Orders for Intravenous Proton Pump Inhibitors After Implementation of an Electronic Alert

Proton pump inhibitors (PPIs) are highly effective in treating gastric acid–related disorders but are often overused.1 Intravenous (IV) PPIs are expensive compared with oral PPIs and have few absolute indications; more than half of hospitalized patients prescribed IV PPIs could instead receive oral PPIs.2 Health information technologies have the potential to improve physician ordering of medications but have not been applied to IV PPIs.3

Methods | This study was approved by the institutional review board of Columbia University with a waiver of consent. On October 21, 2011, our institution (Columbia University Medical Center) introduced an alert that was triggered by all IV PPI orders, excluding continuous infusion PPIs. Esomeprazole is our institution’s only formulary PPI; therefore, the alert applied only to orders for esomeprazole. The alert explains that oral PPIs cost one-tenth as much as IV PPIs, yet they are 90% bioavailable. The response of health care professionals to the alert was automatically captured. Our primary outcome was a change in the proportion of all PPIs given intravenously during 1 year before the alert compared with 1 year after the alert, which we assessed retrospectively using an interrupted time-series analysis.4 No other interventions were made related to PPI ordering during the study period. Multivariable logistic regression modeling was performed to assess predictors of an IV compared with an oral PPI order, stratified by alert period. To characterize orders in terms of indications, we randomly selected 50 medical records from before alert implementation and 50 medical records from after alert implementation. We then classified IV PPI orders as indicated or not indicated based on criteria derived from current guidelines.

Results | During the 2-year study period, there were 65 078 completed orders for PPIs, including 10 050 of 33 520 orders (30.0%) for IV PPIs before alert implementation and 7247 of 31 558 orders (23.0%) for IV PPIs after implementation ($\chi^2$ test, $P < .001$), representing a 7.0% absolute and 23.4% relative reduction in the proportion of IV PPIs (Figure). During the year before the alert, the proportion of IV PPI orders completed decreased a mean of 0.7% monthly ($P = .049$). After adjusting for the trend in IV PPI use before the alert, the proportion of IV PPI orders completed remained significantly decreased after implement-
Figure. Proportion of Intravenous (IV) Proton Pump Inhibitors (PPIs) Given Before and After Implementation of an Electronic Alert, November 2010-October 2012

The alert was implemented on October 21, 2011.

Table. Multivariable Logistic Regression Analysis for Odds of Completing an IV Compared With an Oral PPI Order, Stratified by Alert Period

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Total No. of PPI Orders</th>
<th>No. (%) of IV Orders</th>
<th>Adjusted OR (95% CI)</th>
<th>Total No. of PPI Orders</th>
<th>No. (%) of IV Orders</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Once daily or less</td>
<td>Total</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Medicine</td>
<td>19 796</td>
<td>5637 (28.5)</td>
<td>1 [Reference]</td>
<td>18 265</td>
<td>3627 (19.9)</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>Surgery</td>
<td>9783</td>
<td>3599 (36.8)</td>
<td>1.18 (1.11-1.25)</td>
<td>9797</td>
<td>3193 (32.6)</td>
<td>1.47 (1.38-1.56)</td>
</tr>
<tr>
<td>Neurology</td>
<td>2953</td>
<td>526 (17.8)</td>
<td>0.60 (0.54-0.68)</td>
<td>2600</td>
<td>265 (10.2)</td>
<td>0.46 (0.40-0.53)</td>
</tr>
<tr>
<td>Obstetrics-gynecology</td>
<td>647</td>
<td>280 (43.3)</td>
<td>3.72 (3.10-4.47)</td>
<td>529</td>
<td>159 (30.1)</td>
<td>2.70 (2.18-3.33)</td>
</tr>
<tr>
<td>Psychiatry</td>
<td>341</td>
<td>8 (2.3)</td>
<td>0.11 (0.05-0.22)</td>
<td>367</td>
<td>3 (0.8)</td>
<td>0.06 (0.02-0.19)</td>
</tr>
<tr>
<td>Health care professional role</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>25 950</td>
<td>8023 (30.9)</td>
<td>1 [Reference]</td>
<td>23 169</td>
<td>5364 (23.1)</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>NP or PA</td>
<td>7480</td>
<td>2019 (27.0)</td>
<td>0.75 (0.70-0.81)</td>
<td>8277</td>
<td>1878 (22.3)</td>
<td>0.82 (0.76-0.88)</td>
</tr>
<tr>
<td>Medical student</td>
<td>90</td>
<td>8 (8.9)</td>
<td>0.26 (0.12-0.59)</td>
<td>112</td>
<td>5 (4.5)</td>
<td>0.27 (0.11-0.68)</td>
</tr>
<tr>
<td>Order set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>27 583</td>
<td>6700 (24.3)</td>
<td>1 [Reference]</td>
<td>25 957</td>
<td>4773 (18.4)</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>Yes</td>
<td>5937</td>
<td>3350 (56.4)</td>
<td>3.93 (3.65-4.23)</td>
<td>5601</td>
<td>2474 (44.2)</td>
<td>2.91 (2.70-3.14)</td>
</tr>
<tr>
<td>Diet status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any diet</td>
<td>14 272</td>
<td>1542 (10.8)</td>
<td>1 [Reference]</td>
<td>14 084</td>
<td>1052 (7.5)</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>NPO</td>
<td>7859</td>
<td>5164 (65.7)</td>
<td>14.0 (13.0-15.0)</td>
<td>6821</td>
<td>3812 (55.9)</td>
<td>12.0 (11.0-13.0)</td>
</tr>
<tr>
<td>No order</td>
<td>11 389</td>
<td>3344 (29.4)</td>
<td>4.07 (3.79-4.38)</td>
<td>10 653</td>
<td>2383 (22.4)</td>
<td>3.88 (3.57-4.21)</td>
</tr>
</tbody>
</table>

