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Use of the SONET Score to Evaluate Urgent Care Center Overcrowding

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Title Page:

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Key words: Urgent care center, Crowding, Tool, Patient care outcome

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Abstract

Objectives: To derive a tool to determine Urgent Care Center (UCC) crowding and investigate the association between different levels of UCC overcrowding and negative patient care outcomes.

Design: Prospective pilot study

Setting: Single center study in USA.

Participants: 3,565 patients that registered at UCC during the 21 day study period were included. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study. 3,139 patients were enrolled in the final data analysis.

Primary and secondary outcome measures: A crowding estimation tool (SONET: Severely overcrowded, Overcrowded, and Not overcrowded Estimation Tool) was derived using the linear regression analysis. The average length of stay (LOS) in UCC patients and the number of left without being seen (LWBS) patients were calculated and compared under the three different levels of UCC crowding.

Results: Four independent operational variables could affect the UCC overcrowding score including the total number of patients, the number of results pending patients, the number of patients in the waiting room, and the longest time a patient was stationed in the waiting room. In addition, UCC overcrowding was associated with longer average LOS (not overcrowded: 133±76min, overcrowded: 169±79min, and severely overcrowded: 196±87min, $p<0.001$) and an increased number of LWBS patients (not overcrowded: 0.28±0.69 patients, overcrowded: 0.64±.98, and severely overcrowded: 1.00±0.97).

Conclusions: The overcrowding estimation tool (SONET) derived in this study can be used to determine different levels of crowding in a high volume UCC setting. It also showed UCC overcrowding is associated with negative patient care outcomes.

Key Words: Urgent care center, Crowding, Tool, Patient care outcome

Strengths and Limitations of this study: Strengths: 1) the first prospective study on urgent care overcrowding, 2) the first study reported the link with the overcrowding and patient outcome in the urgent care setting, 3) derived a new overcrowding scoring system for urgent care crowding estimation which has not reported before. Limitations: 1) single center study requiring external validation; 2) special population selection could lead to selection bias.

Introduction

As the demand for real time access to care increases, Emergency Department (ED) overcrowding has become more and more common in recent years.[1,2] One of the solutions to ED overcrowding is to reduce the numbers of low acuity patients presenting for care.[3,4] It is reported that hospitals are adding their own or partnering with existing non-hospital based urgent care centers (UCCs) to offset ED overcrowding.[5,6] According to the report from the Urgent Care Association of America, the number of UCCs has increased over 12% within 3 years and it has provided care to over 3 million patient visits every week.[7] UCCs are now recognized as providing convenient, less expensive access to care as compared to that experienced at an average ED.

In primary care settings, the gap of available providers is expected to continue to grow. The primary care setting workload is expected to increase by 29% from 2005 to 2025. Meanwhile the number of primary care providers is expected to grow by only 2%-7% during the same timeframe.[8,9] Given the prediction that both ED and primary care settings will continue to be resource constrained, a proactive approach to anticipating UCC overcrowding will offer

a means to mitigate patient care risk. To the best of our knowledge, no UCC overcrowding estimation tool has been reported to date.

Accurately estimating UCC overcrowding will not only help reduce ED overcrowding but will also alert administrators to take action by mobilizing resources as an overcrowded condition becomes imminent thereby minimizing the risk of undesirable patient care outcomes.[10,11] The primary goal of this study is to derive a suitable tool we named SONET (Severely overcrowded – Overcrowded – Not overcrowded Estimation Tool) to evaluate overcrowding in a high volume UCC setting. A secondary goal is to determine the association between UCC overcrowding and negative patient care outcomes.

Materials and Methods

Study design and Patient population:

This was a prospective pilot study designed to derive an estimation tool to determine overcrowding status in a moderate to high volume UCC setting. This study was carried out at a publicly funded health system that has both ED and UCC at different locations within the main campus and with separate triage systems. The annual volume of the study UCC is approximately 62,000 visits. Considering no previous UCC overcrowding study reported and no historical data available for sample size estimation, the same study period used for Emergency Department overcrowding study was used in this study.[12] The John Peter Smith Health Network Institutional Review Board approved the study (IRB approval number: 110413.003ex).

All patients that registered initially at UCC were included in this study. Patients were triaged by dedicated nurses at the triage encounter point and individual patient acuity levels were then assigned by using the Emergency Severity Index (ESI). Patients with potentially higher levels of acuity (e.g. ESI 1 and 2) are routed to a physician immediately. Physician discretion is employed to determine if these patients need to transfer to ED for further emergent evaluation and treatment. Those patients at ESI levels 1 and 2 who were not sent to the ED remain in the urgent care workflow. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study.

Study protocol

This study was carried out from Feb 24, 2014 through Mar 16, 2014. During these 21 days, all physicians, advanced practice providers (APP), charge nurses, flow coordinator nurses, and triage nurses were called separately every two hours by a dedicated UCC clerk and asked to report their perception of the current UCC crowding status. The UCC clerk was blinded to this study. The perceptions of UCC overcrowding were rated on a 0-100mm visual analogue scale (VAS). UCC overcrowding was considered to be true if the score on the VAS $\geq$ 50 and was considered severely overcrowded if the score on the VAS $\geq$ 70. An average UCC overcrowding score was then calculated. Since no UCC overcrowding scale was reported before, our study overcrowding score was multiplied by a factor of 2 in order to match an ED overcrowding scale that is widely used nationally.[12] A score $\geq$100 was considered overcrowded and $\geq$140 was considered severely overcrowded. Therefore, three different crowding statuses were considered: not-overcrowded, overcrowded, and severely overcrowded.

UCC opens at 0600 and closes around 2300 during weekdays. During the weekend, UCC opens at 0600 but closes at variable times depending on the volume of patients presenting during the course of the day. UCC triage ends at 2200. Patients who present after 2200 are redirected to ED for further evaluation and treatment. UCC closes after the last patient's disposition which is usually around 2300. The perception of UCC crowding status was queried 8 times

each day during the weekdays at 0700, 0900, 1100, 1300, 1500, 1700, 1900, and 2100 separately. During the weekend, queries occurred at 0700 and then every 2 hours until UCC closed. Patients who registered between 0600 and 0700 were considered under the not-overcrowded category.

At the same time provider perceptions of UCC crowding were asked by the UCC clerk, all variables were also recorded simultaneously by that clerk who did not participate in this study. The clinical or operational variables considered to potentially affect UCC crowding were collected after discussion with a group of those with operational expertise. A scoring tool to determine UCC crowding was then derived from the study that we named SONET (Severely-overcrowded Overcrowded Not-overcrowded Estimation Tool). Additionally, 1,000 sample randomized data sets were employed to validate the study internally by using the bootstrap methods.

Variables

The total number of UCC beds was used as a constant in this study. All the other clinical or operational variables such as the total number of patients at UCC, the number of patients in the waiting room, the number of attending physicians, APPs, and nurses on duty, the number of patients with different Emergency Severity Index (ESI) levels, and the longest wait time of those patients in the waiting room at the time of scoring were also collected (see Table 1). In order to potentially apply the SONET scoring system to different UCC settings, several indices were calculated as well. The total patient index was the total number of patients at UCC divided by the number of UCC beds. The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The results pending patient index was the total number of results pending patients (e.g. patients already seen by healthcare providers at UCC and then placed in the result pending area) divided by the number of active patients (e.g. active patients were the total number of UCC registered patients less the number of patients in the waiting room). The physician index was the total number of patients at UCC divided by the number of physicians on duty. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty.

Table 1. Clinical and operational variables and indices collected in the UCC overcrowding study

Variables		
The total number of patients at UCC	The number of patients already transferred to other facilities in the past two hours	The number of physicians on duty
Total number of patients in the waiting room	The number of patients with ESI 1 or 2 transferred to other facilities in the past two hours	The number of nurses on duty
The number of patients in the results pending area	The number of patients waiting to be transferred to other facilities	The number of APPs on duty
The number of patients with different assigned acuity levels (ESI 1, 2, 3, 4, 5)	The number of patients waiting to be discharged	The number of triage nurses on duty
The number of patients with different assigned acuity levels in the waiting room (ESI 3, 4, 5)	The longest wait time among patients in the waiting room expressed in hours	
Index		
Total patient index	Results pending patient index	Waiting room patient index
Nurse index	APP index	Physician index

Abbreviations: UCC urgent care center, ESI: emergency severity index, APP: advanced practice provider. The number of patients in the results pending area refers to the number of patients that had already been seen by a healthcare provider and were awaiting results of diagnostic testing. After initial provider interview and physical

exam these patients are relocated from the exam room to the results pending area. The total patient index is the total number of patients at UCC divided by the number of UCC beds. The results pending patient index is the total number of patients residing in the results pending status (e.g. patients already seen by healthcare providers at UCC and then transitioned to the results pending area) divided by the number of active patients (e.g. active patients were the total number of patients in UCC less those patients in the waiting room). The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty. The physician index was the total number of patients at UCC divided by the number of physicians on duty.

Outcome measurement

The SONET score was derived after the study was completed and retrospectively entered into the study data. All patients during the study period were assigned to have SONET scores at the time the patients were registered in the UCC and stratified into three different crowding categories. Patients who registered at UCC with incomplete data were excluded from the study as their individual SONET scores could not be calculated.

In order to know whether UCC overcrowding potentially affects UCC operational efficiency, LOS and the number of LWBS patients were used as markers for UCC efficiency measurements. UCC LOS refers to the interval of time starting with initial UCC patient registration and ending at the point when a patient is physically discharged from the UCC track board. For LWBS patients, the LOS was calculated as the interval of time starting with initial UCC registration and ending at the point that no response to a call for further service was documented. We performed three calls to every LWBS patient in a twenty minutes interval. If no response was received after the third call, the patient was considered LWBS and the time of the first call was recorded as the documented time of no response. All patients registered for UCC services during the study period were included in the data analysis. Patient care outcomes were compared among these three groups (not-overcrowded, overcrowded, and severely overcrowded groups).

Data analysis and Statistics

A linear regression model was applied and the independent operational variables that could affect UCC overcrowding status scores were determined. Correlation coefficiency (r) was analyzed on each operational variable with its scatter plot drawn. Variables that had strong correlation ($r>0.6$) with UCC crowding were chosen for linear regression analysis. Variance inflation factor (VIF) quantifies the severity of multi-colinearity in the regression model analysis thereby providing an index to estimate whether the regression coefficient is increased due to colinearity. Operational variables with high VIF (>10) were considered as having colinearity and were therefore excluded from regression analysis.[13,14] A formula was then generated based on the regression coefficient of each independent operational variable and an UCC crowding score was calculated. A bootstrap technique that randomized 1,000 samples was used to internally validate the study score accuracy.

