Vanderbilt University Medical Center

Department of Anesthesiology

A Vital Sign Based Decision Support System for Evaluating Post-Surgical Hospital Patients

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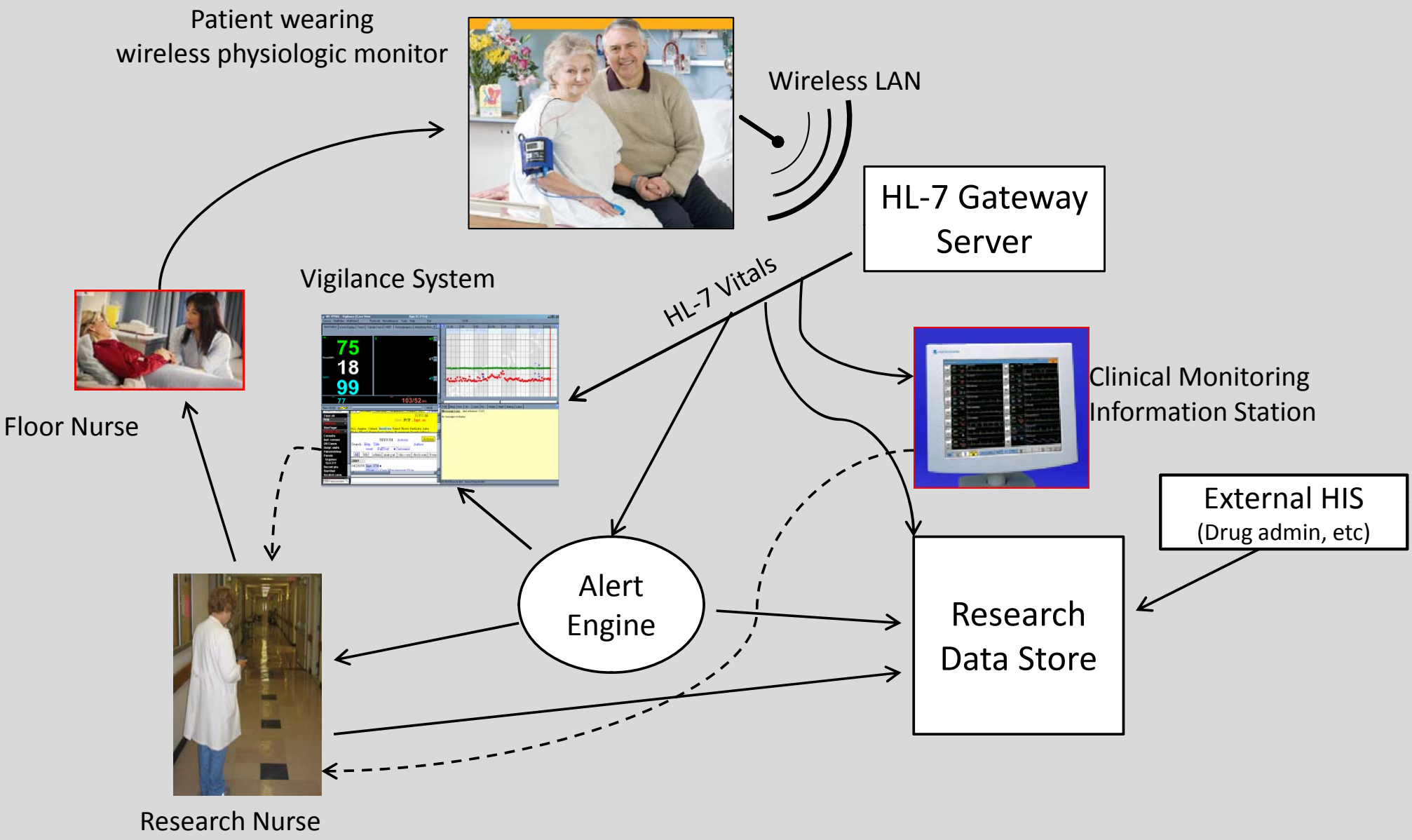
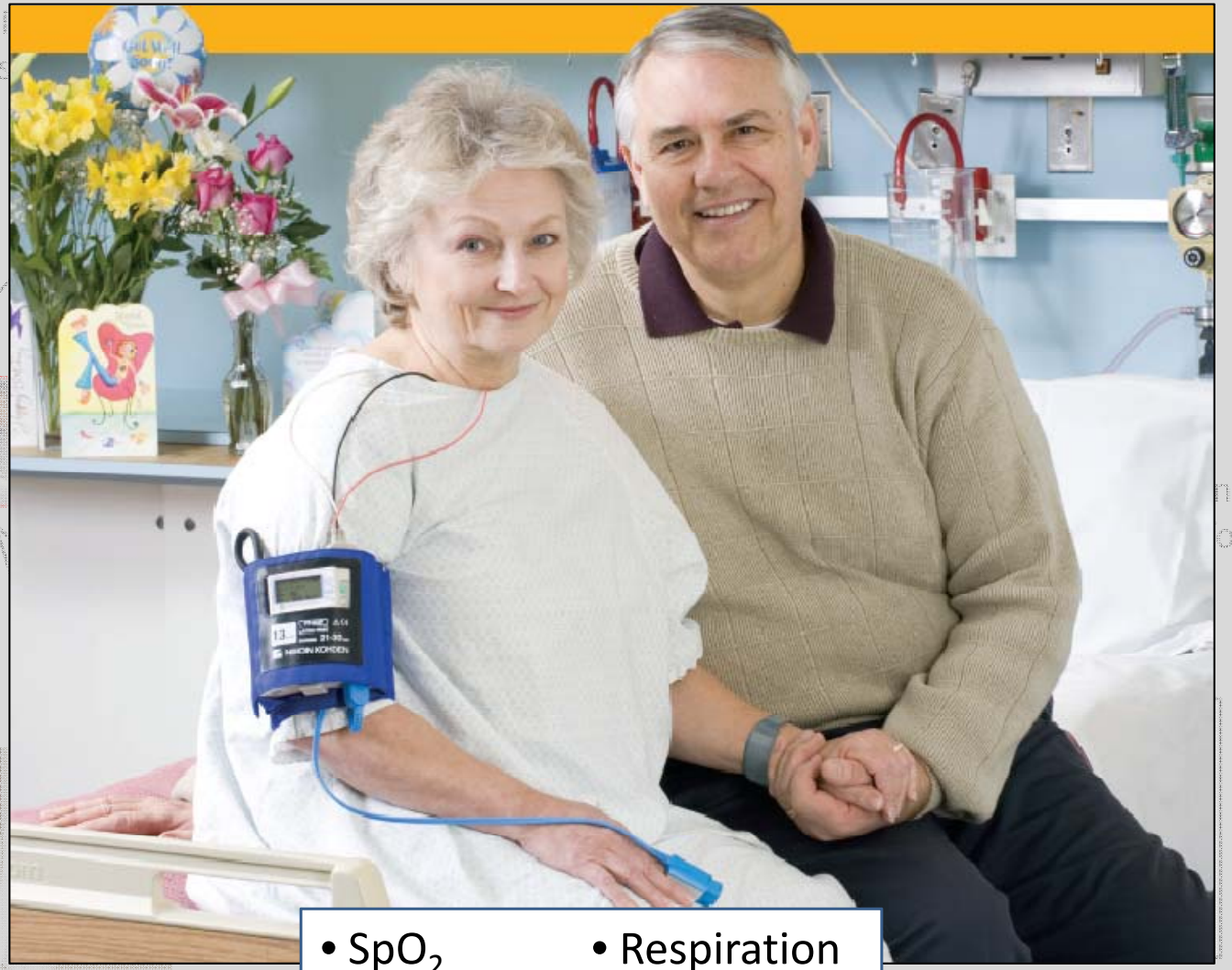
Overview

- Describe post-surgical floor study
  - Challenges & Opportunities
- Need for decision support system
  - Development of data and expert derived system
  - Opportunity to validate system

Post-Surgical Floor Study Overview



Patient On Wireless Monitor



wireles

Floor Nurse

nical Monitoring
ormation Station

External HIS
(Drug admin, etc)

