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Analysis of Patient Alarms in Adult Intensive Care Units

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Patricia Harris, RN, PhD

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AAMI/HTSI National Alarm Coalition

Disclosure Statement

Our study was sponsored by GE Healthcare in agreement with the Industry Contracts Division, Office of Innovation, Technology & Alliances and with oversight by the Internal Review Board of the University of California, San Francisco (UCSF).

UCSF Research Team

Principal Investigator
Barbra Drew, RN, PhD

Co-Principal Investigator, Project Director
Patricia Harris, RN, PhD

Co-Investigators:
Xiao Hu, PhD
Tina Mammone, RN, PhDc
Dan Schindler, RN, MSN
Jessica Zegre-Hemsey, RN, PhD

Drew – Hu Team

UCSF – GE Healthcare Alarm Study

Background
Alarm Fatigue in the intensive care unit

Study Aims

Assess alarm prevalence of patients' physiological monitor alarms

Identify audible alarm burden

Analyze select arrhythmia alarms to determine if true or false

Determine patient characteristics that may be associated with frequent alarms

Ethical Considerations & Preparation

Ethical concerns addressed by the UCSF Committee on Human Research

Study approved with waiver of consent

UCSF Medical Center Privacy Office provided approval

UCSF Departments of Bioengineering and IT Security assisted with installation

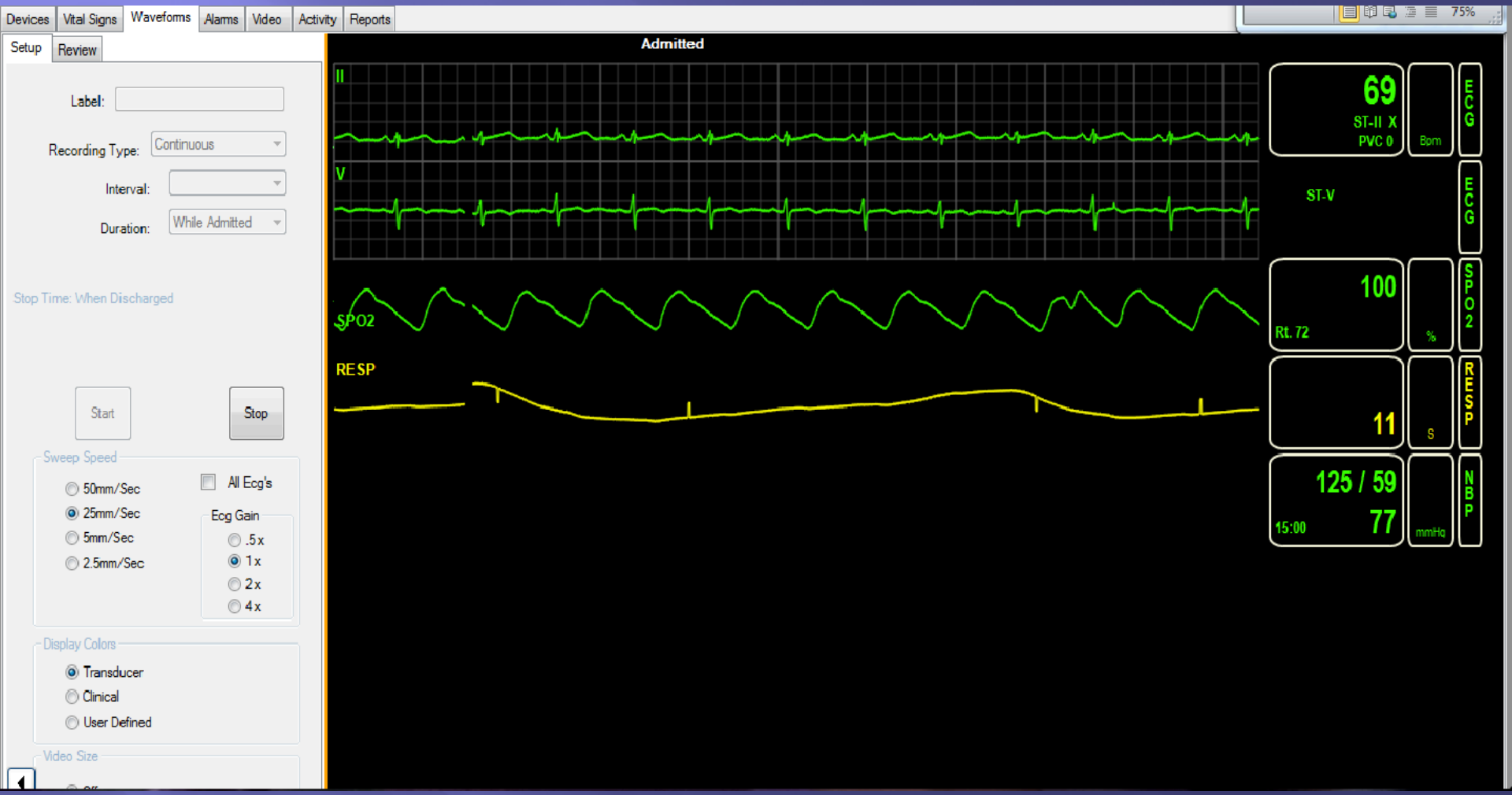
Methods

Used specialized research versions of the GE CareScape Gateway and BedMasterEx, developed specifically for this study

Comprehensively gathered monitoring and alarm data 24/7 over one month period

77 beds in five Adult ICUs at UCSF Medical Center

BedMasterEx



Waveform View

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BedMasterEx

7-Lead ECG View

BedMasterEx

Ventricular Fibrillation

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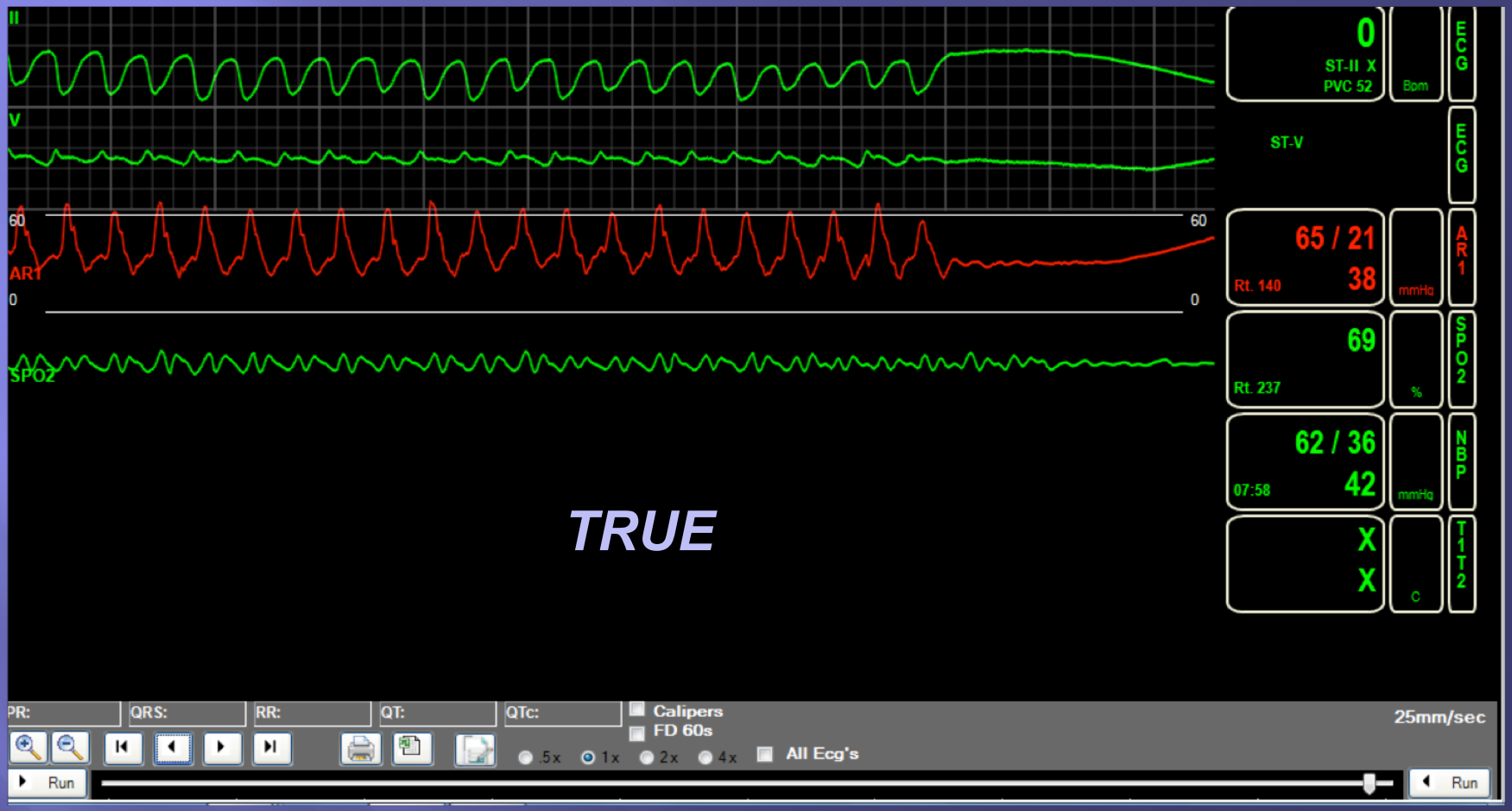
BedMasterEx



