Emergency Department Operations: An Overview

Joshua W. Joseph, MD, MS, MBE[a,*], Benjamin A. White, MD[b]

KEYWORDS

• Emergency department operations • Crowding • Throughput • Observation
• Efficiency

KEY POINTS

- Emergency department (ED) operations represent the systems and processes that are central to the provision of high-quality care in the ED.
- Emergency department operations reflect the intersection of clinical, economic, and cultural factors, and their effects on the care delivered in the emergency department.
- Although many of the factors affecting ED crowding are external to the emergency department, multiple options for considering process improvement along the spectrum of ED input, throughput, and output exist.
- In addition to improving patient flow, ED operational improvements can encompass a wide variety of themes including physical space design, process optimization, communication and patient experience, and staff wellness.

INTRODUCTION

"Why is this taking so long?" It is a question that patients often ask in the emergency department (ED), yet, it is also a question that emergency physicians often find themselves asking. Why is it that they are frequently working at capacity, walking up to several miles a shift,[1] all while neglecting to take any breaks to work faster, and everything is still taking so long to get done?

The answers lie within the domain of clinical operations, and more specifically the systems and processes designed to support provision of care in the ED. Although sometimes caused by the simple fact that a given system is poorly designed to meet its stated goal (eg, a demand-capacity mismatch in which resources are misallocated),[2] in many cases the interdependent processes needed to provide high-quality ED care require a more nuanced understanding of fundamental systems engineering principles, such as shifting bottlenecks, queuing theory, and so forth. In addition,

[a] Department of Emergency Medicine, Beth Israel Deaconess Medical Center, One Deaconess Road, Boston, MA 02215, USA; [b] Department of Emergency Medicine, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114-2696, USA
* Corresponding author.
E-mail address: jwjoseph@bidmc.harvard.edu

Emerg Med Clin N Am 38 (2020) 549–562
https://doi.org/10.1016/j.emc.2020.04.005
emed.theclinics.com

although some systems inefficiencies and delays with inevitably always exist, there are myriad opportunities to optimize other patient care processes and patient experience, and these concepts are covered in detail elsewhere in this issue.

CROWDING AND THE MORAL IMPERATIVE OF EMERGENCY DEPARTMENT OPERATIONS MANAGEMENT

The need for careful operations management and further operations research in emergency medicine has never been more acute. For the past three decades, the most pressing barrier to effective ED operations has been the increasing degree of ED crowding, a phenomenon that is unfortunately present throughout the United States and internationally. The American College of Emergency Physicians' Emergency Medicine Practice Committee reports that more than 90% of EDs within the United States have reported frequently operating under crowded conditions.[3] Although the issue of crowding originally came under scrutiny during the late 1990s, there has yet to be a comprehensive solution implemented on a national, local, or regional level that meaningfully addresses the problem. In addition, ED crowding reflects the interaction of several distinct trends, which are active on a national scale, with issues that are unique to specific hospitals and EDs.[4,5]

The most significant systemic cause of crowding is that the demand for emergency care has continued to rise significantly relative to the availability of inpatient beds for admitted patients.[6,7] It is unclear what is driving the increase in ED visits, although potential causes proposed include the increased access to care provided by insurance coverage obtained under the auspices of the Affordable Care Act.[8,9] There has been a steady increase in certain disease burdens across the population, including drug and alcohol use disorders, and comorbidities of obesity,[10] which frequently lead to ED visits.

This has been paralleled by a substantial decrease in the proportion of low-acuity ED visits.[11] Much of this volume is thought to have been diverted to urgent-care clinics and similar facilities. Conversely, an increasing proportion of patients who require hospital admission are admitted directly through the ED, as a means of expediting laboratory testing, diagnostic imaging, and other workflows for the admission process.[12] The increasing acuity of ED visits may also reflect an increasing chronic disease burden concordant with the aging of the population.

Despite these trends of increasing ED use, there has been no concomitant increase in hospital inpatient capacity to meet the needs of patients requiring admission from the ED, and many hospitals have been reticent to implement improvements that have been shown to alleviate crowding.[5,13] Delays in admitting patients from the ED has been identified across numerous studies as a root cause of crowding.[6] Although hospitals' inpatient capacity and throughput is determined by a variety of social, cultural, regulatory, and economic factors, it is also likely that financial factors play a role, in that many hospitals generate more revenue from elective admissions than from ED admissions, especially given ED patients are more likely to be underinsured or uninsured.[14–16] As a result, many hospitals have little financial incentive to expand the proportion of their inpatient capacity available to patients admitted from the ED.

