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The Effect of Increased Emergency Department Demand on Throughput Times and Disposition Status for Pediatric Psychiatric Patients

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Abstract

Objectives: Emergency department (ED) crowding has been shown to increase throughput measures of length of stay (LOS), wait time, and boarding time. Psychiatric utilization of the ED has increased, particularly among younger patients. This investigation quantifies the effect of ED demand on throughput times and discharge disposition for pediatric psychiatric patients in the ED.

Methods: Using electronic medical record data from 1,151,396 ED visits in eight North Carolina EDs from January 1, 2018, through December 31, 2020, we identified 14,092 pediatric psychiatric visits. Measures of ED daily demand rates included overall occupancy as well as daily proportion

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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of non-psychiatric pediatric patients, adult psychiatric patients, and pediatric psychiatric patients. Controlling for patient-level factors such as age, sex, race, insurance, and triage acuity, we used linear regression to predict throughput times and logistic regression to predict disposition status. We estimated effects of ED demand by academic versus community hospital status due to ED and inpatient resource differences.

Results: Most ED demand measures had insignificant or only very small associations with throughput measures for pediatric psychiatric patients. Notable exceptions were that a one percentage point increase in the proportion of non-psychiatric pediatric ED visits increased boarding times at community sites by 1.06 hours (95% CI: 0.20-1.92), while a one percentage point increase in the proportion of pediatric psychiatric ED visits increased LOS by 3.64 hours (95% CI: 2.04-5.23) at the academic site. We found that ED demand had a minimal effect on disposition status, with small increases in demand rates favoring <1 percentage point increases in the likelihood of discharge. Instead, patient-level factors played a much stronger role in predicting discharge disposition.

Conclusions: ED demand has a meaningful effect on throughput times, but a minimal effect on disposition status. Further research is needed to validate these findings across other state and healthcare systems.

Keywords

Emergency psychiatry; emergency department; mental health; length of stay; throughput time

1. INTRODUCTION

The relationship between emergency department (ED) crowding and prolonged ED throughput times is well-established [1-3]. Understanding the impact of ED crowding on ED outcomes has become a priority for clinicians, hospital administration, and policymakers in light of increasing ED utilization rates over time [4,5]. Psychiatric ED use has been increasing faster than non-psychiatric ED use, particularly in North Carolina (NC) [6]. For psychiatric patients, the ED is a resource for acute care management as well as care-coordination and obtaining services and resources. These patients have different needs and experience a different flow of care in the ED compared to their medical counterparts [7-9]. Notably, ED use among pediatric psychiatric patients has been on the rise [10-13] and further exacerbated in light of the COVID- 19 pandemic [14-15]. Not only are adolescents at risk for new-onset psychiatric illness, but suicide is a leading cause of death among this age group [16]. Increased use of the ED by this patient population makes it essential to better understand factors that influence ED care and ED visit outcomes.

ED providers and staff have anecdotally experienced the impact of increased psychiatric utilization. They have reported first-hand how ED processes have been impacted and have witnessed prolonged boarding times [7], but the impact of increased ED utilization and subsequent ED crowding has not been systematically investigated among pediatric psychiatric patients. Quantifying these impacts is critical to provide a foundation for future research and policy change. This investigation is the first to attempt to quantify what ED providers and staff have anecdotally experienced through rigorous quantitative methods.

The Input-Throughput-Output model of ED crowding provides a foundation for practical policy change by mapping the factors relevant to ED-based patient care for all ED patients [17]. The input portion of the model is defined by ED demand, or the number of patients demonstrating a need for ED services relative to ED capacity. The throughput portion is the door-to-door protocol of the ED, often quantified in length of time. The output portion is the discharge disposition after ED care is completed [17]. We applied this model to pediatric psychiatric patients to quantify the effect of increased ED demand on ED length of stay (LOS), wait time, boarding time, and discharge disposition. We hypothesized that increased ED demand would increase ED LOS, wait time, and boarding time due to the burden placed on ED resources but would not have a significant effect on ED discharge disposition, which should depend on the clinical needs of the patient.

2. METHODS

We conducted a retrospective cross-sectional analysis using existing electronic medical record (EMR) data from ED visits occurring between January 1, 2018, and December 31, 2020, at eight ED sites within a single public healthcare system in NC. Of the eight hospitals in our sample, one was an academic teaching hospital while the other seven were smaller community hospitals. This study was approved by the Institutional Review Board of the University of North Carolina, including a waiver of informed consent due to the nature of administrative data.

2.1 Study Sample

The 8 ED sites were selected due to the availability of their EMR data and diversity in size and geography; they also participated in a parallel study that employed semi-structured interviews to describe the psychiatric resources available in each ED [7]. The qualitative study provided context for quantitative model specification and interpretation of the results presented in this paper. We used data beginning in 2018 as patient triage acuity was not reported in the EMR until 2018. Hospital-level demand rates were calculated using all recorded ED visits. The analyses of pediatric psychiatric visits excluded visits with missing data on patient demographics, discharge disposition, triage acuity, and arrival method, as well as visits with negative or missing throughput times. Wait times were truncated at the 99th percentile of 18.35 hours; length of stay durations and boarding times were not truncated as all observed times were deemed feasible.

Pediatric visits were identified by patient age (<18 years) and International Classification of Diseases, Clinical Modification 10th revision (ICD-10-CM) discharge diagnosis codes. We excluded psychiatric visits in patients under 5 years of age as results from our parallel study suggested that the youngest behavioral health patients to the ED are between 5-7 years [7]. We relied upon the Clinical Classifications Software Refined (CCSR) ICD-10-CM categories published by the Agency for Healthcare Research and Quality (AHRQ) [18]. We modified these categories after clinical review. Our final psychiatric classifications are in Supplementary Table 1. Consistent with existing literature on psychiatric ED visits in NC [6,19], we excluded categories related to substance use due to high comorbidity. Poisoning and injuries codes related to intentional self-harm were included in the suicide/intentional

self-harm category. Visits with any of the listed ICD-10-CM codes were considered psychiatric visits. Of note, ICD-10-CM codes were not ranked or assigned priority scores for each visit; identified visits were considered ED visits with a psychiatric comorbidity, since we lacked information needed to determine primary psychiatric visits.