Asystole

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Alarms to Annotate

ALARM TYPE	DEFAULT LEVEL
ASYSTOLE	CRISIS
VFIB (ventricular fibrillation	CRISIS
VTACH (ventricular tachycardia)	CRISIS
ACCVENT (accelerated ventricular)	WARNING
VBRADY (ventricular bradycardia)	WARNING
PAUSE	WARNING

Standardized Annotation:

1. Written protocol with clear definitions
2. 3-hour annotation training course by Drew (video-taped)
3. Matching Excel Spreadsheet
4. 5 experts (Drew, Harris, Mammone, Zegre-Hemsey, Schindler) with clinical experience in acute/critical care & monitoring; also analyzed all clinical data from EMR (Code Blue data, etc.)
5. Weekly meetings to discuss annotation cases & to reach consensus

February 24, 2013

Alarm Annotation and Analysis Plan for GE-Sponsored Study 123.04-2012-GES-0003

PI: Barbara J. Drew, RN, PhD

CRISIS ECG ALARMS

Alarm Condition	Potential Cause of False Alarm	Proof of True/False Alarm by Investigator
1. ASYSTOLE	• Monitor is not detecting sufficient QRS amplitude in analysis leads (I, II, III, & V). • Noisy signal	Asystole True Alarm Proof: (either condition would confirm true alarm) 1. Simultaneous drop in ***invasive*** arterial or PA pressure to near zero (abrupt decrease in pressure waveform amplitude to near isoelectric line); cannot use non-invasive BP 2. Code Blue documentation of asytolic or PEA arrest at same time (<5 sec asystole would not be expected to cause loss of consciousness/Code Blue so asystole must persist) • Confirm that asystole lasts at least 5 seconds with e-calipers • If rhythm is determined to be low amplitude VF, count asystole alarm as true Asystole False Alarm Proof: (either condition would confirm false alarm) 1. There is no simultaneous drop in ***invasive*** arterial or PA pressure (abrupt decrease in pressure waveform amplitude) 2. There is a visible QRS ***in at least one lead*** (may be low amplitude and barely visible; must examine all available [7] leads)
2. VFIB/VTAC	Noisy signal (motion, electrical interference, or other artifact)	VFIB/VTAC True Alarm Proof: (either condition would confirm true alarm) 1. Simultaneous drop in ***invasive*** arterial or PA pressure to near zero (abrupt decrease in pressure waveform amplitude to near isoelectric line) 2. Code Blue documentation of VF or VT arrest at same time VFIB/VTAC False Alarm Proof: (any of the following conditions would confirm false alarm) 1. There is no simultaneous drop in ***invasive*** arterial or PA pressure (abrupt decrease in pressure waveform amplitude) 2. There are QRS complexes at the same rate as the patient's normal rhythm visible throughout a noisy signal ***in any lead*** (check RR intervals before, during, after event to see if they "march through") 3. VFIB/VTAC episode lasts >60 seconds but no Code Blue or other documentation that it was recognized clinically (syncope, seizure, LOC) 4. VFIB/VTAC episode lasts >60 seconds but no decrease in SpO_2 waveform amplitude

N2

	G	H	I	J	K	L	M	N	
1	Are there regular artifacts on the ECG waveform that may be caused by a tremor or device causing ECG interference?	If yes, comment	Number of ECG leads available for viewing this alarm on BMEX?	Specify leads available	Waveforms monitored	Asystole (True, False, Unable to Determine)	Asystole True Alarm Proof	Asystole False Alarm Proof	Wha crite dete asys was
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									