This represents a challenging moral problem, because the negative effects of crowding on patients, health care providers, and the health care system as a whole are legion. Crowding has been linked to significant decreases in the quality of care provided to patients, such as delayed time to the administration of antibiotics in pneumonia and in treatment of myocardial infarction, decreased compliance with core measures for sepsis, and decreased analgesia for patients with acute pain.[17–20]

Many of these deleterious effects may have an outsized impact on patients who are already suffering from significant health care disparities.[21] Crowding has been linked to increasing levels of burnout and moral distress among health care providers in the ED.[22–26] Finally, crowding has been linked to increases in the proportion of patients leaving the ED without being seen and rates of ambulance diversion.[27–29]

Common Challenges to Operations in Community Practice

In community practice, getting involved in operations is time-consuming and occasionally frustrating. The compensation afforded to ED medical directors varies significantly across institutions, as does the degree of agency that they may have relative to administrators, who might have neither direct clinical experience nor training in operations. Similarly, community physicians who volunteer their time to medical executive committees or focus groups, may find that doing so is difficult or impossible. Meetings may be scheduled without regard to shift-work and overnights. More consequentially, emergency physicians belonging to contract groups or corporate medical companies[30] may find themselves ineligible to sit on such committees, by dint of hospital policy. Most disturbingly, some corporate medicine practices have retaliated against physicians who have reported concerns about the quality of care and issues with ED administration.[30,31]

Challenges to Progress in Emergency Department Operations Research

Operations research within emergency medicine faces unique hurdles. Many traditional paradigms for clinical research cannot be translated into the operational domain. Although a physician and patient can both be blinded to which medication is administered during a randomized control trial, an emergency physician cannot be blinded to a change in the length of the shift she works, nor to whether she assigns herself patients or receives those assignments from a nurse manager. Even less robust trial designs, such as alternating day paradigms, are problematic to implement. A study examining changes to a single area of the ED, such as triage, might necessitate major changes to downstream workflows, making it difficult to change over a short interval. As a result, many operational research studies are only feasible as quasi-experimental (before-and-after) studies of planned changes to workflows.

The significance of results and end points of operations research often have little correspondence to those of outcomes measured within clinical and public health research. A 1% change in the sensitivity or specificity of a diagnostic test rarely provides a meaningful impetus to change practices. However, an improvement of similar magnitude in an ED's average length of stay could mean the difference between a safety-net ED's ongoing viability and closure. Differences in workflows used by different EDs also make multicenter studies hard to conduct and to interpret. Adding scribes to two EDs with similar volumes, physician staff sizes, and patient populations, but with different electronic medical record systems, could yield significant but completely contradictory outcomes at both sites.

CURRENT TRENDS IN EMERGENCY DEPARTMENT OPERATIONS RESEARCH

The root causes of ED crowding demand systemic redress, and are likely to remain in place for the foreseeable future. However, there exist major areas where improvements in efficiency and throughput can have a significant impact on crowding and the quality of patient care, despite the challenges of output factors described previously (**Fig. 1**). Many of the most exciting recent developments within the ED operations literature reflect attempts to make the best of the resources available to the ED,

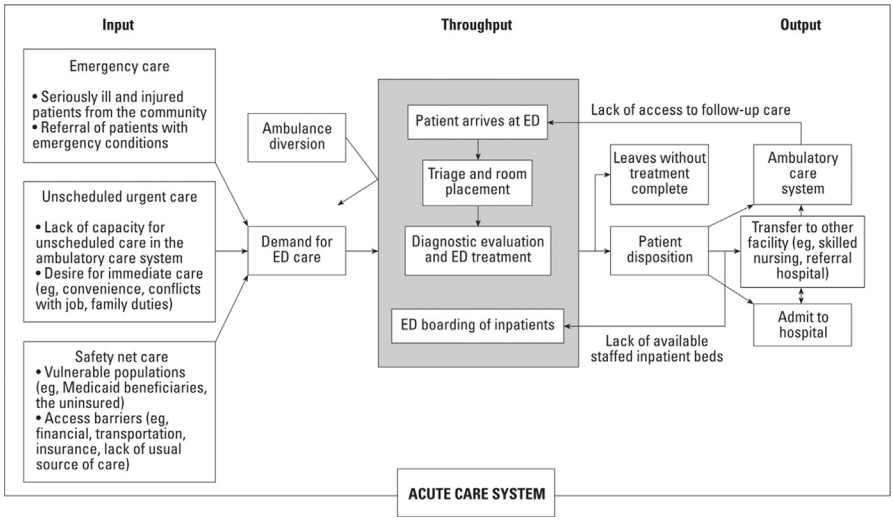

Fig. 1. Asplin input-throughput-output model. (*From* Asplin BR, Magid DJ, Rhodes KV, et al. A conceptual model of emergency department crowding. *Ann Emerg Med*. 2003 Aug;42(2):173-80; with permission.)

including strategies to more efficiently align existing diagnostic testing resources with demand, measures to better quantify throughput and optimize physician productivity, and alternative pathways to prevent inpatient admissions and acute hospital transfers. Although many of these themes are described elsewhere in this issue, a few interventions are worthy of discussion here.

INNOVATIONS TO DIAGNOSTIC TESTING AND RESOURCE ALLOCATION

Point-of-Care Testing

Point-of-care tests have long been an appealing alternative to traditional laboratory diagnostic tests thanks to their rapid turnaround time, but their accuracy and cost-effectiveness have been disputed.[32,33] Over the last decade, studies have demonstrated that point-of-care tests used in the ED setting can provide rapid results at slightly greater costs than traditional laboratory assays, but with comparable accuracy.[32,34] Although concerns about the tests' accuracy have somewhat abated, their limited cost-effectiveness is likely caused by the fact that laboratory testing is only a rate-limiting step for select patients. The most robust evidence demonstrating increased throughput with point-of-care testing addresses specific diagnostic scenarios, such as in obtaining creatinine to determine kidney function before contrast-enhanced computed tomography scans.[35–38] A similarly promising venue is for conditions in which care is protocolized, and in which laboratory testing significantly impacts a patient's disposition, such as in serial troponin measurements for chest pain.[39]