2.2 Hospital-Level Measures

Our explanatory variable of interest was daily ED demand. We chose to include three mutually exclusive demand rates that reflect the ED resources needed to care for pediatric psychiatric patients: non-psychiatric pediatric demand, non-pediatric psychiatric demand, and pediatric psychiatric demand. Each demand rate was defined as the number of population-specific ED visits divided by the total number of ED visits on a patient's day of arrival. We then converted the proportions to percentages and utilized regression analysis to estimate the impact of increases in these percentages on our outcomes of interest. We also added a hospital-level ED occupancy rate. Because we did not have information on the number of available beds or staff on duty in each ED, we calculated an average daily demand rate for all ED visits on the same day of the week in the 30 days prior to patient arrival and divided the total ED demand on the patient's arrival date by this 30-day historical average; proportions >1 indicate a "busier" day in the ED compared to the previous month's average. A hospital fixed effect (dichotomous indicator of hospital site) was included in each model in order to account for unmeasured, time-invariant structural differences across ED sites.

2.3 Patient-Level Measures

Patient-level covariates included age, sex, race, and ethnicity, type of insurance, mode of arrival, arrival time, a weekend arrival indicator, triage acuity, and presence of a neurodevelopmental diagnosis. Covariates were chosen based on (1) published studies examining factors that impact ED throughput times [1-3,20,21], and (2) information from interviews with ED providers and staff [7], Arrival time, divided into four 6-hour increments, was included because our interviews indicated that the availability of psychiatric services in the ED were limited overnight and on weekends [7]. Interviews revealed that patients with a neurodevelopmental diagnosis generally had longer stays in the ED and were difficult to place in inpatient beds [7].

2.4 ED Discharge Disposition

While patient ED discharge disposition is a dependent variable of interest that is determined jointly with LOS, it was included as a measure of acuity in the linear regressions of LOS, wait and boarding time (i.e., to control for differences in throughput times between those patients needing inpatient placement and those able to be discharged home). ED discharge disposition was consolidated into three categories: admit including both medical and psychiatric admissions (which could not be distinguished in our data); transfer including transfers to outside facilities as well as ED-to-ED transfers; and discharge, including patients who were sent home or left against advice.

2.5 ED Throughput Times

ED throughput times included ED length of stay (LOS), wait time, and boarding time, and were defined based on guidelines from the Agency for Healthcare Research and Quality, the American College of Emergency Physicians, and the Joint Commission [22-24]. LOS was determined by subtracting a patient's arrival time from their discharge time. For patients not admitted on site (i.e., discharged, transferred to an outside facility) their ED discharge time was determined by their hospital discharge time. For patients who were admitted on site, their ED discharge time was determined by their ED disposition time, since their hospital discharge time accounted for their inpatient stay. ED wait time was calculated by subtracting a patient's evaluation time from their arrival time. We know from our concurrent interviews that a patient's first evaluation is often for medical clearance and not a psychiatric evaluation, but not all patients received a separate psychiatric evaluation [7]. Often the ED provider determines ED disposition, so we calculated wait time conservatively using the first provider note timestamp in the record. Boarding time, defined as the time from evaluation to ED discharge, was calculated by subtracting a patient's wait time from their overall ED LOS. Boarding time was only assessed among patients either admitted or transferred to another facility. All throughput times were calculated in hours.

2.6 Data Analysis

Regression analysis was used to assess the effect of hospital-level ED demand rates on ED throughput times and ED discharge disposition for pediatric psychiatric patients. Covariate categories with small sample sizes were collapsed (e.g., race, insurance, and mode of arrival). For instance, the rare triage acuity of "Immediate" was combined with "Urgent." Observations with missing data in any of the included covariates were dropped prior to regression analyses. Linear regression was used to estimate throughput times. Logistic regression was used to model ED disposition in which admits were combined with transfers and compared to the likelihood of discharge; combining admits with transfers was appropriate given differences in the resources for accommodating pediatric psychiatric cases in academic versus community hospitals. Multinomial models assessing each of the three dispositions separately are included in the supplementary materials for reference. To facilitate interpretation, average marginal effects (AMEs) giving differences in predicted probability are provided for the logistic regression. Because the academic teaching hospital had greater resources including on-site pediatric psychiatric inpatient beds, we investigated differences in effects between academic and community ED sites for our hospital-level measures using interactions between an academic site indicator with the three demand rates and the ED occupancy rate. Analyses were conducted using Stata version 15.0 (College Station, TX: Stata Corp LLC).

3. RESULTS

3.1 Descriptive Assessment of Pediatric Psychiatric ED Visits

Within our sample of 1,151,396 ED visits, 13.59% were pediatric visits and 19.59% were psychiatric visits. We identified 14,092 pediatric psychiatric visits for children aged 5-17 as our analytic sample, which comprised 9.00% of pediatric visits and 6.25% of psychiatric visits. The average age of our sample was 13 years (SD 3.24) and 49.05% of patients

were female. Most pediatric psychiatric patients were White/Caucasian, insured through Medicaid, arrived in the afternoon or evening via car/vehicle, and were discharged home from the ED (Table 1). Of note, pediatric psychiatric patients had significantly different distributions of triage acuity scores, modes of arrival, and discharge dispositions than other patient groups (Table 1). Pediatric psychiatric patients had a higher frequency of being assigned an "emergent" acuity score compared to their non-psychiatric pediatric peers ($X^2(4)=0.00019$, $p<0.001$) and adult psychiatric patients ($X^2(4)=0.0035$, $p<.001$). They had a higher frequency of ambulance utilization compared to non-psychiatric pediatric patients ($X^2(7)=0.00013$, $p<0.001$), but lower than adult psychiatric patients ($X^2(7)=0.00042$, $p<0.001$). They had a higher frequency of admission than non-psychiatric pediatric patients ($X^2(6)=0.0089$, $p<0.001$) and a higher frequency of discharge than adult psychiatric patients ($X^2(6)=0.0070$, $p<0.001$).