1. There is no simultaneous drop in invasive arterial or PA pressure (abrupt decr
2. There is a visible QRS in at least one lead (may be low amplitude and barely v
3. ASYSTOLE episode lasts >60 seconds but no Code Blue or other document
4. ASYSTOLE episode lasts >60 seconds but no decrease in SpO2 waveform a
1&2

Standardized Annotation

1. Written protocol with clear definitions
2. Three-hour annotation training course by Drew (video-taped)
3. In addition to Dr. Drew, our team includes 4 RN experts with acute/critical care & monitoring experience
4. We analyzed clinical data from EMR (Code Blue data, etc.) corresponding to what was displayed on the monitor
5. Weekly meetings to discuss annotation cases & to reach consensus

Alarm Annotation and Analysis Plan for GE-Sponsored Study

Barbara J. Drew, RN, PhD

CRISIS Alarms

Alarm Condition	Proof of True/False Alarm by Investigator
ASYSTOLE **Potential causes of false alarm:** • Monitor is not detecting sufficient QRS amplitude in analysis leads (I, II, III, & V) • Noisy signal	Asystole True Alarm Proof: (either condition would confirm true alarm) 1. Simultaneous drop in ***invasive*** arterial or PA pressure to near zero (abrupt decrease in pressure waveform amplitude to near isoelectric line); cannot use non-invasive BP 2. Code Blue documentation of asytolic or PEA arrest at same time (<5 sec asystole would not be expected to cause loss of consciousness/Code Blue so asystole must persist) • Confirm that asystole lasts at least 5 seconds with e-calipers • If rhythm is determined to be low amplitude VF, count asystole alarm as true Asystole False Alarm Proof: (either condition would confirm false alarm) 1. There is no simultaneous drop in ***invasive*** arterial or PA pressure (abrupt decrease in pressure waveform amplitude) 2. There is a visible QRS ***in at least one lead*** (may be low amplitude and barely visible; must examine all available [7] leads) Example

ANNOTATION SPREADSHEET

N2

	G	H	I	J	K	L	M	N
1	Are there regular artifacts on the ECG waveform that may be caused by a tremor or device causing ECG interference?	If yes, comment	Number of ECG leads available for viewing this alarm on BMEX?	Specify leads available	Waveforms monitored	Asystole (True, False, Unable to Determine)	Asystole True Alarm Proof	Asystole False Alarm Proof
2								
3								1. There is no simultaneous drop in invasive arterial or PA pressure (abrupt decr
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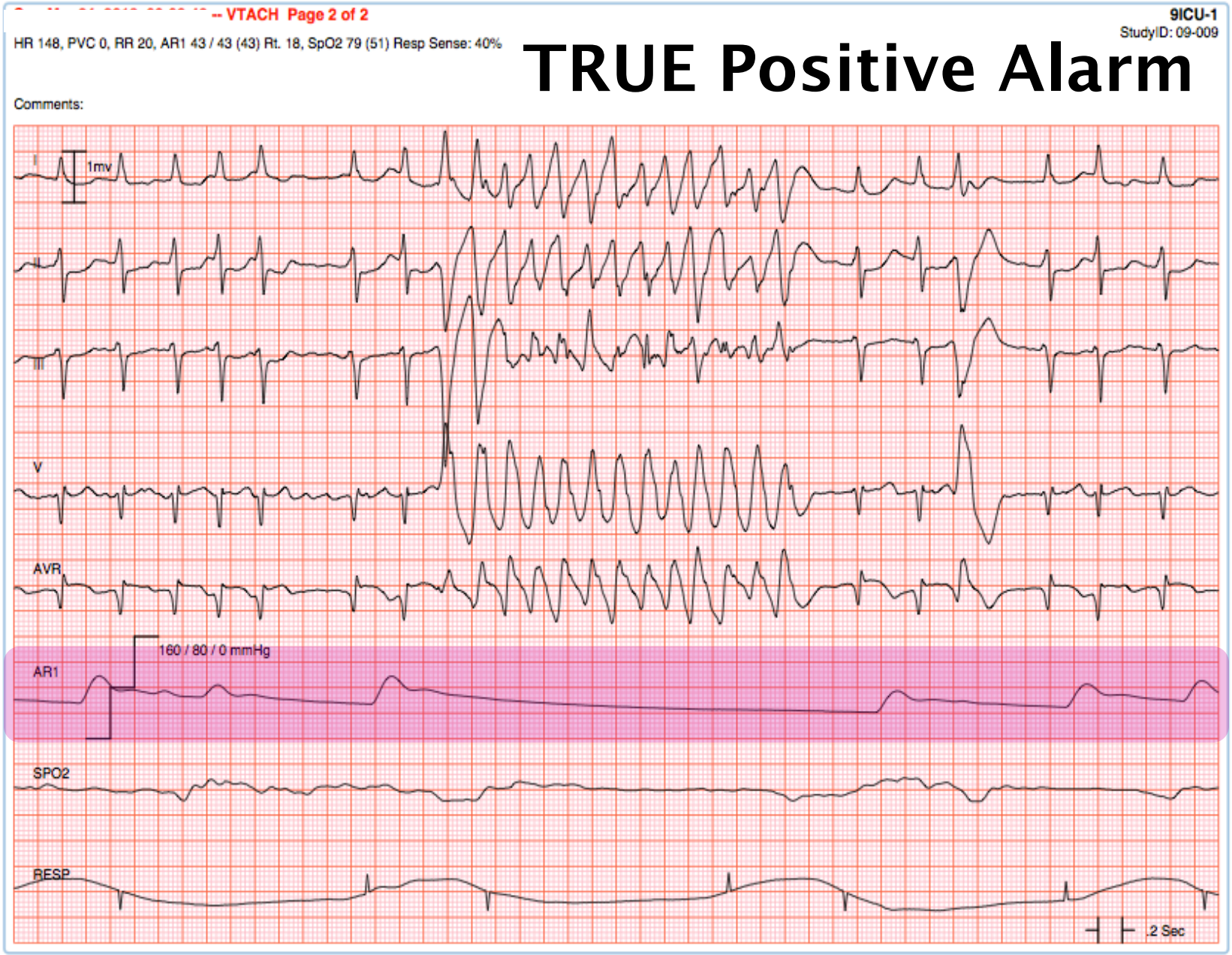
5								3. ASYSTOLE episode lasts >60 seconds but no Code Blue or other document
6								4. ASYSTOLE episode lasts >60 seconds but no decrease in SpO2 waveform a
7								1&2
8								
9								
10								
11								