Nursing Protocols

Nursing triage protocols using standardized order sets for diagnostic tests and certain therapeutic interventions have been shown to improve throughput and improve quality measures, such as time-to-analgesia.[40] The best evidence for an effect of nursing protocols on improving patient throughput comes from protocols

that are based on established evidence-based decision rules (eg, the Ottawa Ankle Rule), although some studies have suggested that by reducing time-to-analgesia, patient throughput is improved as a result.[41,42] Although the overall evidence for nursing protocols improving overall patient throughput remains limited because of the small sample sizes and methodological limitations of prior studies, the potential harms and costs associated with nurse-initiated treatments, such as nonnarcotic analgesia and β-agonists in pediatric asthma, are low and the potential benefits are considerable.[43]

Alternative Triage Workflows

Studies examining use of an emergency physician at triage have shown several improvements across a broad variety of operational metrics, including patient throughput.[38,44–46] A significant part of this effect on throughput may come from the accelerated ordering of diagnostic testing provided by the physician triage evaluation process.[38] Several of the quality benchmarks that the physician-triage process improves are endogenous variables: if a physician sees patients shortly after their arrival in the waiting room, then such measures as the door-to-doctor time and the rate of patients leaving without being seen improve irrespective of any change in overall throughput. Although a growing body of literature suggests that physician triage can improve patient throughput, its cost-effectiveness is not widely reported, and evidence suggests that it is most effective when performed by attending physicians, rather than midlevel practitioners or resident physicians.[47] Until more robust cost-effectiveness data are available, EDs should consider physician triage on a case-by-case basis, particularly when waiting room volumes are disproportionately high relative to other areas within the ED.

One potential offshoot of physician triage that has generated considerable interest is telemedicine physician triage. Telemedicine physician triage has the advantage of flexibility and potentially lower costs, because physicians may staff it remotely and can be activated at times of increased demand and prolonged wait times. Although only a few studies have been conducted examining it to date, they have generally demonstrated equivalent rates of safety and patient satisfaction, suggesting that this may be a viable alternative.[48–50]

THROUGHPUT, PRODUCTIVITY, PHYSICIAN SCHEDULING, AND WORKFLOW ADVANCEMENTS

Measuring Throughput and Productivity

Efforts to evaluate patient throughput as a function of physician productivity, and to further understand the dynamics of the productivity of individual emergency physicians have expanded considerably in recent years. Although previous paradigms of emergency physician productivity had examined productivity as a static average calculated over a shift,[51,52] more recent work suggests that when emergency physicians are responsible for seeing patients at their own pace, productivity tends to begin at a peak pace, and slowly declines over successive hours of a shift.[53,54] This progressive decrease in productivity has several mutually compatible explanations, including the mechanistic challenge of managing a growing roster of patients; decision fatigue; and so-called social loafing, the tendency to decrease work when relief is in sight.[55,56] However, current discussions of physician productivity remain limited in part by the lack of an agreed-on metric of work.

The most natural measure of throughput and physician productivity is the number of patients a physician sees per hour. This has a face validity, because patients are the

ones to whom emergency care is provided, and throughput and crowding are fundamentally measured by the number of patients in the ED and waiting room at a given time. However, this measure belies that the amount of work to take care of patients varies drastically. Although combining this number with patient-level measures of acuity (eg, Emergency Severity Index) is an appealing compromise, doing so elides that acuity and effort are not directly related. For instance, a patient with a higher Emergency Severity Index level, but with care that is highly protocolized, such as a patient with an ST-segment elevation myocardial infarction, may take considerably less time to treat and disposition than a patient with abdominal pain who has a complex medical history.

Relative value units (RVUs) are an alternative measure of productivity tied to compensation, which have the appealing benefit of factoring in elements of the complexity of a history and physical, and measuring procedures. Given their close ties to compensation, they are an essential measure for cost-benefit measurements and projections. However, RVUs are a problematic measure for productivity relative to patient throughput and as a sole measure of physician workload. As in the case of patients per hour, RVUs do not necessarily correlate to the amount of work required to care for a given patient, and are heavily skewed toward procedures. The RVUs provided for a given patient encounter are also directly dependent on a physician's documentation, so two physicians seeing the same patients or performing the same procedures can generate substantially different numbers of RVUs.[57] Finally, the number of RVUs assigned to a procedure may vary significantly from year to year, making comparisons unreliable across time.