Considering the operational significance of determining UCC overcrowding status, the SONET score was divided into three categories: not overcrowded (score<100), overcrowded (score between 100 and 140, including 100 but not including 140), and severely overcrowded (score≥140). Patients were automatically assigned to three groups based on ED overcrowding scores at the time when a specific patient registered for services in the UCC. To compare the differences between LWBS, and LOS at UCC relative to the different UCC overcrowding status groups, analysis of variance (ANOVA) with Bonferroni correction was used to analyze differences between groups.

All statistical analysis was performed using STATA 12 (College Station, TX) and a $p<0.05$ was considered a statistically significant difference.

Results

Derivation of SONET scoring system

The prospective pilot study was performed from 0600 on Feb 24, 2014 until 1900 on Mar. 16, 2014 which included 15 weekdays and 6 weekend days. The UCC closes operations at different times during the weekends resulting in 36 data sets collected at different time points. Therefore, there were a total of 134 data sets collected resulting in a data completion rate of 85.9% (134/156). Among these 134 time points, the UCC was determined by healthcare provider perceptions to be below the not-overcrowded threshold 57.46% (77/134) of the time. The UCC was determined to be below the overcrowded threshold 26.12% (35/134) of the time and below the severely overcrowded threshold 16.42% (22/134) of the time.

Results of linear regression showed only 4 variables that can be considered independent risk factors affecting the UCC crowding status. These are total number of patients, number of results pending patients, number of patients in the waiting room, and longest wait time of patients in the waiting room. Other variables reached either no statistical significance, had no correlation with overcrowding, or had significant colinearity with a VIF (variance inflation factor) greater than 10. In order to suitably apply the tool with respect to different UCC settings, total patient index and waiting room patient index were used. Therefore a UCC crowding scoring formula (SONET) was derived and is defined as:

SONET Score = 24.5 x total patient index + 58.1 x waiting room patient index + 2.7 x number of result pending patients + 12.2 x the longest time in hours of patient in the waiting room + 32.4. (in short form: SONET Score = 24.5T+58.1WI+2.7R+12.2L+32.4 (TWIRL) where T indicates the total patients index, WI indicates the waiting room patient index, R indicates the number of results pending patients in UCC, and L indicates the longest time in hours of patients in the waiting room). SONET score ≥ 100 is considered UCC overcrowded and ≥140 is considered severely overcrowded.

Using the average perceptions of UCC crowding status among different healthcare providers as a "gold standard" demonstrated strong inter-rater reliability between the SONET scores and provider perceptions when compared within the three different crowding statuses (not overcrowded, overcrowded, and severely overcrowded, κ=0.6446). Internal validation using bootstrap methods showed similar results (data not shown).

Outcome measurement

A total of 3,565 patients were registered to receive services in the UCC during the study period. Excluding patients who had no SONET scores calculated due to incomplete collection of operational variables at the time of registration, 3,139 patients were enrolled in data analysis. The general information of these patients is shown in Table 2.

Table 2. General Information of Patients in the study

Age (year±SD)	41.97±15.57 (95%CI 41.43-42.52)
Gender (male, %)	46.70%
Level of Acuity (%, number)	
ESI1	0.16% (5)
ESI2	5.61% (176)
ESI3	24.94% (783)
ESI4	59.64% (1,872)
ESI5	8.00% (251)

unknown	1.66% (52)
Disposition (%, number)	
Discharged	89.58% (2812)
Admitted	4.17% (131)
LWBS	1.94% (61)
Average time intervals (min±SD)	
from patient arrival to triage	7.9±7.0 (95% CI 7.6-8.1)
from patient arrival to placement in an exam room	42.6±41.4 (95% CI 41.2-44.1)
from patient arrival to patient initial encounter with a healthcare provider	75.9±56.6 (95% CI 74.0-77.9)
from patient arrival to disposition (discharge vs. admit) rendered	132.5±82.7 (95% CI 129.6-135.4)
from patient arrival to patient departure from UCC	151.6±89.5 (95%CI 148.5-154.7)

In order to determine whether the UCC overcrowding status could affect UCC operational efficiency and safety, LOS and LWBS were investigated. Patients registered at UCC triage during the study period were assigned to three different UCC crowding statuses determined by SONET scores (N: not overcrowded; O: overcrowded; and S: severely overcrowded).

The average LOS at UCC under each crowding status determined by SONET reached statistically significant differences between groups. Similar results were found when patients were further subdivided into the different ESI level groups (Table 3). The more severe the crowding score in the UCC, the longer the average LOS of all patients, especially those triaged to ESI levels 3, 4, and 5. When analyzing only discharged patients, similar results were found with statistically significant differences among groups (Appendix Table). To more accurately determine the effects of UCC crowding status on delayed patient care LOS was divided into several segments. The segments were time spent at triage, wait time for an available exam room, wait time to arrival of a healthcare provider, and wait time to disposition (Table 4). The results of our study showed that the most significant delay in care occurred during the period while patients awaited an available exam room. No significant difference was noted after patients were initially seen by the healthcare providers.

Appendix Table. The average LOS of discharged patients who registered at UCC under the different crowding statuses as determined by the SONET tool.

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	133±76 (1445)	0	76±72 (35)	140±88 (335)	138±73 (952)	95±46 (120)
Overcrowded	169±79 (858) *p<0.001	0	78±61 (37) *p=1.000	172±93 (218) *p<0.001	179±72 (522) *p<0.001	138±53 (80) *p<0.001
Severely Overcrowded	196±87 (509) **p<0.001	0	69±55 (27) **p=1.000	188±99 (130) **p=0.327	211±75 (315) **p<0.001	189±83 (37) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity Index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

Table 3. The average LOS of patients who registered at UCC as a function of relative acuity status and SONET score

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	130±80 (1581)	57±67 (2)	59±56 (69)	136±95 (385)	139±73 (981)	93±47 (125)
Overcrowded	165±88 (957) *p<0.001	58±55 (3) *p=0.973	71±62 (58) *p=0.733	170±102 (242) *p<0.001	181±79 (549) *p<0.001	139±53 (87) *p<0.001
Severely Overcrowded	186±97 (601) **p<0.001		57±48 (49) **p=0.699	192±114 (156) **p=0.112	208±75 (342) **p<0.001	187±83 (39) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

Table 4. Patient encounter average time intervals as a function of relative crowding status determined by the SONET score

	Average time spend of Patients at different phases (min±SD)					
	Arrival to Triage	Triage encounter	Triage to patient placed in an exam room	Patient placed in an exam room to patient seen by a healthcare provider	Patient seen by a healthcare provider to disposition decision	Disposition decision to patient departure from UCC
Not overcrowded	6.8±6.4	2.3±2.2	17.4±25.7	30.3±30.7	54.8±57.5	19.6±17.4
Overcrowded	7.9±6.8 *p<0.001	2.5±2.2 *p=0.097	38.5±35.6 *p<0.001	39.4±33.8 *p<0.001	56.1±63.0 *p=1.000	21.0±20.8 *p=0.267
Severely Overcrowded	10.6±8.1 **p<0.001	2.8±2.5 **p=0.210	60.9±52.7 **p<0.001	31.3±30.0 **p<0.001	57.6±69.2 **p=1.000	21.3±21.0 **p=1.000

Abbreviation: UCC: urgent care center; SD: standard deviation. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

LWBS data was collected every two hours. The numbers of LWBS patients was 0.28±0.69 every two hours if UCC was under a not-overcrowded status, 0.64±0.98 when at an overcrowded status, and 1.00±0.97 when at a severely overcrowded status. The results show the numbers of LWBS patients were associated with the severity of UCC crowding as determined by the SONET scores however not sufficiently powered to reach statistical significance ($p>0.05$).

Discussion

Providing urgent care services to meet the needs of the evolving healthcare consumer is gaining considerable interest by the industry. The number of UCC patients has increased substantially every year resulting in the potential for UCC saturation and resultant overcrowding. To date no UCC overcrowding estimation tool was available.[15,16] In order to maintain a high standard of clinical and operational performance in the urgent care setting, assessment of UCC overcrowding is critical to effective management. Much research has been done on ED overcrowding, but

minimal attention has been paid to overcrowding as it relates to UCC workflow.[17-19] Our institution operates both an ED and UCC at different locations with different triage system providing us an opportunity to investigate overcrowding at each discreet location. In this study, a UCC overcrowding estimation tool (SONET) was derived and also showed the prolonged average LOS and increased number of LWBS patients linked closely with the severity levels of UCC overcrowding.

Since no UCC overcrowding tool has been reported, the operational variables chosen for deriving our UCC overcrowding tool were gleaned from either expert opinions or the experiences obtained from ED overcrowding studies.[12,20,21] Twenty different operational variables and 5 indices were included in this derivation study (see table 1) in order to match the requirements of the different UCC settings. The majority of these variables were similar to the ones used in ED overcrowding studies,[12] except 1) the numbers of patients triaged to ESI levels1 and 2 were not considered due to significantly fewer presentations of these patients to the UCC resulting in insufficient power to perform statistical analysis; 2) the numbers of critical care patients which would be transferred to intensive care settings relatively quickly. On the other hand, the number of APPs on duty and the number of patients waiting in the results pending area were added for investigation particularly in this study because 1) the majority of UCC settings have APPs, and 2) the majority of UCC patients do not present with conditions requiring a monitored bed. The overwhelming majority of patients presenting to an UCC can be safely managed in a non-monitored area while awaiting diagnostic results and/or receiving medications thereby releasing exam beds for new patients.

Our results showed that 4 different independent variables could affect the UCC overcrowding status. These variables include total patient index, number of results pending patents, waiting room patient index, and the longest time in hours of patients in the waiting room. Two variables (total patient index and the longest time in hours of patients in the waiting room) have also been used to evaluate ED overcrowding in previous studies[12]. The number of patients triaged at an acuity level of ESI-3 or its equivalent in the waiting room has shown to affect ED overcrowding in previous studies. These patients accounted for the majority of patients waiting for an initial provider encounter when the ED was determined to be overcrowded.[22,23] Different conditions may occur in the UCC setting. The majority of UCC patients in the waiting room will be ESI-4 and 5 level patients. Considering that ESI-1 and 2 patients will be transferred out of an UCC to a higher acuity setting, ESI-3 patients are therefore the highest priority patients to be seen in the average UCC. It is therefore appropriate to consider the waiting room patient index as an independent variable for UCC overcrowding evaluation. The number of results pending patients is another variable that is similar with respect to vertical flow patients at an ED.[24] Briefly, patients presenting to an ED that are determined not to require a monitored bed are often processed through a pathway involving minimal time spent in an exam room followed by the majority of their time in a results pending area awaiting diagnostics, medications delivery, and re-evaluation. This is a recognized method to reduce ED overcrowding and has been reported in other studies. [25-27] In a busy UCC, this method is also employed to effectively manage UCC patient flow.