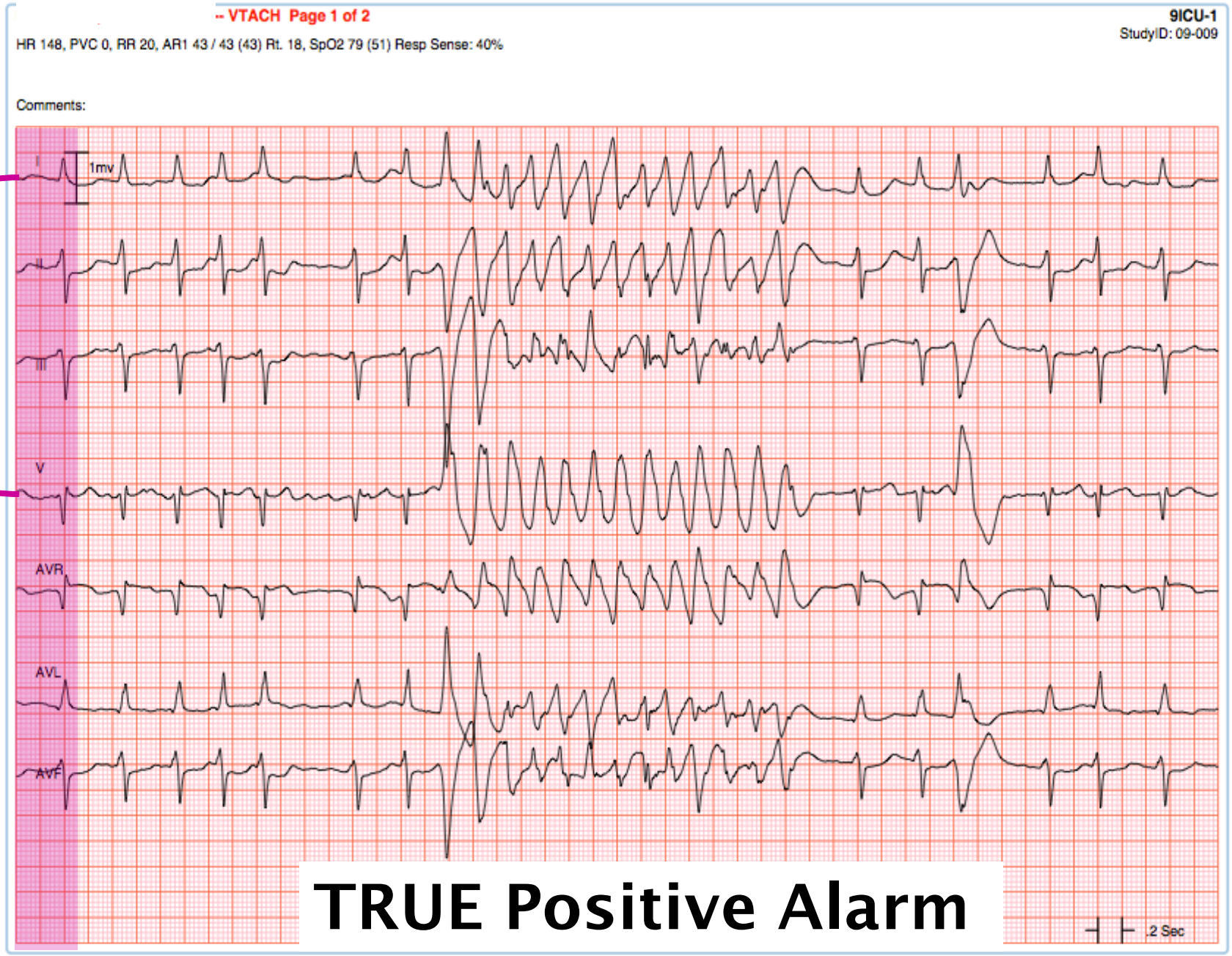
2nd Page for Annotation: all available non-ECG waveforms