3.2 Descriptive Assessment of Pediatric Psychiatric Diagnoses

Among the 14,092 pediatric psychiatric visits, the most common diagnostic categories were neurodevelopmental disorders (58.52%), anxiety and fear-related disorders (31.24%), depression (27.89%), and suicide/intentional self-harm (22.37%); 44.88% of visits were for more than one category of psychiatric ICD-10-CM code discharge diagnosis (Table 2). Neurodevelopmental disorders, including autism spectrum disorder, attention deficit hyperactivity disorder, and intellectual disabilities, was the most frequent category in patients younger than 16 years including 5-8 year-olds. Of the 8,246 visits with a neurodevelopmental code, 4,890 visits (59.30%) had only the neurodevelopmental code; the remaining 40.70% had at least one other psychiatric comorbidity. Anxiety disorders were most prevalent in children 16-years and older. Depression was most prevalent in children 13-years and older. Suicide and intentional self-harm were most prevalent in 13-15 year-olds, which was the modal age category for this sample.

3.3 Descriptive Analysis of Hospital-Level Demand Rates and Throughput Times

The ED sites in our sample had a mean of 176 ED visits per day (all ages and diagnoses), with a range of 47 to 236 visits per day per hospital site (Table 3). On average, 1.26% of those visits were pediatric psychiatric visits (range: 0.28% to 2.41% across sites); sites A and B contributed most of the pediatric psychiatric visits. The percentage of non-psychiatric pediatric visits ranged from 4.21% to 18.29% and the percentage of adult psychiatric visits ranged from 11.16% to 23.17% across sites. Site A saw the largest proportion of psychiatric visits. Site C saw the lowest proportion of pediatric visits (Table 3). The median LOS for pediatric psychiatric visits was 4.16 hours, while the mean LOS was 21.61 hours (SD 56.64). LOS varied by ED disposition status. The median LOS for admitted patients was 9.37 hours, compared to 32.30 hours for transferred patients, and 3.14 hours for patients who were discharged home. The median wait time was 0.85 hours (roughly 50 minutes) while the mean wait time was 1.29 hours (SD 1.44). The median boarding time, which we reported only for patients who were admitted or transferred, was 17.96 hours (range: 7.92 to 28.41 hours across sites), while the mean boarding time was 35.71 hours (SD 61.43) (Table 3).

3.4 Linear Regression Models of Throughput Times

Regression coefficients and standard errors are presented in Table 4. Each ED demand coefficient represents the change in throughput time in hours associated with a 1 unit increase in the variable, while controlling for all other variables in the model. For example, at non-academic community ED sites, a one percentage point increase in the proportion of ED visits that were non-psychiatric pediatric visits predicted an increase in boarding time of 1.06 hours (95% CI: 0.20-1.92) for admitted and transferred patients, all else held equal. The academic partial effect coefficients represent the difference in effect size between the academic and community ED sites. For example, a one percentage point increase in the proportion of ED visits that were pediatric psychiatric visits predicted increased length of stay at community sites by 0.38 hours (95% CI: −0.50 to 1.25) and at the academic site by 3.64 hours (95% CI: 2.04-5.23), all else held equal, and these effects were significantly different from one another. Demand rates with significant differences between site types were further tested to see if the linear combination of partial and full effect coefficients were significant for academic sites (Table 4).

For LOS, partial effects indicated that the effect of adult psychiatric demand was significantly lower, and the effect of pediatric psychiatric demand was significantly higher, at academic compared to community sites. Despite this, the effect of adult psychiatric demand on LOS was not significant for either academic or community sites, and the effect of pediatric psychiatric demand on LOS was only significant for the academic site (Table 4). Ultimately, the only demand rate that was significantly associated with LOS was the pediatric psychiatric demand rate at the academic site, which indicated that a one percentage point increase in the pediatric psychiatric demand rate would increase LOS by 3.64 hours (95% CI: 2.04-5.23), all else held equal.

For wait time, partial effects indicated that the effects of non-psychiatric pediatric demand and pediatric psychiatric demand were both significantly higher at the academic site compared to community sites. The total effect of non-psychiatric pediatric demand was only significant at the academic site and not at the community sites. A one percentage point increase in the non-psychiatric pediatric demand increased wait times by 0.04 hours (95% CI: 0.02-0.05) at the academic site, all else held equal. Adult psychiatric demand did not have a significant effect on wait time at either site type. The effect of pediatric psychiatric demand was significant at the academic site, but not at community sites. At the academic site, a one percentage point increase in pediatric psychiatric demand increased wait times by 0.11 hours (95% CI: 0.07-0.15), all else held equal. Of note, the effect of ED occupancy on wait times was significant for both academic and community sites; however, the effect was not significantly different between the academic and community sites.

For boarding time, there were no significant differences in effects between academic and community sites. The relationship between non-psychiatric pediatric demand and boarding time was significant only at community sites with a one percentage point increase in non-psychiatric pediatric demand increasing boarding time by 1.06 hours (95% CI: 0.20-1.92); the effect was not significant at the academic site. The relationship between pediatric psychiatric demand and boarding time was significant only at the academic site, with a one

percentage point increase in pediatric psychiatric demand increasing boarding time by 5.50 hours (95% CI: 2.91-8.09); the effect was not significant at community sites.

Throughput times for pediatric psychiatric patients were also significantly associated with patient-level factors, including insurance, mode of arrival, arrival time, triage acuity, neurodevelopmental comorbidities, and discharge disposition (Table 4). Patients with commercial insurance, Tricare, or Medicare had significantly shorter LOS and boarding times compared to Medicaid patients. Patients arriving via ambulance or EMS had shorter wait times and boarding times compared to patients who walked in; patients who arrived with police had a significantly longer LOS and boarding time. Throughput times, especially wait times, were significantly shorter for patients who avoided evening arrivals. Presence of a neurodevelopmental comorbidity extended LOS and boarding times by over ten hours compared to patients without a comorbid ICD-10-CM code. Patients who needed to be transferred to another facility experienced a 14-hour increase in LOS compared to those who were discharged.

