Correlating data from different sensors to increase the positive predictive value of alarms: an empiric assessment

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High false alarm rate is a well-described phenomenon in intensive care units. Our goal is to develop an algorithm that replicates the ways clinicians discriminate artifact from real signal, and thus suppress false alarms. Definitions that correlated information across sensors were installed in the monitors of a 10 bed cardiothoracic intensive care unit and evaluated over an 85 day study period. The performance of these definitions was evaluated by an expert clinician via a daily review of the patient’s chart and the tracings associated with these events. The positive predictive value of the definitions ranged from approximately 10% to 84%.

INTRODUCTION

Historically, desire for high performance and concern over legal liability has motivated the design of alarm systems in clinical medicine that are highly sensitive, but which also have a very high false positive rate. False positive alarms have multiple causes, including ‘low threshold’ settings, motion interference, and false signals generated from a variety of clinical activities.

Paradoxically, the high rate of false positive (80-99%) alarms trains practitioners to ignore alarms. Alarm fatigue is a phenomenon where practitioners come to ignore alarms. Advanced software could be programmed to replicate the logic that caregivers utilize to discriminate real conditions from artifact, increasing the positive predictive value of an alarm above the threshold where practitioners would ignore it.

One strategy to increase the clinical utility of alarms is to increase the sophistication of the alarm software, in effect, making the monitor analyze data across sensors to verify the alarm condition. The correlation of information across sensors has great potential to reduce artifact related false alarms. For example, when a patient moves, she can disturb her EKG electrodes and produce an EKG signal that appears to be ventricular fibrillation (a pulseless rhythm) while her pulse-oximeter documents no change in her pulse. Simply correlating information from these different sensors would prevent the false alarm.

Another strategy to increase response to alarms is to assess parameters that are clinically important in the context of the abnormal parameter. For example, tachycardia associated with a precipitous decline in blood pressure is clinically different and more significant than tachycardia associated with no change in blood pressure. Advanced alarms that alert caregivers to important patterns of change are far more likely to generate the appropriate clinical response than monitors that continually alarm for situations that represent little or no danger. Such alarms would have lower rate of false alarm and a high PPV.

In this study, we utilized Philips Event Monitoring software (Intellivue Monitors - MP70/90) to define alarm conditions that correlated information across sensors, and which were prospectively intended to have a high positive predictive value.

METHODS

Philips Event Surveillance software was installed into a 10 bed cardiac surgery Intensive Care Unit monitors. It was operational in parallel with the factory installed monitors for the purpose of determining the incidence of true positive events as compared with false positive events. Five clinically important alarm scenarios (‘smart alarms’) were programmed in to the bedside monitors using the Event Surveillance software.
When any alarm (factory installed or event surveillance software) is triggered, a log of monitor data from the event is stored in the central monitoring station. Every day, the log file of events from the previous 24 hours was reviewed with the ICU physician (attending or fellow), and all events were classified.

The data we have collected suggests that information correlated across sensors might generate more reliable alarms (example: the SVT+BP). Some of the events we were surveying (like Vtach+BP) were sufficiently rare and we remain unable to evaluate their performance.

RESULTS

Events were recorded for 85 days, 564 total patient days were monitored. The results are shown in Table 1 (Below).

DISCUSSION

No alarm system in use or under development can perform perfectly. Hence, practitioners are compelled to trade-off among the kinds of failures that are acceptable to them. While there is ample literature that demonstrates that simple monitors generate vastly more false alarms than real alarms, the regulatory environment of most medical practice has generated regulations that require these alarms to be activated.

Correlation of information across sensors can be used to detect and suppress artifact in a manner similar to how human operators analyze data. Simple algorithms can generate alarms with a much higher positive predictive value than simple single-sensor alarms. Additionally, the ability to correlate information across sensors may allow the monitor to detect important clinical conditions in manner similar to human operators. The most important limitation to the correlation of information across sensors is that the failure rate becomes at least the sum of the artifact rate of the individual sensors.

The event surveillance software employed in the present study could not access all of the information generated from all of the sensors in the monitor, which constrained the events that could be surveyed and the definitions that were generated. More recent generations of the event surveillance software incorporate expanded ability to capture information and might be used to generate definitions that will be more useful than most of those used for the current study.

Table 1. Results summary

<table>
<thead>
<tr>
<th>Group</th>
<th># Events</th>
<th>Tru Pos (pts)</th>
<th>FP art</th>
<th>FP def</th>
<th>PPV</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVT+BP</td>
<td>221</td>
<td>170 (10)</td>
<td>17</td>
<td>22</td>
<td>0.8</td>
<td>9</td>
</tr>
<tr>
<td>Vtach+BP</td>
<td>1</td>
<td>1 (1)</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>LVshock</td>
<td>42</td>
<td>34(6)</td>
<td>8</td>
<td>0</td>
<td>0.81</td>
<td>1</td>
</tr>
<tr>
<td>Tamponade</td>
<td>24</td>
<td>1(1)</td>
<td>23</td>
<td>0</td>
<td>0.04</td>
<td>1</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>29</td>
<td>8</td>
<td>21</td>
<td>0</td>
<td>0.27</td>
<td>2</td>
</tr>
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