Use of Computer Modeling to Streamline Care in a Psychiatric Emergency Room: A Case Report

Seewan Kim, B.S., Lara G. Chepenik, M.D., Ph.D.

Computer simulation using JaamSim tested the impact of changing the number of providers, proportion of independent to supervised providers, shift provider added, time to hospitalization, and the number of beds in order to identify bottlenecks in a psychiatric emergency department. Adding an independent provider from 4 p.m. to midnight produced the largest improvements: reductions in time to bed, time to provider, and length of stay by 82%, 68%, and 31%, respectively. Decreasing time to hospitalization and adding beds achieved modest improvements. Modeling allows simulated changes to one parameter at a time and provides bespoke analysis for a variety of clinical settings.

Psychiatric Services 2020; 71:92–95; doi: 10.1176/appi.ps.201900040

Hospital visits for psychiatric emergencies have increased at a greater rate than visits not related to mental health (1). Because patients with psychiatric complaints tend to stay in the emergency department (ED) longer (2), this trend exacerbates overcrowding, which can increase patient morbidity and mortality (3), and contributes to approximately $2,264 in lost hospital revenue for each patient awaiting hospitalization (2). Ideally, hospital systems challenged to improve services should be able to test potential interventions prior to reconfiguring, rebuilding, or restructuring staffing patterns.

The application of computer simulation models derived from the manufacturing industry to identify system bottlenecks can reduce ED overcrowding. Simulations can predict the effects of matching staffing patterns to changes in patient volume based on the day of the week or time of day and show that relatively small increases in staffing can alleviate problems with patient flow (4, 5). These simulations can be developed by on-site experts, although open-source packages that require only minimal programming skills are also available. For example, JaamSim, which uses Java programming language to build discrete event simulations, has been used to improve efficiency and reduce costs in medical settings (6). Its user-friendly interface employs visual icons to represent patients, staff, and other resources, making it accessible to those without extensive programming expertise (7).

The psychiatric ED of the nonprofit university hospital in this study experienced increasing patient volume that strained the existing system. This increase contributed to longer waits for patients to be evaluated, prolonged length of stay (LOS), and patient overflow into hallways—areas not intended for treatment. Prior to implementation of potentially costly and disruptive changes to any of these areas, we sought to test proposed interventions using computer modeling. We first built a simulation calibrated to actual metrics and then tested the effects of modifying steps in the process over which the department had control. This column illustrates the utility of separating patient flow into a series of timed variables to identify those interfering most with timely patient care.

Methods

Clinical setting. Metrics gathered from existing psychiatric ED processes informed the development and calibration of the simulation. The psychiatric ED, which contains 12 beds and accommodates approximately 7,500 patient visits per year, is a locked unit within a university hospital ED.

Triage nurses screen all patients upon their arrival to the ED. Patients with acute medical conditions or disruptive behavior are evaluated and treated prior to transfer to the psychiatric ED, allowing patients to be seen on a first-come-first-serve basis.

HIGHLIGHTS

- Computer modeling based on simulations used in manufacturing can evaluate treatment efficiency by separating patient flow into a series of time blocks to identify system bottlenecks.
- Modeling indicated relative efficiencies of adding independent practitioners versus those requiring supervision and identified the work shifts most affected by adding staff.

During weekdays, the unit is staffed by an attending psychiatrist, an advanced-practice registered nurse (APRN), and a junior resident. An attending M.D. and APRN continue coverage through the evening, and an attending M.D. and senior resident staff the overnight shift (midnight–8 a.m.) and weekends.

Upon arrival, patients are placed in a queue for available beds, complete an initial evaluation by a registered nurse, and are placed in a second queue to await evaluation by a provider. Evaluations include a physical exam, orders, and a comprehensive psychiatric assessment that could also serve as the admission documentation should the patient be admitted. Patients are then discharged, admitted, or placed on observation for reevaluation, all of which include some delay. The available inpatient psychiatric wards have 50 beds for adults, 15 beds for adolescents, and eight beds for those over 60 years old.

Data collection (fixed parameters). Data from all adult patient visits to the psychiatric ED between February and July 2013 (N=3,066) were used to calculate patient arrival rates (N=17 patients per day: 2 per hour, midnight–4 a.m.; 1.2 per hour, 4 a.m.–8 a.m.; 2.2 per hour, 8 a.m.–noon; 4 per hour, noon–4 p.m.; 3.8 per hour, 4 p.m.–8 p.m.; and 3.7 per hour, 8 p.m.–midnight), distribution frequency for potential dispositions (40% discharged, 25% observed, and 35% admitted), and LOS (median=14.8 hours, mean=19.8 hours). LOS was calculated after removing patients with stays greater than three standard deviations from the mean, given that those with exceptionally long LOS represented severely disabled patients requiring placement outside the hospital system. Delays to disposition included 1 hour for patients discharged, 5 hours for reevaluation, and 7 hours for admission, according to data collected from electronic medical records.