Alarm - VTACH



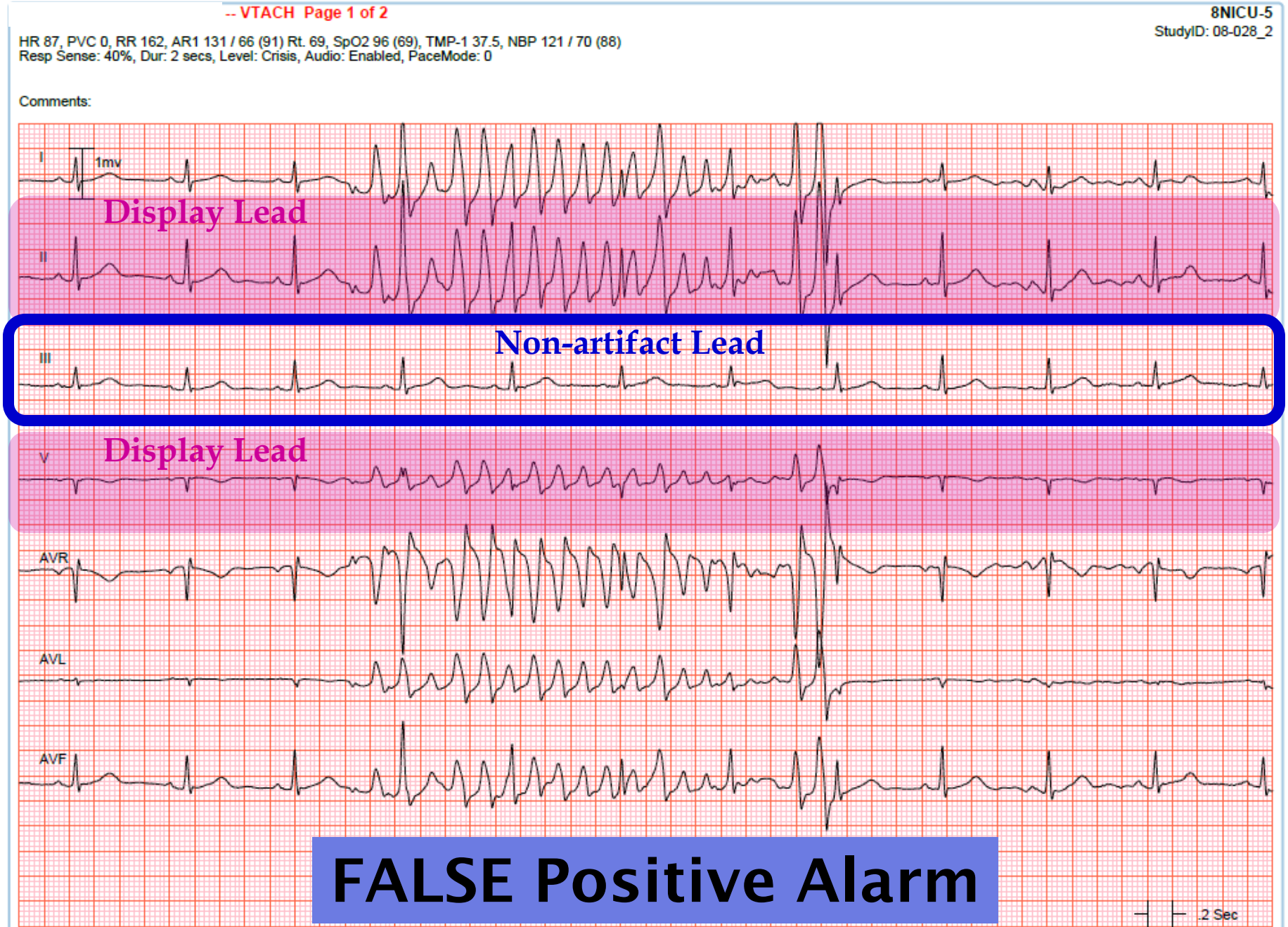
TRUE Positive Alarm

1st Page for Annotation: all available (7) ECG leads



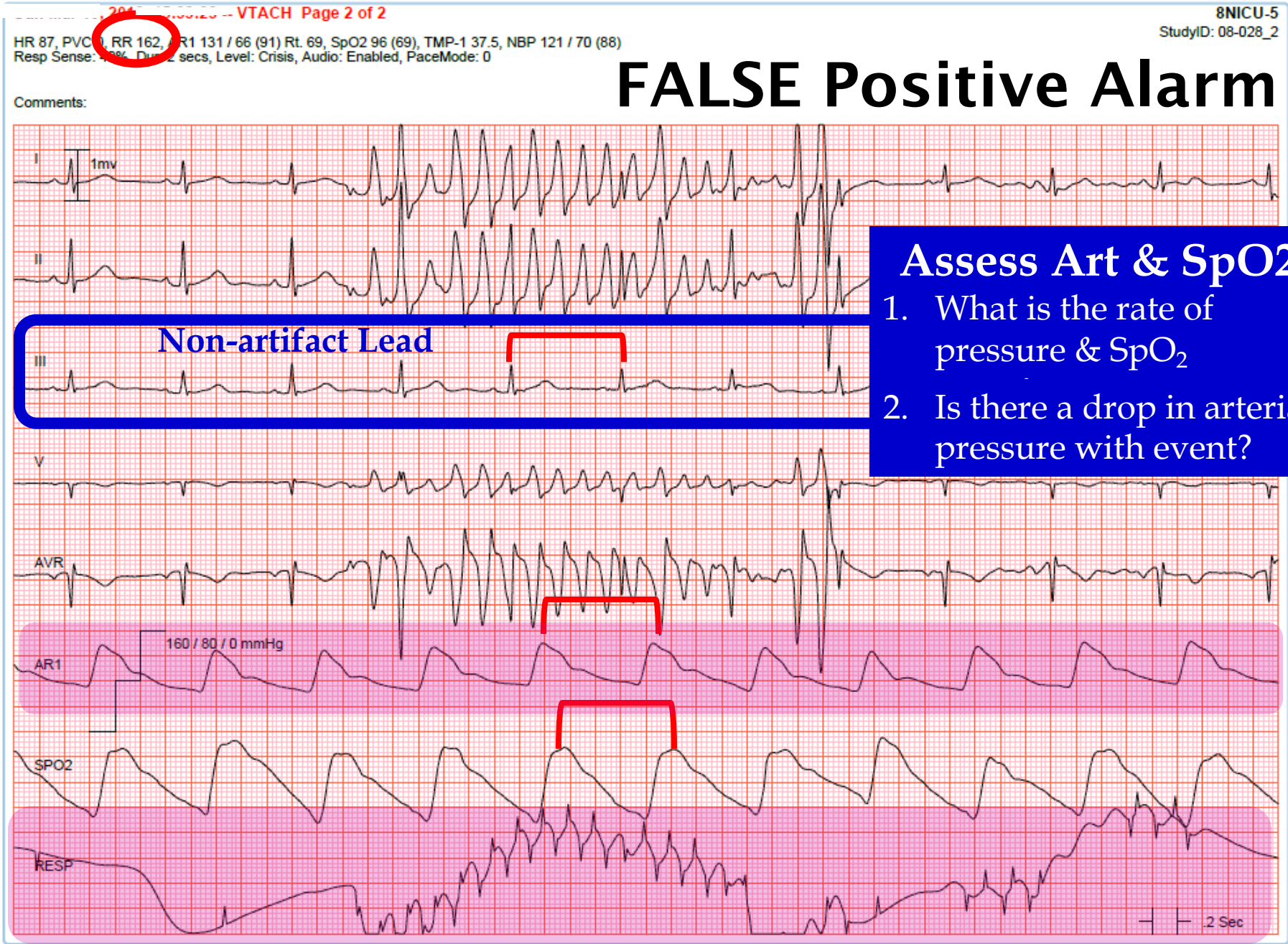
1st Page for Annotation: all available (7) ECG leads