Higher acuity patients experienced longer throughput times; an effect that grew stronger as acuity increased. Patients assigned an acuity level of “emergent” saw a 34-hour increase in LOS and a 52-hour increase in boarding times. The magnitude of these coefficients led us to explore differences between academic and community hospitals with regards to the effect of triage acuity scores on throughput times (Supplementary Table 2). Addition of the triage acuity interaction with academic status did not alter our main findings. Interaction coefficients were significant for all three throughput times, indicating differences between academic and community sites. For LOS, the effect of acuity was larger at the academic site, with “emergent” patients having an additional increase in LOS of 12 hours compared to community sites. In contrast, the effect of triage acuity on boarding time was smaller at the academic site, with “emergent” patients seeing a 24-hour decrease in boarding times compared to patients at community sites.

3.5 Logistic Model of Disposition Status (Admission or Transfer versus Discharge)

AMEs, standard errors, and 95% confidence intervals for our two-outcome model predicting ED discharge versus admission/transfer are presented in Table 5. AMEs can be interpreted as the proportional increase in the likelihood of an outcome associated with a small increase in the explanatory variable, while controlling for all other variables in the model [25]; our discussion multiplies them by 100 so the interpretation is a percentage point difference. AMEs for academic and community sites were calculated and interpreted separately. For example, a small increase in non-psychiatric pediatric demand decreased the likelihood of admission/transfer by 0.31 percentage points (95% CI: −0.57 to −0.06) at community sites and by 0.36 percentage points (95% CI: −0.69 to −0.03) at the academic site, all else held equal (Table 5). An alternative 3-outcome multinomial logistic model predicting admissions, transfers and discharges separately is presented in Supplementary Table 3. For community sites, the only ED demand measure with a significant effect was non-psychiatric pediatric demand; when compared to the 3-outcome model in Table S3, the demand rate significantly predicted discharge, but not admission or transfer. At the academic site, both non-psychiatric pediatric demand and pediatric psychiatric demand had significant AMEs. A small increase

in pediatric psychiatric demand increased the likelihood of discharge and decreased the likelihood of admission. Overall, AMEs for the different ED demand measures were very small.

Patient-level explanatory variables that had a significant association with the likelihood of admission/transfer or discharge included patient sex, race, insurance, mode of arrival, arrival time, triage acuity, and neurodevelopmental comorbidities. Based on the results from the two-outcome model, male patients had a 2.75 percentage point (95% CI: −4.25 to −1.25) lower likelihood of admission/transfer compared to females, African American patients had a 1.92 percentage point (95% CI: −3.66 to −0.17) lower likelihood of admission/transfer compared to White patients, and patients with no listed insurance had a 10.51 percentage point (95% CI: −13.72 to −7.30) lower likelihood of admission/transfer compared to patients with Medicaid (Table 5). Patients who arrived via ambulance or with police had higher likelihoods of admission/transfer and lower likelihoods of discharge compared to patients who walked in. Patients who arrived overnight were more likely to be admitted/transferred compared to patients who arrived in the evening. Patients with higher levels of acuity were more likely to be admitted or transferred and less likely to be discharged. Patients with an acuity level of “emergent” had a 44.46 percentage point (95% CI: 42.46-46.47) increased likelihood of admission/transfer compared to patients with “non-urgent” acuity levels. Patients with a neurodevelopmental comorbidity were 2.68 percentage points (95% CI: −4.24 to −1.12) less likely to be admitted/transferred compared to those without a comorbidity, all else held equal (Table 5).

Table S3 offers additional insight in predicting admissions versus transfers separately. Based on the three-outcome model, arrival via ambulance significantly increases the likelihood of admission while arrival via police significantly increases the likelihood of transfer. Presence of a neurodevelopmental comorbidity significantly decreases the likelihood of being transferred but has minimal effect on the likelihood of admission when predicted separately. Additionally, patient age was not identified as a significant explanatory variable in the two-outcome model, but the three-outcome model shows that it effects the likelihood of being transferred. The youngest age group of 5-8 years had 3.55 percentage point (95% CI: 0.79-6.32) higher likelihood of being discharged and a 4.71 percentage point (95% CI: −6.81 to −2.61) lower likelihood of being transferred compared to the oldest age group of 16-17 years (Table S3).

4. DISCUSSION

ED providers and staff have anecdotally reported the impact of increased psychiatric utilization on the process of care [7]. Using EMR data from ED visits at seven community and one academic ED sites within a single public healthcare system in NC, our goal was to examine the relationship between increased ED demand and two outcomes: ED throughput times and patient discharge disposition. We hypothesized that increased demand would increase throughput times due to the burden placed on limited ED resources by increased patient volume. We found limited support for this hypothesis. For community ED sites, demand rates were not significantly associated with increased LOS or wait times, but boarding times increased significantly with increased non-psychiatric pediatric

demand. For the academic ED site, LOS and boarding times increased significantly with increased pediatric psychiatric demand, and wait times increased significantly with both non-psychiatric and psychiatric pediatric demand. Increased ED occupancy significantly increased wait times at all sites. While the magnitude of increase was not clinically relevant, the relationship makes logical sense; wait times should increase when the ED is busier than average.

Pediatric demand (both psychiatric and non-psychiatric) was more important in predicting throughput times than adult psychiatric demand. Existing literature has established the importance of having psychiatric resources in the ED, particularly in-person psychiatric services [26-28]. To help pediatric psychiatric patients connect with treatment services sooner, the focus may need to shift to supplying pediatric resources in the ED. The American Academy of Pediatrics recommends the presence of appropriate resources and staff to care for pediatric patients in the ED, particularly a physician and/or nurse pediatric emergency care coordinator [29]. Surveys have shown that approximately half of EDs nationally lack this resource [30]. While hiring additional staff may not be an option for EDs with low pediatric volumes, alternatives exist. Sites with pediatric inpatient services may work with the inpatient team to provide consultations in the ED. Alternatively, the use of telemedicine services has grown in the ED setting [31], and services for pediatric patients are being made available [32].