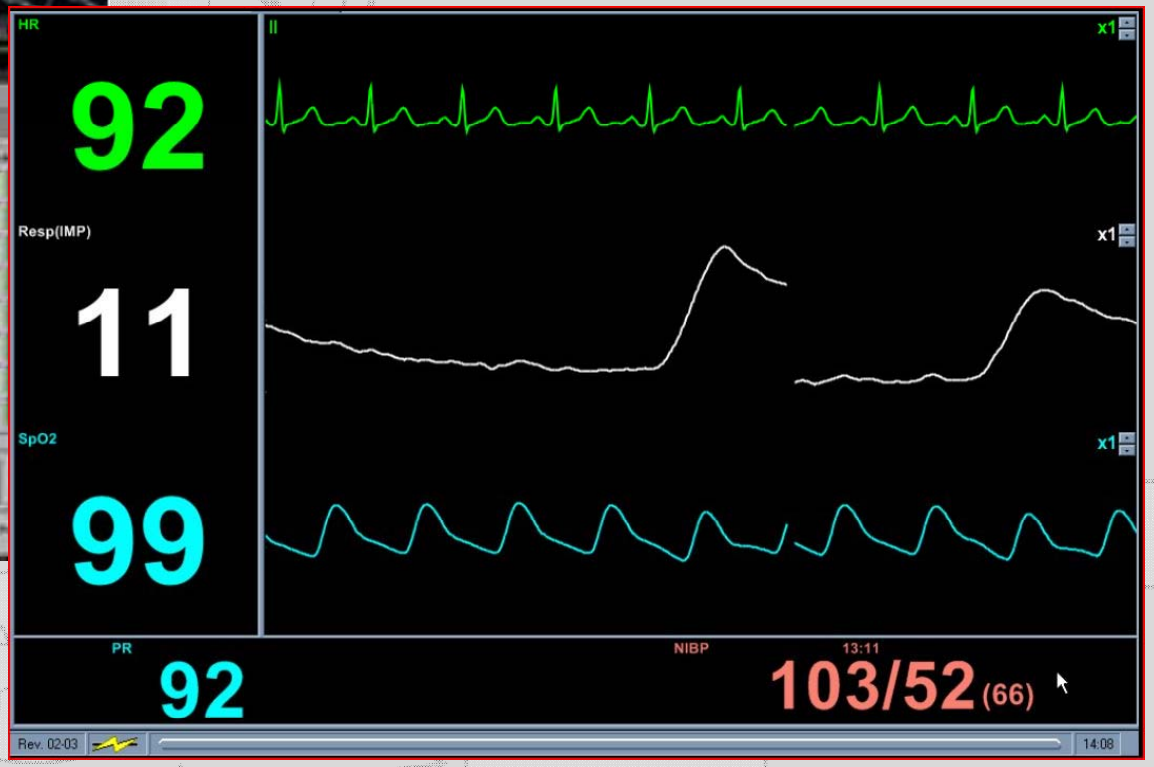
Research Nurse

- SpO_2
- HR
- PR
- BP
- Respiration
- Apnea
- ST
- PVC

Clinical Monitoring Information Station

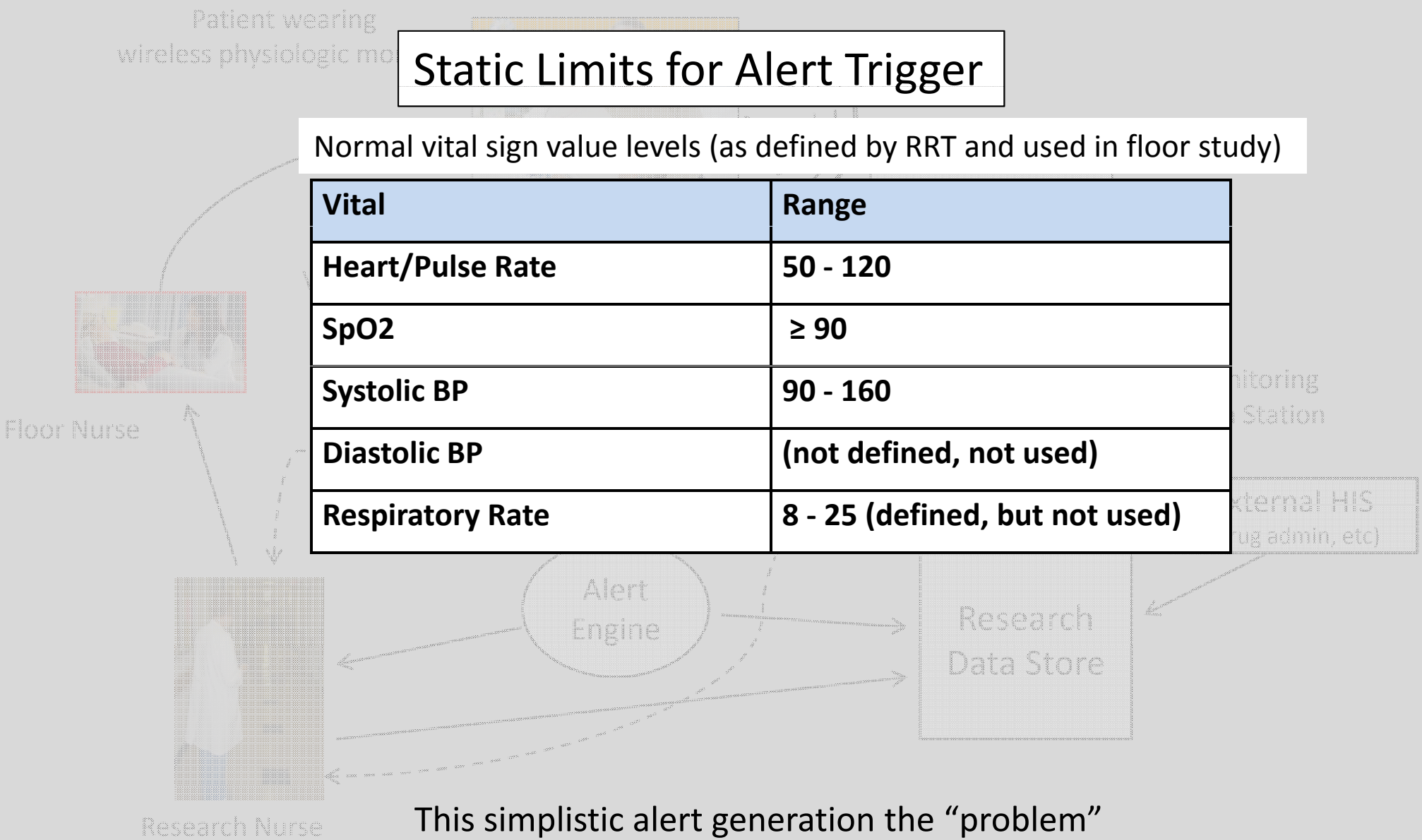
Nihon Kohden America

Transforming patient care with technology.



- Arrhythmia recall
- 72 hour full review
- Trends
- Reports
- Web Access

Alert Engine



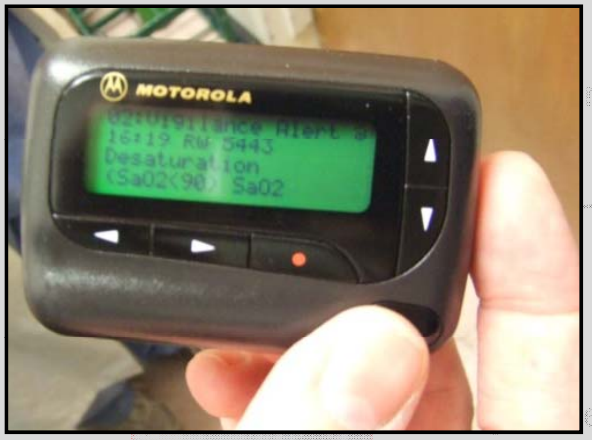
Static Limits for Alert Trigger

Normal vital sign value levels (as defined by RRT and used in floor study)

Vital	Range
Heart/Pulse Rate	**50 - 120**
SpO2	**≥ 90**
Systolic BP	**90 - 160**
Diastolic BP	**(not defined, not used)**
Respiratory Rate	**8 - 25 (defined, but not used)**