Alarm - VTACH



FALSE Positive Alarm

2nd Page for Annotation: all available non-ECG waveforms



Preliminary Prevalence Results

(using specialized software to capture all alarms)

Recordings for 461 unique patients for 31 days

Total Alarms		2,507,822
	Arrhythmia	1,633,323 (~ 65.1%)
	Parameter	665,136 (26.5%)
	Technical	209,363 (8.3%)
Audible alarms		*381,560*
Alarm burden (audible alarms per bed per day)		~ 160 audible alarms/bed/day

Preliminary Arrhythmia Alarm Analysis Results

Annotation of 12,674 arrhythmia alarms collected during the month of March

Analysis showed ~ 87% of the alarms were technically false, similar to reports of other researchers*

* Aboukhalil et al (2008); Graham & Cvach (2010)

Patient Characteristics
N = 461

Characteristic	n
Smoker	71 (15.4%)
Obesity (BMI >30)	142 (30.8%)
Tremor	36 (7.8%)
Confused	198 (43.0%)
Ventricular-Pacing	17 permanent 16 temporary (33 = 7.2%)
Left Ventricular Assist Device (LVAD)	3 (<1%)
Mechanical ventilation	165 (35.8%)

Demographics

N	461
Female	211 (45.8%)
Age (median = 60 years)	59.6 years
Latino	52 (11.3%)
Race	
Asian	76 (16.5%)
African American	35 (7.7%)
Pacific Islander	8 (1.7%)
White	281 (61.0%)
Unknown/decline to state	61 (13,2%)

Patients with Annotated Alarms

Total number of unique patients admitted to the ICU during March 2013	461 (100%)
Total number of patients with at least one annotatable alarm	252 (54.7%)
Total number of patients with zero annotatable alarms	209 (45.3%)

ICU Patients' Annotated Alarms

N = 461 ICU patients

Annotated Alarms = 12,674
(representing 252 patients)

Range of number of alarms, Min to Max = 0 – 5725
(5725 = 45.2%; N=461)

Total monitoring time > 48,000 hours (N=461)

Mean monitoring time = ~78 hours per patient
(N-461)

Signal Quality = GOOD

Alarm	TOTAL ALARM	TOTAL GOOD (% TOT)	TRUE	TRUE % GOOD	FALSE	FALSE % GOOD	UNABLE TO DETERMINE
ASYS	792	500	260	52	240	48	0
VFIB	158	127	88	69.3	39	30.7	0
VTACH	3,860	2682	473	17.6	2209	82.4	0
ACC VENT	4,366	3826	216	5.7	3608	94.3	2
PAUSE	2,238	1211	314	25.9	897	74.1	0
VB	1,260	1147	39	3.4	1108	96.6	0
TOTAL	**12,674**	**9493 (74.9%)**	**390**	**14.6**	**8101**	**85.4**	**2**

ASYS = Asystole; VFIB = Ventricular Fibrillation; VTACH = Ventricular Tachycardia; ACC VENT = Accelerated Ventricular; PAUSE = Pause; VB = Ventricular Bradycardia

Challenge

Reconciliation of inaccurate or missing patient information entered on the monitor with correct data in medical record

Next Steps

Complete analysis of patient characteristics associated with false alarms

Continue work with engineers to improve ECG detection algorithms and alarm specificity

Select References

Aboukhalil A, Nielsen L, Saeed M, Mark RG and Clifford GD. Reducing false alarm rates for critical arrhythmias using the arterial blood pressure waveform. Journal of Biomedical Informatics, 41(3), 2008.

Behar J, Oster J, Li Q and Clifford GD. ECG signal quality during arrhythmia and its application to false alarm reduction. IEEE Transactions On Biomedical Engineering 60(6) 2013.

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THANK YOU!