurant, allows more patients to be seen in the same space, effectively expanding the capacity of the ED.

Med Teams

Knowledge about teams and their superiority in complex work environments is well established in other service industries (Barker, 1993; Hackman, 1987; Kozlowski & Bell, 2003; Scholtes, Joiner, & Streibel, 2003; Serfaty, Entin, & Johnston, 1998; Wageman, 1997). Beginning in the late 1990s, research on *med teams* and formal teamwork training appeared in the medical literature, often applied to the ED (Barrett, Gifford, Morey, Risser, & Salisbury, 2001; Morey et al., 2002; Risser et al., 1999; Sexton, Thomas, & Helmreich, 2000). In the past decade this research has taken off with applications to most hospital-based service lines including labor and delivery, the ED, the operating room, and the trauma suite (Awad et al., 2005; Capella et al., 2010; Guise et al., 2010; Kilner & Sheppard, 2010; McConaughey, 2008; Patel & Vinson, 2005). An example of a med team in an ED would include a physician, two nurses, four techs, and a unit clerk all assigned to the same patient care area, working together to care for the same set of patients.

Geographic Zones

In a busy ED, a med team's approach is married to a geographic zone to create a functional operating unit that improves communication and clinical care (Asplin et al., 2008; Eitel, Rudkin, Malvehy, Killeen, & Pines, 2010; Jensen & Crane, 2008; Olshaker, 2009). According to the Studer Group, ED nurses walk 5.2 miles per shift (Leighty, 2006). This could be reduced by placing staff in a large ED in one geographic area of the department for the duration of a shift. One of the largest EDs in the country demonstrating high-level performance on operating metrics is William Beaumont Medical Center in Royal Oak, Michigan. This department, which sees more than 120,000 visits annually in a whopping 110-bed ED, is divided into seven functional units to improve quality, safety, efficiency, and flow (Welch, 2009).

Internal Waiting Room

Another new and important concept relative to ED operations has been termed "keeping patients vertical." Nationwide statistics reveal that EDs admit approximately 14% of all visits (McCaig & Nawar, 2006); this means that 86% of ED patients go home. In addition, the majority of patients are ambulatory upon arrival. Thus, EDs are experimenting with keeping patients ambulatory and having them wait for results in an internal waiting room, as opposed to occupying an ED room for the entire LOS.

At Massachusetts General Hospital, located in Boston, Massachusetts, the ED sees in excess of 88,000 visits annually. It has implemented a complex new ED flow process that begins with patient segmentation by acuity. Also presented as a case study at an AHRQ conference in 2010, the data demonstrated improvement. An important change in the physical plant to support this process involved the creation of an internal waiting room called the *post-screening area* with comfortable chairs. The internal waiting room enables less acute patients to remain vertical instead of occupying bed space while awaiting test results. The sum of these changes to the physical plant and operations resulted in an 8% decrease

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in LOS and a drop in LWBS rate from 4.1% to 2.4% (Welch & Davidson, 2010).

Reclining Chair Units

The idea of using reclining chairs for intake has already been discussed. One study showed that most patients—particularly elderly patients—found reclining chairs much more comfortable than ED stretchers and had higher patient satisfaction when they were allowed to sit in them while waiting for test results and receiving care (Wilber, Burger, Gerson, & Blanda, 2005). The Chandler Medical Center at the University of Kentucky (part of the Pebble Project) is another example of the effective use of chairs as treatment spaces. This new ED was built using evidence-based design (Taylor & Cheng, 2011). One of the design features involved the design of the fast track area. As an evidence-based design project, the multidisciplinary team trialed both stretchers and reclining chairs for treating low-acuity patients. Their as-yet-unpublished data revealed increased patient satisfaction and decreased throughput times using the chair model. Reclining chairs were employed in the final design.

Information Technology

The advantages of an electronic whiteboard or tracking system in the ED have been recognized (France et al., 2005). Increasingly, EDs are using physician order entry and charting along with electronic tracking systems. In addition, the benefits of information technology (IT) that is integrated into workflow have been reported in the literature, but it is still an area in its infancy (Baumlin et al., 2010; Shapiro et al., 2010). EDs must take into account the space that such technology support requires. The most advanced departments (in terms of IT integrated into workflow) are operating with a computer for each member of the healthcare team, including social workers and case managers. This means that computer stations to accommodate all staff members will need to be factored into the ED design.

In addition, banks of common-use computers that any staff member can use are required. For instance, respiratory therapists, EKG technicians, and x-ray technicians are in the department transiently while involved in patient care, but they need to communicate on the electronic tracking system when the encounter with the patient has both started and finished. This information is vital to the healthcare team in tracking patient flow in real time, and it requires computer space. To get an idea of how many computers might be needed as hospitals become fully invested in a comprehensive electronic health record, the Pebble Project at the University of Kentucky Chandler ED used predictive modeling and forecasting to design a 50-bed ED with 240 computers for staff.

The development and success of patient segmentation, med teams, and geographic zones once again highlight the benefits to workflow of creating functional units in the ED.

Applications to Design

The development and success of patient segmentation, med teams, and geographic zones once again highlight the benefits to workflow of creating functional units in the ED. The acuity of the patients to be cared for will determine what the zone looks like. For instance, higher-acuity patients would likely be managed best on stretchers in larger rooms that can accommodate a resuscitation team, ventilator, EKG machine, and portable x-ray machine all at once. These rooms should be directly visible from the staff work station. Lower-acuity patients can be managed in reclining chairs in a zone of cubicles, and visibility is less critical.

