Critical Review Form

Prognosis

Measuring and Forecasting Emergency Department Crowding in Real Time, *Annals EM* 2007; 49: 747-755

Objective: **"To assess the usefulness of the EDWIN, the NEDOCS, the READI Demand Value, and the Work Score as monitoring instruments of ED crowding" (p.748) by asking three questions:**

1) **Is it feasible to evaluate the measures in real time?**
2) **How accurately do the measures reflect present crowding?**
3) **Can the measures reliably forecast the future state of crowding?**

Methods: **Prospective trial over 8-weeks (June 21, 2006 – August 16, 2006) at Vanderbilt ED, an academic adult-only Level I trauma center. The ED staff was unaware of the ongoing study. The investigators used their electronic health record to compute the following crowding measures:**

A. EDWIN $= \sum n_i t_i / [N_a \times (B_t - P_{board})]$

n_i = number of nonboarding patients in triage category *i;*
t_i = reversed ESI triage category (5 = sickest)
N_a = number of attending physicians on duty
B_t = number of beds in the ED
P_{board} = number of boarding patients in the ED

B. NEDOCS $= [(P_{bed}/B_t) \times (85.8) + (P_{admit}/B_h) \times (600)] + [(W_{time}) \times (5.64)] + [(A_{time}) \times (0.93)] + [(R_n) \times (13.4)] - 20$

P_{bed} = number of patients in ED, hallways, and chairs
B_t = number of licensed treatment beds
P_{admit} = number of admitted patients
B_h = number of hospital beds
W_{time} = waiting time for the last patient put into bed
A_{time} = longest time since registration among boarding patients
R_n = number of respirators in use (substituted number of trauma beds)

C. Demand Value of the READI score = (BR + PR) x AR

$$BR = (P_{total} + A_{pred} - D_{pred})/B_t$$
$$AR = \sum n_i t_i / P_{triage}$$
$$PR = A_{hour} / \sum PPH$$

BR = bed ratio
AR= acuity ratio
PR = provider ratio
P_{total} = number of ED patients
A_{pred} = number of predicted arrivals } --- (used 9-month historical data for these
D_{pred} = number of predicted departures } --- two variables)
B_t = number of licensed treatment beds
n_i = number of patients in triage category i
P_{triage} = number of patients in the ED with an assigned triage category
A_{hour} = number of arrivals in the last hour
PPH = average patients seen per hour for each attending physician and resident on duty

D. Work Score = $[(3.23) \times (P_{wait}/B_t)] + [(0.097) \times (\sum n_i t_i / N_n)] + [(10.92) \times (P_{board}/B_t)]$

P_{wait} = number of waiting patients
B_t = number of licensed beds
n_i = number of patients in triage category i
t_i = triage category i
N_n = number of nurses on duty
P_{board} = number of boarding patients

E. Occupancy level = $(100) \times (P_{bed}/B_t)$

P_{bed} = number of patients in beds and overflow areas
B_t = number of licensed treatment beds

At 10-minute intervals, the electronic medical record computed these values and saved in a research database. <u>The primary outcome was crowding as measured by ambulance diversion.</u> At this institution diversion could only occur if any of the following occur without possibility of 1-hour remedy:

1) **All critical care beds in ED are occupied with at least 10 patients in waiting.**

2) **Acuity level exist placing additional patients at risk.**
3) **All ED monitored beds are full**

The investigators analyzed ROC curves for the point-of-care ability of the 5 crowding measures to predict ambulance diversion. For pairwise comparison the Bonferroni correction was used to define significance as $p \leq 0.0125$ (.05/4). The operating characteristics of each tool were reported with sensitivity fixed at 90%.

Finally using CDC bio-surveillance system assessment methods, the investigators evaluated each tools timeliness score against false-alarm rates. A false-alarm was defined as a positive result more than 4-hours before diversion occurred. One to three false-alarms were permitted. This computation permitted investigators to assess overcrowding in the near future.