Novel Approaches to Physician Workflow and Shifts

Redesigning physician shift schedules and workflows to better align with patient volumes has shown significant potential to improve throughput and enhance patient safety. Approaches to optimizing physician shift schedules have ranged from those using tools that are complex, such as queueing theory and discrete event simulation models, to more straightforward approaches, such as roughly aligning physician schedules with times of higher patient arrivals.[58–61] Many of these studies have suggested that marked improvements in throughput and left without being seen rates are achieved through small realignments of physician schedules. However, with the noted exception of the landmark study by Green and colleagues[58] on the use of a queueing analysis to optimize a community hospital's shift schedule, there have been many simulated analyses of emergency physician staffing and few reports of real-world implementation, suggesting that this varied toolset has yet to be widely embraced.[62]

One of the most promising workflow designs entering use is rotational patient assignment. Originally described in the context of nurse-physician teams, rotational patient assignment consists of assigning patients alternatively to teams of clinicians as they arrive, rather than allowing physicians to assign themselves to patients at their own pace.[63,64] Rotational assignment is a distinct alternative to ED zones, which establish separate patient queues based on geography. Rotational assignment enforces a discipline of steady workflow, eliminating the unconscious tendency of emergency physicians to "peak" early in their shift, which is associated with decreased overall productivity,[65] and reduces spikes in arrivals across multiple teams, leading to robust decreases in door-to-doctor times, left without being seen rates, and overall patient length of stay.[66,67] Modern implementations of rotational patient assignment use a computer algorithm to distribute arrivals between teams, suggesting that

machine learning approaches may have a future role in load-balancing teams over the course of shifts.

ALTERNATIVE SYSTEMS OF PATIENT ARRIVALS AND DISPOSITION

Observation Care and Observation Pathways

A lack of inpatient beds for admitted patients is a major driver of ED crowding, whereas conversely, strategies to reduce hospital admissions through ED-based observation units have demonstrated admirable cost-effectiveness relative to inpatient care.[68–72] Placing patients in ED observation care directly decreases the demand for inpatient beds, and a robust body of evidence demonstrates that for many conditions, such as low-risk chest pain, syncope, new-onset atrial fibrillation, and cellulitis, 24-hour observation within the ED following protocolized guidelines can substantially decrease patients' overall length of stay without an appreciable incidence of adverse outcomes.[69,73,74] The population of inpatients eligible for ED observation care represents a much wider variety of conditions beyond those that have common observation pathways.[75] Many of the patients who are cared for within observation units may leave the hospital considerably faster than they might otherwise if they were admitted to an inpatient ward or still boarding within the ED, and this likely represents the salutatory effects on crowding that have been observed in hospitals that have implemented ED observation units.[76] Many hospitals are also considering other alternatives to admission models of care, including home hospital and mobile observation unit models; however, further studies of effectiveness and scalability are needed.

Managing Patient Inflow and Secondary Disposition

A complementary set of strategies used by some EDs is to actively manage patient inflow and outflow. Several centers have described successfully directing lower-acuity patients (many of whom might otherwise go into a traditional fast-track setting) into designated "vertical care" areas. These areas consist of groups of chairs or recliners that can serve as intermediate waiting areas (when patients are taken to a separate area for examination and testing) or as a comprehensive space for patient care. Incorporating vertical areas has been shown to significantly improve throughput for lower-acuity complaints.[77–79]

A related intervention is transferring patients who are identified as falling within certain low-risk parameters directly to primary care or urgent care clinic appointments. Although this has not been widely adopted, it may be appealing to EDs with close relationships to affiliated primary or urgent care clinics.[80] Alternative strategies for diverting lower-acuity patients have been trialed across a variety of settings (including prehospital), but the results of these studies have been anecdotal and conflicting.[81] For hospitals with nearby affiliate sites, secondary disposition, in which a patient is treated in one ED, but transferred within network to another site with available inpatient beds, is a useful option to actively minimize boarding and crowding whenever inpatient beds are in short supply.[82]

Some hospitals have seen improvements with the implementation of a hospital-wide "full-capacity protocol." Full-capacity protocols leverage changes across hospital inpatient wards, such as expediting discharges and moving ED boarders to inpatient hallway beds. Although these protocols are an effective means of reducing crowding specifically at times of high admission volumes, their effectiveness may depend significantly on how consistently hospitals implement the protocol, and on the degree of cooperation from inpatient stakeholders. A designated hospital "bed

czar" or nurse navigator can help to facilitate compliance with these protocols, and can smooth inpatient flow during less critical periods.[83,84]

FUTURE DIRECTIONS OF EMERGENCY DEPARTMENT OPERATIONS RESEARCH AND DEVELOPMENT

Measures Examining Physician Practice Patterns

The rates at which emergency physicians order diagnostic imaging and admit patients can have an outsized effect on overall throughput in the ED.[85] There is considerable variation in emergency physicians' practice patterns for ordering imaging, even when there are well-known evidence-based guidelines for practice, such as for computed tomography imaging in patients with low-risk head injury.[86,87] An emerging body of evidence implies that more conservative (and resource-intensive) practice patterns are correlated.[88] Although embedding decision support for imaging within electronic medical records is an appealing way to combat overuse, studies of its effectiveness have shown mixed results, potentially reflecting a host of causes for overuse.[89–91] More research is needed to understand the causes of these variations and to address them, but they represent some of the greatest areas for improvement within the ED itself.

