



NEWSLETTER

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Postoperative Monitoring—The Dartmouth Experience

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Hospital inpatients represent a large constituency in the health care system—the National Center for Health Statistics estimated a total of 34.7 million discharges in 2005.¹ Accordingly, much effort has historically been expended to keep these patients safe during their stay. In its 2001 report “Crossing the quality chasm: A new health system for the 21st century,”² the Institute of Medicine identified *failure to rescue*—first defined by Silber in 1992 as hospital deaths following adverse occurrences such as post-surgical complications³—as a primary patient safety target.

The Anesthesia Patient Safety Foundation in “Essential Monitoring Strategies to Detect Clinically Significant Drug-Induced Respiratory Depression in the Postoperative Period” conference summary stated that, “The consensus of conference attendees was that continual electronic monitoring should be utilized for inpatients receiving postoperative opioids.”⁴

Patient surveillance or continuous monitoring on normally unmonitored wards⁵ is a departure from the concept of optimized individual care to optimized population care. It is a necessary conceptual

paradigm shift for anesthesiologists, but common practice in preventative medicine. This change in approach became necessary because of the documented failure of successfully identifying patients at risk for adverse events.⁶ Historically, postoperative monitoring was electively used on some patients perceived to be at a particular risk (e.g., patients with sleep apnea), a strategy based on condition monitoring. Equally important, retrospective reviews demonstrated that adverse events are preceded by a period of physiologic instability of 6-8 hours.^{7,8} Therefore, identification of at-risk patients by spot checks every 6 hours for 10 minutes, which observes vital signs only 5% of the time, begs for improvement. Hence, patient surveillance was introduced with the full understanding that we must do better. While monitoring cannot prevent all physiologic deterioration, it can function as a “patient safety airbag.”

Patient surveillance (PS) is still in its infancy. While there are initial encouraging results,⁹ there are some common misunderstandings regarding the concepts and many questions remain. Thus, we appreciate the invitation by the APSF to provide more

information in this newsletter on our use of patient surveillance since 2007.

In this report we will summarize the Dartmouth experience in the following areas:

- Are alarm settings for heart rate (HR) and oxygen saturation (SpO₂) transferable among different surgical populations, or even between surgical and medical populations?
- Were our initially reported results reproducible on other units?⁹
- Is patient surveillance cost-effective?
- What are the next steps we should implement?

Universal Alarm Settings?

Patients on medical and surgical floors show remarkable similarities regarding their physiological status. Knowledge of these similarities allows the use of similar static alarm settings when introducing patient surveillance systems. Only minor observable

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Postoperative Monitoring Improved Outcomes

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differences exist between different surgical and medical wards (Table 1, Figures 1 and 2). Patients spent about 6% of the time with oxygen saturations of <90% and 13% at <93% SpO₂. Heart rates were >80 bpm 50% of the time for all units; in medicine 14% of the time was spent >100 bpm, while in surgery the figure was 11%. Mean SpO₂ and HR were very similar among surgical units and between surgical and medical wards.

With the exception of the pediatric unit, we used the same alarm settings as in our original description (SpO₂ <80%, HR <50 or >140),⁹ with alarm adjustments by nursing staff of ±10%, and further adjustments with a physician order. All medical and surgical patients at Dartmouth have been continuously monitored since 2010.

Results on Other Units

Expansion of patient surveillance using SafetyNet™, Version 2.0.1.3 (Masimo Corp., Irvine, CA) to other units had positive effects on outcomes on all surgical, but not medical units. Figure 3 demonstrates a reduction in average rescue events on the surgical units. This was accompanied by a reduction in care escalations to units of higher intensive care (intermediate and intensive care units), as seen in Figure 4. We use rescue events identified as Rapid Response Team (RRT) activations for cardiopulmonary and respiratory arrests as our main measure of success of early intervention prompted by continuous monitoring. In contrast to measuring escalation of care to intermediate or intensive care units (ICU), the triggering of the rescue team is not dependent on resource availability (ICU beds) or institutional practice patterns. Therefore, we find reduction of rescue events to be a more meaningful measure of early interventions that also makes comparisons among institutions possible.