This simplistic alert generation the “problem”
we are working to improve

Research Nurse



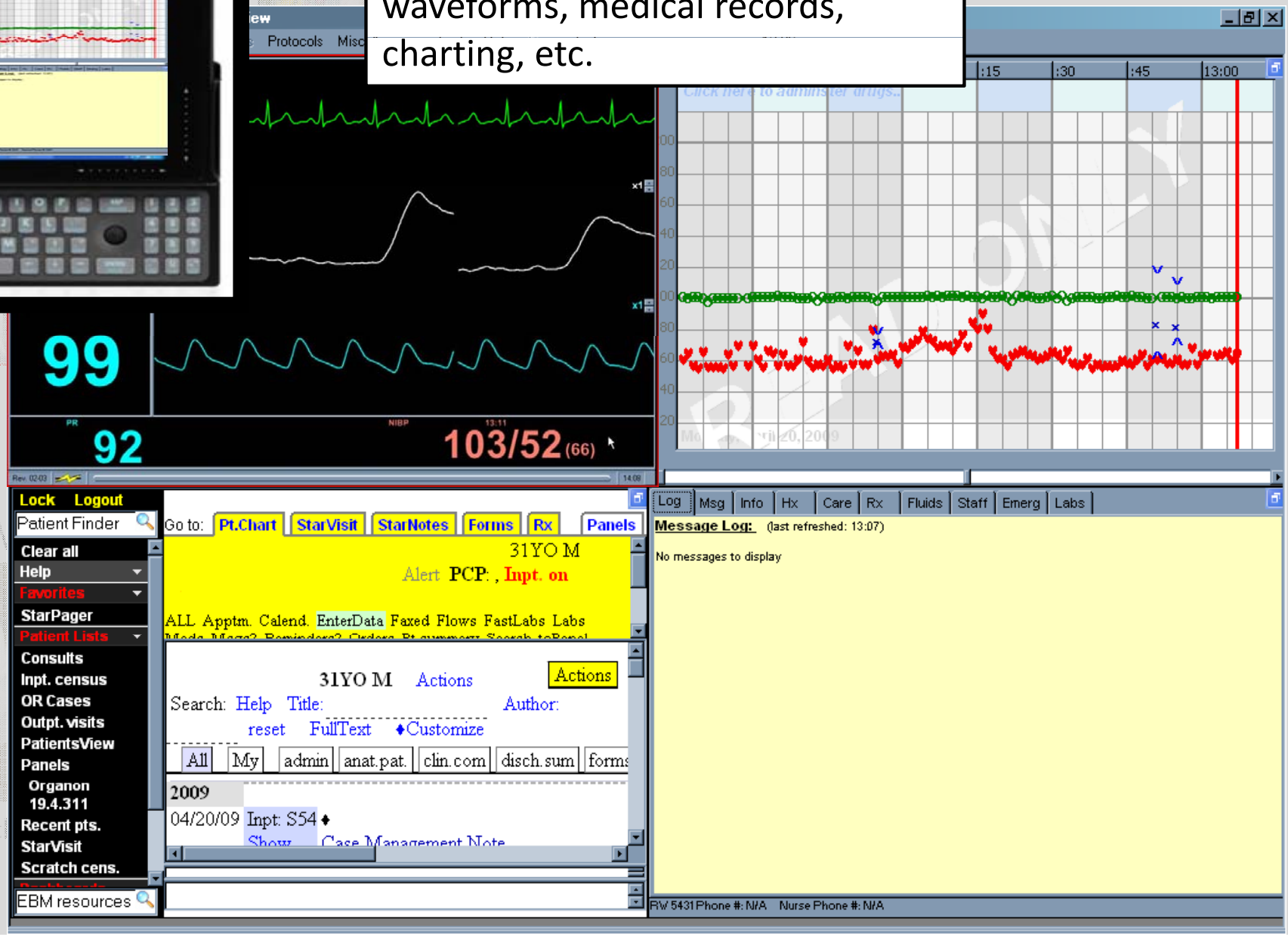
- **Research clinicians receive pager alerts**
- **Wireless remote viewing of monitors and records allows immediate patient assessment and intervention**

May notify floor nurse if review of data and records indicate a patient care action is required.

Vigilance System

Vigilance System

System integrates monitor data, waveforms, medical records, charting, etc.



Floor Nurse

Notified by research nurse if the research nurse determines an alert is valid and warrants patient care action.

- Ideally, the floor nurse checks the patient and provides care as necessary.
  - May determine action is unnecessary
  - May not record action (re-apply oxygen)
  - May require extreme action such as code or RRT call

Research Data Store

1,000 patients have completed study

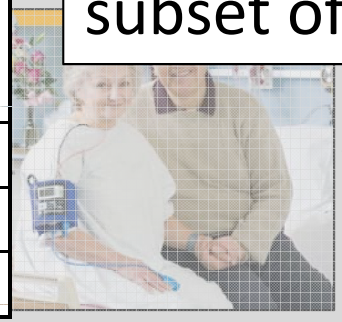
(17,000 hours monitor data)

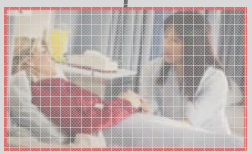
- Electronic
  - Vital raw data
  - Generated alerts
  - Nursing care data (drugs, vitals, etc.)
  - Perioperative care data
  - …
- Paper
  - Research nurse notes
  - Print out of waveforms

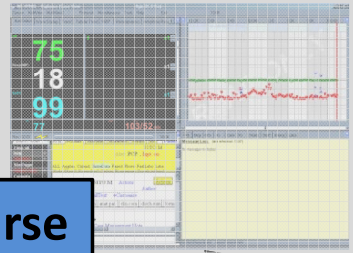
Data Flow Summary

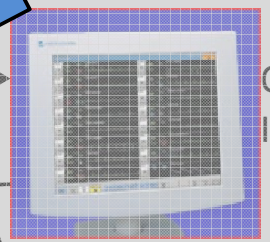
Patient Type	Cases	Hours On Study
Monitor	122	1,829
Control	120	1,767
Total	242	**3,596**

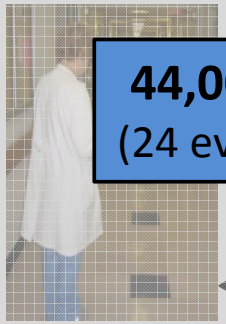
subset of Jan, Feb, March ’09 Case Data











Wireless LAN

HL-7 Gateway Server

Vigilance System

HL-7 Vitals

15 Million
(4,171/hr/patient)

Clinical Monitoring Information Station

Floor Nurse

309 Alerts to Floor Nurse
(0.17/hr/patient)

External HIS
(Drug admin, etc)

Alert Engine

Research Data Store

44,000 events
(24 events/hr/pt)

Research Nurse

Data Summary

subset of Jan, Feb, March ’09 Case Data

Patient Type	Cases	Hours On Study
Monitor	122	1,829
Control	120	1,767
Total	242	**3,596**

	From 1/12 to 3/31	
Selected Vital	**Control**	**Monitor**
SpO2	827,885	838,280
HR	804,852	837,563
PR(spo2)	806,027	809,602
RESP	814,612	844,491

Event	Nurse Calls From 1/12 to 3/31
Tachycardia	43
Bradycardia	5
Desaturation	207
Hypertension	28
Hypotension	26
Total	**309**

309 Floor Nurse “alerts”/ 1,829 hours = 0.17 alerts/hr

122 Monitor Cases	
Selected Vital	**Events**
SpO2 (desat)	9,219
HR (Bradycardia)	133
HR (Tachycardia)	1,948
PR (Bradycardia)	475
PR (Tachycardia)	3,877
RESP (Bradypnea)	18,004
RESP (Tachypnea)	10,085

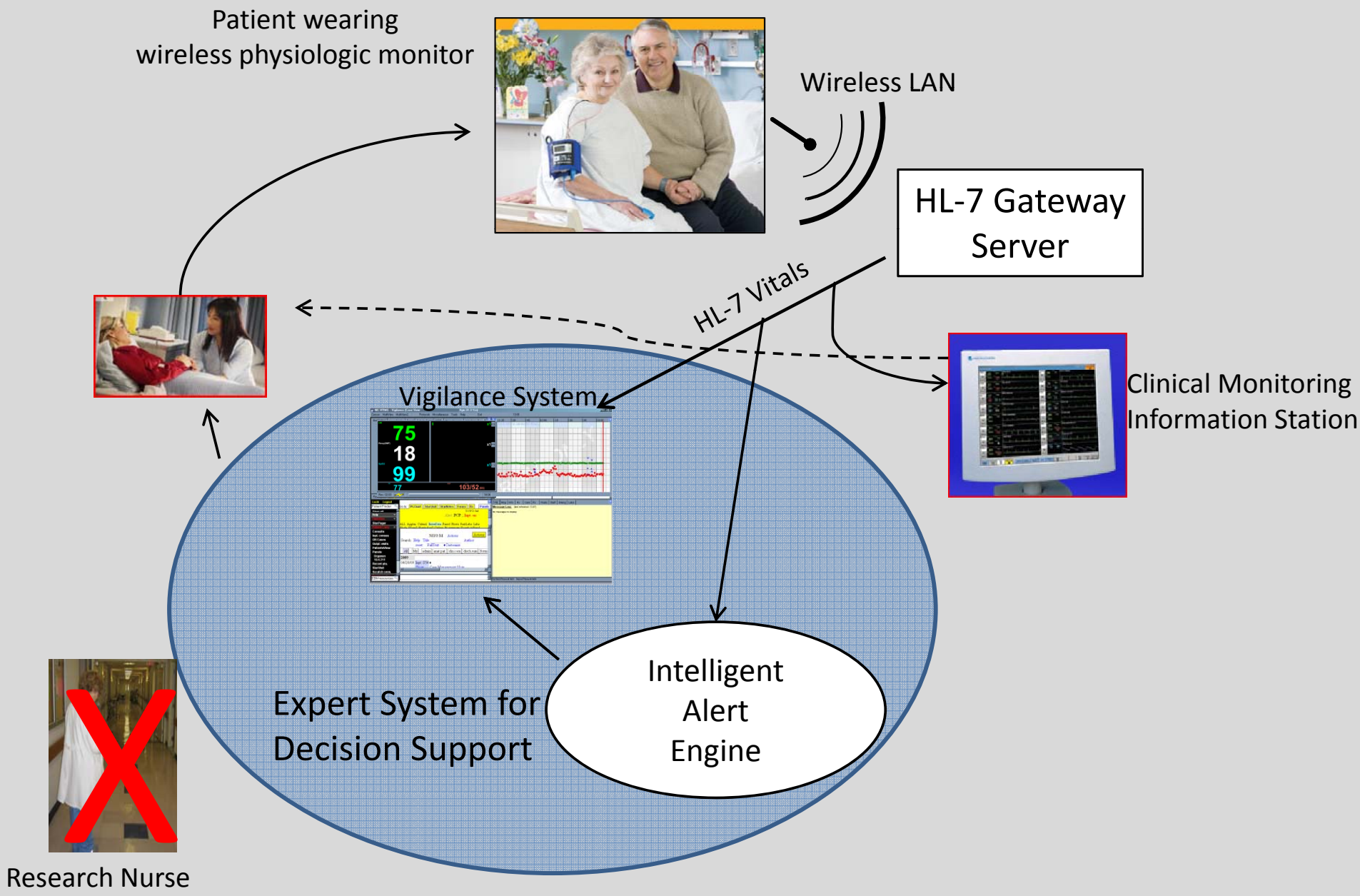
9,219 events / 1,829 hours = 5 Desats/hr