Strategies to Optimize Physician Well-Being

Physician well-being, resilience, and burnout likely exert significant effects on the quality and efficiency of care delivered within the ED, and may help to explain some of the practice variation among emergency physicians.[92] Recent research suggests that the degree of burnout reported by emergency physicians' can serve as a predictor of the waiting times that their patients will experience as they go on shift, independent of other factors including the time of day and department census.[93] Emergency physicians report giving suboptimal care as their sense of burnout increases, and burnout among physicians has been broadly linked to higher rates of errors.[94,95]

Although enthusiasm for investigating burnout and resilience is growing, tangible solutions remain elusive.[96] Future avenues for improving physicians' resilience include investigating the roles of shift timing, length, and sleep patterns on cognitive performance and physiologic measures of stress.[97,98] Efforts to reduce the degree of overhead and interruptions emergency physicians face from electronic health records and alerts have the potential to reduce burnout and directly improve physicians' on-shift efficiency.[99,100]

SUMMARY

ED operations management poses challenges to physicians and researchers, stemming from factors external to the ED. Although these challenges are substantial, ED medical directors and even individual emergency physicians can still make important changes that can improve throughput and patient care. Emergency physicians have a duty to advocate for the resources needed to provide quality care for their patients, but also to help ensure that the work of emergency medicine does not require them to run themselves ragged in the process.

DISCLOSURE

The authors have nothing to disclose.

REFERENCES

1. Peters GA, Wong ML, Sanchez LD. Pedometer-measured physical activity among emergency physicians during shifts. Am J Emerg Med 2019;38(1):118–21. Available

at: http://www.sciencedirect.com/science/article/pii/S0735675719304668. Accessed November 4, 2019.
2. Rogg JG, Huckman R, Lev M, et al. Describing wait time bottlenecks for ED patients undergoing head CT. Am J Emerg Med 2017;35(10):1510–3.
3. American College of Emergency Physicians: Emergency Medicine Practice Committee. Emergency department crowding: high impact solutions. 2016. Available at: https://www.acep.org/globalassets/sites/acep/media/crowding/empc_crowding-ip_092016.pdf. Accessed October 1, 2019.
4. Morley C, Unwin M, Peterson GM, et al. Emergency department crowding: a systematic review of causes, consequences and solutions. PLoS One 2018; 13(8):e0203316. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6117060/. Accessed November 4, 2019.
5. Chang AM, Cohen DJ, Lin A, et al. Hospital strategies for reducing emergency department crowding: a mixed-methods study. Ann Emerg Med 2018;71(4): 497–505.e4.
6. Hoot NR, Aronsky D. Systematic review of emergency department crowding: causes, effects, and solutions. Ann Emerg Med 2008;52(2):126–36.e1.
7. Sun R, Karaca Z, Wong H. Trends in hospital emergency department visits by age and payer, 2006-2015 HCUP statistical brief #238. Rockville, MD: Agency for Healthcare Research and Quality; 2018. Available at: https://www.hcup-us.ahrq.gov/reports/statbriefs/sb238-Emergency-Department-Age-Payer-2006-2015.pdf. Accessed November 4, 2019.
8. Nikpay S, Freedman S, Levy H, et al. Effect of the Affordable Care Act Medicaid expansion on emergency department visits: evidence from state-level emergency department databases. Ann Emerg Med 2017;70(2):215–25.e6.
9. Dresden SM, Powell ES, Kang R, et al. Increased emergency department use in Illinois after implementation of the patient protection and affordable care act. Ann Emerg Med 2017;69(2):172–80.
10. Mokdad AH, Ballestros K, Echko M, et al. The state of US health, 1990-2016: burden of diseases, injuries, and risk factors among US states. JAMA 2018; 319(14):1444–72.
11. Poon SJ, Schuur JD, Mehrotra A. Trends in visits to acute care venues for treatment of low-acuity conditions in the United States from 2008 to 2015. JAMA Intern Med 2018 01;178(10):1342–9.
12. Schuur JD, Venkatesh AK. The growing role of emergency departments in hospital admissions. N Engl J Med 2012;367(5):391–3.
13. Warner LSH, Pines JM, Chambers JG, et al. The most crowded US hospital emergency departments did not adopt effective interventions to improve flow, 2007-10. Health Aff (Millwood) 2015;34(12):2151–2159A.
14. McHugh M, Regenstein M, Siegel B. The profitability of medicare admissions based on source of admission. Acad Emerg Med 2008;15(10):900–7.
15. Schuur JD. Overcrowded emergency departments: is sunlight enough of a disinfectant? JAMA Intern Med 2014;174(11):1846–7.
16. Moskop JC, Sklar DP, Geiderman JM, et al. Emergency department crowding. Part 1: concept, causes, and moral consequences. Ann Emerg Med 2009; 53(5):605–11.
17. Pines JM, Hollander JE, Localio AR, et al. The association between emergency department crowding and hospital performance on antibiotic timing for pneumonia and percutaneous intervention for myocardial infarction. Acad Emerg Med 2006;13(8):873–8.

