Electronic Detection of Early Acute Kidney Injury

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Acute Kidney Injury and the Limits of Standard Reporting of Creatinine Results

Example Case

• A 86 year old man was admitted and placed on nafcillin

<table>
<thead>
<tr>
<th>Day</th>
<th>Cr (mg/dl)</th>
<th>eGFR (mL/min/1.73m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.81</td>
<td>&gt;60</td>
</tr>
<tr>
<td>2</td>
<td>0.91</td>
<td>&gt;60</td>
</tr>
<tr>
<td>3</td>
<td>1.03</td>
<td>&gt;60</td>
</tr>
<tr>
<td>4</td>
<td>1.37</td>
<td>54</td>
</tr>
</tbody>
</table>

• Day 5: Cr 1.48 (still within the reference range)
  – Patient rising creatinine noted
  – Diagnosed with acute interstitial nephritis secondary to nafcillin

Acute Kidney Injury (AKI)

• Acute kidney injury, AKI is a common problem in hospitalized patients

  Issues with current Cr reporting

• Values are only flagged if outside of the reference range

• Values indicative of AKI often remain within the reference range

• Clinicians often quickly scan lab values for flagged result outside of reference range
Clinical Criteria

<table>
<thead>
<tr>
<th><strong>RIFLE</strong></th>
<th><strong>Other Criteria and Details</strong></th>
</tr>
</thead>
</table>
| AKI diagnosed based upon creatinine increase from baseline | • Within RIFLE other criteria can also be used:  
• decreased urine output or GFR  
• smaller increase in the setting of creatinine ≥ 4mg/dl |
| Increase by  
– ≥1.5 fold but <2 fold → **Risk**  
– ≥2.0 fold but <3 fold → **Injury**  
– ≥3.0 fold → **Failure** | • Other classification schemes (e.g. AKIN also available) |
| • With respect to our analysis, the components of RIFLE use are those shown above  
• We took baseline creatinine as the 7 day minimum |
Scope of the Problem

We examined 42,297 inpatient creatinine results (over ~ two months) using relational database tools.

42,297 results

<table>
<thead>
<tr>
<th>3785 Results</th>
<th>38,512 Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>9% yes Met RIFLE criteria (risk or greater)?</td>
<td>No 91%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1994 Risk</th>
<th>1,260 Injury</th>
<th>531 Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>53%</td>
<td>33%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Were these patients readily identifiable by clinicians with current reporting?

<table>
<thead>
<tr>
<th>Creatineline within reference range (≤ 1.5 mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,011 (51%)</td>
</tr>
</tbody>
</table>

Overall, 35% of creatinine values indicative of AKI were within the reference range and could have been overlooked.
Our hospital’s nephrology service requested that we flag results concerning for AKI within our laboratory information system (LIS).

Nephrology specifically asked that we flag results that were:

- Increased by 0.5 mg/dl or more over the patient’s 72 hour baseline (72 hour minimum)

OR

- Increased by 0.3 mg/dl or more over the patient’s 72 hour baseline, when the 72 hour baseline was ≤2 mg /dl

However, our LIS cannot calculate 72 hour minimum values.
“Tracked Minimums”

• We proposed using a surrogate for the 72 hour minimum which we called the “tracked-minimum”

• The tracked-minimum is a single rolling value calculated with each new creatinine result (implemented as “dummy-test”)

• The tracked minimum is updated to the current creatine result when either
  i. The new creatinine result is less than or equal to the prior tracked minimum OR
  ii. When the prior tracked minimum “expires” (has not been updated in 72 hours)

  Otherwise, each new tracked minimum is just the prior tracked minimum

• Calculating a tracked minimum requires looking only at the current creatinine and the prior tracked minimum
  • Our LIS can reference the single prior value for tests in calculations
  • Tracked minimum rules are therefore implementable
How Well Do Tracked Minimum Flags Approximate True Minimum Rules?

42297 Inpatient Cr Values Over ~ 2 months

9% Yes Flagged under true minimum rules as proposed by nephrology?

3955 Values

18% No Flagged under tracked minimum rules?

697 “Discrepant” Values

82% Yes Flagged under tracked minimum rules?

3258 “Concordant” Values

38343 Values

Only 50 of these results (1.3% of the total flagged under true minimum rules) were deemed to be potentially problematic. In other cases the results were:

• On a patient who would have had a prior result flagged under tracked minimum rules

And/Or

• Were above the reference range (and would have been flagged accordingly)
We can further try each rule with the 72 hour baseline creatinine calculated in three different ways:

1. **72 hr tracked-minimum** (tracked minimum based)

2. **Single most recent prior creatinine result within 72 hrs** (delta check based)

3. **Combination of track-minimum and delta-check based rules**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Rule fires if:</th>
<th>Rule fires if:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Baseline creatinine is ≤2 AND 2. Creatinine is increased over baseline by:</td>
<td>1. Baseline creatinine is &gt;2 AND 2. Creatinine is increased over baseline by:</td>
</tr>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.5 (&quot;original rule&quot;)</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Cr units= mg/dl; Baseline is over 72 hrs

Rules are 2 through 4 are successively less stringent (fire with smaller creatinine increases)
Flagging Rules Compared to RIFLE

Rule  
1  
2  
3  
4  
Baseline Cr calculated by

1
2
4
3
Tracked minimum

Delta check

Tracked minimum + delta check

% of concordance between flag and RIFLE

40% 60% 80%

Rule | Cr increase threshold if baseline Cr ≤ 2 (mg/dl) | Cr increase threshold if baseline Cr > 2 (mg/dl)
--- | --- | ---
1 | 0.3 | 0.5
2 | 0.3 | 0.4
3 | 0.3 | 0.3
4 | 0.2 | 0.2

Patient RIFLE Status

Specificity

Sensitivity
What are the False Positives?

Tracked minimum + delta rule 4:
- 2826 discrepant ("false positive") results
- From 1209 unique patients

18% Yes Patient previously met RIFLE criteria? No 82%

214 Unique patients

995 unique patients

210 unique patients

48% 110 unique patients reached injury or failure

17% of 1209 patients

9% of 1209 patients

11% of 995 patients

21% Yes Later met RIFLE criteria? No 79%

785 Unique patients

65% of 1209 patients

False positives or early warnings?
Summary and Conclusions

1. Creatinine values indicative of acute kidney injury are often within the reference range and can be easily overlooked

2. Flagging rising creatinine results may be clinically beneficial

3. Tracked-minimum creatinine levels may serve as a useful surrogate for true minimum levels when developing flagging rules

4. The creatinine change thresholds proposed by RIFLE and AKIN criteria are not necessarily optimal for use in LIS based flags
   • Laboratories may wish implement flags that are highly sensitive, even at the expense of specificity

5. This is a work in progress; there is more to come
Thank You and Questions

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Questions?