Simulation model development. Using JaamSim and the parameters described above, we built a simulation model to mimic patient flow through the psychiatric ED. Patient arrival frequency was modeled by using an exponential distribution. Once placed into a bed, patients were assigned any available provider regardless of provider type. After evaluation, patients were randomly assigned a disposition in accordance with the distribution rate. To prevent infinite looping of patients assigned to reevaluation, patients could only be assigned to this pathway once.

Model validation. Evaluation and supervision times were based on daily time logs kept by the clinicians and were confirmed against electronic medical records. Final modeling reflected adjustments calibrated in order to yield LOS that was closest to actual data, resulting in evaluation times of 2.1 hours for independent practitioners and 3.5 hours for supervised providers. Longer times for supervised providers reflected increased time spent in evaluation, documentation, and supervision. Evaluation time was assigned as a uniform distribution with a 0.5-hour range around the average.

TABLE 1. Actual and modeled duration of patient flow measures in a psychiatric emergency department, in hours

	Actual baseline		Modeled baseline
Measure	Mean	Median	(mean)
Time to bed	5.6	2.6	2.2
Time to provider	6.8	6.0	5.9
Total length of stay	19.9	14.8	14.7

The simulation calculated a running mean for the dependent variables of time to bed (2.2 hours), time to provider (5.9 hours), and total LOS (14.7 hours). Initially, these mean values fluctuated because of inherent variability in the model before eventually converging to a constant. In this study, the simulation ran for 1 year to minimize random variability. Outputs were checked against actual data to validate the model, and medians were preferred over means because of a large positive skew (Table 1).

Interventions. Interventions included increasing the number of designated providers, decreasing the time delay to inpatient admission (which would reflect faster discharges from the hospital units), and increasing the number of beds. Providers could be added for a day shift (8 a.m.−4 p.m.), evening shift (4 p.m.–midnight) or night shift (midnight–8 a.m.), reflecting existing hospital staffing patterns. We tested the addition of both independent and supervised providers in each of these shifts.

Cost-benefit analysis. Analysis of the annual cost to reduce average patient LOS by 1 hour (reported as dollars/hour) was performed by using starting salaries specific to this institution in order to maintain internal consistency: $170,000 for an attending M.D., $98,800 for an APRN, $74,000 for a licensed clinical social worker (LCSW) with at least 5 years' experience, and $68,500 for a junior psychiatry resident. To calculate comparative costs, this number was then divided by the reduction in LOS observed after the addition of each type of provider.

Results

Adding staff. The addition of either independent or supervised providers to any of the shifts resulted in reductions in time to bed, time to provider, and LOS. The largest decrease in these measures resulted from the addition of an independent provider to the evening shift, resulting in waits of 0.4 hours, 1.9 hours, and 10.1 hours, respectively, reflecting reductions of 82%, 68%, and 31%. The addition of supervised providers during the evening shift yielded average waits of 1.1 hours, 3.6 hours, and 12.3 hours for the same measures, or reductions of 50%, 40%, and 16%, respectively. Further reductions in wait times could be achieved by adding staff for two shifts, with the greatest reduction resulting from the addition of an independent practitioner for the evening and night shifts (4 p.m.–8 a.m.). This staffing pattern yielded wait times of 0.2 hours, 1.1 hours, and 9.1 hours for time to bed, time to provider, and LOS, respectively, or reductions of 91%, 81%, and 38%.

Adding beds. The addition of ED beds reduced patient time to bed for each value tested. However, time to provider and total LOS remained relatively unchanged.

Reducing wait for hospitalization. Reducing wait time to hospitalization showed little effect on time to provider. However, time to bed was reduced from 2.2 hours to 1.5 hours when hospitalization waits dropped to 1 hour. Total LOS also decreased from 14.7 hours to 12.1 hours when delay to hospitalization dropped to 1 hour. For each hourly decrease in wait for hospitalization, LOS decreased by 0.4 hours.

Efficiency calculation. Calculations of yearly costs to reduce patient LOS by 1 hour showed that the most efficient use of money was to hire one full-time APRN for the evening shift. Adding an APRN cost $29,939, compared with $51,515 for an M.D., $43,529 for an LCSW, and $40,294 for a junior psychiatry resident. For each profession, the cost of adding staff to reduce patient LOS was higher during the day shift than during the evening shift.