18. Fee C, Weber EJ, Maak CA, et al. Effect of emergency department crowding on time to antibiotics in patients admitted with community-acquired pneumonia. Ann Emerg Med 2007;50(5):501–9.e1.
19. Pines JM, Hollander JE. Emergency department crowding is associated with poor care for patients with severe pain. Ann Emerg Med 2008;51(1):1–5.
20. Shin TG, Jo IJ, Choi DJ, et al. The adverse effect of emergency department crowding on compliance with the resuscitation bundle in the management of severe sepsis and septic shock. Crit Care 2013;17(5):R224.
21. Pines JM, Localio AR, Hollander JE. Racial disparities in emergency department length of stay for admitted patients in the United States. Acad Emerg Med 2009;16(5):403–10.
22. Fernandez-Parsons R, Rodriguez L, Goyal D. Moral distress in emergency nurses. J Emerg Nurs 2013;39(6):547–52.
23. Popa F, Arafat R, Purcărea V, et al. Occupational burnout levels in emergency medicine: a nationwide study and analysis. J Med Life 2010;3(3):207–15.
24. Wolf LA, Perhats C, Delao AM, et al. "It's a burden you carry": describing moral distress in emergency nursing. J Emerg Nurs 2016;42(1):37–46.
25. Moskop JC, Geiderman JM, Marshall KD, et al. Another look at the persistent moral problem of emergency department crowding. Ann Emerg Med 2019;74(3):357–64.
26. Chang BP, Cato KD, Cassai M, et al. Clinician burnout and its association with team based care in the emergency department. Am J Emerg Med 2019;37(11):2113–4. Available at: http://www.sciencedirect.com/science/article/pii/S0735675719304139. Accessed November 4, 2019.
27. Weiss SJ, Ernst AA, Derlet R, et al. Relationship between the National ED Overcrowding Scale and the number of patients who leave without being seen in an academic ED. Am J Emerg Med 2005;23(3):288–94.
28. Kulstad EB, Hart KM, Waghchoure S. Occupancy rates and emergency department work index scores correlate with leaving without being seen. West J Emerg Med 2010;11(4):324–8.
29. Carter EJ, Pouch SM, Larson EL. The relationship between emergency department crowding and patient outcomes: a systematic review. J Nurs Scholarsh 2014;46(2):106–15.
30. Derlet RW, McNamara RM, Plantz SH, et al. Corporate and hospital profiteering in emergency medicine: problems of the past, present, and future. J Emerg Med 2016;50(6):902–9.
31. McNamara RM, Beier K, Blumstein H, et al. A survey of emergency physicians regarding due process, financial pressures, and the ability to advocate for patients. J Emerg Med 2013;45(1):111–6.e3.
32. Asha SE, Chan ACF, Walter E, et al. Impact from point-of-care devices on emergency department patient processing times compared with central laboratory testing of blood samples: a randomised controlled trial and cost-effectiveness analysis. Emerg Med J 2014;31(9):714–9.
33. Somma SD, Zampini G, Vetrone F, et al. Opinion paper on utility of point-of-care biomarkers in the emergency department pathways decision making. Clin Chem Lab Med 2014;52(10):1401–7.
34. McIntosh BW, Vasek J, Taylor M, et al. Accuracy of bedside point of care testing in critical emergency department patients. Am J Emerg Med 2018;36(4):567–70.
35. Lee-Lewandrowski E, Chang C, Gregory K, et al. Evaluation of rapid point-of-care creatinine testing in the radiology service of a large academic medical

center: impact on clinical operations and patient disposition. Clin Chim Acta 2012;413(1):88–92.
36. You JS, Chung YE, Park JW, et al. The usefulness of rapid point-of-care creatinine testing for the prevention of contrast-induced nephropathy in the emergency department. Emerg Med J 2013;30(7):555–8.
37. Singer AJ, Williams J, Taylor M, et al. Comprehensive bedside point of care testing in critical ED patients: a before and after study. Am J Emerg Med 2015;33(6):776–80.
38. Singer AJ, Taylor M, LeBlanc D, et al. Early point-of-care testing at triage reduces care time in stable adult emergency department patients. J Emerg Med 2018;55(2):172–8.
39. Slagman A, von Recum J, Möckel M, et al. Diagnostic performance of a high-sensitive troponin T assay and a troponin T point of care assay in the clinical routine of an emergency department: a clinical cohort study. Int J Cardiol 2017;230:454–60.
40. Douma MJ, Drake CA, O'Dochartaigh D, et al. A pragmatic randomized evaluation of a nurse-initiated protocol to improve timeliness of care in an urban emergency department. Ann Emerg Med 2016;68(5):546–52.
41. Rowe BH, Villa-Roel C, Guo X, et al. The role of triage nurse ordering on mitigating overcrowding in emergency departments: a systematic review. Acad Emerg Med 2011;18(12):1349–57.
42. Hughes JA, Brown NJ, Chiu J, et al. The relationship between time to analgesic administration and emergency department length of stay: a retrospective review. J Adv Nurs 2020;76(1):183–90. Available at: http://onlinelibrary.wiley.com/doi/abs/10.1111/jan.14216. Accessed November 2, 2019.
43. Cabilan CJ, Boyde M. A systematic review of the impact of nurse-initiated medications in the emergency department. Australas Emerg Nurs J 2017;20(2):53–62.
44. Imperato J, Morris DS, Binder D, et al. Physician in triage improves emergency department patient throughput. Intern Emerg Med 2012;7(5):457–62.
45. Cheng I, Lee J, Mittmann N, et al. Implementing wait-time reductions under Ontario government benchmarks (pay-for-results): a cluster randomized trial of the effect of a physician-nurse supplementary triage assistance team (MDRNSTAT) on emergency department patient wait times. BMC Emerg Med 2013;13(1):17.
46. Rogg JG, White BA, Biddinger PD, et al. A long-term analysis of physician triage screening in the emergency department. Acad Emerg Med 2013;20(4):374–80.
47. Abdulwahid MA, Booth A, Kuczawski M, et al. The impact of senior doctor assessment at triage on emergency department performance measures: systematic review and meta-analysis of comparative studies. Emerg Med J 2016;33(7):504–13.
48. Tolia V, Castillo E, Guss D. EDTITRATE (Emergency Department Telemedicine Initiative to Rapidly Accommodate in Times of Emergency). J Telemed Telecare 2017;23(4):484–8.
49. Izzo JA, Watson J, Bhat R, et al. Diagnostic accuracy of a rapid telemedicine encounter in the emergency department. Am J Emerg Med 2018;36(11):2061–3.
50. Rademacher NJ, Cole G, Psoter KJ, et al. Use of telemedicine to screen patients in the emergency department: matched cohort study evaluating efficiency and patient safety of telemedicine. JMIR Med Inform 2019;7(2):e11233.