Guide		Comments
I.	**Are the results valid?**	
A.	**Was the sample of patients representative?** *In other words, how were subjects selected and did they pass through some sort of "filtering" system which could bias your results based on a non-representative sample. Also, were objective criteria used to diagnose the patients with the disorder?*	Yes. Nearly all10-minute intervals were successfully collected (98.6%) with lost data due to computer breakdowns unlikely to bias patient sampling.
B.	**Were the patients sufficiently homogeneous with respect to prognostic risk?** *In other words, did all patients share a similar risk from during the study period or was one group expected to begin with a higher morbidity or mortality risk?*	Yes. All patients encounters were included in the analysis.
C.	**Was follow-up sufficiently complete?** *In other words, were the investigators able to follow-up on subjects as planned or were a significant number lost to follow-up?*	No loss to follow-up was reported.
D.	**Were objective and unbiased outcome criteria used?** Investigators should clearly specify and define their target outcomes before the study and whenever possible they should base their criteria on objective measures.	Yes, although ambulance diversion criteria and diversion frequency likely vary significantly between hospitals and geographic regions.

<table>
<tr><th>II.</th><th>What are the results?</th><th></th></tr>
<tr><td>A.</td><td>How likely are the outcomes over time?</td><td>

37 ambulance diversion episodes occurred during the study interval lasting 11.7 hours/episode and representing 30% of the intervals observed.
<u>For assessing current ED diversion work score and occupancy level were superior</u> (sensitivity fixed @ 90%) (Table 2, p.752)

<table>
<tr><th>Tool</th><th>Sen</th><th>Spec</th><th>LR+</th><th>LR-</th><th>AUC (95% CI)</th></tr>
<tr><td>EDWIN</td><td>90%</td><td>63</td><td>2.4</td><td>0.15</td><td>.81 (.77-0.85)</td></tr>
<tr><td>NEDOCS</td><td>90%</td><td>67</td><td>2.8</td><td>0.15</td><td>.88 (.85-.91)</td></tr>
<tr><td>READI</td><td>90%</td><td>32</td><td>1.3</td><td>0.32</td><td>.65 (.60-.71)</td></tr>
<tr><td>Work score</td><td>90%</td><td>71</td><td>3.1</td><td>0.14</td><td>.90 (.86-.92)</td></tr>
<tr><td>Occupancy level</td><td>90%</td><td>70</td><td>3.1</td><td>0.13</td><td>.90 (.87-.93)</td></tr>
</table>

<u>For predicting near-future (<4 hour) crowding, the READI was the only tool more useful other than the occupancy level and even then only if three-false alarms per week.</u> In that scenario the READI would provide 1-hour and 16-minute advanced warning of unbalance divergence (98.75% CI 0-2.05).

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<tr><td>B.</td><td>How precise are the estimates of likelihood?
In other words, what are the confidence intervals for the given outcome likelihoods?</td><td>Sufficiently narrow Bonferroni corrected CI (see above).</td></tr>
<tr><th>III.</th><th>How can I apply the results to patient care?</th><th></th></tr>
<tr><td>A.</td><td>Were the study patients and their management similar to those in my practice?</td><td>Yes – ED patients at a busy academic Level I ED (although ICU patients go immediately to ICU per authors).</td></tr>
<tr><td>B.</td><td>Was the follow-up sufficiently long?</td><td>No loss to follow-up was reported, but no follow-up or patient-important outcomes were assessed at all. Patients and physicians might also care about illness severity scores, diagnostic and therapeutic errors, QI cases, AMA rates, and ED recidivism.</td></tr>
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C.	**Can I use the results in the management of patients in my practice?**	Yes, if value found in assessing need to go on diversion or predicting need for ambulance diversion in the next 1-2 hours. Those investigators ability to program their electronic medical records to compute all five measures from already present variables in the medical record database bodes well for the future uptake of these algebraic computations since nobody will be able to compute them real-time by hand.

Limitations

1) **Single center ED with half the volume of BJH limits external validity.**
2) **Lack of patient important outcomes as surrogate markers of crowding (AMA cases, QI referral cases, etc.).**
3) **Lack of external validity of ambulance diversion criteria and diversion rates.**
4) **Is the definition of overcrowding (ambulance diversion) adequate?**
5) **Inability to compute these formulas using HMED without IT assistance.**

Bottom Line

Single-center eight-week trial suggests that occupancy level is superior to EDWIN, NEDOCS, and READI and equal to the Work Score in identifying the need for ambulance diversion now. When assessing the ability to predict ambulance diversion in the next 4-hours, occupancy level is superior to all four tools. However, if permitted three-false-alarms per week, READI can provide over one-hour-advanced notice of the need for ambulance diversion compared with the other tools. While each of these now validated tools may offer valuable, additions to the over-crowding research and administrative armamentarium, future investigations should evaluate the ability of each to trigger interventions to offset the sequelae of over-crowding: ambulance diversion, prolonged waiting times, patient dissatisfaction, increased error rates, and staff burnout.