We have seen institutional reductions in rescue events (0-65%) and in ICU transfers (0-50%). Greater reductions are seen on wards with higher utilization of the system, greater baseline risks, and higher opioid consumption. Use of opioids and number of opioid reversals have not changed (Table 2); opioid antagonists are given for respiratory rates of 5 or less and are administered by nurses per our protocol. However, no patients have suffered irreversible severe brain damage or died since PS was instituted on the original study unit in December of 2007 as a result of respiratory depression from opioids. On surgical units, opioid consumption is greater than on medical units, and the majority of rescue events (>75%) are respiratory in nature.

These results have prompted our institution to mandate continuous monitoring of all patients when they are not being directly observed by a health care provider. If patients refuse such monitoring, they are asked to acknowledge the increased risk using an institutional refusal form.

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Table 1: Comparison of 3 Surgical Units.

	General Surgery (%)	Orthopedic (%)	Vascular-Thoracic (%)
SpO ₂ <93%	12	13	15
SpO ₂ 93-97%	56	53	59
SpO ₂ >97%	32	33	26
Heart Rate 60-79	38	46	50
Heart Rate 80-99	46	43	40
Heart Rate 100-119	14	10	9
Heart Rate ≥120	2	1	1
2-4 Patient days	733	1940	1818
Data points	63,356,247	167,655,437	157,108,126
Mean SpO ₂ [SD]	95.8 [±3.0]	95.8 [±3.3]	96.5 [±3.1]
Mean Heart Rate [SD]	82.5 [±16.5]	80.6 [±15.1]	78.7 [±15.4]
DRG index	1.44	2.0	1.92

SD: standard deviation. DRG index: diagnosis related group relative weight index (an indicator for severity of illness with higher numbers reflecting higher severity).

SpO₂ Histogram Comparison

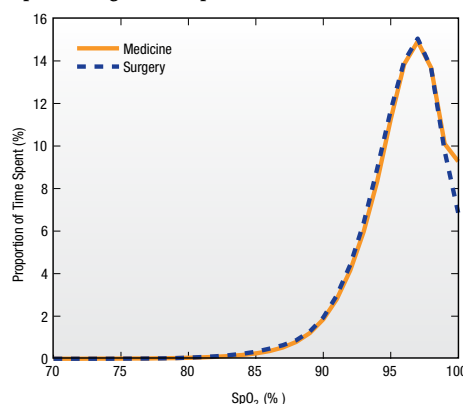


Figure 1: Distribution of oxygen saturation by pulse oximetry comparing patients on surgical and medical units.

HR Histogram Comparison

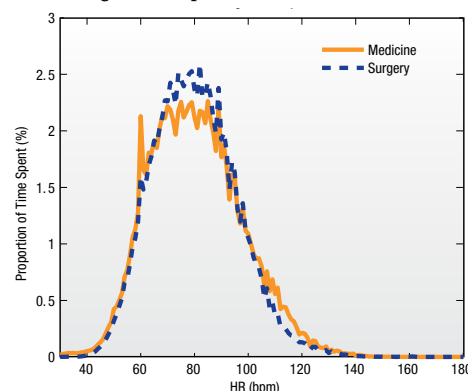


Figure 2: Time spent in heart rate states comparing patients on surgical and medical units.