51. Arya R, Salovich DM, Ohman-Strickland P, et al. Impact of scribes on performance indicators in the emergency department. Acad Emerg Med 2010; 17(5):490–4.
52. Hamden K, Jeanmonod D, Gualtieri D, et al. Comparison of resident and midlevel provider productivity in a high-acuity emergency department setting. Emerg Med J 2014;31(3):216–9.
53. Joseph JW, Henning DJ, Strouse CS, et al. Modeling hourly resident productivity in the emergency department. Ann Emerg Med 2017;70(2):185–90.e6.
54. Joseph JW, Davis S, Wilker EH, et al. Modelling attending physician productivity in the emergency department: a multicentre study. Emerg Med J 2018;35(5): 317–22.
55. Laxmisan A, Hakimzada F, Sayan OR, et al. The multitasking clinician: decision-making and cognitive demand during and after team handoffs in emergency care. Int J Med Inf 2007;76(11):801–11.
56. Song H, Tucker AL, Murrell KL. The diseconomies of queue pooling: an empirical investigation of emergency department length of stay. Manag Sci 2015; 61(12):3032–53.
57. Martin DR, Moskop JC, Bookman K, et al. Compensation models in emergency medicine: an ethical perspective. Am J Emerg Med 2020;38(1):138–42. Available at: http://www.sciencedirect.com/science/article/pii/S0735675719305029. Accessed November 4, 2019.
58. Green LV, Soares J, Giglio JF, et al. Using queueing theory to increase the effectiveness of emergency department provider staffing. Acad Emerg Med 2006; 13(1):61–8.
59. Wang T, Guinet A, Belaidi A, et al. Modelling and simulation of emergency services with ARIS and Arena. Case study: the emergency department of Saint Joseph and Saint Luc Hospital. Production Planning & Control 2009;20(6):484–95.
60. Hung GR, Whitehouse SR, O'Neill C, et al. Computer modeling of patient flow in a pediatric emergency department using discrete event simulation. Pediatr Emerg Care 2007;23(1):5–10.
61. Wutthisirisart P, Martinez G, Heaton HA, et al. Maximizing patient coverage through optimal allocation of residents and scribes to shifts in an emergency department. J Med Syst 2018;42(11):212.
62. Saghafian S, Austin G, Traub SJ. Operations research/management contributions to emergency department patient flow optimization: review and research prospects. IIE Trans Healthc Syst Eng 2015;5(2):101–23.
63. DeBehnke D, Decker MC. The effects of a physician-nurse patient care team on patient satisfaction in an academic. Am J Emerg Med 2002;20(4):267–70.
64. Patel PB, Vinson DR. Team assignment system: expediting emergency department care. Ann Emerg Med 2005;46(6):499–506.
65. Joseph JW, Novack V, Wong ML, et al. Do slow and steady residents win the race? Modeling the effects of peak and overall resident productivity in the emergency department. J Emerg Med 2017;53(2):252–9.
66. Traub SJ, Bartley AC, Smith VD, et al. Physician in triage versus rotational patient assignment. J Emerg Med 2016;50(5):784–90.
67. Traub SJ, Saghafian S, Bartley AC, et al. The durability of operational improvements with rotational patient assignment. Am J Emerg Med 2018;36(8):1367–71.
68. Goodacre SW, Morris FM, Campbell S, et al. A prospective, observational study of a chest pain observation unit in a British hospital. Emerg Med J 2002;19(2): 117–21.