SONET was derived in this study to estimate UCC overcrowding. Three different levels of crowding were developed to include severely overcrowded, overcrowded, and not overcrowded. The ranges of the SONET score for the different crowding statuses match those of NEDOCS (national emergency department overcrowding study) which is widely used nationally[12]. UCC workflow is considered efficiently managed at an appropriate level when the SONET score falls under the not overcrowded threshold. When the overcrowding threshold is approached UCC and hospital administrators are alerted of the high potential for severely overcrowding and to employ pre-determined actions to avoid reaching a severely overcrowded status. When operational outcomes were measured in this study, it confirmed the importance of dividing relative overcrowding into these three categories. The number of LWBS patients and the average LOS of ESI levels 4 and 5 patients increased with the severity of UCC crowding. There was an average of 22 minutes increase in ESI level 3 patients when UCC was deemed to be severely overcrowded as compared with a determination of overcrowded though no statistically significant difference was appreciated. This was in part due to a tendency for more ESI level 3 patients being transferred out of UCC under severely overcrowded conditions (data not shown). As previously mentioned average LOS among ESI levels 1 and 2 patients was not a contributing factor in this study as this cohort of patients is not treated in the lower acuity setting of an UCC. When total LOS is viewed as a function of relative crowding status significantly prolonged delay to patient placement in an exam room was notable and is consistent with previous reports.[28,29]

Limitations

This study was performed in a single urban UCC affiliated with a publicly funded hospital system which could inevitably have population selection bias and limit its use in a more general setting. Considering the study was performed in a relatively high volume UCC setting, this crowding estimation tool might only accurately reflect conditions typically encountered in a similar setting. In addition, the study facility has an emergency psychiatric unit which directly and indirectly accepts patients with urgent and emergent psychiatric conditions. As such very few patients with psychiatric problems present to UCC resulting in a potential bias in terms of population selection. Therefore, results of this study need to be validated in a multicenter study involving different UCC settings and populations. Operational variables chosen in this study were based upon previous ED overcrowding studies and expertise recommendations, As such other variables that potentially affect UCC crowding might have been missed. During our study period, the process of triaging a low acuity (ESI levels 4 and 5) ED patient to UCC when the ED is determined to be severely overcrowded was not yet initiated. Therefore, the number of patients transferred from ED to UCC was not considered a risk factor impacting UCC crowding. Furthermore, consideration of average LOS and numbers of LWBS patients as the only patient care outcome measurements may not be enough to determine the most accurate association to UCC crowding. Other patient care outcome variables such as 72h UCC/ED returns, patient satisfaction, and nosocomial accidents might need to be included.

Conclusion

An overcrowding estimation tool (SONET) used to determine relative crowding status in a high volume UCC setting was derived in this study. The study also showed that UCC overcrowding is associated with negative patient care outcomes.

Competing Interests: N/A

Author contributions: HW and RDR conceived the study and developed the design in consultation with all of the authors. CDC[1], VAG, and CDC[2] assembled the data set and collected the data. HW, RDR, EKG, CDS, RDJ, and NRZ conducted the statistical analyses and drafted the article, and all authors read and approved the final manuscript. HW takes responsibility for the paper as a whole. (1: CDC: Chad D. Cowden; 2: CDC: Christopher D. Cook)

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Table legend:

Table 1 shows the clinical and operational variables and index collected in the UCC overcrowding study. There were total 20 individual operational variables and 5 indexes collected based on the previous ED overcrowding study and expertise's opinions.

Table 2 shows the general information of patients in this study

Table 3 shows the average LOS of patients who registered at UCC under the different crowding statuses determined by the SONET.

Table 4 shows the average time spend at different stages in patients who registered at UCC under the different crowding statuses determined by the SONET

Appendix table shows the average LOS of discharged patients who registered at UCC under the different crowding statuses determined by the SONET

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Explanation: a) **Yes**. This is a prospective study and was reported in the abstract section. b) **Yes**. In abstract, clearly addressed what was done and in result section, the findings were also reported.
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Yes**, we address the scientific background and the rationale for this study.
Objectives	3	State specific objectives, including any prespecified hypotheses **Yes**, in the end of the introduction section, we reported a specific urgent care center overcrowding estimation tool will be derived and study primary and secondary goals (hypotheses)
Methods		
Study design	4	Present key elements of study design early in the paper **Yes**, study design was reported in Line 70.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Yes**, location: Line 71-72, periods of recruitment: Line 87, exposure, follow-up: Line 78-84, this study did not require follow-up. Data collection: Line 111-154.
Participants	6	*Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Yes**, Line 78-84, this study did not require follow up.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Yes**, see section Variables: Line111-138 and table 1.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Yes**, see section Variables: Line111-138 and table 1.
Bias	9	Describe any efforts to address potential sources of bias **Yes**, single center study with population selection bias will be inevitably occurred and this is addressed in our limitation section.
Study size	10	Explain how the study size was arrived at **Yes**, line 73-75.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Yes**, three groups were divided in this study (N: not overcrowding; O: overcrowding; and S: severely overcrowding groups) and outcome measurements were compared with these three groups. See Line 145-154. How quantitative variables were handled

		in the analyses were also addressed in the statistics section See Line 166-171.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed **Yes**, a): statistical methods addressed in detail in Line 155-172. b): see Line 166-170. c) see line 78-84. d) this study did not require any follow-up.
		(*e*) Describe any sensitivity analyses N/A: no sensitivity analyses addressed in this study since there is no standard or previous similar study reported. However, consider the perceptions of overcrowding of healthcare providers as a "glod standard", inter-rater reliability between the SONET scores and provider perceptions was measured. Line 197-200

Continued on next page

Results		
Participants	13*	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Yes, see line 202-205. Table 2
		Give reasons for non-participation at each stage Yes, see line 202-203
		Consider use of a flow diagram No, since this is very easy to address in the manuscript, no flow diagram drawn.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Yes, see Table 2.
		(b) Indicate number of participants with missing data for each variable of interest Yes, see line 179-180, and 202-205.
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) No, this study did not require follow-up.
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures Yes, see result section: outcome measurements Line 201-244.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Yes, see Line 184-196. Results showed only 4 variables can be independent variables while others are the confounding factors.
		(*b*) Report category boundaries when continuous variables were categorized Yes, continuous variables are converted to categorical variables based on the results of previous study. See line 90-96.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Yes, see Table 4 and Appendix Table.
Discussion		
Key results	18	Summarise key results with reference to study objectives Yes, see Line 247-256.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Yes, see limitation section Line 302-317.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Yes, see discussion Line 257-300.
Generalisability	21	Discuss the generalisability (external validity) of the study results Yes, internal validation performed and no external validation reported in this study and also

		addressed in the limitation. see Line 200, 310-311.
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based N/A

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Use of the SONET Score to Evaluate Urgent Care Center Overcrowding

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Title Page:

Title: Use of the SONET Score to Evaluate Urgent Care Center Overcrowding

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Key words: Urgent care center, Crowding, Tool, Patient care outcome

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Use of the SONET Score to Evaluate Urgent Care Center Overcrowding

Abstract

Objectives: To derive a tool to determine Urgent Care Center (UCC) crowding and investigate the association between different levels of UCC overcrowding and negative patient care outcomes.

Design: Prospective pilot study

Setting: Single center study in USA.

Participants: 3,565 patients that registered at UCC during the 21 day study period were included. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study. 3,139 patients were enrolled in the final data analysis.

Primary and secondary outcome measures: A crowding estimation tool (SONET: Severely overcrowded, Overcrowded, and Not overcrowded Estimation Tool) was derived using the linear regression analysis. The average length of stay (LOS) in UCC patients and the number of left without being seen (LWBS) patients were calculated and compared under the three different levels of UCC crowding.

Results: Four independent operational variables could affect the UCC overcrowding score including the total number of patients, the number of results pending patients, the number of patients in the waiting room, and the longest time a patient was stationed in the waiting room. In addition, UCC overcrowding was associated with longer average LOS (not overcrowded: 133±76min, overcrowded: 169±79min, and severely overcrowded: 196±87min, $p<0.001$) and an increased number of LWBS patients (not overcrowded: 0.28±0.69 patients, overcrowded: 0.64±.98, and severely overcrowded: 1.00±0.97).

Conclusions: The overcrowding estimation tool (SONET) derived in this study can be used to determine different levels of crowding in a high volume UCC setting. It also showed UCC overcrowding is associated with negative patient care outcomes.

Key Words: Urgent care center, Crowding, Tool, Patient care outcome

Strengths and Limitations of this study: Strengths: 1) the first prospective study on urgent care overcrowding, 2) the first study reported the link with the overcrowding and patient outcome in the urgent care setting, 3) derived a new overcrowding scoring system for urgent care crowding estimation which has not reported before. Limitations: 1) single center study requiring external validation; 2) special population selection could lead to selection bias.

Introduction

As the demand for real time access to care increases, Emergency Department (ED) overcrowding has become more and more common in recent years.[1;2] One of the solutions to ED overcrowding is to reduce the numbers of low acuity patients presenting for care.[3;4] It is reported that hospitals are adding their own or partnering with existing non-hospital based urgent care centers (UCCs) to offset ED overcrowding.[5;6] According to the report from the Urgent Care Association of America, the number of UCCs has increased over 12% within 3 years and it has provided care to over 3 million patient visits every week.[7] UCCs are now recognized as providing convenient, less expensive access to care as compared to that experienced at an average ED.

In primary care settings, the gap of available providers is expected to continue to grow. The primary care setting workload is expected to increase by 29% from 2005 to 2025. Meanwhile the number of primary care providers is expected to grow by only 2%-7% during the same timeframe.[8;9] Given the prediction that both ED and primary care settings will continue to be resource constrained, a proactive approach to anticipating UCC overcrowding will offer

a means to mitigate patient care risk. To the best of our knowledge, no UCC overcrowding estimation tool has been reported to date.

Accurately estimating UCC overcrowding will not only help reduce ED overcrowding but will also alert administrators to take action by mobilizing resources as an overcrowded condition becomes imminent thereby minimizing the risk of undesirable patient care outcomes.[10;11] The primary goal of this study is to derive a suitable tool we named SONET (Severely overcrowded – Overcrowded – Not overcrowded Estimation Tool) to evaluate overcrowding in a high volume UCC setting. A secondary goal is to determine the association between UCC overcrowding and negative patient care outcomes.

Materials and Methods

Study design and Patient population:

This was a prospective pilot study designed to derive an estimation tool to determine overcrowding status in a moderate to high volume UCC setting. This study was carried out at a publicly funded health system that has both ED and UCC at different locations within the main campus and with separate triage systems. The annual volume of the study UCC is approximately 62,000 visits. Considering no previous UCC overcrowding study reported and no historical data available for sample size estimation, the same study period used for Emergency Department overcrowding study was used in this study.[12] The John Peter Smith Health Network Institutional Review Board approved the study (IRB approval number: 110413.003ex).