We also examined patient-level factors that influenced throughput times. Patients with access to private insurance had shorter LOS and boarding times compared to patients with Medicaid. Results from concurrent interviews suggest that insurance status influences the identification of outpatient and inpatient resources for patients prior to discharge [7]. Arrival with an emergency medical service (EMS) decreased wait times and boarding times. This may have been due to the completion of an initial evaluation by EMS and/or avoidance of ED registration and triage due to mode of arrival. Arrival with police prolonged LOS and boarding time, potentially due to patient aggression or violence, which may have prompted the police to be called initially. Concurrent interviews support that patient aggression and/or violence makes it difficult to find inpatient placement and may prolong ED stays [7]. This same pattern holds true for patients with a neurodevelopmental comorbidity. Patient arrival time reflects both ED staffing and ED volume. The ED is busiest in the evenings, resulting in longer wait times. Meanwhile, overnight arrivals tend to have shorter LOS and boarding times, in part because psychiatric services are often not available overnight and patients may be discharged or admitted/transferred by the medicine team without waiting for a psychiatric evaluation [7]. High acuity patients have longer throughput times. They are more likely to need inpatient care, which requires waiting for additional psychiatric evaluation and bed placement. This pattern also holds for patients who are transferred, since they must wait both for a bed and transportation to the facility. Our results corroborate the practical knowledge shared with us through our parallel qualitative study, as well as existing studies on factors that affect ED boarding times for psychiatric patients [7,33,34].

Our second outcome of interest was discharge disposition. We hypothesized that demand rates would not be associated with the likelihood of disposition, since disposition decisions should be made based on the clinical needs of the patient. While we did find statistically

significant AMEs for certain demand rates, no AMEs indicated more than a 1 percentage point increase in the likelihood of admission, discharge, or transfer. In comparison to the patient-level factors included in the model, the ED demand rates had a minimal effect. What mattered most in predicting disposition status was patient age, sex, insurance coverage, mode of arrival, arrival time, triage acuity, and neurodevelopmental comorbidities. We learned through our interviews that these are key factors in finding inpatient bed placement, and the importance of patient acuity aligns with our hypothesis that patient clinical needs should dictate disposition status [7]. Despite appropriate discharge disposition being the goal of ED-based care, the availability of appropriate inpatient and outpatient services within the local community is not within the control of the ED. Pediatric psychiatric work force shortages [35,36] and inpatient bed closures are issues that must be addressed through state-level policy change rather than changes to ED protocols. Our results make clear that increasing access to pediatric psychiatric resources outside the ED, specifically for patients with high acuity needs (i.e., suicidality) and neurodevelopmental diagnoses, will benefit the patients currently relying on the ED for psychiatric care.

5. LIMITATIONS

Our investigation utilized electronic medical record data from a diverse sample of EDs across NC. Secondary data are generally limited in their ability to account for much variation in the dependent variable of interest. For example, we had data on ED visits, but previous research has also controlled for local inpatient capacity when evaluating throughput times in the ED [3]. Additionally, we could not differentiate between medical and psychiatric admissions from our data, which would be useful in evaluating ED outcomes among our target patient population in the future. Future work must also expand upon our limited sample. Despite including 8 ED sites, only one was an academic teaching hospital. Because of the identified differences between academic and community sites, a larger sample of academic sites is needed for more robust comparison. We were also surprised by the prevalence of neurodevelopmental disorders in our sample of pediatric psychiatric patients (58.52%); among all pediatric visits (psychiatric and non-psychiatric combined N=156,532) there was a 5.67% prevalence of neurodevelopmental disorders, which is in line with national prevalence estimates [37]. Future work should expand our modeling techniques as well. We modeled throughput times using linear regression, which assigns a single coefficient to the relationship between a throughput time and a covariate. This does not account for situations where the relationship changes with respect to the outcome. For example, pediatric demand may no longer have a significant impact on LOS, once LOS exceeds 48 hours. Thus, it may be useful to consider alternative modeling techniques such as discrete time survival analysis, which allows coefficients to change as time elapses [20]. Despite these limitations, we are reassured by the alignment of our quantitative results with the qualitative results from our concurrent study [7].

6. CONCLUSION

Frontline ED providers and staff have anecdotally experienced the impact of increased ED demand on care for pediatric psychiatric patients in the ED [7]. This study was designed to quantify the relationship between ED demand measures, throughputs, and outputs for

these patients. We found that increased pediatric demand increased certain throughput times. We also found that ED demand did not influence patient disposition as strongly as patient-level factors. These patient-level factors such as age, sex, insurance, and triage acuity, influence disposition planning within the ED, and are a crucial component of the throughput process. Thus, we have evidence that ED demand (input) does effect ED throughput, and ED throughput does affect ED disposition (output) for our sample. Our results provide a foundation for crafting a version of the Input-Throughput-Output model specifically for pediatric psychiatric patients. Our results also suggest that in order to optimize the throughput process, we must consider patient-level factors, not just ED-level factors. More research is needed to validate these findings across a larger sample of hospitals and states and apply these findings to further the expansion of psychiatric resources for these patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Emergency Department Visit Characteristics by Patient Type (2018-2020)