The functional unit will need space for team members to carry out both clinical and clerical work, and adequate room for IT support is a must. Workflow should never be constrained because a healthcare worker cannot access a computer in the ED. The common practice of placing lovely granite countertops too narrow to hold computers and keyboards in the ED should be checked. All counter surfaces should be functional spaces.

Improvements at Outflow

The least studied area of operational improvement for the ED is the back end. This may be because the outflow of admitted patients has been such a difficult area for EDs. Addressing problems of overcrowding and boarding (holding admitted patients in the ED for long periods of time) requires hospital-wide flow solutions, and these are not under the control of the ED alone. Nonetheless, strategies that improve the outflow of patients who no longer need the services of the ED have been identified, and they are articulated in the following section.

Discharge Kiosks

Driven by the dire economic situation in the community that his ED served, Dr. Todd Taylor set up a discharge kiosk in the ED at Good Samaritan Medical Center in Phoenix, Arizona. When his 55,000-volume department was overrun with immigrant workers with no health insurance, he designed these kiosks to get low-wage workers signed up for any public assistance programs for which they were eligible. He had patients pass through these discharge kiosks to help usher them through the morass of paperwork involved and to help them find clinic care for future healthcare problems.

His program, which began as a revenue capture opportunity, was dubbed the "Turnstile ED," meaning patients passed through the virtual turnstile in the discharge kiosk. Discharge paperwork and prescriptions were then given. This program proved successful and kept his department financially viable, but it also turned out to be an operational success (Taylor, 2003; Welch, Viccellio, Davidson, McCabe, & Janiak, 2007).

Express Admission Unit

With bed space at a premium in the ED, strategies that allow patients to be moved away from acute care areas have proved an effective way to combat crowding. This has given rise to a new concept: *the express admission unit*, where pa-

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tients can wait until their rooms are ready. It is also a place where admission paperwork and processing can take place. When ED patients are ready for transfer to an inpatient bed (excluding critical care patients), they typically are in a phase of care that requires less clinical intensity. Diagnostics have been completed and early therapy has begun. Such patients no longer need the services of the ED and often need minimal observation by medical staff. The University of San Diego in San Diego, California, which sees 36,000 visits annually and is a teaching hospital with an emergency medicine residency, has published the first study showing the positive operational impact of an express admission unit (Buckley, Castillo, Killeen, Guss, & Chan, 2010).

The Clinical Decision Unit

There are data on the efficacy of an ED observation unit (Baugh, Venkatesh, & Bohan, 2011; Daly, Campbell, & Cameron, 2003). As pressures to avoid hospitalization (and readmissions) grow, a variation on the observation unit has evolved and is referred to as the *clinical decision unit.* Accumulating studies suggest that keeping patients for 6 to 8 hours for certain clinical conditions is a viable clinical management plan. Many patients requiring prolonged diagnostic testing, observation for overdoses, and other conditions, but who likely will not need 12–24 hours of care, might occupy such a unit (Calello et al., 2009; Nahab et al., 2011; Ross & Nahab, 2009; Ross et al., 2003; Schrock, Reznikova, & Weller, 2010). The lower-volume ED might segment any patients in need of 6 hours or more and send them to the observation unit. High-volume departments might have the numbers to support both a clinical decision unit and an observation unit as service lines with unique, dedicated space.

Applications for Back-End Design

There is a knowledge deficit surrounding the back end of the ED visit. Research regarding patient flow out of the ED is in its early days. Whether patients are admitted or discharged or placed into observation, operational best practices have yet to be determined. Is an express admission unit more efficacious than boarding a patient in the ED? Is a discharge team more efficacious than primary care nurse discharge? Relative to research on the front end, there is clearly work to be done.

A number of factors will influence and change discharge from the ED as healthcare reform in the United States moves forward. As mentioned previously, with the aging of the population comes an increase in the complexity of the patients receiving care. This means that more discharge planning will be needed as patients exit the ED. Healthcare reform will mean increased pressure to prevent readmissions for certain chronic conditions like chronic heart failure, acute heart attack, and pneumonia (Haglund, 2011). Hence a rebirth of interest in the observation unit concept and its many variations is being seen. Physicians and hospitals will be deterred from admitting certain patients under threat of financial penalty, and this will mean the involvement of a new member of the ED team, the case manager (Dunnion & Kelly, 2005; Kanaan, 2009). Zones

where case managers can work with the healthcare team involving the patient and the patient's family are evolving.

Concern for crowding should encourage design professionals to work with clinicians to design spaces that allow patients who no longer need the clinical intensity of the ED to be moved quickly out.

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Limitations

Many of the operational innovations described in this review are new and have not been validated by randomized controlled studies or formal peer review. These process innovations and suggested design changes may have unintended consequences in terms of workflows, and this should be noted. In addition, these changes may have practical constraints. Still, in the spirit of innovation, this review organizes and collates these new operational ideas for the sake of expanding knowledge in the field. Finally, this paper looks at ED design in the United States and focuses on anticipated reforms. That said, many of these design strategies are appearing in Europe and Australia, and some of the studies cited in this paper were from outside the United States.

Conclusions

ED operational research has begun to capture the attention of practitioners trying to improve the delivery of care in the ED. Most departments are struggling to deliver safe and efficient care in emergency rooms that were designed in a different era. Most clinicians looking at the prospect of a new build or redesign of their departments will be largely unaware of this body of research and new information. Unpublished data can help inform ED design; unpublished innovations demonstrate ways to improve ED operations.

As evidence-based design concepts take hold in the architecture, design, research, and clinical arenas, we can look forward to EDs designed for the work being done in them. This metasynthesis is an attempt to summarize the latest research and data available involving ED operations and to apply it conceptually to ED design. It is written in the hope that design professionals and clinicians can work together to design effective spaces for safe, efficient, quality-driven healthcare.

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