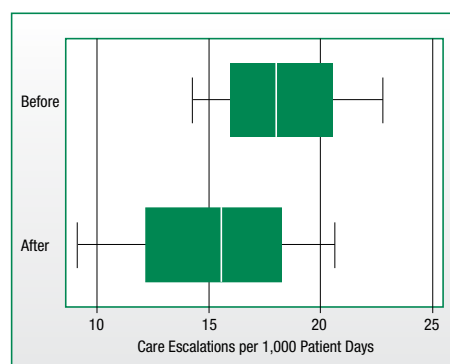


Figure 3: Rescue events (Rapid Response Team activations, arrests, and respiratory codes) per 1,000 patient days per month over 2 years with patient surveillance deployment after 12 months on 3 surgical units. Box plots: white line displays median, dark boxes contain 25-75% percentiles, whiskers 5-95% percentiles. Wilcoxon rank sum test $p < 0.05$ for all surgical units.

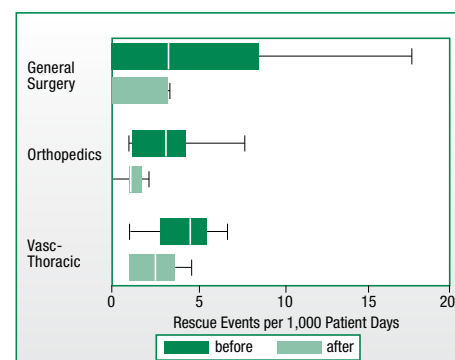


Figure 4: Care escalations (Transfers to Intermediate or Intensive Care Units) per 1,000 patient days per month in the 12 months before and after implementation of patient surveillance. Box plots: white line displays median, dark boxes contain 25-75% percentiles, whiskers 4-95% percentiles. Wilcoxon rank sum test: $p = 0.02$.

Patient Acceptance and Cost-Effectiveness Are Key Factors

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Cost-Effectiveness

We also conducted a cost-effectiveness analysis for continuous patient monitoring. The costs we used included hardware costs, hospital charges, and fees, and should be considered estimates. These costs are dependent on institutional factors such as volume purchasing and discounts and would vary from institution to institution. The cost-effectiveness depends upon the impact of patient surveillance. For purposes of simplicity, the model presented here is based on reduction of ICU transfers and days spent in ICU. We do not try to estimate other cost opportunities such as medicolegal cost or reduced utilization of rapid response teams, nor did we use a financial penalty for adverse outcomes as is commonly done in cost-effectiveness studies. These potential costs could dramatically increase the cost savings shown in this article. The study of the relationship of quality improvement and cost savings is complex; thus, we are giving a broad overview of *cost opportunity* without trying to attempt an estimate of various levels of realizable cost reductions.¹⁰

Initial implementation costs for a 36-bed unit amounted to \$167,993 (Table 3), plus annual costs of \$58,261 (Table 4). The cost per patient per hospital episode is \$85 for the implementation year and \$22 for subsequent years. Averaged hospital costs for a patient on the original study unit without an ICU Transfer were \$17,585 vs. \$76,044 with an ICU transfer (Table 5).

Prior to introduction of patient surveillance the length of stay (LOS) of a patient with ICU transfer was 24.39 days (7.67 days in ICU plus 16.72 days on the regular floor), afterwards average LOS was 19.32 days (5.87 days in ICU plus 13.45 days).

Annual opportunity cost savings¹¹ due to decreased ICU transfer rate amount to \$1,479,012 for the initial study unit (as described in reference 9). These opportunity cost savings at DHMC helped address the ICU capacity limitations that were leading to missed opportunities to care for patients in addition to the financial impact. On the other end of the spectrum we had increased cost in a medical unit where the introduction of surveillance was not associated with any change in outcome (implementation and ongoing maintenance costs of the system).

Sensitivity Analysis. Varying the baseline ICU transfer rate demonstrated a greater effect of using patient surveillance as the baseline ICU transfer rate increases. Varying the relationship between ICU transfers with and without PS showed equality when the rate (per 1000 patient days per month) of ICU transfers on the patient surveillance unit is 1.09 (9% higher) that of the non-PS unit.