Visit Type	All ED Visits	Non-Psych Ped ED Visits	Adult Psych ED Visits	(Analysis Sample) Ped Psych ED Visits
N	1,151,396	142,440	211,488	14,092
Mean Age (SD)	44.30 (23.98)	6.90 (5.62)	50.92 (18.97)	13.00 (3.24)
Age (%)				
0-4	5.42	43.80	-	-
5-8	2.44	18.51	-	12.16
9-12	2.19	15.16	-	25.60
13-15	1.92	12.01	-	35.18
16-17	1.63	10.54	-	27.06
18+	86.41	-	100.00	-
Female (%)	56.55	49.13	63.65	49.05
Race (%)				
Am Indian/AK Native	0.43	0.39	0.57	0.31
Asian	0.70	0.87	0.41	1.09
African American	33.01	34.83	23.56	27.19
Native Hawaiian/PI	0.07	0.10	0.04	0.10
White/Caucasian	56.60	40.90	71.40	58.10
Other	9.19	22.91	4.02	13.21
Hispanic/Latino (%)	8.58	21.48	3.77	11.67
Insurance (%)				
Commercial	21.33	16.29	17.87	24.12
Medicaid	21.22	69.00	18.67	64.16
Medicare	29.72	0.03	41.92	0.06
State Health Plan	3.12	2.51	2.85	3.94
Tricare	1.55	2.75	1.14	2.97
Other	2.58	1.12	1.76	0.63
None Listed	20.47	7.96	15.79	4.12
Triage Acuity (%)				
Emergent	15.85	6.42	28.31	44.30
Immediate	1.13	0.50	1.50	0.62
Urgent	53.62	35.52	55.18	29.50
Less Urgent	26.83	51.54	13.76	23.38
Non-Urgent	2.57	6.01	1.25	2.20
Mode of Arrival (%)				
Ambulance	21.61	6.50	32.47	11.17
Car/Vehicle	76.29	92.72	62.61	78.38
Medical Flight	0.18	0.22	0.18	0.28
On Foot	0.42	0.18	0.59	0.17
Police	0.83	0.08	3.09	9.63

Visit Type	All ED Visits	Non-Psych Ped ED Visits	Adult Psych ED Visits	(Analysis Sample) Ped Psych ED Visits
Public Transport	0.11	0.02	0.23	0.05
ED Transfer	0.13	0.07	0.24	0.08
Other	0.43	0.22	0.57	0.24
Arrival Time (%)				
Overnight	10.37	10.19	10.86	7.93
Morning	26.28	19.95	25.03	18.20
Afternoon	35.32	31.33	37.19	36.62
Evening	28.03	38.54	26.92	37.26
Weekend Visits (%)	27.51	30.76	26.78	23.79
Discharge Disposition (%)				
Admit	21.12	4.61	39.07	14.35
Discharge	75.29	92.61	56.30	71.29
Transfer	1.96	2.11	2.62	12.61
ED to ED Transfer	0.21	0.16	0.38	0.34
Obs/ED Psych Service	0.08	-	0.31	1.07
Left/Eloped	1.24	0.47	1.27	0.35
Died	0.10	0.03	0.05	-

Note: Patient groups (columns 2-4) are mutually exclusive; data for non-psychiatric adult visits are not shown in a separate column but are included in all ED visits (column 1). Ages 0-4 are not included in column 4 (the pediatric psychiatric visit group). Race/ethnicity groups: Am. Indian/AK Native = American Indian or Alaskan Native, PI = Pacific Islander, Psych = Psychiatric. Other abbreviations: ED = Emergency Department, Obs = Observation, Ped = Pediatric.

Table 2.

Patient Analysis Sample: Pediatric Psychiatric Diagnoses by Age Group (2018-2020)

Patient Age	5-8 Years	9-12 Years	13-15 Years	16-17 Years	Total
Ped Psych Visits (N)	1,713	3,608	4,958	3,813	14,092
Diagnostic Categories (%)					
Schizophrenia/Psychotic	0.53	1.72	2.44	3.83	2.40
Depression	2.16	17.90	35.90	38.47	27.89
Bipolar/Other Mood	4.09	8.51	11.82	12.59	10.24
Anxiety/Fear-related	11.73	22.03	35.28	43.46	31.24
OCD-related	0.76	1.08	1.96	1.99	1.60
Trauma/Stress-related	6.48	11.61	11.44	11.64	10.94
Disruptive/Conduct	10.45	13.91	12.95	9.70	12.01
Personality-related	0.47	0.53	1.19	1.84	1.11
Eating/Feeding	0.35	0.89	1.75	2.36	1.53
Somatic	0.12	0.06	0.16	0.18	0.13
Suicide/Intentional Self-Harm	4.55	18.02	30.11	24.42	22.37
Neurodevelopmental	85.76	73.09	51.82	41.20	58.52
Miscellaneous	1.28	1.72	1.98	2.52	1.97
Visits w/ Multiple Categories (%)	17.28	39.27	52.56	52.58	44.88

Notes: Diagnostic categories are not mutually exclusive. The somatic category includes diagnosis such as hypochondria and factitious disorder. OCD = Obsessive Compulsive Disorder, Ped = Pediatric, Psych = Psychiatric.

Table 3.

Average Daily ED Demand Rates and Throughput Times in Hours by ED Site from 2018-2020

Site ID	Site A*	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Overall
All ED Visits (N)	245,868	214,594	196,381	144,149	135,584	84,474	82,411	47,935	1,151,396
Ped Psych Visits (N)	5,907	3,437	513	1,248	1,192	475	897	423	14,092
Average Daily ED Demand Rates - Mean									
Avg. Daily EDVisits	236.28	204.41	185.06	181.91	171.42	80.68	77.84	46.58	176.50
Ped Psych %	2.41%	1.62%	0.28%	0.87%	1.05%	0.62%	1.12%	0.92%	1.26%
Non-Psych Ped %	14.85%	14.48%	4.21%	16.20%	11.89%	9.04%	13.46%	18.29%	12.40%
Adult Psych %	23.17%	19.89%	17.72%	12.65%	16.26%	17.83%	16.07%	11.16%	18.10%
Throughput Times in Hours for Pediatric Psychiatric ED Visits – Median [Mean] (Min, Max)									
ED Length of Stay	6.33 [28.34] (0.31, 1474.78)	3.07 [16.22] (0.23, 888.43)	3.48 [16.57] (0.36, 461.96)	3.57 [27.20] (0.25, 999.72)	3.66 [17.41] (0.17, 518.06)	3.57 [13.95] (0.37, 260.36)	2.38 [9.09] (0.41, 239.78)	2.39 [7.84] (0.44, 280.14)	4.16 [21.61] (0.17, 1474.78)
ED Wait Time	0.85 [1.35] (0.00, 18.35)	0.75 [1.06] (0.02, 18.35)	0.55 [0.93] (0.00, 10.32)	0.68 [1.05] (0.02, 17.02)	1.85 [2.23] (0.02, 15.37)	1.23 [1.58] (0.05, 10.22)	0.78 [1.10] (0.03, 6.52)	0.72 [1.01] (0.00, 7.48)	0.85 [1.29] (0.00, 18.35)
ED Boarding Time (Patients Admitted or Transferred)	16.46 [35.31] (0.02, 876.91)	21.22 [37.95] (0.40, 887.60)	22.71 [32.85] (0.00, 235.82)	28.41 [51.17] (1.27, 931.91)	18.91 [30.19] (0.04, 448.77)	17.96 [35.71] (0.00, 931.91)	7.92 [21.37] (0.08, 258.93)	18.70 [28.27] (0.23, 197.11)	7.74 [21.14] (0.16, 278.72)