All patients that registered initially at UCC were included in this study. Patients were triaged by dedicated nurses at the triage encounter point and individual patient acuity levels were then assigned by using the Emergency Severity Index (ESI). ESI is a standardized ED/UCC triage system confirmed to be a reliable and valid triage system in US to determine the different acuity levels upon each patients' entry into the service.[13] Patients with potentially higher levels of acuity (e.g. ESI 1 and 2) are routed to a physician immediately. Physician discretion is employed to determine if these patients need to transfer to ED for further emergent evaluation and treatment. Those patients at ESI levels 1 and 2 who were not sent to the ED remain in the urgent care workflow. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study.

Study protocol

This study was carried out from Feb 24, 2014 through Mar 16, 2014. During these 21 days, all physicians, advanced practice providers (APP), charge nurses, flow coordinator nurses, and triage nurses were called separately every two hours by a dedicated UCC clerk and asked to report their perception of the current UCC crowding status. The UCC clerk was blinded to this study. The perceptions of UCC overcrowding were rated on a 0-100mm visual analogue scale (VAS). UCC overcrowding was considered to be true if the score on the VAS $\geq$ 50 and was considered severely overcrowded if the score on the VAS $\geq$ 70. An average UCC overcrowding score was then calculated. Since no UCC overcrowding scale was reported before, our study overcrowding score was multiplied by a factor of 2 in order to match an ED overcrowding scale that is widely used nationally.[12] A score $\geq$100 was considered overcrowded and $\geq$140 was considered severely overcrowded. Therefore, three different crowding statuses were considered: not-overcrowded, overcrowded, and severely overcrowded.

UCC opens at 0600 and closes around 2300 during weekdays. During the weekend, UCC opens at 0600 but closes at variable times depending on the volume of patients presenting during the course of the day. UCC triage ends at 2200.

Patients who present after 2200 are redirected to ED for further evaluation and treatment. UCC closes after the last patient's disposition which is usually around 2300. The perception of UCC crowding status was queried 8 times each day during the weekdays at 0700, 0900, 1100, 1300, 1500, 1700, 1900, and 2100 separately. During the weekend, queries occurred at 0700 and then every 2 hours until UCC closed. Patients who registered between 0600 and 0700 were considered under the not-overcrowded category.

At the same time provider perceptions of UCC crowding were asked by the UCC clerk, all variables were also recorded simultaneously by that clerk who did not participate in this study. The clinical or operational variables considered to potentially affect UCC crowding were collected after discussion with a group of those with operational expertise. A scoring tool to determine UCC crowding was then derived from the study that we named SONET (Severely-overcrowded Overcrowded Not-overcrowded Estimation Tool). Additionally, 1,000 sample randomized data sets were employed to validate the study internally by using the bootstrap methods.

Variables

The total number of UCC beds was used as a constant in this study. All the other clinical or operational variables such as the total number of patients at UCC, the number of patients in the waiting room, the number of attending physicians, APPs, and nurses on duty, the number of patients with different Emergency Severity Index (ESI) levels, and the longest wait time of those patients in the waiting room at the time of scoring were also collected (see Table 1). In order to potentially apply the SONET scoring system to different UCC settings, several indices were calculated as well. The total patient index was the total number of patients at UCC divided by the number of UCC beds. The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The results pending patient index was the total number of results pending patients (e.g. patients already seen by healthcare providers at UCC and then placed in the result pending area) divided by the number of active patients (e.g. active patients were the total number of UCC registered patients less the number of patients in the waiting room). The physician index was the total number of patients at UCC divided by the number of physicians on duty. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty.

Table 1. Clinical and operational variables and indices collected in the UCC overcrowding study

Variables		
The total number of patients at UCC	The number of patients already transferred to other facilities in the past two hours	The number of physicians on duty
Total number of patients in the waiting room	The number of patients with ESI 1 or 2 transferred to other facilities in the past two hours	The number of nurses on duty
The number of patients in the results pending area	The number of patients waiting to be transferred to other facilities	The number of APPs on duty
The number of patients with different assigned acuity levels (ESI 1, 2, 3, 4, 5)	The number of patients waiting to be discharged	The number of triage nurses on duty
The number of patients with different assigned acuity levels in the waiting room (ESI 3, 4, 5)	The longest wait time among patients in the waiting room expressed in hours	
Index		
Total patient index	Results pending patient index	Waiting room patient index
Nurse index	APP index	Physician index

Abbreviations: UCC urgent care center, ESI: emergency severity index, APP: advanced practice provider. The number of patients in the results pending area refers to the number of patients that had already been seen by a healthcare provider and were awaiting results of diagnostic testing. After initial provider interview and physical exam these patients are relocated from the exam room to the results pending area. The total patient index is the total number of patients at UCC divided by the number of UCC beds. The results pending patient index is the total number of patients residing in the results pending status (e.g. patients already seen by healthcare providers at UCC and then transitioned to the results pending area) divided by the number of active patients (e.g. active patients were the total number of patients in UCC less those patients in the waiting room). The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty. The physician index was the total number of patients at UCC divided by the number of physicians on duty.

Outcome measurement

The SONET score was derived after the study was completed and retrospectively entered into the study data. All patients during the study period were assigned to have SONET scores at the time the patients were registered in the UCC and stratified into three different crowding categories. Patients who registered at UCC with incomplete data were excluded from the study as their individual SONET scores could not be calculated.

In order to know whether UCC overcrowding potentially affects UCC operational efficiency, LOS and the number of LWBS patients were used as markers for UCC efficiency measurements. UCC LOS refers to the interval of time starting with initial UCC patient registration and ending at the point when a patient is physically discharged from the UCC track board. For LWBS patients, the LOS was calculated as the interval of time starting with initial UCC registration and ending at the point that no response to a call for further service was documented. We performed three calls to every LWBS patient in a twenty minutes interval. If no response was received after the third call, the patient was considered LWBS and the time of the first call was recorded as the documented time of no response. All patients registered for UCC services during the study period were included in the data analysis. Patient care outcomes were compared among these three groups (not-overcrowded, overcrowded, and severely overcrowded groups).

Data analysis and Statistics

A linear regression model was applied and the independent operational variables that could affect UCC overcrowding status scores were determined. Correlation coefficiency (r) was analyzed on each operational variable with its scatter plot drawn. Variables that had strong correlation ($r>0.6$) with UCC crowding were chosen for linear regression analysis. Variance inflation factor (VIF) quantifies the severity of multi-colinearity in the regression model analysis thereby providing an index to estimate whether the regression coefficient is increased due to colinearity. Operational variables with high VIF (>10) were considered as having colinearity and were therefore excluded from regression analysis.[14;15] A formula was then generated based on the regression coefficient of each independent operational variable and an UCC crowding score was calculated. A bootstrap technique that randomized 1,000 samples was used to internally validate the study score accuracy.

Considering the operational significance of determining UCC overcrowding status, the SONET score was divided into three categories: not overcrowded (score<100), overcrowded (score between 100 and 140, including 100 but not including 140), and severely overcrowded (score≥140). Patients were automatically assigned to three groups based on ED overcrowding scores at the time when a specific patient registered for services in the UCC. To compare the differences between LWBS, and LOS at UCC relative to the different UCC overcrowding status groups, analysis of variance (ANOVA) with Bonferroni correction was used to analyze differences between groups.

All statistical analysis was performed using STATA 12 (College Station, TX) and a $p<0.05$ was considered a statistically significant difference.

Results

Derivation of SONET scoring system

The prospective pilot study was performed from 0600 on Feb 24, 2014 until 1900 on Mar. 16, 2014 which included 15 weekdays and 6 weekend days. The UCC closes operations at different times during the weekends resulting in 36 data sets collected at different time points. Therefore, there were a total of 134 data sets collected resulting in a data completion rate of 85.9% (134/156). Among these 134 time points, the UCC was determined by healthcare provider perceptions to be below the not-overcrowded threshold 57.46% (77/134) of the time. The UCC was determined to be below the overcrowded threshold 26.12% (35/134) of the time and below the severely overcrowded threshold 16.42% (22/134) of the time.

Results of linear regression showed only 4 variables that can be considered independent risk factors affecting the UCC crowding status. These are total number of patients, number of results pending patients, number of patients in the waiting room, and longest wait time of patients in the waiting room. Other variables reached either no statistical significance, had no correlation with overcrowding, or had significant colinearity with a VIF (variance inflation factor) greater than 10. In order to suitably apply the tool with respect to different UCC settings, total patient index and waiting room patient index were used. Therefore a UCC crowding scoring formula (SONET) was derived and is defined as:

SONET Score = 24.5 x total patient index + 58.1 x waiting room patient index + 2.7 x number of result pending patients + 12.2 x the longest time in hours of patient in the waiting room + 32.4. (in short form: SONET Score = 24.5T+58.1WI+2.7R+12.2L+32.4 (TWIRL) where T indicates the total patients index, WI indicates the waiting room patient index, R indicates the number of results pending patients in UCC, and L indicates the longest time in hours of patients in the waiting room). SONET score ≥ 100 is considered UCC overcrowded and ≥140 is considered severely overcrowded.

Using the average perceptions of UCC crowding status among different healthcare providers as a "gold standard" demonstrated strong inter-rater reliability between the SONET scores and provider perceptions when compared within the three different crowding statuses (not overcrowded, overcrowded, and severely overcrowded, $\kappa=0.6446$). Internal validation using bootstrap methods showed similar results (data not shown).

Outcome measurement

A total of 3,565 patients were registered to receive services in the UCC during the study period. Excluding patients who had no SONET scores calculated due to incomplete collection of operational variables at the time of registration, 3,139 patients were enrolled in data analysis. The general information of these patients is shown in Table 2.

Table 2. General Information of Patients in the study

Age (year±SD)	41.97±15.57 (95%CI 41.43-42.52)
Gender (male, %)	46.70%
Level of Acuity (%, number)	
ESI1	0.16% (5)
ESI2	5.61% (176)

ESI3	24.94% (783)
ESI4	59.64% (1,872)
ESI5	8.00% (251)
unknown	1.66% (52)
Disposition (%, number)	
Discharged	89.58% (2812)
Admitted	4.17% (131)
LWBS	1.94% (61)
Average time intervals (min±SD)	
from patient arrival to triage	7.9±7.0 (95% CI 7.6-8.1)
from patient arrival to placement in an exam room	42.6±41.4 (95% CI 41.2-44.1)
from patient arrival to patient initial encounter with a healthcare provider	75.9±56.6 (95% CI 74.0-77.9)
from patient arrival to disposition (discharge vs. admit) rendered	132.5±82.7 (95% CI 129.6-135.4)
from patient arrival to patient departure from UCC	151.6±89.5 (95%CI 148.5-154.7)

In order to determine whether the UCC overcrowding status could affect UCC operational efficiency and safety, LOS and LWBS were investigated. Patients registered at UCC triage during the study period were assigned to three different UCC crowding statuses determined by SONET scores (N: not overcrowded; O: overcrowded; and S: severely overcrowded).

