A Statistical Approach for Detecting Deviations from Usual Medical Care

James Mezger MS, Shyam Visweswaran MD, PhD,
Milos Hauskrecht PhD, Gilles Clermont MD, MSc, Gregory F. Cooper MD, PhD
University of Pittsburgh, Pittsburgh, PA

Abstract
Detecting deviations from usual medical care is valuable in identifying potentially concerning patient management events, both in real time and retrospectively. We describe a statistical method for identification of deviations in medication administration. The preliminary results reported here characterize the statistical properties of the identified deviations. Future research will investigate which deviations are clinically useful.

Introduction
Developing automatic methods to detect deviations from usual medical care may be useful in alerting clinicians to treatment choices that warrant additional consideration. Here we investigate a statistical approach for identifying intensive care unit (ICU) patients who did not receive expected medications.

Methods
A dataset of 9,000 admissions to the ICU at a major metropolitan hospital was used to construct and evaluate models of usual care. Patient attributes of admitting diagnosis, floor location, age, gender, and APACHE score were used as the predictor variables. The treatment decisions being predicted consisted of the medications administered within the first 24 hours. The dataset was temporally split into a training set of 6,000 cases and a test set of 3,000 cases. For each medication a logistic regression model was constructed from the training set and applied to the test cases to predict the probability of the medication being given. From the probabilities obtained from the test cases, the area under the ROC curve (AUROC) and the p-value of the Hosmer-Lemeshow calibration statistic (HLS) were computed for each medication model. Models that had both good discrimination and good calibration (AUROC greater than 0.80 and HLS p-value greater than 0.05 respectively) were deemed reliable, and their predictions on the test cases were examined. A deviation was defined as a predicted probability ≥ 0.80 that a medication would have been given, and yet, the patient actually did not receive it.

Results and Discussion
A total of 152 models were generated of which nine were above the thresholds set for the AUROC and the HLS p-value (see Figure 1). These nine models yielded 54 test cases with deviations (representing a 0.2% rate of deviation from usual care). As an example, Table 1 shows the two patient cases (of the 3000 test cases) that did not receive lactulose, yet the lactulose model predicted with high probability that these two cases would have received it. Since lactulose is used in hepatic encephalopathy and acute hepatic failure to counteract hyperammonemia, the recognition of these deviations seems clinically appropriate. We next plan to investigate the specific clinical reasons for the deviations and quantify the utility of our approach.

Acknowledgements
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Table 1 Deviations found by the lactulose model.

<table>
<thead>
<tr>
<th>Age</th>
<th>ICU</th>
<th>Sex</th>
<th>APACHE</th>
<th>Diagnosis</th>
<th>Prob.</th>
</tr>
</thead>
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<tr>
<td>51</td>
<td>11F</td>
<td>M</td>
<td>87</td>
<td>hep. encep.</td>
<td>0.98</td>
</tr>
<tr>
<td>24</td>
<td>MICU</td>
<td>M</td>
<td>38</td>
<td>ac. hep. fa.</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Figure 1. Each point represents a model that predicts the use of a medication. The shaded box shows the nine models that passed the two performance thresholds.