Discussion and Conclusions

Using data from electronic medical records, we built a computer simulation model that mimicked the steps of patient flow through the psychiatric ED. This model allowed for manipulation of each step in order to identify bottlenecks and to test proposed changes virtually. Consistent with other studies, a small but targeted change to the hospital system yielded dramatic reductions in patient wait times and LOS (4, 5). Of the variables tested, availability of providers was identified by this model as the initial bottleneck in patient flow. In particular, the addition of either an independent or supervised provider to the evening shift resulted in improved flow compared with adding a provider to the day or night shifts. This finding may reflect the higher staff presence during day shifts in current staffing patterns; adding a provider to the day shift represented a 33% increase in staffing, while adding a provider to the evening shift represented a 50% increase. The evening shift also typically receives the greatest volume of new arrivals, suggesting that this new staffing pattern better matched workload.

Although adding beds and reducing time to hospitalization resulted in only modest improvements in patient flow, these results may not be universal. Our findings could reflect already sufficient totals of ED and inpatient beds. Alternatively, these findings might constitute secondary bottlenecks, hidden because of the larger effects from inadequate staffing. However, consistent with other reports, adding beds does little to alleviate crowding or shorten LOS if staff and other resources remain unchanged (8).

Calculation of relative cost to reduce patient LOS revealed a measure of efficiency that could be used to streamline evaluations. Reducing the time clinicians spend with each patient could achieve the same benefits as adding personnel. Efforts to reduce documentation requirements and evaluation redundancy or to redistribute data collection could all potentially achieve the same benefit as hiring more providers.

General limitations to computer modeling arise from smoothing of input factors. Although JaamSim can accommodate some variability around time inputs, it fails to capture the ranges more typical of EDs. For example, positive skew in LOS can be exaggerated in JaamSim because upper ranges are measured in days; however, shorter LOS may be only minutes or hours below the median. Because we assumed that the longest times to bed, times to provider, and LOS reflected events independent of ED treatment, such as waits for residential placement, we attempted to calibrate the simulation to match actual medians rather than means. This simulation also failed to capture variability based on season, holidays, or weekends, which can affect patient arrivals as well as hospital discharges. Analysis was further limited by the paucity of data on provider time required for each step in the evaluation process. To address this limitation, clinicians kept daily logs of the time they spent in various stages of patient care during the period of data collection. When possible, these logs were checked against electronic medical records. Although this simulation attempted to model loss of clinician productivity due to supervision and redundancy, there was little data available to verify our assumptions. More sophisticated manipulations can be programmed based on available software; however, this upgrade might require personnel or costs beyond a hospital's resources.

Despite these limitations, modeling may offer novel insights to help improve delivery of care. Simulation of bed number and availability, acuity-based evaluations, and modifications to inpatient bed availability have all been examined as options to reduce ED boarding. Adjustments to M.D., APRN, and resident schedules seem particularly promising because variability in the ED workload creates periods of staff underutilization alternating with burdensome overdemand (8). By reframing clinical interactions as a succession of resource uses (e.g., evaluations) with queues between resources (e.g., wait for bed, wait for provider), modeling allows for bespoke analysis of parameters adjusted to the specifics of each system and thus delivers results tailored to available resources.

AUTHOR AND ARTICLE INFORMATION

Yale School of Medicine (Kim), and Department of Psychiatry and Department of Emergency Medicine (Chepenik), Yale School of Medicine, New Haven, Connecticut. Marcela Horvitz-Lennon, M.D., and Kenneth Minkoff, M.D., are editors of this column. Send correspondence to Dr. Chepenik (lara.chepenik@yale.edu).

The authors acknowledge Seth Powsner, M.D., for his thoughtful contributions and programming expertise.

The authors report no financial relationships with commercial interests.

Received January 21, 2019; revision received July 19, 2019; accepted August 26, 2019; published online October 8, 2019.

REFERENCES

1. Ting SA, Sullivan AF, Boudreaux ED, et al: Trends in US emergency department visits for attempted suicide and self-inflicted injury, 1993–2008. Gen Hosp Psychiatry 2012; 34:557–565
2. Nicks BA, Manthey DM: The impact of psychiatric patient boarding in emergency departments. Emerg Med Int 2012; 2012:360308
3. Miró O, Antonio MT, Jiménez S, et al: Decreased health care quality associated with emergency department overcrowding. Eur J Emerg Med 1999; 6:105–107
4. Green LV, Soares J, Giglio JF, et al: Using queueing theory to increase the effectiveness of emergency department provider staffing. Acad Emerg Med 2006; 13:61–685
5. Chepenik L, Pinker E: The impact of increasing staff resources on patient flow in a psychiatric emergency service. Psychiatr Serv 2017; 68:470–475
6. Sarnikar S, Shrestha S: A simulation model for evaluating alarm routing policies in ICU patient monitoring information systems. 21st Americas Conference on Information Systems, Puerto Rico, August 13–15, 2015
7. Dagkakis G, Heavey C: A review of open-source discrete event simulation software for operations research. J Simul 2016; 10: 193–206
8. Paul SA, Reddy MC, DeFlitch CJ: A systematic review of simulation studies investigating emergency department overcrowding. Simulation 2010; 86:559–570