Cost-effectiveness on other units depend primarily on incidence of adverse events and reduction of event rate. Our thoraco-vascular unit had a higher baseline event rate than the original study unit with a smaller reduction of ICU transfers by about 30% and rescue

events by 50%. Because of the higher incidence of transfers, a total of 168 days in the ICU were saved in the 12 months after implementation of PS compared to before, about 10 more days than the original study unit. On some medical units with low event rates and smaller or no change with PS, cost-effectiveness is neutral or even negative when using this opportunity cost-based analysis. Due to high utilization of patient bed capacity (98% at DHMC), standard bed monitoring capacity in all medical and surgical beds allows a flexible floating team of nurses that can provide care for patients on a temporary, as-needed, basis. This flexibility assists our management of our entire inpatient census.

Next Steps

Despite our best efforts, patients still have adverse events requiring rescue interventions and escalations of care. PS as an airbag has worked; we have had no death on the original PS unit since 2007.

We are investigating the use of acoustic respiratory monitoring in addition to our current pulse oximetry network to determine if it has an impact on overall outcome and to identify population groups at risk that would have the greatest benefit from additional monitoring (such as postoperative patients on supplemental

oxygen). Early results show that the monitors are relatively well-received by patients. These monitors are better tolerated than our earlier trials in the immediate postoperative phase with chest straps for respiratory rate monitoring or nasal cannulas for end tidal CO₂ monitoring, but not as well as finger pulse oximeter probes. Patient comfort and acceptance and minimizing false positive alarms are of great importance when evaluating continuous surveillance devices. In the future we will likely see pulse oximetry surveillance for all, and additional monitoring for some until monitors with the accuracy and comfort of pulse oximetry become available.

Static alarm triggers need to be combined with smart alarms, which have the ability to identify and track patterns associated with clinical deterioration. Our early results are encouraging, while the ability to identify patients likely to deteriorate remains challenging. In a recent roll-out of continuous monitoring in a pediatric unit we have started to use patient dependent alarm settings (age-dependent heart rate alarms). Ideally, systems could be integrated and exchange information between electronic record systems and bedside monitors to allow the seamless calculation of early warning scores based on physiologic, demographic, and

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Table 2: Rescue Events (RRT activations, arrests and respiratory codes) per 1,000 patient days per month over 2 years with patient surveillance deployment after 12 months on 3 surgical units. Morphine equivalents in mg per patient per month. Opioid Reversals per 1,000 patient days.

	Before [mean (SD)]	After	p Values
Rescue events	4.4 (3.9)	1.90 (1.7)	p<0.01
Morphine equivalents	21.2 (3.8)	24.9 (6.5)	NS
Opioid reversal	1.6 (1.8)	1.8 (1.6)	NS

SD: Standard Deviation. Statistics by Wilcoxon rank sum test.

Table 3: Fixed Costs

36 bedside devices, connectors, cables, SafetyNet™ for 36 instruments, pagers, vendor installation cost

Item	Cost (\$)
Surveillance System for a 36-bed unit	165,493
Training	2,500

Table 4: Annual Costs for Surveillance System

Item	Cost (\$)
Implementation and Continuing Operations. Implementation: 2.5 hours per bed, 3-4 hours per unit, Operation: 2 hours per week per unit (65-70 hours)	8450
Implementation and Operation of wireless pager system	3380
Patient Surveillance System Consumables (8.25 per unit with 469 sensors on average per month)	46431

Table 5: Average Hospital Costs Per Patient on Original Study Unit

Costs	Average (\$)	SD	CI
With transfer to ICU	76,044	71,847	60,770-91,319
No transfer	17,585	10,608	17,129-18,041

ICU: Intensive Care Unit, SD: Standard Deviation, CI: 95% Confidence Interval

Improved Safety Requires Collaboration

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comorbidity data, without the need for the user to provide additional input or set alarms and triggers.

Finally, we would like to emphasize the importance of strong collaboration between engineers, nurse, physicians, and technology providers to make patient surveillance work. All stakeholders must be engaged and work together to facilitate the establishment of a safer clinical environment.

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