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Authors
Suba, Sukardi
Sandoval, Cass Piper
Zègre-Hemsey, Jessica K
et al.

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Contribution of Electrocardiographic Accelerated Ventricular Rhythm Alarms to Alarm Fatigue

Sukardi Suba, MS, RN, ACCNS-AG,
doctoral student, Department of Physiological Nursing, School of Nursing, University of California, San Francisco (UCSF), San Francisco, California

Cass Piper Sandoval, MS, RN, CCRN, CCNS,
adult critical care clinical nurse specialist and clinical nurse coordinator, Interventional Cardiology, UCSF Heart and Vascular Center, UCSF Health, San Francisco, California

Jessica K. Zègre-Hemsey, PhD, RN,
assistant professor, School of Nursing and an adjunct assistant professor, Department of Emergency Medicine, The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

Xiao Hu, PhD,
professor, Department of Physiological Nursing, School of Nursing, and Department of Neurological Surgery, and a core member, Institute for Computational Health Sciences, UCSF-UC Berkeley Joint Graduate Program in Bioengineering, UCSF

Michele M. Pelter, PhD, RN
assistant professor, School of Nursing, and director, ECG Monitoring Research Lab, UCSF

Abstract

Background—Excessive electrocardiographic alarms contribute to “alarm fatigue,” which can lead to patient harm. In a prior study, one-third of audible electrocardiographic alarms were for accelerated ventricular rhythm (AVR), and most of these alarms were false. It is uncertain whether true AVR alarms are clinically relevant.

Objectives—To determine from bedside electrocardiographic monitoring data (1) how often true AVR alarms are acknowledged by clinicians, (2) whether such alarms are actionable, and (3) whether such alarms are associated with adverse outcomes (“code blue,” death).

Corresponding author: Sukardi Suba, MS, RN, ACCNS-AG, ECG Monitoring Research Laboratory, Department of Physiological Nursing, University of California, San Francisco, 2 Koret Way, Box 0610, San Francisco, CA 94143-0610 (sukardi.suba@ucsf.edu).

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Methods—Secondary analysis using data from a study conducted in an academic medical center involving 5 adult intensive care units with 77 beds. Electronic health records of 23 patients with 223 true alarms for AVR were examined.

Results—The mean age of the patients was 62.9 years, and 61% were white and male. All 223 of the true alarms were configured at the warning level (ie, 2 continuous beeps), and 215 (96.4%) lasted less than 30 seconds.

Only 1 alarm was acknowledged in the electronic health record. None of the alarms were clinically actionable or led to a code blue or death.

Conclusions—True AVR alarms may contribute to alarm fatigue. Hospitals should reevaluate the need for close monitoring of AVR and consider configuring this alarm to an inaudible message setting to reduce the risk of patient harm due to alarm fatigue. Prospective studies involving larger patient samples and varied monitors are warranted.

Excessive clinical alarms can cause "alarm fatigue,"[1–5] in which nurses become desensitized to alarms,[6–8] delay their response to the alarms,[6,7,9] and in extreme cases turn the alarms off, all of which may result in patient harm due to missed true emergencies.[10,11] The Joint Commission reported that 98 alarm-related events occurred between 2009 and 2013, with 80 of them resulting in death.[10] The problem of alarm fatigue highlights not only the large volume of clinical alarms that clinicians must attend to (eg, electrocardiographic [ECG], vital signs, ventilators, intravenous pumps), but also the ongoing need for better clinical alarm management and questions about the clinical relevance of alarms to patient care. For example, is every true alarm clinically actionable, and does it improve patient outcomes and/or save lives?

In previous studies, researchers have investigated the relevance and frequency of alarms generally considered clinically actionable. Some research has indicated that a low proportion of clinical alarms actually require clinical action, from less than 1% to 26% in adult intensive care units (ICUs)[3,12] and 3% to 13% in pediatric ICUs.[3,12] Most of the studies included in these systematic reviews investigated clinically actionable alarms of almost all types (eg, ECG, heart rate, respiration rate, pulse oximetry, and ventilator).[3,12] However, only a few studies have explored the frequency of clinically actionable *true* arrhythmia alarms such as those for asystole, ventricular tachycardia (VT), ventricular fibrillation, premature ventricular contractions, ventricular bradycardia, and tachycardia.[13–15]

Few research studies have examined the clinical relevance of accelerated ventricular rhythm (AVR). Originally termed *accelerated idioventricular rhythm* or *slow ventricular tachycardia*,[16] AVR is an arrhythmia characterized by 3 or more consecutive wide QRS complexes at a rate of 50 to 100 beats per minute. The wide QRS complex occurs because this arrhythmia is generated from pacemaker cells located at the distal end of the conduction system.[16–18] Accelerated ventricular rhythm has been associated with acute myocardial infarction[16,18–20] and toxic effects of digitalis.[16,18] Studies also showed that AVR frequently occurred in patients with ST-elevation myocardial infarction following reperfusion after administration of thrombolytic agents or percutaneous coronary intervention[19,21] and was considered a marker of successful reperfusion.[21–23] In addition. AVR was found to be benign among

patients with idiopathic dilated cardiomyopathy. although patients with ischemic cardiomyopathy were excluded in that study.[24]