An event is defined as starting when threshold is passed and ends when vital returns to “normal”

Need to Develop DSS

> Sent: Wednesday, October 29, 2008 9:56 AM
➢To: Rick
➢Subject: excessive messages to pager 615-835-xxxx & 835-xxxx
>
> Rick,
> Pager number 615-835-xxxx received 612 messages yesterday. The
> message count for this pager number since 14 October is already over 10,000.
>
> The content of the message appears to indicate an automated
> application that should be telemetry rather than paging**. I can not**
> imagine a human is monitoring this messages and getting ANY work done when there are about 100 messages per hour.
>
> This volume of traffic is detrimental to the overall paging network.
>
> Can you suggest someone with whom I can speak about this use of paging?
>
> Regards,
> Nick

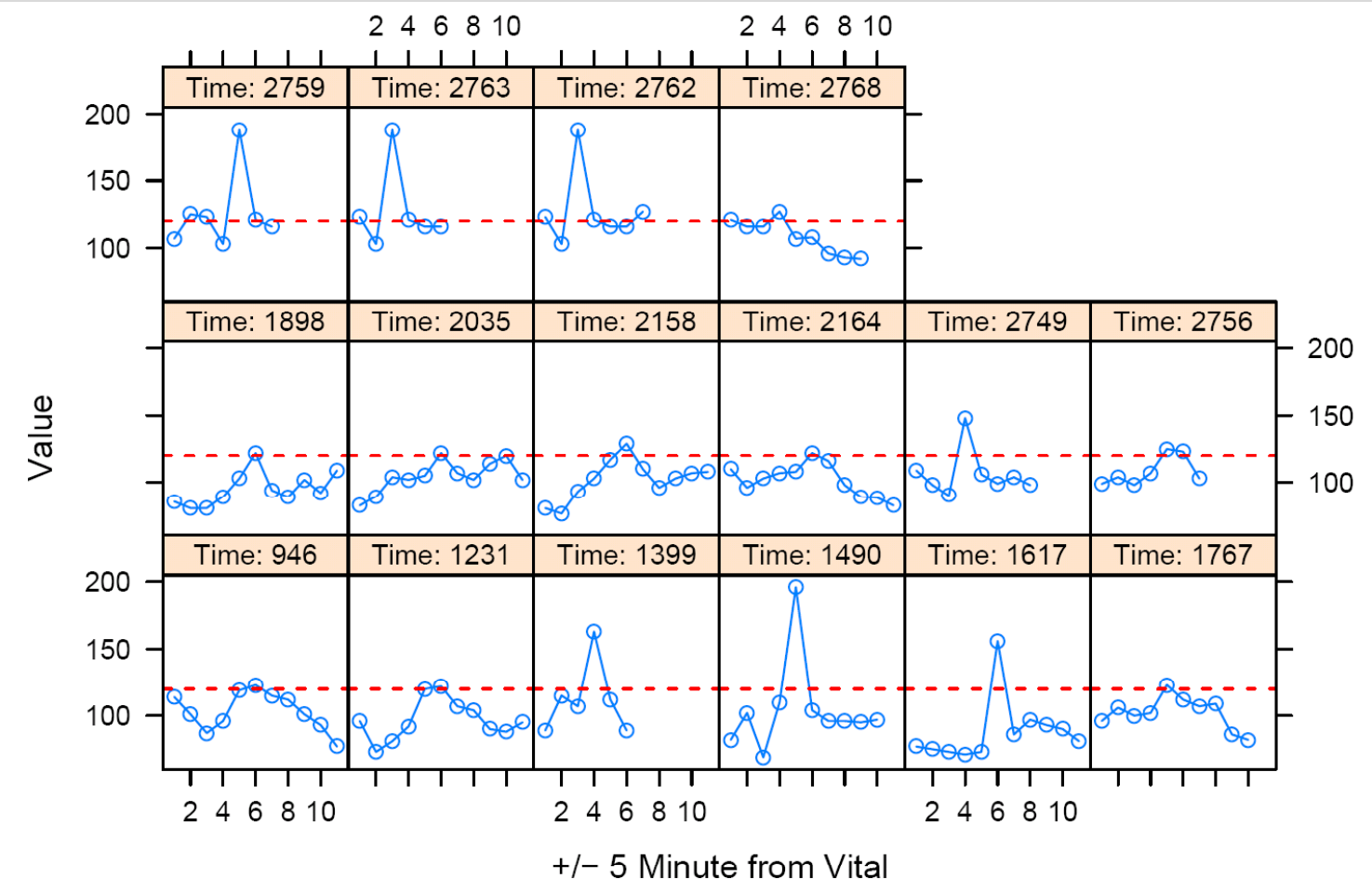
Opportunity to Develop DSS



1st Step in Improvement

What is causing the unnecessary 23.8 events/hr ?

Heart rate events for a case



Large quantity of events appears to be significantly due to brief spikes in value