69. Goodacre S, Nicholl J, Dixon S, et al. Randomised controlled trial and economic evaluation of a chest pain observation unit compared with routine care. BMJ 2004;328(7434):254.
70. Wiler JL, Ross MA, Ginde AA. National study of emergency department observation services. Acad Emerg Med 2011;18(9):959–65.
71. Baugh CW, Venkatesh AK, Bohan JS. Emergency department observation units: a clinical and financial benefit for hospitals. Health Care Manage Rev 2011; 36(1):28.
72. Venkatesh AK, Geisler BP, Chambers JJG, et al. Use of observation care in US emergency departments, 2001 to 2008. PLoS One 2011;6(9):e24326.
73. Baugh CW, Greenberg JO, Mahler SA, et al. Implementation of a risk stratification and management pathway for acute chest pain in the emergency department. Crit Pathw Cardiol 2016;15(4):131–7.
74. Bellew SD, Bremer ML, Kopecky SL, et al. Impact of an emergency department observation unit management algorithm for atrial fibrillation. J Am Heart Assoc 2016;5(2) [pii:e002984] Available at: https://www.ahajournals.org/doi/10.1161/JAHA.115.002984. Accessed November 2, 2019.
75. Southerland LT, Simerlink SR, Vargas AJ, et al. Beyond observation: protocols and capabilities of an emergency department observation unit. Am J Emerg Med 2018;37(10):1864–70. Available at: http://www.sciencedirect.com/science/article/pii/S0735675718310118. Accessed Novemeber 2, 2019.
76. Lo SM, Choi KTY, Wong EML, et al. Effectiveness of emergency medicine wards in reducing length of stay and overcrowding in emergency departments. Int Emerg Nurs 2014;22(2):116–20.
77. McGrath J, LeGare A, Hermanson L, et al. The impact of a flexible care area on throughput measures in an academic emergency department. J Emerg Nurs 2015;41(6):503–9.
78. Garrett JS, Berry C, Wong H, et al. The effect of vertical split-flow patient management on emergency department throughput and efficiency. Am J Emerg Med 2018;36(9):1581–4.
79. Wallingford G, Joshi N, Callagy P, et al. Introduction of a horizontal and vertical split flow model of emergency department patients as a response to overcrowding. J Emerg Nurs 2018;44(4):345–52.
80. Doran KM, Colucci AC, Hessler RA, et al. An intervention connecting low-acuity emergency department patients with primary care: effect on future primary care linkage. Ann Emerg Med 2013;61(3):312–21.e7.
81. Kirkland SW, Soleimani A, Rowe BH, et al. A systematic review examining the impact of redirecting low-acuity patients seeking emergency department care: is the juice worth the squeeze? Emerg Med J 2019;36(2):97–106.
82. Cha WC, Shin SD, Song KJ, et al. Effect of an independent-capacity protocol on overcrowding in an urban emergency department. Acad Emerg Med 2009; 16(12):1277–83.
83. Murphy SO, Barth BE, Carlton EF, et al. Does an ED flow coordinator improve patient throughput? J Emerg Nurs 2014;40(6):605–12.
84. Fulbrook P, Jessup M, Kinnear F. Implementation and evaluation of a 'navigator' role to improve emergency department throughput. Australas Emerg Nurs J 2017;20(3):114–21.
85. Traub SJ, Saghafian S, Judson K, et al. Interphysician differences in emergency department length of stay. J Emerg Med 2018;54(5):702–10.e1.
86. Melnick ER, Szlezak CM, Bentley SK, et al. CT overuse for mild traumatic brain injury. Jt Comm J Qual Patient Saf 2012;38(11):483–9.

87. Sharp AL, Nagaraj G, Rippberger EJ, et al. Computed tomography use for adults with head injury: describing likely avoidable emergency department imaging based on the Canadian CT head rule. Acad Emerg Med 2017;24(1):22–30.
88. Hodgson NR, Saghafian S, Mi L, et al. Are testers also admitters? Comparing emergency physician resource utilization and admitting practices. Am J Emerg Med 2018;36(10):1865–9.
89. Carnevale TJ, Meng D, Wang JJ, et al. Impact of an emergency medicine decision support and risk education system on computed tomography and magnetic resonance imaging use. J Emerg Med 2015;48(1):53–7.
90. Kadhim-Saleh A, Worrall JC, Taljaard M, et al. Self-awareness of computed tomography ordering in the emergency department. CJEM 2018;20(2):275–83.
91. Valtchinov VI, Ip IK, Khorasani R, et al. Use of imaging in the emergency department: do individual physicians contribute to variation? Am J Roentgenol 2019;213(3):637–43.
92. Wolfe RE, Sanchez LD. Effect of emergency physician burnout on patient waiting times. Intern Emerg Med 2018;13(3):373–4.
93. De Stefano C, Philippon A-L, Krastinova E, et al. Effect of emergency physician burnout on patient waiting times. Intern Emerg Med 2018;13(3):421–8.
94. Tawfik DS, Profit J, Morgenthaler TI, et al. Physician burnout, well-being, and work unit safety grades in relationship to reported medical errors. Mayo Clin Proc 2018;93(11):1571–80.
95. Lu DW, Dresden S, McCloskey C, et al. Impact of burnout on self-reported patient care among emergency physicians. West J Emerg Med 2015;16(7):996–1001.
96. Chung AS, Wong ML, Sanchez LD, et al. Research priorities for physician wellness in academic emergency medicine: consensus from the Society of Academic Emergency Medicine Wellness Committee. AEM Educ Train 2018;2:S40–7.
97. Persico N, Maltese F, Ferrigno C, et al. Influence of shift duration on cognitive performance of emergency physicians: a prospective cross-sectional study. Ann Emerg Med 2018;72(2):171–80.
98. Wong ML, Anderson J, Knorr T, et al. Grit, anxiety, and stress in emergency physicians. Am J Emerg Med 2018;36(6):1036–9.
99. Eng MS-B, Fierro K, Abdouche S, et al. Perceived vs. actual distractions in the emergency department. Am J Emerg Med 2019;37(10):1896–903. Available at: http://www.sciencedirect.com/science/article/pii/S0735675719300051. Accessed November 4, 2019.
100. Shanafelt TD, Dyrbye LN, Sinsky C, et al. Relationship between clerical burden and characteristics of the electronic environment with physician burnout and professional satisfaction. Mayo Clin Proc 2016;91(7):836–48.