Notes: The Avg. Daily Visit count represents the average number of ED visits per day per ED based on all ED visit types. Wait times were truncated at the 99th percentile of 18.35 hours. All throughput times are reported in hours.

*Site A was an academic teaching hospital. Avg. = Average, Ped = Pediatric, Psych = Psychiatric.

Table 4.

Results from Linear Regression Model of ED Throughput Times for Pediatric Psychiatric ED Visits from 2018-2020

Throughput Times	ED Length of Stay		ED Wait Time		ED Boarding Time (Admits & Transfers Only)	
Explanatory Variables	**Coefficient**	**Robust SE**	**Coefficient**	**Robust SE**	**Coefficient**	**Robust SE**
Community Site Total Effect						
Non-Psych Ped Daily Demand	0.111	0.145	0.001	0.003	1.058 *	0.439
Adult Psych Daily Demand	0.113	0.119	0.002	0.003	0.392	0.328
Ped Psych Daily Demand	0.376	0.447	0.006	0.013	2.092	1.264
ED Occupancy Rate	0.012	0.037	0.009 ***	0.001	−0.006	0.104
Academic Site Partial Effect						
Non-Psych Ped Daily Demand	−0.221	0.325	0.034 ***	0.007	−0.192	0.612
Adult Psych Daily Demand	−0.586 *	0.295	−0.003	0.007	−0.597	0.492
Ped Psych Daily Demand	3.259 ***	0.926	0.103 ***	0.024	3.404	1.828
ED Occupancy Rate	−0.045	0.087	0.001	0.002	−0.031	0.157
Academic Site Total Effect						
Non-Psych Ped Daily Demand	−0.110	0.305	0.035 ***	0.007	0.866	0.577
Adult Psych Daily Demand	−0.472	0.274	−0.001	0.007	−0.205	0.363
Ped Psych Daily Demand	3.635 ***	0.813	0.110 ***	0.020	5.496 ***	1.321
ED Occupancy Rate	−0.032	0.079	0.010 ***	0.002	−0.037	0.117
Age						
5-8	−0.913	1.570	−0.020	0.042	3.639	5.597
9-12	1.731	1.411	−0.003	0.036	3.266	2.943
13-15	−0.122	1.103	−0.042	0.032	−1.732	2.143
16-17	Reference	Reference	Reference	Reference	Reference	Reference
Sex (Male)	−0.418	1.052	−0.025	0.027	2.778	2.021
Race						
White or Caucasian	Reference	Reference	Reference	Reference	Reference	Reference
African American	0.315	1.243	0.053	0.029	−2.874	2.731
Other	1.993	2.348	−0.019	0.040	−8.638 **	2.627
Hispanic/Latino	−4.085	2.178	0.014	0.045	3.049	3.176
Insurance						
Commercial	−4.387 ***	1.162	0.044	0.029	−6.462 **	2.229
Medicaid	Reference	Reference	Reference	Reference	Reference	Reference
Tricare/Medicare/Other	−6.552 ***	1.806	−0.072	0.054	−10.582 *	4.485
None Listed	0.180	2.251	0.042	0.064	−8.400	4.620
Mode of Arrival						
Ambulance/Flight	0.533	1.397	−0.376 ***	0.035	−4.923 *	2.383
Walk-In	Reference	Reference	Reference	Reference	Reference	Reference

Throughput Times	ED Length of Stay		ED Wait Time		ED Boarding Time (Admits & Transfers Only)	
Explanatory Variables	**Coefficient**	**Robust SE**	**Coefficient**	**Robust SE**	**Coefficient**	**Robust SE**
Police	23.666***	2.853	0.025	0.056	13.612***	3.352
Arrival Time						
Overnight (12am-5:59am)	−3.565*	1.781	−0.329***	0.039	−7.580*	3.039
Morning (6am-11:59am)	−2.729*	1.194	−0.372***	0.032	−3.654	2.944
Afternoon (12pm-5:59pm)	−0.261	1.152	−0.177***	0.029	−0.675	2.449
Evening (6pm-11:59pm)	Reference	Reference	Reference	Reference	Reference	Reference
Weekend Visits	−1.259	1.151	−0.170***	0.026	−0.401	2.993
Acuity						
Emergent	33.635***	1.579	0.438***	0.061	51.625***	11.003
Urgent	6.489***	0.869	0.200***	0.057	20.624	10.742
Less Urgent	1.741**	0.601	0.091	0.056	20.938	10.982
Non-Urgent	Reference	Reference	Reference	Reference	Reference	Reference
Neurodev. Comorbidity	11.297***	1.171	−0.008	0.031	10.700***	2.102
Discharge Disposition						
Admit	−3.229	1.679	−0.046	0.041	-	-
Discharge	Reference	Reference	Reference	Reference	-	-
Transfer	13.992***	2.087	0.074	0.049	-	-
Hospital Site						
Site A	Reference	Reference	Reference	Reference	Reference	Reference
Site B	−21.989	12.451	0.673	0.350	−12.989	21.509
Site C	−18.120	12.338	0.512	0.351	5.511	21.371
Site D	−18.633	12.541	0.598	0.346	−1.600	22.184
Site E	−22.345	12.244	1.882***	0.349	−17.023	20.782
Site F	−27.693*	12.295	1 192***	0.352	−16.545	21.147
Site G	−23.458	12.300	0.797*	0.350	−13.436	20.579
Site H	−23.831	12.322	0.593	0.352	−25.624	21.139
Mar-Dec 2020 (PHE)	−1.437	2.852	−0.160*	0.065	−5.239	5.372
Visit Year						
2018	Reference	Reference	Reference	Reference	Reference	Reference
2019	3.730***	0.975	−0.010	0.030	7.769**	2.470
2020	10.716***	2.430	0.085	0.056	18.692***	4.789
Constant	3.878	11.566	−0.547	0.327	−35.400	21.207
N	12,487		12,487		3,630	
R^2	0.152		0.110		0.100	