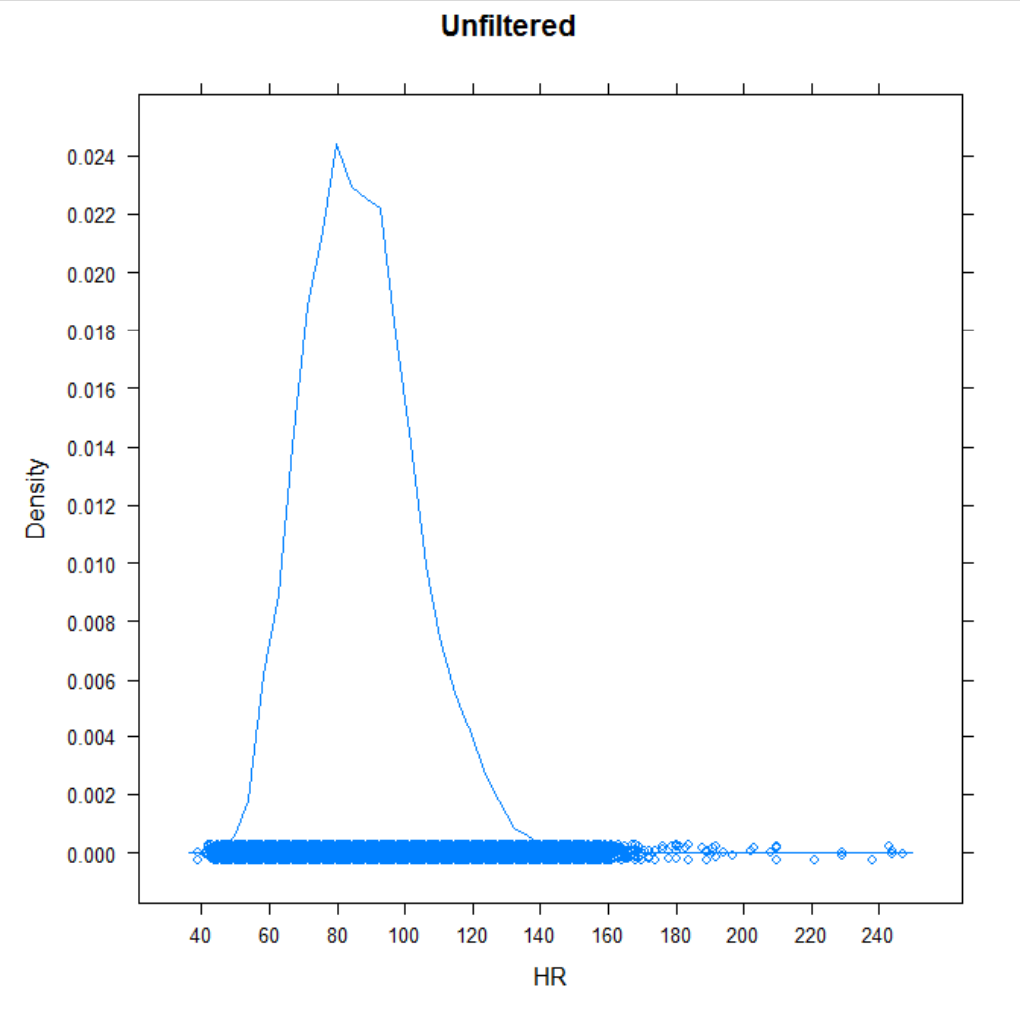
Filter for Event Reduction

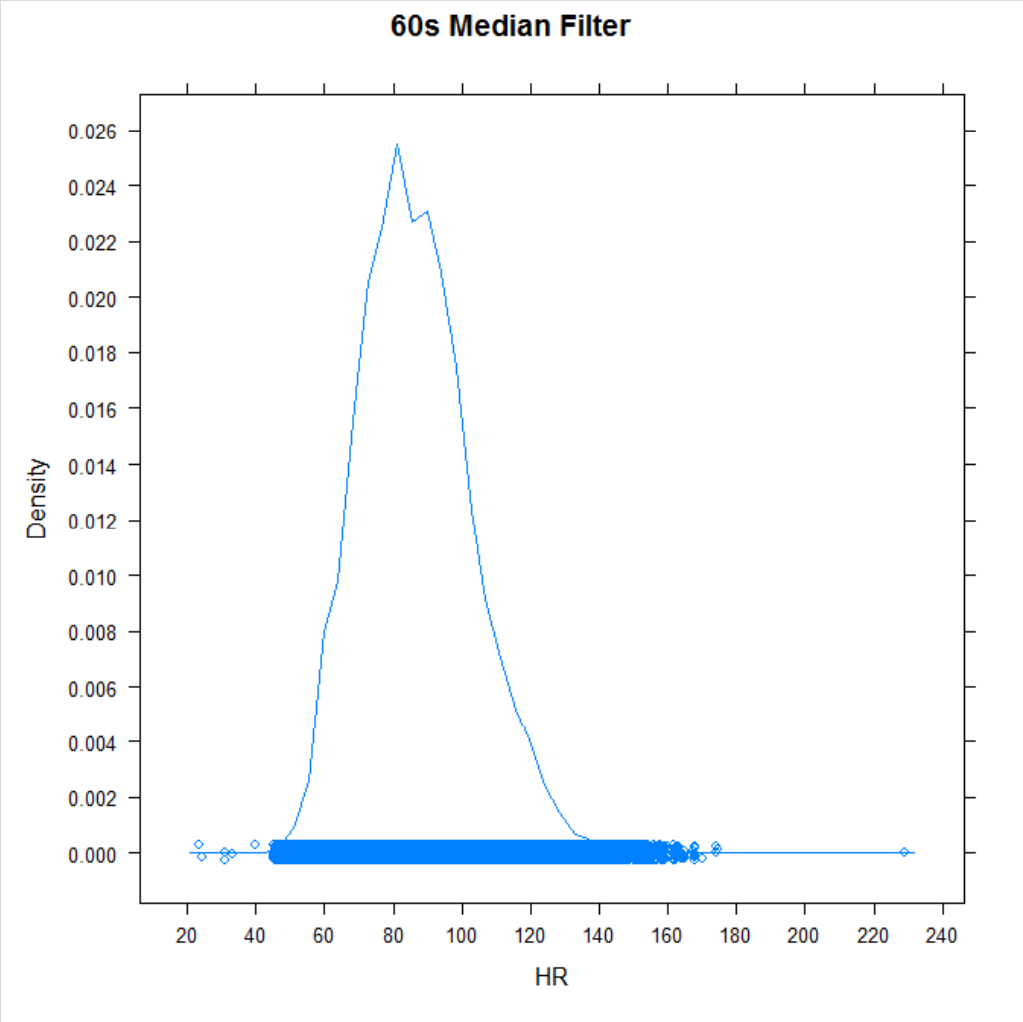
Median Filter

Time (sec)	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
SaO2	85	87	85	85	85	83	85	85	87	90	90	89	85	85	83	83	85	85	87	90
	Avg: 85.7 Median: 85										Avg: 86.2 Median: 85									

A median filter sorts the vital sign values in a given time period and picks the middle value of the sorted list. This is commonly used in signal processing and eliminates the influence of significant outliers better than an arithmetic average of the values.