The average LOS at UCC under each crowding status determined by SONET reached statistically significant differences between groups. Similar results were found when patients were further subdivided into the different ESI level groups (Table 3). The more severe the crowding score in the UCC, the longer the average LOS of all patients, especially those triaged to ESI levels 3, 4, and 5. When analyzing only discharged patients, similar results were found with statistically significant differences among groups (Appendix Table). To more accurately determine the effects of UCC crowding status on delayed patient care LOS was divided into several segments. The segments were time spent at triage, wait time for an available exam room, wait time to arrival of a healthcare provider, and wait time to disposition (Table 4). The results of our study showed that the most significant delay in care occurred during the period while patients awaited an available exam room. No significant difference was noted after patients were initially seen by the healthcare providers.

Appendix Table. The average LOS of discharged patients who registered at UCC under the different crowding statuses as determined by the SONET tool.

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	133±76 (1445)	0	76±72 (35)	140±88 (335)	138±73 (952)	95±46 (120)
Overcrowded	169±79 (858) *p<0.001	0	78±61 (37) *p=1.000	172±93 (218) *p<0.001	179±72 (522) *p<0.001	138±53 (80) *p<0.001
Severely Overcrowded	196±87 (509) **p<0.001	0	69±55 (27) **p=1.000	188±99 (130) **p=0.327	211±75 (315) **p<0.001	189±83 (37) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity Index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

Table 3. The average LOS of patients who registered at UCC as a function of relative acuity status and SONET score

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	130±80 (1581)	57±67 (2)	59±56 (69)	136±95 (385)	139±73 (981)	93±47 (125)
Overcrowded	165±88 (957) *p<0.001	58±55 (3) *p=0.973	71±62 (58) *p=0.733	170±102 (242) *p<0.001	181±79 (549) *p<0.001	139±53 (87) *p<0.001
Severely Overcrowded	186±97 (601) **p<0.001		57±48 (49) **p=0.699	192±114 (156) **p=0.112	208±75 (342) **p<0.001	187±83 (39) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

Table 4. Patient encounter average time intervals as a function of relative crowding status determined by the SONET score

	Average time spend of Patients at different phases (min±SD)					
	Arrival to Triage	Triage encounter	Triage to patient placed in an exam room	Patient placed in an exam room to patient seen by a healthcare provider	Patient seen by a healthcare provider to disposition decision	Disposition decision to patient departure from UCC
Not overcrowded	6.8±6.4	2.3±2.2	17.4±25.7	30.3±30.7	54.8±57.5	19.6±17.4
Overcrowded	7.9±6.8 *p<0.001	2.5±2.2 *p=0.097	38.5±35.6 *p<0.001	39.4±33.8 *p<0.001	56.1±63.0 *p=1.000	21.0±20.8 *p=0.267
Severely Overcrowded	10.6±8.1 **p<0.001	2.8±2.5 **p=0.210	60.9±52.7 **p<0.001	31.3±30.0 **p<0.001	57.6±69.2 **p=1.000	21.3±21.0 **p=1.000

Abbreviation: UCC: urgent care center; SD: standard deviation. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

LWBS data was collected every two hours. The numbers of LWBS patients was 0.28±0.69 every two hours if UCC was under a not-overcrowded status, 0.64±0.98 when at an overcrowded status, and 1.00±0.97 when at a severely overcrowded status. The results show the numbers of LWBS patients were associated with the severity of UCC crowding as determined by the SONET scores however not sufficiently powered to reach statistical significance ($p>0.05$).

Discussion

Providing urgent care services to meet the needs of the evolving healthcare consumer is gaining considerable interest by the industry. The number of UCC patients has increased substantially every year resulting in the potential for UCC saturation and resultant overcrowding. To date no UCC overcrowding estimation tool was available.[16;17] In order to maintain a high standard of clinical and operational performance in the urgent care setting, assessment of UCC overcrowding is critical to effective management. Much research has been done on ED overcrowding, but

minimal attention has been paid to overcrowding as it relates to UCC workflow.[18-20] Our institution operates both an ED and UCC at different locations with different triage system providing us an opportunity to investigate overcrowding at each discreet location. In this study, a UCC overcrowding estimation tool (SONET) was derived and also showed the prolonged average LOS and increased number of LWBS patients linked closely with the severity levels of UCC overcrowding.

Since no UCC overcrowding tool has been reported, the operational variables chosen for deriving our UCC overcrowding tool were gleaned from either expert opinions or the experiences obtained from ED overcrowding studies.[12;21;22] Twenty different operational variables and 5 indices were included in this derivation study (see table 1) in order to match the requirements of the different UCC settings. The majority of these variables were similar to the ones used in ED overcrowding studies,[12] except 1) the numbers of patients triaged to ESI levels1 and 2 were not considered due to significantly fewer presentations of these patients to the UCC resulting in insufficient power to perform statistical analysis; 2) the numbers of critical care patients which would be transferred to intensive care settings relatively quickly. On the other hand, the number of APPs on duty and the number of patients waiting in the results pending area were added for investigation particularly in this study because 1) the majority of UCC settings have APPs, and 2) the majority of UCC patients do not present with conditions requiring a monitored bed. The overwhelming majority of patients presenting to an UCC can be safely managed in a non-monitored area while awaiting diagnostic results and/or receiving medications thereby releasing exam beds for new patients.

Our results showed that 4 different independent variables could affect the UCC overcrowding status. These variables include total patient index, number of results pending patents, waiting room patient index, and the longest time in hours of patients in the waiting room. Two variables (total patient index and the longest time in hours of patients in the waiting room) have also been used to evaluate ED overcrowding in previous studies[12]. The number of patients triaged at an acuity level of ESI-3 or its equivalent in the waiting room has shown to affect ED overcrowding in previous studies. These patients accounted for the majority of patients waiting for an initial provider encounter when the ED was determined to be overcrowded.[23;24] Different conditions may occur in the UCC setting. The majority of UCC patients in the waiting room will be ESI-4 and 5 level patients. Considering that ESI-1 and 2 patients will be transferred out of an UCC to a higher acuity setting, ESI-3 patients are therefore the highest priority patients to be seen in the average UCC. It is therefore appropriate to consider the waiting room patient index as an independent variable for UCC overcrowding evaluation. The number of results pending patients is another variable that is similar with respect to vertical flow patients at an ED.[25] Briefly, patients presenting to an ED that are determined not to require a monitored bed are often processed through a pathway involving minimal time spent in an exam room followed by the majority of their time in a results pending area awaiting diagnostics, medications delivery, and re-evaluation. This is a recognized method to reduce ED overcrowding and has been reported in other studies. [25-27] In a busy UCC, this method is also employed to effectively manage UCC patient flow.

SONET was derived in this study to estimate UCC overcrowding. Three different levels of crowding were developed to include severely overcrowded, overcrowded, and not overcrowded. The ranges of the SONET score for the different crowding statuses match those of NEDOCS (national emergency department overcrowding study) which is widely used nationally[12]. UCC workflow is considered efficiently managed at an appropriate level when the SONET score falls under the not overcrowded threshold. When the overcrowding threshold is approached UCC and hospital administrators are alerted of the high potential for severely overcrowding and to employ pre-determined actions to avoid reaching a severely overcrowded status. When operational outcomes were measured in this study, it confirmed the importance of dividing relative overcrowding into these three categories. The number of LWBS patients and the average LOS of ESI levels 4 and 5 patients increased with the severity of UCC crowding. There was an average of 22 minutes increase in ESI level 3 patients when UCC was deemed to be severely overcrowded as compared with a determination of overcrowded though no statistically significant difference was appreciated. This was in part due to a tendency for more ESI level 3 patients being transferred out of UCC under severely overcrowded conditions (data not shown). As previously mentioned average LOS among ESI levels 1 and 2 patients was not a contributing factor in this study as this cohort of patients is not treated in the lower acuity setting of an UCC. When total LOS is viewed as a function of relative crowding status significantly prolonged delay to patient placement in an exam room was notable and is consistent with previous reports.[26;27]

Overall, a novel tool is derived to determine UCC overcrowding status and our findings also show the severity of overcrowding could link to the negative patient outcomes. Based on the results of this study, future research can be focused on external validations in different UCC settings.

Limitations

This study was performed in a single urban UCC affiliated with a publicly funded hospital system which could inevitably have population selection bias and limit its use in a more general setting. Considering the study was performed in a relatively high volume UCC setting, this crowding estimation tool might only accurately reflect conditions typically encountered in a similar setting. In addition, the study facility has an emergency psychiatric unit which directly and indirectly accepts patients with urgent and emergent psychiatric conditions. As such very few patients with psychiatric problems present to UCC resulting in a potential bias in terms of population selection. Therefore, results of this study need to be validated in a multicenter study involving different UCC settings and populations. Operational variables chosen in this study were based upon previous ED overcrowding studies and expertise recommendations, As such other variables that potentially affect UCC crowding might have been missed. During our study period, the process of triaging a low acuity (ESI levels 4 and 5) ED patient to UCC when the ED is determined to be severely overcrowded was not yet initiated. Therefore, the number of patients transferred from ED to UCC was not considered a risk factor impacting UCC crowding. Furthermore, consideration of average LOS and numbers of LWBS patients as the only patient care outcome measurements may not be enough to determine the most accurate association to UCC crowding. Other patient care outcome variables such as 72h UCC/ED returns, patient satisfaction, and nosocomial accidents might need to be included.

Conclusion

An overcrowding estimation tool (SONET) used to determine relative crowding status in a high volume UCC setting was derived in this study. The study also showed that UCC overcrowding is associated with negative patient care outcomes.

Competing Interests: N/A

Author contributions: HW and RDR conceived the study and developed the design in consultation with all of the authors. CDC[1], VAG, and CDC[2] assembled the data set and collected the data. HW, RDR, EKG, CDS, RDJ, and NRZ conducted the statistical analyses and drafted the article, and all authors read and approved the final manuscript. HW takes responsibility for the paper as a whole. (1: CDC: Chad D. Cowden; 2: CDC: Christopher D. Cook)

Acknowledgement: We would like to thank all the UCC attending physicians, APPs, nursing staff, and unit clerks participating in this study.

Table legend:

Table 1 shows the clinical and operational variables and index collected in the UCC overcrowding study. There were total 20 individual operational variables and 5 indexes collected based on the previous ED overcrowding study and expertise's opinions.

Table 2 shows the general information of patients in this study

Table 3 shows the average LOS of patients who registered at UCC under the different crowding statuses determined by the SONET.