*p<0.05

**p<0.01

*** p<0.001

Notes: Academic ED Site Partial Effects are the coefficients resulting from interaction terms between the ED demand variables and an academic site indicator. Academic ED Site Total Effects are the linear combination of the partial effects for academic sites. The main academic ED site indicator was not included in the model due to collinearity with the hospital site indicators. The ED Occupancy Rate variable was calculated by dividing the daily ED volume by the historical daily average ED volume at the same ED site on the same day of the week over the 30 days prior to the observed visit date. The majority of patients in the Tricare/Medicare/Other insurance group had Tricare. SE=Standard Error, Neurodev = Neurodevelopmental, PHE=Public Health Emergency (COVID-19 Pandemic)

Table 5.

Marginal Effects from Logit Model Predicting ED Disposition Among Pediatric Psychiatric ED Visits from 2018-2020

Explanatory Variables	Admission/Transfer versus Discharge		
	Point Estimate	Delta-Method SE	95% CI
	Average Marginal Effects For Community Sites		
Non-Psych Ped Daily Demand	−0.003 *	0.001	[−0.006, −0.001]
Adult Psych Daily Demand	−0.002	0.001	[−0.004, 0.000]
Ped Psych Daily Demand	−0.000	0.005	[−0.011, 0.010]
ED Occupancy Rate	0.001	0.000	[−0.000, 0.001]
	Average Marginal Effects For Academic Sites		
Non-Psych Ped Daily Demand	−0.004 *	0.002	[−0.007, −0.000]
Adult Psych Daily Demand	0.000	0.002	[−0.003, 0.003]
Ped Psych Daily Demand	−0.009 *	0.004	[−0.018, −0.001]
ED Occupancy Rate	0.001	0.001	[−0.000, 0.002]
	Average Marginal Effects Across All ED Sites		
Academic Indicator	0.035	0.094	[−0.149, 0.220]
Age			
5-8	−0.025	0.0 14	[−0.053, 0.003]
9-12	−0.018	0.010	[−0.038, 0.001]
13-15	0.016	0.009	[−0.001, 0.033]
16-17	Reference	Reference	Reference
Sex (Male)	−0.028 ***	0.008	[−0.043, −0.013]
Race			
White or Caucasian	Reference	Reference	Reference
African American	−0.019 *	0.009	[−0.037, −0.002]
Other	−0.016	0.013	[−0.042, 0.009]
Hispanic/Latino	0.009	0.014	[−0.019, 0.037]
Insurance			
Commercial	0.008	0.009	[−0.009, 0.025]
Medicaid	Reference	Reference	Reference
Tricare/Medicare/Other	0.051 **	0.019	[0.013, 0.089]
None Listed	−0.105 ***	0.016	[−0.137, −0.073]
Mode of Arrival			
Ambulance/Flight	0.079 ***	0.011	[0.058, 0.100]
Walk-In	Reference	Reference	Reference
Police	0.050 ***	0.012	[0.027, 0.073]
Arrival Time			
Overnight (12am-5:59am)	0.067 ***	0.014	[0.040, 0.094]
Morning (6am-11:59am)	−0.001	0.010	[−0.022, 0.019]

Explanatory Variables	Admission/Transfer versus Discharge		
	Point Estimate	Delta-Method SE	95% CI
Afternoon (12pm-5:59pm)	0.018*	0.008	[0.002, 0.034]
Evening (6pm-11:59pm)	Reference	Reference	Reference
Weekend Visits	−0.008	0.009	[−0.026, 0.010]
Acuity			
Emergent	0.445***	0.010	[0.425, 0.465]
Urgent	0.200***	0.010	[0.181, 0.219]
Less Urgent	0.020*	0.008	[0.004, 0.036]
Non-Urgent	Reference	Reference	Reference
Neurodev. Comorbidity	−0.027**	0.008	[−0.042, −0.011]
Hospital Site			
Site A	Reference	Reference	Reference
Site B	−0.168	0.095	[−0.354, 0.017]
Site C	−0.174	0.092	[−0.354, 0.006]
Site D	−0.087	0.100	[−0.283, 0.109]
Site E	−0.064	0.101	[−0.262, 0.135]
Site F	−0.151	0.096	[−0.339, 0.036]
Site G	−0.152	0.096	[−0.341, 0.037]
Site H	−0.088	0.105	[−0.293, 0.118]
Mar-Dec 2020 (PHE)	−0.029	0.017	[−0.062, 0.004]
Visit Year			
2018	Reference	Reference	Reference
2019	−0.016	0.009	[−0.034, 0.002]
2020	0.004	0.015	[−0.025, 0.034]
N	12,487		
Pseudo R^2	0.239		

*p<0.05

**p<0.01

***p<0.001

Notes: Point estimates indicate the change in the likelihood of admission/transfer compared to discharge. The ED Occupancy Rate variable was calculated by dividing the daily ED volume by the historical daily average ED volume at the same ED site on the same day of the week over the 30 days prior to the observed visit date. The logit model included interaction terms between the ED demand variables and an academic site indicator. Academic and Non-Academic site AMEs were calculated for the interacted demand variables by holding the academic indicator either equal to 1 or 0. The majority of patients in the Tricare/Medicare/Other insurance group had Tricare. CI = Confidence Interval, Neurodev = Neurodevelopmental, PHE=Public Health Emergency (COVID-19 Pandemic), SE=Standard Error.