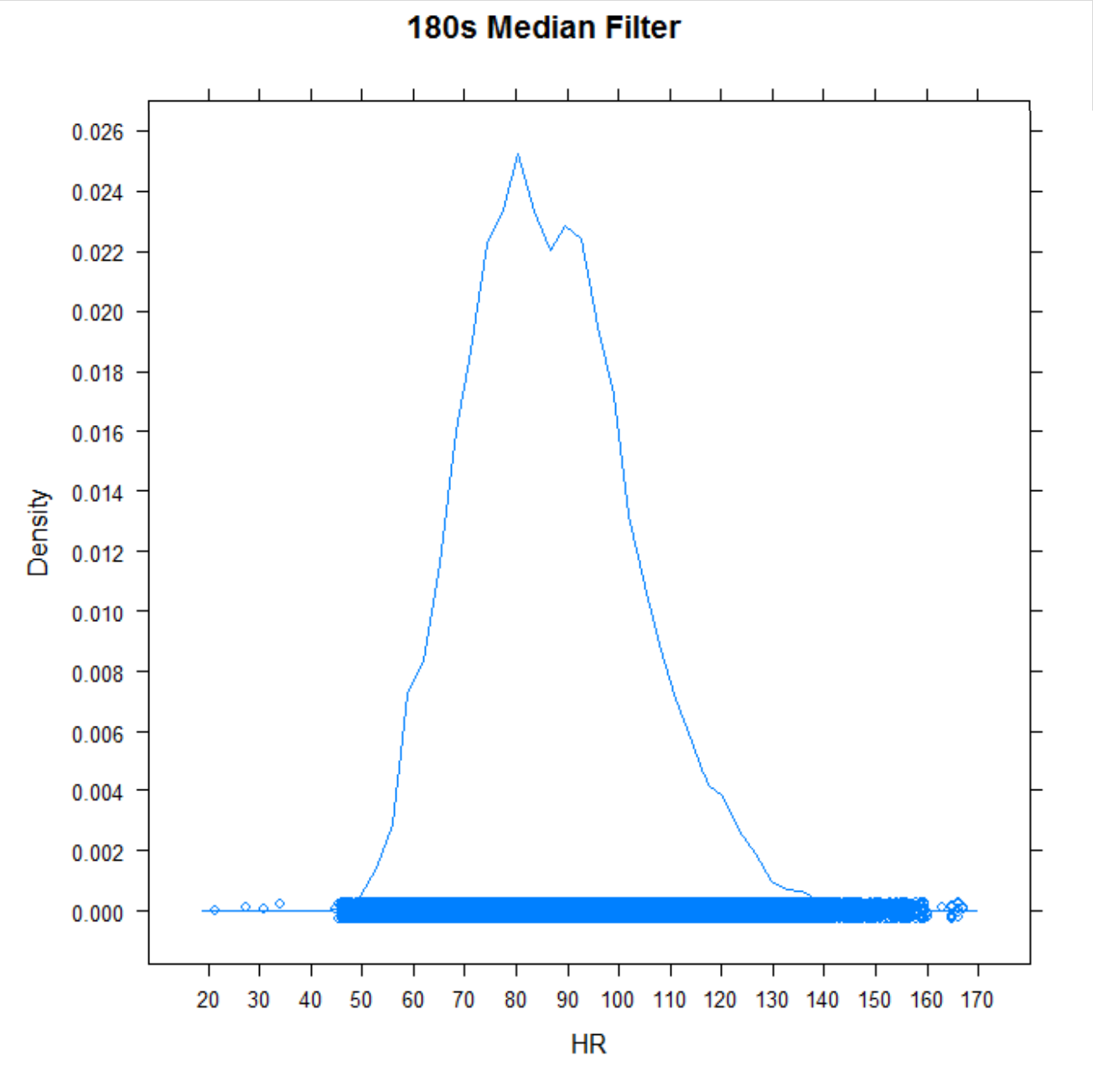
Overall Filter Impact



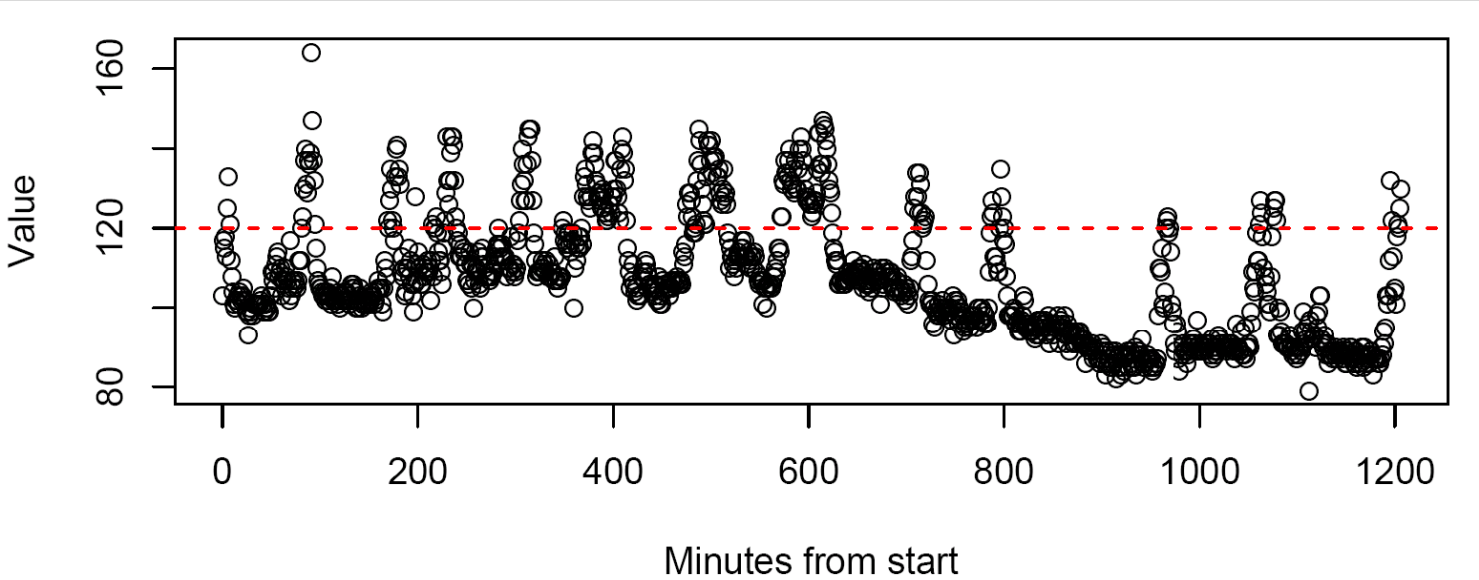


Impact is not too obvious from this analysis

Overall Filter Impact

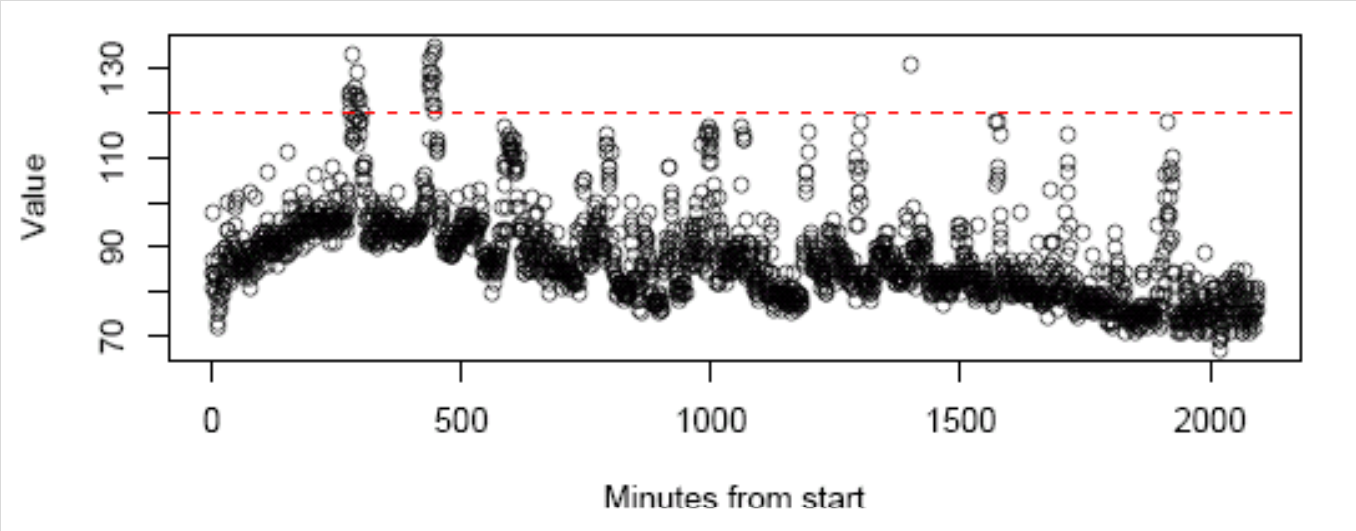


Data Visualization

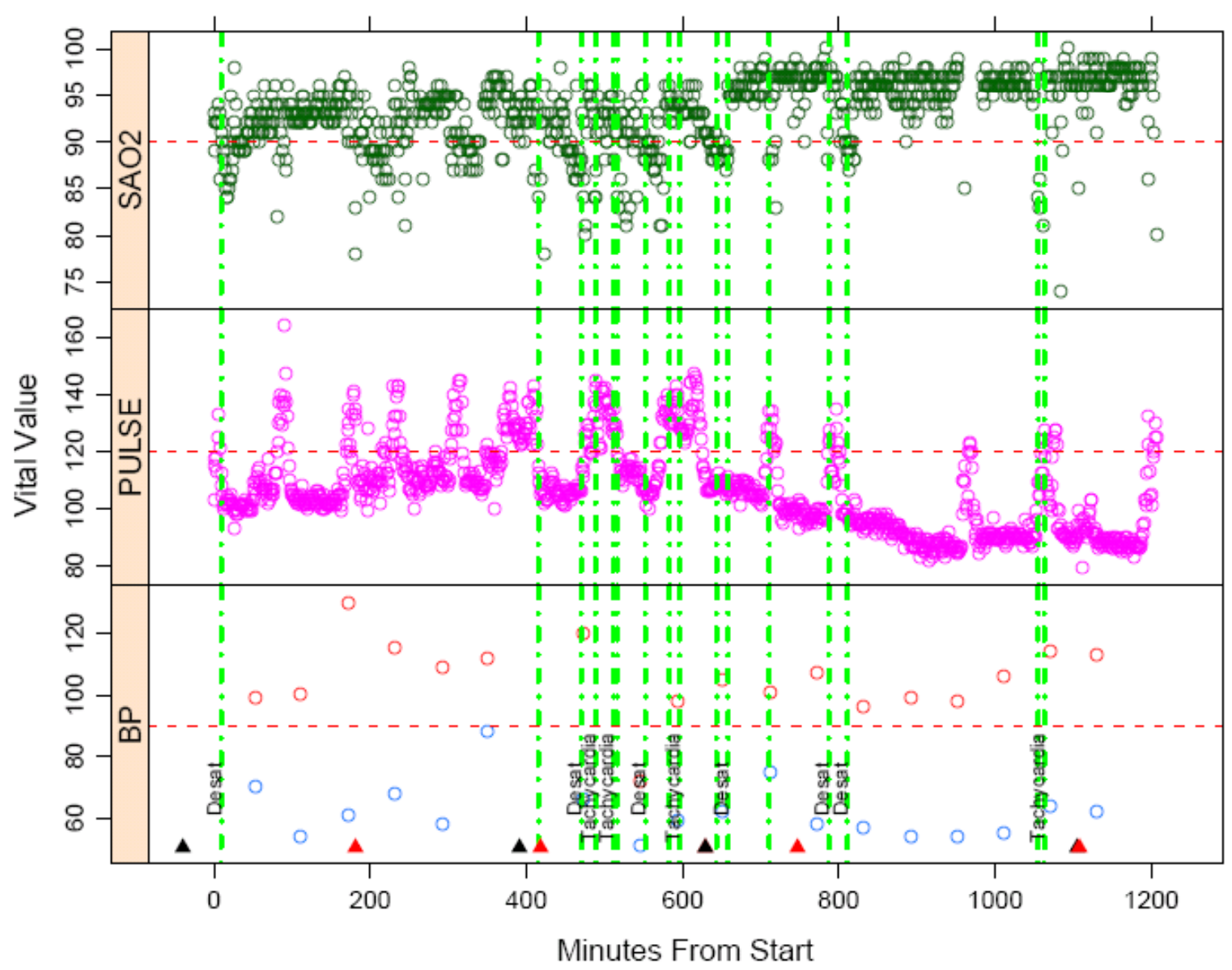


Two samples of visualizing the data (HR) and noticing patterns in the data when compressed to this scale.

Periodic spikes were hypothesized to be due to pain control issues.