Table 4 shows the average time spend at different stages in patients who registered at UCC under the different crowding statuses determined by the SONET

Appendix table shows the average LOS of discharged patients who registered at UCC under the different crowding statuses determined by the SONET

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Explanation: a) **Yes**. This is a prospective study and was reported in the abstract section. b) **Yes**. In abstract, clearly addressed what was done and in result section, the findings were also reported.
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Yes**, we address the scientific background and the rationale for this study.
Objectives	3	State specific objectives, including any prespecified hypotheses **Yes**, in the end of the introduction section, we reported a specific urgent care center overcrowding estimation tool will be derived and study primary and secondary goals (hypotheses)
Methods		
Study design	4	Present key elements of study design early in the paper **Yes**, study design was reported in Line 70.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Yes**, location: Line 71-72, periods of recruitment: Line 87, exposure, follow-up: Line 78-84, this study did not require follow-up. Data collection: Line 111-154.
Participants	6	*Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Yes**, Line 78-84, this study did not require follow up.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Yes**, see section Variables: Line111-138 and table 1.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Yes**, see section Variables: Line111-138 and table 1.
Bias	9	Describe any efforts to address potential sources of bias **Yes**, single center study with population selection bias will be inevitably occurred and this is addressed in our limitation section.
Study size	10	Explain how the study size was arrived at **Yes**, line 73-75.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Yes**, three groups were divided in this study (N: not overcrowding; O: overcrowding; and S: severely overcrowding groups) and outcome measurements were compared with these three groups. See Line 145-154. How quantitative variables were handled

		in the analyses were also addressed in the statistics section See Line 166-171.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed **Yes**, a): statistical methods addressed in detail in Line 155-172. b): see Line 166-170. c) see line 78-84. d) this study did not require any follow-up.
		(*e*) Describe any sensitivity analyses N/A: no sensitivity analyses addressed in this study since there is no standard or previous similar study reported. However, consider the perceptions of overcrowding of healthcare providers as a "glod standard", inter-rater reliability between the SONET scores and provider perceptions was measured. Line 197-200

Continued on next page

Results		
Participants	13*	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Yes, see line 202-205. Table 2
		Give reasons for non-participation at each stage Yes, see line 202-203
		Consider use of a flow diagram No, since this is very easy to address in the manuscript, no flow diagram drawn.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Yes, see Table 2.
		(b) Indicate number of participants with missing data for each variable of interest Yes, see line 179-180, and 202-205.
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) No, this study did not require follow-up.
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures Yes, see result section: outcome measurements Line 201-244.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Yes, see Line 184-196. Results showed only 4 variables can be independent variables while others are the confounding factors.
		(*b*) Report category boundaries when continuous variables were categorized Yes, continuous variables are converted to categorical variables based on the results of previous study. See line 90-96.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Yes, see Table 4 and Appendix Table.
Discussion		
Key results	18	Summarise key results with reference to study objectives Yes, see Line 247-256.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Yes, see limitation section Line 302-317.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Yes, see discussion Line 257-300.
Generalisability	21	Discuss the generalisability (external validity) of the study results Yes, internal validation performed and no external validation reported in this study and also

		addressed in the limitation. see Line 200, 310-311.
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based N/A

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Use of the SONET Score to Evaluate Urgent Care Center Overcrowding: A Prospective Pilot Study

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Title Page:

Title: Use of the SONET Score to Evaluate Urgent Care Center Overcrowding: A Prospective Pilot Study

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Key words: Urgent care center, Crowding, Tool, Patient care outcome

Word count: 3869

Use of the SONET Score to Evaluate Urgent Care Center Overcrowding: A Prospective Pilot Study

Abstract

Objectives: To derive a tool to determine Urgent Care Center (UCC) crowding and investigate the association between different levels of UCC overcrowding and negative patient care outcomes.

Design: Prospective pilot study

Setting: Single center study in USA.

Participants: 3,565 patients that registered at UCC during the 21 day study period were included. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study. 3,139 patients were enrolled in the final data analysis.

Primary and secondary outcome measures: A crowding estimation tool (SONET: Severely overcrowded, Overcrowded, and Not overcrowded Estimation Tool) was derived using the linear regression analysis. The average length of stay (LOS) in UCC patients and the number of left without being seen (LWBS) patients were calculated and compared under the three different levels of UCC crowding.

Results: Four independent operational variables could affect the UCC overcrowding score including the total number of patients, the number of results pending patients, the number of patients in the waiting room, and the longest time a patient was stationed in the waiting room. In addition, UCC overcrowding was associated with longer average LOS (not overcrowded: 133±76min, overcrowded: 169±79min, and severely overcrowded: 196±87min, $p<0.001$) and an increased number of LWBS patients (not overcrowded: 0.28±0.69 patients, overcrowded: 0.64±.98, and severely overcrowded: 1.00±0.97).

Conclusions: The overcrowding estimation tool (SONET) derived in this study might be used to determine different levels of crowding in a high volume UCC setting. It also showed UCC overcrowding might be associated with negative patient care outcomes.

Key Words: Urgent care center, Crowding, Tool, Patient care outcome

Strengths and Limitations of this study: Strengths: 1) the first prospective study on urgent care overcrowding, 2) the first study reported the link with the overcrowding and patient outcome in the urgent care setting, 3) derived a new overcrowding scoring system for urgent care crowding estimation which has not reported before. Limitations: 1) single center study requiring external validation; 2) special population selection could lead to selection bias.

Introduction

As the demand for real time access to care increases, Emergency Department (ED) overcrowding has become more and more common in recent years.[1;2] One of the solutions to ED overcrowding is to reduce the numbers of low acuity patients presenting for care.[3;4] It is reported that hospitals are adding their own or partnering with existing non-hospital based urgent care centers (UCCs) to offset ED overcrowding.[5;6] According to the report from the Urgent Care Association of America, the number of UCCs has increased over 12% within 3 years and it has provided care to over 3 million patient visits every week.[7] UCCs are now recognized as providing convenient, less expensive access to care as compared to that experienced at an average ED.

In primary care settings, the gap of available providers is expected to continue to grow. The primary care setting workload is expected to increase by 29% from 2005 to 2025. Meanwhile the number of primary care providers is expected to grow by only 2%-7% during the same timeframe.[8;9] Given the prediction that both ED and primary care

settings will continue to be resource constrained, a proactive approach to anticipating UCC overcrowding will offer a means to mitigate patient care risk. To the best of our knowledge, no UCC overcrowding estimation tool has been reported to date.

Accurately estimating UCC overcrowding will not only help reduce ED overcrowding but will also alert administrators to take action by mobilizing resources as an overcrowded condition becomes imminent thereby minimizing the risk of undesirable patient care outcomes.[10;11] The primary goal of this study is to derive a suitable tool we named SONET (Severely overcrowded – Overcrowded – Not overcrowded Estimation Tool) to evaluate overcrowding in a high volume UCC setting. A secondary goal is to determine the association between UCC overcrowding and negative patient care outcomes.

Materials and Methods

Study design and Patient population:

This was a prospective pilot study designed to derive an estimation tool to determine overcrowding status in a moderate to high volume UCC setting. This study was carried out at a publicly funded health system that has both ED and UCC at different locations within the main campus and with separate triage systems. The annual volume of the study UCC is approximately 62,000 visits. Considering no previous UCC overcrowding study reported and no historical data available for sample size estimation, the same study period used for Emergency Department overcrowding study was used in this study.[12] The John Peter Smith Health Network Institutional Review Board approved the study (IRB approval number: 110413.003ex).

All patients that registered initially at UCC were included in this study. Patients were triaged by dedicated nurses at the triage encounter point and individual patient acuity levels were then assigned by using the Emergency Severity Index (ESI). ESI is a standardized ED/UCC triage system confirmed to be a reliable and valid triage system in US to determine the different acuity levels upon each patients' entry into the service.[13] Patients with potentially higher levels of acuity (e.g. ESI 1 and 2) are routed to a physician immediately. Physician discretion is employed to determine if these patients need to transfer to ED for further emergent evaluation and treatment. Those patients at ESI levels 1 and 2 who were not sent to the ED remain in the urgent care workflow. Patients who had no overcrowding statuses estimated due to incomplete collection of operational variables at the time of registration were excluded in this study.

Study protocol

This study was carried out from Feb 24, 2014 through Mar 16, 2014. During these 21 days, all physicians, advanced practice providers (APP), charge nurses, flow coordinator nurses, and triage nurses were called separately every two hours by a dedicated UCC clerk and asked to report their perception of the current UCC crowding status. The UCC clerk was blinded to this study. The perceptions of UCC overcrowding were rated on a 0-100mm visual analogue scale (VAS). UCC overcrowding was considered to be true if the score on the VAS $\geq$ 50 and was considered severely overcrowded if the score on the VAS $\geq$ 70. An average UCC overcrowding score was then calculated. Since no UCC overcrowding scale was reported before, our study overcrowding score was multiplied by a factor of 2 in order to match an ED overcrowding scale that is widely used nationally.[12] A score $\geq$100 was considered overcrowded and $\geq$140 was considered severely overcrowded. Therefore, three different crowding statuses were considered: not-overcrowded, overcrowded, and severely overcrowded.

UCC opens at 0600 and closes around 2300 during weekdays. During the weekend, UCC opens at 0600 but closes at variable times depending on the volume of patients presenting during the course of the day. UCC triage ends at 2200. Patients who present after 2200 are redirected to ED for further evaluation and treatment. UCC closes after the last patient's disposition which is usually around 2300. The perception of UCC crowding status was queried 8 times each day during the weekdays at 0700, 0900, 1100, 1300, 1500, 1700, 1900, and 2100 separately. During the weekend, queries occurred at 0700 and then every 2 hours until UCC closed. Patients who registered between 0600 and 0700 were considered under the not-overcrowded category.

At the same time provider perceptions of UCC crowding were asked by the UCC clerk, all variables were also recorded simultaneously by that clerk who did not participate in this study. The clinical or operational variables considered to potentially affect UCC crowding were collected after discussion with a group of those with operational expertise. A scoring tool to determine UCC crowding was then derived from the study that we named SONET (Severely-overcrowded Overcrowded Not-overcrowded Estimation Tool). Additionally, 1,000 sample randomized data sets were employed to validate the study internally by using the bootstrap methods.

Variables

The total number of UCC beds was used as a constant in this study. All the other clinical or operational variables such as the total number of patients at UCC, the number of patients in the waiting room, the number of attending physicians, APPs, and nurses on duty, the number of patients with different Emergency Severity Index (ESI) levels, and the longest wait time of those patients in the waiting room at the time of scoring were also collected (see Table 1). In order to potentially apply the SONET scoring system to different UCC settings, several indices were calculated as well. The total patient index was the total number of patients at UCC divided by the number of UCC beds. The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The results pending patient index was the total number of results pending patients (e.g. patients already seen by healthcare providers at UCC and then placed in the result pending area) divided by the number of active patients (e.g. active patients were the total number of UCC registered patients less the number of patients in the waiting room). The physician index was the total number of patients at UCC divided by the number of physicians on duty. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty.