A previous study of 461 ICU patients showed AVR to be the most common audible alarm category. accounting for 34% of 12 671 annotated arrhythmia alarms.[1] In that study, the investigators operationally defined AVR as a wide QRS complex rhythm at a rate of 50 to 100 beats per minute. In that study, the vast majority of the AVR alarms (94.8%) were false, contributing to the high overall volume of false alarms. Although it might be argued that this alarm could be turned off given its high false-positive rate, careful evaluation is needed of whether true AVR alarms are clinically actionable or lead to adverse patient outcomes.

Therefore, this study was conducted to address 3 primary questions: (1) How often are true AVR alarms acknowledged by clinicians in the electronic health record (ie, charted in the flow sheet, nurses' notes, or progress notes)? (2) Are true AVR alarms actionable (ie, new medication or change of medication dose, pacemaker, or cardioversion)? (3) Do true AVR alarms lead to adverse patient outcomes ("code blue" events or death)?

Methods

This secondary analysis used data from an alarm study conducted at the University of California, San Francisco, Medical Center, an academic medical center on the West Coast of the United States.[1] The original researchers prospectively collected bedside physiological waveform data (ECG, arterial blood pressure, pulse oximetry, and respiration rate), numerical measurements of vital signs, alarm parameter settings, and the incidences of both audible and inaudible (text message) alarms (arrhythmia, parameter, and technical) from all 77 of the bedside monitors in 5 adult ICUs during a 31-day period.

Each of the 77 ICU beds was equipped with a Solar 8000i bedside monitor (version 5.4 software, GE Healthcare). A state-of-the-art technology infrastructure was used to securely transmit all of the physiological bedside monitoring data to an external server (Figure 1). All of the data were collected, stored, and analyzed retrospectively offline; therefore, the data collection process did not interfere with patient care. The study was approved by the academic medical center's institutional review board, which waived the requirement of written patient consent because continuous physiological monitoring is part of routine care and the study data would not be used for clinical decision-making. Thus, all consecutive patients were enrolled in the study.

ECG Alarm Annotation

In the primary study, 4 nurse scientists with doctoral-level training used a standardized protocol to analyze cardiac rhythms that triggered any of 6 arrhythmia alarms and determined whether the alarms were true or false. All of the annotators completed a 10-week course in clinical electrocardiography and a 3-hour certification course in alarm annotation. Measurement of the interrater reliability of alarm annotation showed 95% agreement for true- or false-positive alarms between the annotators (Cohen κ, 0.86).[1]

The 6 ECG arrhythmia alarms that were annotated as true or false were asystole, ventricular fibrillation, VT, AVR, pause, and ventricular bradycardia. These ECG arrhythmia alarms were selected for annotation because they were configured as audible alarms. In the present study, we evaluated only the true AVR alarms.

Acknowledgment of True AVR Alarms

In this study, for each true AVR alarm, we noted the time stamp of the alarm and then reviewed the patient's electronic health record (EHR) to determine whether the alarm was acknowledged. We operationally defined "acknowledged" as the presence of a clinical note indicating the AVR event (ie, nurse documentation in the flow sheet or progress notes) or manual scanning of a rhythm strip into the EHR, which was the protocol at our institution.

Determination of Actionable AVR Alarms

An AVR alarm was considered "actionable" if the patient underwent clinical intervention within 15 minutes after the alarm sounded. For example, if an alarm sounded at 9:15 AM, we carefully examined the EHR from 9:15 AM until 9:30 AM to determine whether a clinical action related to the alarm occurred. Although previous studies do not indicate a standardized time window to use for our research purpose, we selected this window on the basis of our clinical experience that 15 minutes was a sufficient amount of time for clinicians to respond to and acknowledge a clinical alarm. An alarm was considered actionable if any of the following occurred: a new medication was started to treat AVR, a change was made in the current arrhythmia medication dose, or a pacemaker and/or cardioversion was instituted. In deciding whether an AVR alarm was actionable, we performed a 2-step case review: First, an initial review was conducted by the first author (S.S.). Second, for unclear cases, an independent review was also performed by the last author (M.M.P.). This process resulted in 100% agreement for all cases. During the review process, we carefully examined the EHR, including history and physical examination findings; consultation, progress, and significant event notes; medication reports; orders; procedures; diagnostic tests; and discharge summaries. In addition, vital signs, flow sheet documentation, laboratory values, and clinically relevant scanned documents were carefully examined.

Adverse Patient Outcomes Following True AVR Alarms

An adverse patient outcome related to a true AVR alarm was defined as a code blue event (ie, cardiopulmonary arrest or life-threatening medical emergency) or death. As just described, the EHR was reviewed carefully to determine the occurrence of these events.

