Operational Evaluation of High-Throughput Community-Based Mass Prophylaxis Using Just-in-Time Training

James D. Spitzer MBA, MS^a Nathaniel Hupert, MD, MPH^b Jonathan Duckart MPS^a Wei Xiong, PhD^b

SYNOPSIS

Community-based mass prophylaxis is a core public health operational competency, but staffing needs may overwhelm the local trained health workforce. Just-in-time (JIT) training of emergency staff and computer modeling of workforce requirements represent two complementary approaches to address this logistical problem.

Multnomah County, Oregon, conducted a high-throughput point of dispensing (POD) exercise to test JIT training and computer modeling to validate POD staffing estimates. The POD had 84% non-health-care worker staff and processed 500 patients per hour. Post-exercise modeling replicated observed staff utilization levels and queue formation, including development and amelioration of a large medical evaluation queue caused by lengthy processing times and understaffing in the first half-hour of the exercise.

The exercise confirmed the feasibility of using JIT training for high-throughput antibiotic dispensing clinics staffed largely by nonmedical professionals. Patient processing times varied over the course of the exercise, with important implications for both staff reallocation and future POD modeling efforts. Overall underutilization of staff revealed the opportunity for greater efficiencies and even higher future throughputs.

^aMultnomah County Health Department, Portland, OR

^bWeill Medical College, Cornell University, New York, NY

Address correspondence to: Nathaniel Hupert, MD, MPH, Department of Public Health, Weill Cornell Medical College, 411 E. 69th St., KB-309, New York, NY 10021; tel. 212-746-3049; fax 212-746-8544; e-mail <nah2005@med.cornell.edu>. ©2007 Association of Schools of Public Health

Community-based mass prophylaxis is a core operational competency of public health agencies, but staffing needs for these dispensing campaigns are difficult to predict and may overwhelm the local trained health workforce.¹⁻³ The 2001 U.S. anthrax attacks led public health authorities to dispense thousands of antibiotic courses along the Eastern seaboard over a multiweek period, but larger-scale attacks or outbreaks of communicable diseases like influenza may require much more rapid mobilization of the public health workforce.4-6 Recent statewide exercises have documented success in receiving, distributing, and dispensing the contents of the Centers for Disease Control and Prevention (CDC) Strategic National Stockpile (SNS), though to date the dispensing rates attained and total exercise throughputs have remained relatively low (i.e., in the range of 200 to 300 patients per hour).7-11

Just-in-time (JIT) training is now considered a critical element of emergency mobilization for interventions like mass prophylaxis, where there is a rapid surge in workforce requirements for tasks that may be protocolized.^{1,8,12} Such high-consequence, low-probability operations may not justify full, pre-event training and exercising of community health professionals; may require a far greater workforce than exists in available medical and allied health professionals; and may require event-specific responses that necessitate staff training regardless of prior preparedness. Computer modeling of dispensing site operations has been used to help determine efficient staffing levels for training exercises, but validation of these models for operational use has been hindered by a lack of published processing time data.13

Multnomah County, Oregon, conducted a mass prophylaxis exercise that combined JIT training of largely nonmedical staff with high-flow patient processing in a point of dispensing (POD) clinic also known as a module in the health department's plan.¹⁴ This POD would be one of 30 planned throughout the county to accomplish a larger command post-exercise objective of dispensing medicine to more than 300,000 people in 24 hours (i.e., each POD operating at approximately 417 people per hour).^{14,15} The goal of the exercise was to meet or exceed the highest productivity expectations of the planned modules and analyze the process to make further improvements and project productivity rates under other conditions.

This exercise represented the first documented SNS exercise of a high-capacity mass prophylaxis clinic combining JIT training of largely nonmedical staff and queuing analysis based on detailed process time measurement, time-lapse video analysis, and computer modeling.

METHODS

Background and exercise planning

A previous year's mass vaccination exercise (2004) successfully deployed a standardized POD module of a defined layout, triage and medical evaluation process, and recommended staffing levels¹⁶ (Figure 1). All staff were medical/health professionals. The module throughput rate for that exercise was 300 individual patients per hour using conservative medical standards that would minimize the chances of administering a vaccine or medicine that would harm the patient.

Two PODs were set up in Multnomah County as part of a larger series of state and county exercises conducted from November 1–3, 2005—one at Benson Polytechnic High School and the other at Portland State University (PSU). All data here refer to the Benson exercise only, as the PSU exercise failed to generate sufficient volunteer patients and staff to test the POD system. The Benson POD was set up in an approximately 12,000-square-foot gym with retracted bleachers (about three times the size of a standard high school basketball court).