Table 1. Clinical and operational variables and indices collected in the UCC overcrowding study

Variables		
The total number of patients at UCC	The number of patients already transferred to other facilities in the past two hours	The number of physicians on duty
Total number of patients in the waiting room	The number of patients with ESI 1 or 2 transferred to other facilities in the past two hours	The number of nurses on duty
The number of patients in the results pending area	The number of patients waiting to be transferred to other facilities	The number of APPs on duty
The number of patients with different assigned acuity levels (ESI 1, 2, 3, 4, 5)	The number of patients waiting to be discharged	The number of triage nurses on duty
The number of patients with different assigned acuity levels in the waiting room (ESI 3, 4, 5)	The longest wait time among patients in the waiting room expressed in hours	
Index		
Total patient index	Results pending patient index	Waiting room patient index

Nurse index	APP index	Physician index

Abbreviations: UCC urgent care center, ESI: emergency severity index, APP: advanced practice provider. The number of patients in the results pending area refers to the number of patients that had already been seen by a healthcare provider and were awaiting results of diagnostic testing. After initial provider interview and physical exam these patients are relocated from the exam room to the results pending area. The total patient index is the total number of patients at UCC divided by the number of UCC beds. The results pending patient index is the total number of patients residing in the results pending status (e.g. patients already seen by healthcare providers at UCC and then transitioned to the results pending area) divided by the number of active patients (e.g. active patients were the total number of patients in UCC less those patients in the waiting room). The waiting room patient index was the number of patients in the waiting room divided by the number of UCC beds. The nurse index was the total number of patients at UCC divided by the number of nurses on duty. The APP index was the total number of patients at UCC divided by the number of APPs on duty. The physician index was the total number of patients at UCC divided by the number of physicians on duty.

Outcome measurement

The SONET score was derived after the study was completed and retrospectively entered into the study data. All patients during the study period were assigned to have SONET scores at the time the patients were registered in the UCC and stratified into three different crowding categories. Patients who registered at UCC with incomplete data were excluded from the study as their individual SONET scores could not be calculated.

In order to know whether UCC overcrowding potentially affects UCC operational efficiency, LOS and the number of LWBS patients were used as markers for UCC efficiency measurements. UCC LOS refers to the interval of time starting with initial UCC patient registration and ending at the point when a patient is physically discharged from the UCC track board. For LWBS patients, the LOS was calculated as the interval of time starting with initial UCC registration and ending at the point that no response to a call for further service was documented. We performed three calls to every LWBS patient in a twenty minutes interval. If no response was received after the third call, the patient was considered LWBS and the time of the first call was recorded as the documented time of no response. All patients registered for UCC services during the study period were included in the data analysis. Patient care outcomes were compared among these three groups (not-overcrowded, overcrowded, and severely overcrowded groups).

Data analysis and Statistics

A linear regression model was applied and the independent operational variables that could affect UCC overcrowding status scores were determined. Correlation coefficiency (r) was analyzed on each operational variable with its scatter plot drawn. Variables that had strong correlation ($r>0.6$) with UCC crowding were chosen for linear regression analysis. Variance inflation factor (VIF) quantifies the severity of multi-colinearity in the regression model analysis thereby providing an index to estimate whether the regression coefficient is increased due to colinearity. Operational variables with high VIF (>10) were considered as having colinearity and were therefore excluded from regression analysis.[14;15] A formula was then generated based on the regression coefficient of each independent operational variable and an UCC crowding score was calculated. A bootstrap technique that randomized 1,000 samples was used to internally validate the study score accuracy.

Considering the operational significance of determining UCC overcrowding status, the SONET score was divided into three categories: not overcrowded (score<100), overcrowded (score between 100 and 140, including 100 but not including 140), and severely overcrowded (score≥140). Patients were automatically assigned to three groups based on ED overcrowding scores at the time when a specific patient registered for services in the UCC. To compare the

differences between LWBS, and LOS at UCC relative to the different UCC overcrowding status groups, analysis of variance (ANOVA) with Bonferroni correction was used to analyze differences between groups.

All statistical analysis was performed using STATA 12 (College Station, TX) and a $p<0.05$ was considered a statistically significant difference.

Results

Derivation of SONET scoring system

The prospective pilot study was performed from 0600 on Feb 24, 2014 until 1900 on Mar. 16, 2014 which included 15 weekdays and 6 weekend days. The UCC closes operations at different times during the weekends resulting in 36 data sets collected at different time points. Therefore, there were a total of 134 data sets collected resulting in a data completion rate of 85.9% (134/156). Among these 134 time points, the UCC was determined by healthcare provider perceptions to be below the not-overcrowded threshold 57.46% (77/134) of the time. The UCC was determined to be below the overcrowded threshold 26.12% (35/134) of the time and below the severely overcrowded threshold 16.42% (22/134) of the time.

Results of linear regression showed only 4 variables that can be considered independent risk factors affecting the UCC crowding status. These are total number of patients, number of results pending patients, number of patients in the waiting room, and longest wait time of patients in the waiting room. Other variables reached either no statistical significance, had no correlation with overcrowding, or had significant colinearity with a VIF (variance inflation factor) greater than 10. In order to suitably apply the tool with respect to different UCC settings, total patient index and waiting room patient index were used. Therefore a UCC crowding scoring formula (SONET) was derived and is defined as:

SONET Score = 24.5 x total patient index + 58.1 x waiting room patient index + 2.7 x number of result pending patients + 12.2 x the longest time in hours of patient in the waiting room + 32.4. (in short form: SONET Score = 24.5T+58.1WI+2.7R+12.2L+32.4 (TWIRL) where T indicates the total patients index, WI indicates the waiting room patient index, R indicates the number of results pending patients in UCC, and L indicates the longest time in hours of patients in the waiting room). SONET score ≥ 100 is considered UCC overcrowded and ≥140 is considered severely overcrowded.

Using the average perceptions of UCC crowding status among different healthcare providers as a "gold standard" demonstrated strong inter-rater reliability between the SONET scores and provider perceptions when compared within the three different crowding statuses (not overcrowded, overcrowded, and severely overcrowded, $\kappa=0.6446$). Internal validation using bootstrap methods showed similar results (data not shown).

Outcome measurement

A total of 3,565 patients were registered to receive services in the UCC during the study period. Excluding patients who had no SONET scores calculated due to incomplete collection of operational variables at the time of registration, 3,139 patients were enrolled in data analysis. The general information of these patients is shown in Table 2.

Table 2. General Information of Patients in the study

Age (year±SD)	41.97±15.57 (95%CI 41.43-42.52)
Gender (male, %)	46.70%

Level of Acuity (%, number)	
ESI1	0.16% (5)
ESI2	5.61% (176)
ESI3	24.94% (783)
ESI4	59.64% (1,872)
ESI5	8.00% (251)
unknown	1.66% (52)
Disposition (%, number)	
Discharged	89.58% (2812)
Admitted	4.17% (131)
LWBS	1.94% (61)
Average time intervals (min±SD)	
from patient arrival to triage	7.9±7.0 (95% CI 7.6-8.1)
from patient arrival to placement in an exam room	42.6±41.4 (95% CI 41.2-44.1)
from patient arrival to patient initial encounter with a healthcare provider	75.9±56.6 (95% CI 74.0-77.9)
from patient arrival to disposition (discharge vs. admit) rendered	132.5±82.7 (95% CI 129.6-135.4)
from patient arrival to patient departure from UCC	151.6±89.5 (95%CI 148.5-154.7)

In order to determine whether the UCC overcrowding status could affect UCC operational efficiency and safety, LOS and LWBS were investigated. Patients registered at UCC triage during the study period were assigned to three different UCC crowding statuses determined by SONET scores (N: not overcrowded; O: overcrowded; and S: severely overcrowded).

The average LOS at UCC under each crowding status determined by SONET reached statistically significant differences between groups. Similar results were found when patients were further subdivided into the different ESI level groups (Table 3). The more severe the crowding score in the UCC, the longer the average LOS of all patients, especially those triaged to ESI levels 3, 4, and 5. When analyzing only discharged patients, similar results were found with statistically significant differences among groups (Appendix Table). To more accurately determine the effects of UCC crowding status on delayed patient care LOS was divided into several segments. The segments were time spent at triage, wait time for an available exam room, wait time to arrival of a healthcare provider, and wait time to disposition (Table 4). The results of our study showed that the most significant delay in care occurred during the period while patients awaited an available exam room. No significant difference was noted after patients were initially seen by the healthcare providers.

Table 3. The average LOS of patients who registered at UCC as a function of relative acuity status and SONET score

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	130±80 (1581)	57±67 (2)	59±56 (69)	136±95 (385)	139±73 (981)	93±47 (125)
Overcrowded	165±88 (957) *p<0.001	58±55 (3) *p=0.973	71±62 (58) *p=0.733	170±102 (242) *p<0.001	181±79 (549) *p<0.001	139±53 (87) *p<0.001
Severely Overcrowded	186±97 (601) **p<0.001		57±48 (49) **p=0.699	192±114 (156) **p=0.112	208±75 (342) **p<0.001	187±83 (39) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

Table 4. Patient encounter average time intervals as a function of relative crowding status determined by the SONET score

	Average time spend of Patients at different phases (min±SD)					
	Arrival to Triage	Triage encounter	Triage to patient placed in an exam room	Patient placed in an exam room to patient seen by a healthcare provider	Patient seen by a healthcare provider to disposition decision	Disposition decision to patient departure from UCC
Not overcrowded	6.8±6.4	2.3±2.2	17.4±25.7	30.3±30.7	54.8±57.5	19.6±17.4
Overcrowded	7.9±6.8 *p<0.001	2.5±2.2 *p=0.097	38.5±35.6 *p<0.001	39.4±33.8 *p<0.001	56.1±63.0 *p=1.000	21.0±20.8 *p=0.267
Severely Overcrowded	10.6±8.1 **p<0.001	2.8±2.5 **p=0.210	60.9±52.7 **p<0.001	31.3±30.0 **p<0.001	57.6±69.2 **p=1.000	21.3±21.0 **p=1.000

Abbreviation: UCC: urgent care center; SD: standard deviation. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups

LWBS data was collected every two hours. The numbers of LWBS patients was 0.28±0.69 every two hours if UCC was under a not-overcrowded status, 0.64±0.98 when at an overcrowded status, and 1.00±0.97 when at a severely overcrowded status. The results show the numbers of LWBS patients were associated with the severity of UCC crowding as determined by the SONET scores however not sufficiently powered to reach statistical significance ($p>0.05$).

Discussion

Providing urgent care services to meet the needs of the evolving healthcare consumer is gaining considerable interest by the industry. The number of UCC patients has increased substantially every year resulting in the potential for UCC saturation and resultant overcrowding. To date no UCC overcrowding estimation tool was available.[16;17] In order to maintain a high standard of clinical and operational performance in the urgent care setting, assessment of UCC overcrowding is critical to effective management. Much research has been done on ED overcrowding, but minimal attention has been paid to overcrowding as it relates to UCC workflow.[18-20] Our institution operates both an ED and UCC at different locations with different triage system providing us an opportunity to investigate overcrowding at each discreet location. In this study, a UCC overcrowding estimation tool (SONET) was derived and also showed the prolonged average LOS and increased number of LWBS patients linked closely with the severity levels of UCC overcrowding.