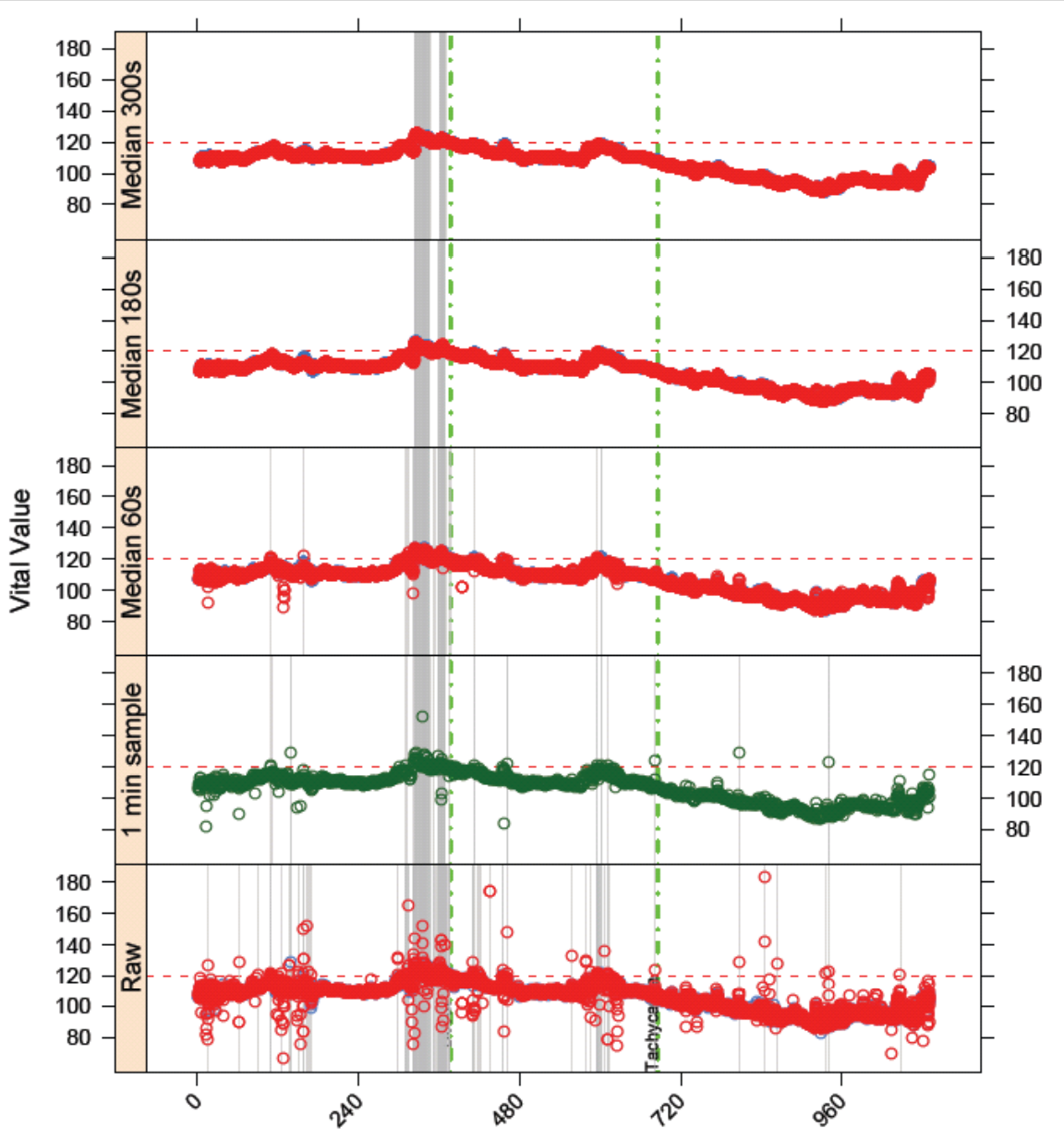


Data Visualization



Filter Impact by Individual Case

Heart Rate



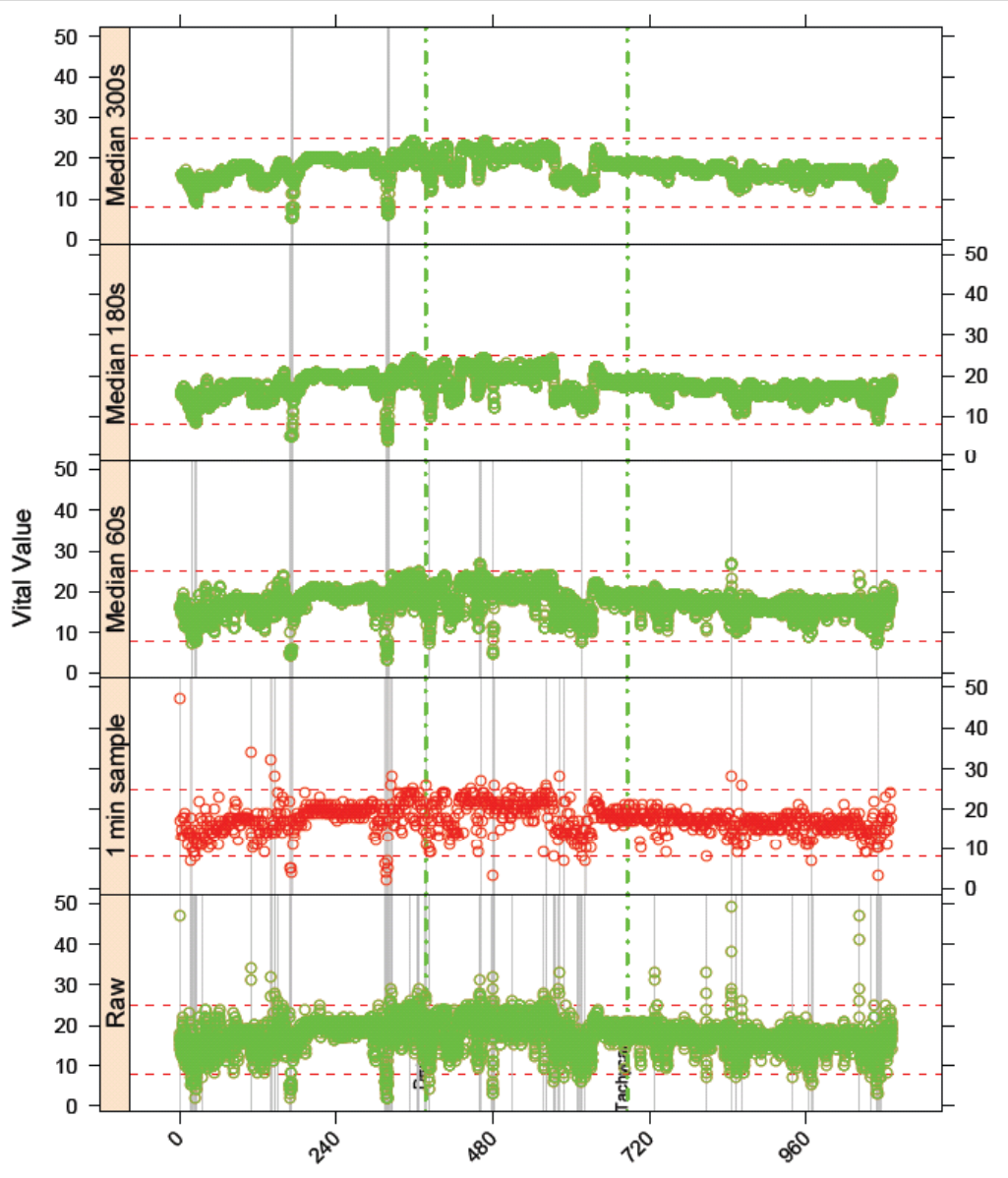
Various smoothing filter options visualized for a specific 1,000 minute case.

Grey shading highlights “events”

Filter reduces the quantity of events from 115 to 5

Data Visualization

Respiratory Rate



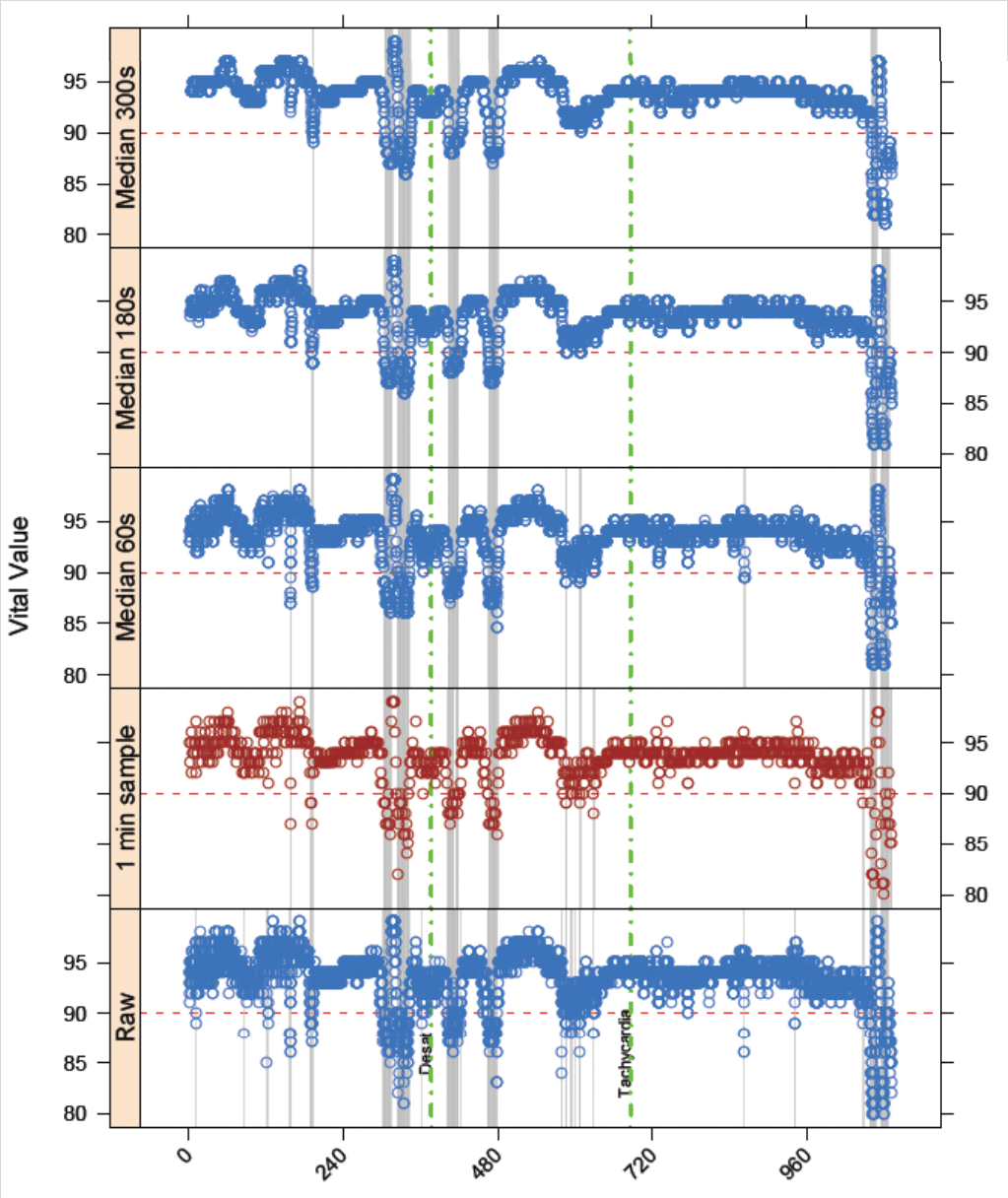
Various smoothing filter options visualized for a specific 1,000 minute case.