The exercise scenario involved a hypothetical aerosol pneumonic plague exposure requiring large-scale antibiotic prophylaxis.^{3,15,17,18} A small cadre of POD leaders was briefed on the scenario less than 24 hours before operations. Staff consisted of mostly nonmedical profession high school student volunteers who were given JIT training within the hour before operations began. Two hours of operations included approximately one hour at maximal capacity (Figure 2). The exercise concluded with one hour of takedown and debriefing. JIT training comprised an overview of the entire POD setup and process, followed by focused instruction on procedures and protocols for five stations: Greeting, Entry, Triage, Medical Evaluation, and Dispensing. Activities at each station and initial recommended and allocated staff are listed in Figure 3.

Because the volunteer patients were all high school students, demographically representative script cards were distributed with the request that the students act out the brief set of characteristics listed on those cards (gender, age, allergies, medical history, and symptoms) to better represent a general population of Multnomah County. All patients underwent triage at the Medical Screening 1 station; only those with scripts portraying allergy or other medical contraindication to prophylaxis medications were sent to medical evaluation at the Medical Screening 2 station. A subset of volunteer staff was cross-trained to allow reassignment during clinic operation.

Staff recorded the time on patient intake forms at five points in the process in one-minute intervals.



Figure 1. Point of dispensing clinic flow

Watches were synchronized prior to exercise initiation. High-resolution video cameras captured clinic activity including queue formation. Exercise leaders were instructed to respond to perceived bottlenecks by reallocating staff to areas experiencing queue formation.

Data analysis and computer modeling

Two methods were used to calculate station-specific processing times. First, interstation routing times were used to approximate the combination of waiting time at station i and processing time at station i-1 (because time stamps were applied at the start of each encounter). For the specific station that experienced large queues (i.e., Medical Evaluation), review of the time-stamped exercise video permitted estimation of per-patient processing time.

We used a goodness-of-fit Chi-square test from the Input Analyzer function of the Arena simulation software package¹⁹ to assess whether the distribution of arrivals to the POD constituted a Poisson process, which is the default assumption of standard modeling tools. Estimated staff utilization—the average percentage of time that a staff member is busy with a patient—and recommended optimal staffing levels for a target of 85% utilization were calculated with a custom-built model created using Queuing Toolpack software,²⁰ a free add-on to Microsoft[®] Excel. These calculations were based on two station-specific data elements: the patient arrival rate and the estimated service time.

RESULTS

Exercise

The design and physical layout of the Benson POD matched the Multnomah County health department plan, but the staffing assigned during the exercise differed from expert-recommended levels. Fewer staff were placed at the Medical Evaluation (Medical Screening 2) station due to a shortage of qualified individuals at the time of the exercise, and fewer flow/pedestrian traffic monitors were employed. In contrast, more staff than recommended in the plan were placed at the Greeting/Education and Medicine Dispensing stations (Figure 3).





The POD processed a total of 925 patients starting at 9 a.m. and ending at 10:50 a.m., for a mean throughput of 8.33 patients per minute (PPM) (500 patients per hour). Arrival rates to the POD varied from zero PPM for eight of the 120 exercise minutes to 20 PPM over three nonconsecutive minutes, with a standard deviation of 5.21. Figure 2 displays these arrival rates sequentially according to clock time (i.e., as they appeared to the staff working at the Greeting/Education station during the exercise). Analysis of the arrivals strongly suggests that they did not constitute a Poisson process (goodness-of-fit Chi-square 47.8, p < 0.005).

Arrival distributions to Triage, Dispensing, and Checkout were nearly identical to that for Greeting/ Education, but arrivals to the Medical Evaluation station had a lower mean of 3.63 PPM (standard deviation [SD] = 3.86) consistent with the fact that only a subset of patients was sent for more extensive evaluation.

	Activity	POD plan guideline	POD exercise staffing
Greeting/Education	Prescreening/intake forms issued to fill out at Education/interpreter area	15	4 greeting 16 education
Triage (Medical Screening 1)	Intake form reviewed, patient sent to Medical Evaluation or Dispensing	9	9
Evaluation (Medical Screening 2)	Evaluation of patients with medical contraindications (e.g., allergy or medical complication)	6	2
Dispensing/Checkout	Dispensing of doxycycline or ciprofloxacin; collection of intake form	18	29
Supervisor flow/support		1	1
		12	4
Total staffing (not including security/traffic)		70	64
Staff who were not medical/health professionals		NA	54
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Figure 3. Recon	nmended and	actual POD	exercise	staffing
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POD = point of dispensing

NA = not applicable

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POD = point of dispensing

The mean door-to-door processing time for all patients was 6.2 minutes, with a range of 1 to 18 minutes and a 95% confidence interval (CI) of ± 0.2 minutes (Table 1). Patients who did not require medical evaluation (521 patients) had a mean total treatment time of 5 minutes (range = 1 to 15 minutes, 95% CI ± 0.2 minutes), while those who did have medical evaluation (403 patients) had a mean time of 7.7 minutes (range = 1 to 18 minutes, 95% CI ± 0.3 minutes).