Since no UCC overcrowding tool has been reported, the operational variables chosen for deriving our UCC overcrowding tool were gleaned from either expert opinions or the experiences obtained from ED overcrowding studies.[12;21;22] Twenty different operational variables and 5 indices were included in this derivation study (see table 1) in order to match the requirements of the different UCC settings. The majority of these variables were similar to the ones used in ED overcrowding studies,[12] except 1) the numbers of patients triaged to ESI levels1 and 2 were not considered due to significantly fewer presentations of these patients to the UCC resulting in insufficient power to perform statistical analysis; 2) the numbers of critical care patients which would be transferred to intensive care

settings relatively quickly. On the other hand, the number of APPs on duty and the number of patients waiting in the results pending area were added for investigation particularly in this study because 1) the majority of UCC settings have APPs, and 2) the majority of UCC patients do not present with conditions requiring a monitored bed. The overwhelming majority of patients presenting to an UCC can be safely managed in a non-monitored area while awaiting diagnostic results and/or receiving medications thereby releasing exam beds for new patients.

Our results showed that 4 different independent variables could affect the UCC overcrowding status. These variables include total patient index, number of results pending patents, waiting room patient index, and the longest time in hours of patients in the waiting room. Two variables (total patient index and the longest time in hours of patients in the waiting room) have also been used to evaluate ED overcrowding in previous studies[12]. The number of patients triaged at an acuity level of ESI-3 or its equivalent in the waiting room has shown to affect ED overcrowding in previous studies. These patients accounted for the majority of patients waiting for an initial provider encounter when the ED was determined to be overcrowded.[23;24] Different conditions may occur in the UCC setting. The majority of UCC patients in the waiting room will be ESI-4 and 5 level patients. Considering that ESI-1 and 2 patients will be transferred out of an UCC to a higher acuity setting, ESI-3 patients are therefore the highest priority patients to be seen in the average UCC. It is therefore appropriate to consider the waiting room patient index as an independent variable for UCC overcrowding evaluation. The number of results pending patients is another variable that is similar with respect to vertical flow patients at an ED.[25] Briefly, patients presenting to an ED that are determined not to require a monitored bed are often processed through a pathway involving minimal time spent in an exam room followed by the majority of their time in a results pending area awaiting diagnostics, medications delivery, and re-evaluation. This is a recognized method to reduce ED overcrowding and has been reported in other studies. [25-27] In a busy UCC, this method is also employed to effectively manage UCC patient flow.

SONET was derived in this study to estimate UCC overcrowding. Three different levels of crowding were developed to include severely overcrowded, overcrowded, and not overcrowded. The ranges of the SONET score for the different crowding statuses match those of NEDOCS (national emergency department overcrowding study) which is widely used nationally[12]. UCC workflow is considered efficiently managed at an appropriate level when the SONET score falls under the not overcrowded threshold. When the overcrowding threshold is approached UCC and hospital administrators are alerted of the high potential for severely overcrowding and to employ pre-determined actions to avoid reaching a severely overcrowded status. When operational outcomes were measured in this study, it confirmed the importance of dividing relative overcrowding into these three categories. The number of LWBS patients and the average LOS of ESI levels 4 and 5 patients increased with the severity of UCC crowding. There was an average of 22 minutes increase in ESI level 3 patients when UCC was deemed to be severely overcrowded as compared with a determination of overcrowded though no statistically significant difference was appreciated. This was in part due to a tendency for more ESI level 3 patients being transferred out of UCC under severely overcrowded conditions (data not shown). As previously mentioned average LOS among ESI levels 1 and 2 patients was not a contributing factor in this study as this cohort of patients is not treated in the lower acuity setting of an UCC. When total LOS is viewed as a function of relative crowding status significantly prolonged delay to patient placement in an exam room was notable and is consistent with previous reports.[26;27]

Overall, a novel tool is derived to determine UCC overcrowding status and our findings also show the severity of overcrowding could link to the negative patient outcomes. Based on the preliminary results of this study, a multi-center prospective study that focused on external validations and outcome measurements in different UCC settings has already been started.

Limitations

This study was performed in a single urban UCC affiliated with a publicly funded hospital system which could inevitably have population selection bias and limit its use in a more general setting. Considering the study was performed in a relatively high volume UCC setting, this crowding estimation tool might only accurately reflect conditions typically encountered in a similar setting. In addition, the study facility has an emergency psychiatric unit which directly and indirectly accepts patients with urgent and emergent psychiatric conditions. As such very few

patients with psychiatric problems present to UCC resulting in a potential bias in terms of population selection. Therefore, results of this study need to be validated in a multicenter study involving different UCC settings and populations. Operational variables chosen in this study were based upon previous ED overcrowding studies and expertise recommendations, as such other variables that potentially affect UCC crowding might have been missed. During our study period, the process of triaging a low acuity (ESI levels 4 and 5) ED patient to UCC when the ED is determined to be severely overcrowded was not yet initiated. Therefore, the number of patients transferred from ED to UCC was not considered a risk factor impacting UCC crowding. Furthermore, consideration of average LOS and numbers of LWBS patients as the only patient care outcome measurements may not be enough to determine the most accurate association to UCC crowding. Other patient care outcome variables such as 72h UCC/ED returns, patient satisfaction, and nosocomial accidents which will be included in our ongoing multi-center validation study.

Conclusion

An overcrowding estimation tool (SONET) might be used to determine relative crowding status in a high volume UCC setting was derived in this study. The study also showed that UCC overcrowding might be associated with negative patient care outcomes.

Competing Interests: N/A

Author contributions: HW and RDR conceived the study and developed the design in consultation with all of the authors. CDC[1], VAG, and CDC[2] assembled the data set and collected the data. HW, RDR, EKG, CDS, RDJ, and NRZ conducted the statistical analyses and drafted the article, and all authors read and approved the final manuscript. HW takes responsibility for the paper as a whole. (1: CDC: Chad D. Cowden; 2: CDC: Christopher D. Cook)

Acknowledgement: We would like to thank all the UCC attending physicians, APPs, nursing staff, and unit clerks participating in this study.

Table legend:

Table 1 shows the clinical and operational variables and index collected in the UCC overcrowding study. There were total 20 individual operational variables and 5 indexes collected based on the previous ED overcrowding study and expertise's opinions.

Table 2 shows the general information of patients in this study

Table 3 shows the average LOS of patients who registered at UCC under the different crowding statuses determined by the SONET.

Table 4 shows the average time spend at different stages in patients who registered at UCC under the different crowding statuses determined by the SONET

Appendix table shows the average LOS of discharged patients who registered at UCC under the different crowding statuses determined by the SONET

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Explanation: a) **Yes**. This is a prospective study and was reported in the abstract section. b) **Yes**. In abstract, clearly addressed what was done and in result section, the findings were also reported.
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Yes**, we address the scientific background and the rationale for this study.
Objectives	3	State specific objectives, including any prespecified hypotheses **Yes**, in the end of the introduction section, we reported a specific urgent care center overcrowding estimation tool will be derived and study primary and secondary goals (hypotheses)
Methods		
Study design	4	Present key elements of study design early in the paper **Yes**, study design was reported in Line 70.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Yes**, location: Line 71-72, periods of recruitment: Line 87, exposure, follow-up: Line 78-84, this study did not require follow-up. Data collection: Line 111-154.
Participants	6	*Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Yes**, Line 78-84, this study did not require follow up.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Yes**, see section Variables: Line111-138 and table 1.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Yes**, see section Variables: Line111-138 and table 1.
Bias	9	Describe any efforts to address potential sources of bias **Yes**, single center study with population selection bias will be inevitably occurred and this is addressed in our limitation section.
Study size	10	Explain how the study size was arrived at **Yes**, line 73-75.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Yes**, three groups were divided in this study (N: not overcrowding; O: overcrowding; and S: severely overcrowding groups) and outcome measurements were compared with these three groups. See Line 145-154. How quantitative variables were handled

		in the analyses were also addressed in the statistics section See Line 166-171.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed **Yes**, a): statistical methods addressed in detail in Line 155-172. b): see Line 166-170. c) see line 78-84. d) this study did not require any follow-up.
		(*e*) Describe any sensitivity analyses N/A: no sensitivity analyses addressed in this study since there is no standard or previous similar study reported. However, consider the perceptions of overcrowding of healthcare providers as a "glod standard", inter-rater reliability between the SONET scores and provider perceptions was measured. Line 197-200

Continued on next page

Results		
Participants	13*	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Yes, see line 202-205. Table 2
		Give reasons for non-participation at each stage Yes, see line 202-203
		Consider use of a flow diagram No, since this is very easy to address in the manuscript, no flow diagram drawn.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Yes, see Table 2.
		(b) Indicate number of participants with missing data for each variable of interest Yes, see line 179-180, and 202-205.
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) No, this study did not require follow-up.
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures Yes, see result section: outcome measurements Line 201-244.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Yes, see Line 184-196. Results showed only 4 variables can be independent variables while others are the confounding factors.
		(*b*) Report category boundaries when continuous variables were categorized Yes, continuous variables are converted to categorical variables based on the results of previous study. See line 90-96.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Yes, see Table 4 and Appendix Table.
Discussion		
Key results	18	Summarise key results with reference to study objectives Yes, see Line 247-256.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Yes, see limitation section Line 302-317.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Yes, see discussion Line 257-300.
Generalisability	21	Discuss the generalisability (external validity) of the study results Yes, internal validation performed and no external validation reported in this study and also

		addressed in the limitation. see Line 200, 310-311.
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based N/A

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Appendix Table. The average LOS of discharged patients who registered at UCC under the different crowding statuses as determined by the SONET tool.

	Average LOS of Patients at UCC (min±SD, number of patients)					
	All patients	ESI-1	ESI-2	ESI-3	ESI-4	ESI-5
Not Overcrowded	133±76 (1445)	0	76±72 (35)	140±88 (335)	138±73 (952)	95±46 (120)
Overcrowded	169±79 (858) *p<0.001	0	78±61 (37) *p=1.000	172±93 (218) *p<0.001	179±72 (522) *p<0.001	138±53 (80) *p<0.001
Severely Overcrowded	196±87 (509) **p<0.001	0	69±55 (27) **p=1.000	188±99 (130) **p=0.327	211±75 (315) **p<0.001	189±83 (37) **p<0.001

Abbreviation: LOS: length of stay (time interval from initial patient registration to departure from UCC); UCC: urgent care center; SD: standard deviation; ESI: Emergency Severity Index. *: comparison between not overcrowded and overcrowded groups; **: comparison between overcrowded and severely overcrowded groups