Grey shading highlights “events”

Filter reduces the quantity of events from 134 to 4

Data Visualization

SaO_2

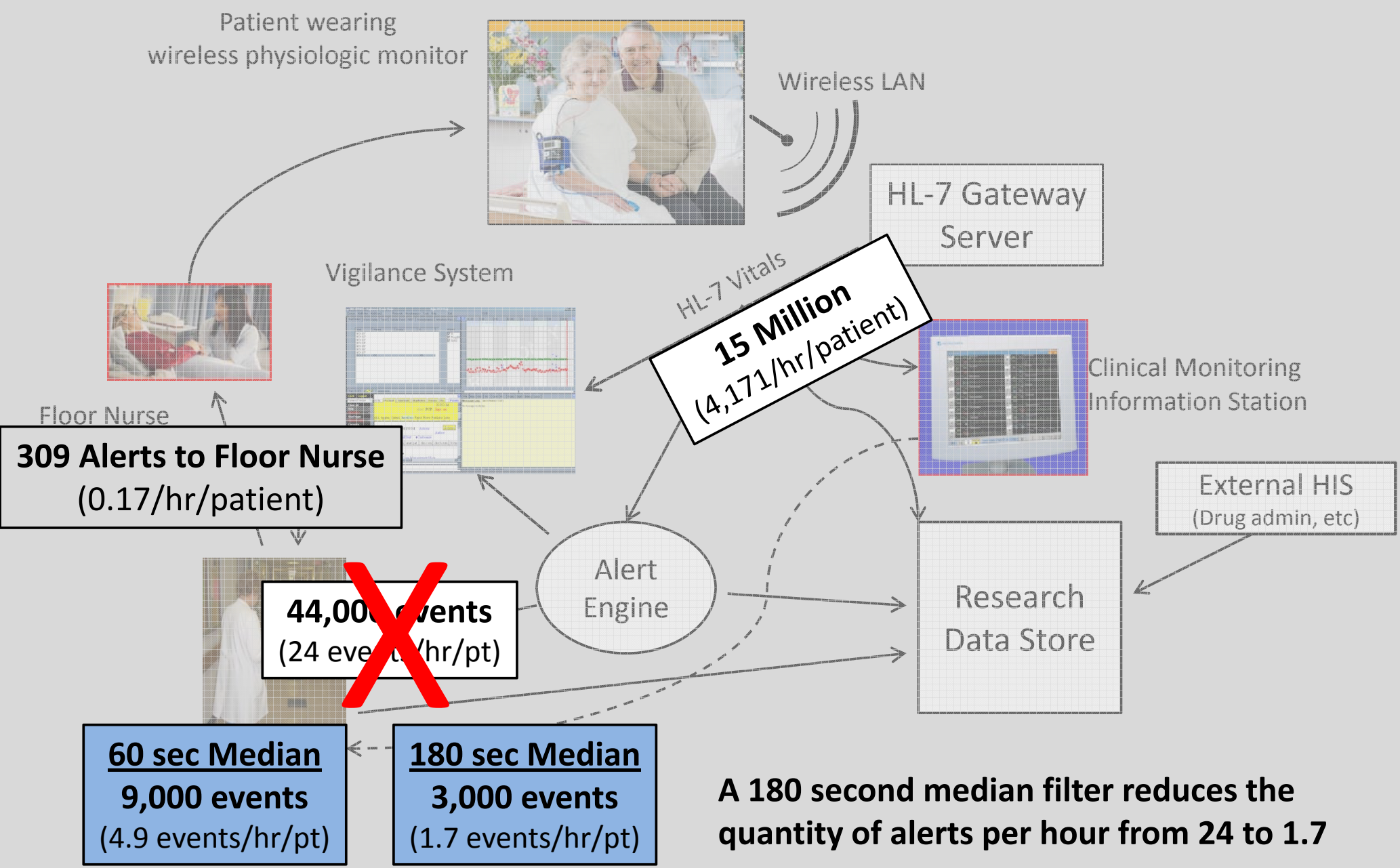


Various smoothing filter options visualized for a specific 1,000 minute case.

Grey shading highlights “events”

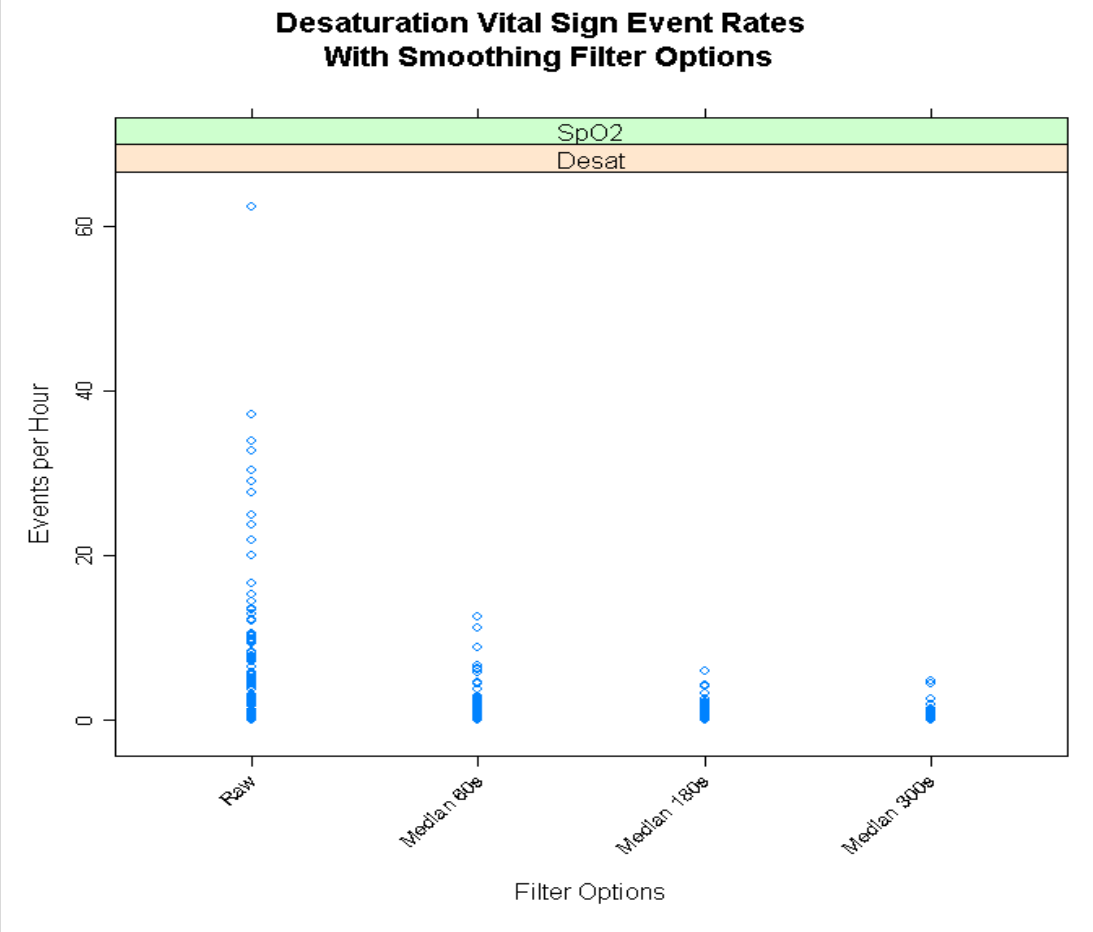
Filter reduces the quantity of events from 54 to 6

Filter Results Summary



A 180 second median filter reduces the quantity of alerts per hour from 24 to 1.7

Results of Filter



75% - 95% reduction in events

- Much better result than expected
- Originally intended only as a data pre-processing step

Is this useful?

Future Direction

- Continue validation of filter results
- Filters and simple alerts
  - Prospective study on selected patient population
- Filters with intelligent alerts
  - Add “intelligence” to the alert engine
    - Expert derived rules
    - Artificial Intelligence algorithm based on data
  - User acceptance and human factors studies
- …

Acknowledgements

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  - Mike Higgins, M.D.
- Patients participating in the study!