Patient processing time data for selected POD functions are listed in Table 2. We focused on processing time at the Medical Evaluation station, as this was the site of the largest patient queue of the exercise (18 patients). The evaluation process demonstrated marked patient-to-patient variability as well as a nonstationary mean as the exercise progressed (Figure 4). In the first half-hour, mean treatment time was 1.08 minutes with a range of 0.5 to 1.67 minutes; subsequent to that, the mean decreased to 0.52 minutes with a range of 0.17 to 1.42 minutes. Queuing at this station was a function of both treatment time and referral patterns (dictated by the patient scripts created for the exercise).

Performance of the Medical Evaluation station might have been worse (i.e., longer waiting times) had it not been for the POD supervisor shifting an additional nurse to the station in response to queues appearing at roughly the half-hour mark. Using observed and estimated processing times and arrival rates, we used the computer queuing model to estimate station-specific staff utilization rates and calculate optimal staffing levels for a target utilization level of 85% (Table 2, columns 4 and 5).

DISCUSSION

Multnomah County successfully exercised a highthroughput POD operation involving rapid setup with JIT training of largely nonmedical staff and extensive data capture permitting post-exercise modeling. Total patient throughput exceeded the target by 46 patients per hour, which, if extrapolated to the planned 30-POD response for 300,000 people over 24 hours, represents a time savings of 2.6 hours or a reduction in required number of PODs to 27 (assuming uniformly high production rates).

The average patient processing time was approximately 6 minutes, which matches the results of a previously reported simulation model of a similar mass prophylaxis clinic that used published data to estimate station-specific service times.¹³ In the Multnomah County exercise, station-by-station tracking of patient processing times was validated by qualitative postexercise reports by observers and quantitative review of video documentation. These qualitative and quantitative data all indicated excessive staffing at baseline (with the exception of the Medical Evaluation station) at levels higher than those recommended by the POD plan. The POD Supervisor applied her discretion to deviate from the plan based on her perception of the operation and available staffing.

When actual patient arrival rates and processing times from the exercise were entered into the queuing model of exercise patient flow, the model outputs confirmed underutilization of assigned staff at all stations except Medical Evaluation, where at least initially

	Average time (minutes)	95% CI (minutes)	Median time (minutes)	Range (minutes)	
All patients					
Total time	62	60 64	6	1–18	
Greeting to Triage	2.7	2.6.2.9	2	<1-15	
Dispensing to Checkout	1.2	1.1, 1.3	1	<1–9	
No medical evaluation					
Total time	5.0	4.8, 5.2	5	1–15	
Greeting to Triage	2.7	2.6, 2.9	2	<1–14	
Triage to Dispensing	1.4	1.3, 1.6	1	<1–9	
Dispensing to Checkout	1.1	1.0, 1.2	1	<1–9	
With medical evaluation					
Total time	7.7	7.4, 8.0	7	1–18	
Greeting to Triage	2.8	2.6, 3.3	2	<1–15	
Triage to Evaluation	2.9	2.7, 3.1	2	<1-14	
Evaluation to Dispensing	1.0	0.9, 1.2	1	<1–11	
Dispensing to Checkout	1.4	1.3, 1.6	1	<1–9	

Table 1. Interstation routing times

CI = confidence interval

			Computer m	Computer model results	
Station	Active exercise staff	Observed service times (lower bound to upper bound, in minutes)	Model-based staff utilization rate at observed service times—lower bound to upper bound (percent)	Proposed optimal staffing based on 85% utilization goal (lower bound to upper bound)	
Greeting	4	0.17-0.25	36–55	2–3	
Triage (Medical Screen 1)	9	0.17-0.33	16–32	2–3	
Evaluation (Medical Screen 2) First half-hour	1	0.5–1.67 (mean 1.08)	192–640 (417 at mean	3–7 (5 at mean service time)	
Remainder of exercise	1	0.17–1.42 (mean 0.52)	64–544 (192 at mean service time)	1–6 (3 at mean	
	2	0.17–1.42 (mean 0.52)	32–272 (96 at mean service time)		
Medicine Dispensing	23	0.33–0.67	13–25	3–7	
Checkout	5	0.25–0.33	44–58	3–4	

Table 2. Selected staffing and processing parameters

there was considerable overutilization (which during the exercise led to queue formation). Both under- and overutilization of staff may have negative consequences for mass prophylaxis operations taking place in a limited resource setting. Inefficient use of staff may preclude the opening of sufficient PODs to serve an entire affected community. Overextended PODs may result in disruptive activity or reneging (walkaways) on the part of potential patients who are forced to wait for critical services.