Abbreviations: IV, intravenous; NA, not applicable; NPO, nothing by mouth; NP, nurse practitioner; OR, odds ratio; PA, physician assistant; PPI, proton pump inhibitor.
tation of the alert (P < .001). Health care professional-level factors were significant predictors of IV compared with oral PPI administration, including the presence of the PPI within an order set (Table). There was improved indication after implementation of the alert, but the findings were not significant (88.0% indicated after vs 74.0% before; P = .07). On the basis of the institutional cost differences between IV and oral PPIs and the observed reduction in IV PPI orders during the year after the alert, we estimate a $450 692 annual decrease in institutional costs related to IV PPI use.

Discussion | Intravenous PPIs are frequently given in situations in which oral PPIs would suffice. We found that implementation of an electronic alert for IV PPI orders was associated with a 23.0% relative decrease in the proportion of orders of PPI. This result was significant after adjusting for the trend in the proportion of IV PPIs ordered before implementation of the alert. The decrease in the proportion of IV PPIs ordered was immediate, sustained, accompanied by an overall decrease in IV PPI orders, and associated with significant cost savings.

Few prior data on electronic interventions seeking to improve PPI use are available. In the outpatient setting, pharmacist-based electronic interventions may reduce overall PPI use. Inpatient studies have evaluated the use of computerized decision support in changing IV to oral medication orders but have not targeted IV PPIs. Our findings suggest that, if health care professionals are educated to make a clearly defined change with a simple but focused alert, oral PPIs will frequently be substituted for IV PPIs. Health care professional–level factors were also an important determinant of PPI route of administration. Compared with the medical service, the surgery or obstetrics-gynecology service were more likely to order IV vs oral PPIs. This was true before and after the alert and after adjusting for patient diet status; however, this study was not designed to address the reasons underlying these differences. Notably, presence of the IV PPI within an order set strongly predicted IV compared with oral PPI use and after alert implementation.

Our study highlights the potential for electronic alerts to alter ordering behavior for IV PPIs. Institutions seeking to decrease IV PPI use should consider removing IV PPIs from order sets, and future studies should test whether additional targeted interventions using clinical decision support systems can improve PPI overuse.

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Acquisition, analysis, or interpretation of data: Freedberg, Salmasian, Abrams.

Drafting of the manuscript: All authors.

Critical revision of the manuscript for important intellectual content: Freedberg, Salmasian, Abrams.

Statistical analysis: Freedberg, Abrams, Green.

Administrative, technical, or material support: Freedberg, Abrams, Green.

Study supervision: Freedberg, Abrams.

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5. Smeets HM, Hoes AW, de Witt NJ. Effectiveness and costs of implementation strategies to reduce acid suppressive drug prescriptions: a systematic review. BMC Health Serv Res. 2007;7:177.

Population Trends in Rates of Coronary Revascularization

Improvements in prevention have led to declines in rates of myocardial infarction (MD). Simultaneously, evidence from randomized trials has confirmed the role of medical therapy as a first-line treatment for stable coronary disease. Together, these forces could lead to significant declines in population-wide rates of coronary revascularization. We examined recent temporal trends in population rates of coronary revascularization using comprehensive clinical data collected in Massachusetts.