Clinical experience with past prophylaxis clinics led to initial staff assignments for this exercise





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that were generally conservative (i.e., wasteful) even under conditions of great variability in patient arrival rates. However, POD leaders noted extensive delays were occurring at the Medical Evaluation station and doubled its staff. Although this intervention coincided with elimination of the queue, it is unclear whether it was truly necessary, as the mean treatment times fell quite rapidly during the first hour of clinic operation, and this alone may have eliminated the backup (albeit more slowly).

The use of validated computer models of POD activities may help other communities avoid over- or understaffing PODs in a range of expected patient throughput scenarios. Primary collection of detailed operational data during POD exercises is critical to model validation. In this light, two features of the current exercise regarding distribution of patient arrivals to the POD and patient processing times within the POD are relevant to future model development.

First, we found that arrivals to the POD do not constitute a stationary Poisson process, a finding that has important implications for attempts to apply queuing models to the design and optimization of POD activities. For tractability purposes (i.e., for ease in calculating steady state characteristics of queuing systems), most standard queuing modeling tools-including the one used here—assume that arrivals follow a stationary Poisson process (i.e., with an exponential distribution of interarrival times). If the actual arrival process has less or more variability than predicted by use of the Poisson assumption, the model will overestimate or underestimate, respectively, the number of staff required to process patients through a POD, even if the distribution of treatment times remains the same. Future exercises should include stopwatch or other exact measurement and recording of the time between each patient arrival to the POD entrance and at each POD station (i.e., the patient interarrival times, in addition to individual patient waiting and processing times) to validate this assumption.

Second, this is to our knowledge the first reported documentation of a nonstationary mean processing time inside a high-throughput POD. This finding has implications for a range of POD operations (i.e., staffing, quality assurance, and command and control) as well as the mathematical modeling of POD operations, such as requiring more sophisticated mathematical analyses for nonstationary processes than standard steady-state queuing equations.

Although this was only a two-hour exercise, we found that treatment times asymptotically approached a mean of less than half the amount seen in the opening hour of operation. Failure to anticipate this type of improvement in operations may lead either to overstaffing or inappropriate switching of staff assignments in the early hours of high-flow POD operations. Documentation of processing times and triage accuracy at multiple times during future exercises will help to clarify the shape of these nonstationary means, which will help in creating more accurate planning models and hopefully more efficient use of staff.

Because actual patient arrival patterns may be unpredictable, certain crowd-management measures (such as controlled entry and reporting of POD wait times), active leadership, and flexible, reassignable staffing can match POD staffing to patient arrival rates. In this exercise, experienced POD leaders adapted to periodically high patient arrival rates by identifying chokepoints and adjusting staff to relieve them. This flexibility was permitted by JIT training with some crossover training that allowed the flexibility to fill perceived gaps. Few positions required deep technical competence, as most had to perform a set of protocol-driven functions that are the hallmark of the SNS dispensing operation.

The lessons learned in this article might be applied to using JIT-trained volunteers to staff many kinds of production-like operations during disasters, including mass feeding kitchens, sandbagging, and shelter setup. JIT-trained volunteers may not be appropriate in situations in which proven qualifications, deeper systems understanding, or prior experience are needed. Further work might determine the limits of using JITtrained volunteers for emergency response.

Limitations

There were several important limitations to this exercise. Chief among them was the fact that time stamping was not sufficiently granular (i.e., clocks were synchronized to minutes, not seconds) to capture some of the data richness of very fast dispensing operations. Review of high-definition video using DVD formats allowed posthoc recording of per-patient processing times, but this was highly labor-intensive.

Future data-collection efforts should focus on direct recording of additional information, including time of arrival in a queue, time of entry into service (i.e., after waiting in the queue), and time of exit from service, all linked to a single exercise clock. Ideally, data collection should become an integral component of exercise formulation, and data collectors will be provided sufficient primary and backup tools (e.g., clipboards, stopwatches, and stop-motion video cameras) to accomplish this task in the dynamic and often stressful setting of a full-scale dispensing exercise.

CONCLUSION

While all dispensing exercises are fundamentally local affairs—and should be to train a cadre of skilled workers familiar with such operations—their results may be extrapolated to improve modeling and planning at the regional and national levels. The process time data obtained during this exercise should prove useful for validating both the model developed here and other models created for this purpose over the past four years (e.g., the Bioterrorism and Epidemic Outbreak Response Model created for the Department of Health and Human Services, Agency for Healthcare Research and Quality).²¹ In the future, such validated models may provide assistance in the development of national performance standards for various types of public health emergency response operations.

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