Results

The primary study involved 461 consecutive ICU patients with a total of 12 671 annotated ECG alarms. Of these 12 671 alarms, 4361 (34.4%) were for AVR, affecting 99 patients (21.5%). Of these 4361 AVR alarms, 4137 (94.9%) were annotated to be false. One alarm was determined to be unanalyzable; therefore, there were 223 (5.1%) true AVR alarms in 23 patients; these were the focus of the present study.

The demographics of the study sample are shown in the Table. Of the 23 patients with 223 true AVR alarms, 61% were aged 65 years or older (mean age, 62.9 years), white, and male. The greatest proportion of patients (43%) were treated in the medical/surgical ICU, followed by the cardiac ICU (39%) and then the neurologic/neurosurgical ICU (17%). Ten patients (43%) received mechanical ventilation.

All 223 alarms were configured as warning-level alarms, resulting in an audible alarm that sounded 2 beeps continuously until the nurse silenced the alarm. None of the ICU units used a monitor watcher; thus, all of the alarms were silenced by the primary nurse for a given patient. Of the 223 true alarms, 215 (96.4%) lasted less than 30 seconds. Forty-three (19.3%) of the alarms had the audio feature paused, which means that someone physically paused the audio alarm by pressing the “silence alarm” button. When paused, these alarms do not sound, alarm histories are not stored, alarm graphs do not print, and alarms are not sent to the central monitoring station. This action might be taken following an alarm or when the nurse is in the room performing a procedure that might provoke alarms (eg, suctioning, turning, bathing). Because we reviewed these data retrospectively, we could not determine why the silence alarm button was pressed.

We found that only 1 true AVR alarm event was acknowledged, as indicated by manual scanning of the bedside monitor ECG rhythm strip into the EHR (Figure 2). The rhythm strip was from a 38-year-old woman admitted for respiratory failure with comorbidities including end-stage renal disease, congenital disorders, and diabetes. It was unclear why only this single strip was scanned into the EHR, and no clinical notes were found that could explain the situation during the alarm event. We found that none of the true AVR alarms resulted in a clinical action (ie, new medication, change of medication dose, pacemaker, or cardioversion). None of the true AVR alarms was associated with a code blue or death (Figure 3).

Discussion

To our knowledge, this study is the first to investigate whether true AVR alarms in hospitalized adult ICU patients are associated with a clinical action(s) or adverse patient outcomes. We found that none of the AVR alarms annotated as true alarms were clinically actionable and none were associated with a code blue or death. Current practice guidelines for the management of in-hospital ventricular arrhythmias state that only sustained (ie, > 30 seconds) or symptomatic ventricular rhythms are clinically important and thus require treatment.[25] Our findings support this recommendation and suggest that the need to configure bedside monitors to alarm for AVR should be reevaluated.

Although 11 of the 23 patients with true AVR alarms included in our study died during hospitalization, not one of these deaths was associated with a true AVR alarm. All of the patients who died were seriously ill, with multiple medical and/or surgical conditions, which placed them at high risk for death during their ICU admission. In fact, 8 patients had “do not resuscitate” orders or were placed on comfort care because death was determined to be imminent. Whether to continuously monitor patients once their status is do not resuscitate or comfort care has been the subject of debate. This topic requires further investigation.

At our institution, the bedside ECG monitors currently cannot send ECG alarms directly to the EHR, requiring nurses to print rhythm strips for true alarms and then scan them into the EHR. This process is labor-intensive and frustrating because it pulls nurses away from direct patient care. Our data indicate that this alarm burden is exacerbated by the extremely high rate of false-positive AVR alarms. Our finding that only 1 true AVR alarm was acknowledged, as indicated by scanning of a rhythm strip into the EHR, suggests the presence of alarm fatigue. In our study[26] of human factors in physiological monitoring, we found that clinicians often silence alarms without knowing what type of alarm occurred. We also found that when alarms were silenced at the central monitoring station, many clinicians could not recall which specific patient's alarm was silenced.[26] We hypothesize that over time, clinicians learn that the vast majority of alarms are false, leading them to develop an automatic reaction of silencing an alarm. Because our study was retrospective, we could not determine whether the true AVR alarms were noted but not recorded in the EHR or were missed altogether. Regardless, our findings raise concerns about alarm fatigue. Solutions to the problem of alarm fatigue must include lowering the rate of false arrhythmia alarms by improving algorithms and eliminating unnecessary alarms.

In our study, we found that true AVR alarms are infrequent (5.1%) and that AVR alarms constitute the highest proportion of false alarms. These findings suggest that AVR alarms are "nuisance" alarms (even if true, not clinically actionable) and thus that they should not be configured as audible alarms because of their major contribution to alarm fatigue. A previous study by Bonafide et al[9] provided a clear picture of the detrimental effects of nonactionable physiological alarms in clinical practice, showing that as exposure to nonactionable alarms increased, nurses' response time also increased. Our study con firms that when AVR alarms are configured as audible alarms, nurses are exposed to a high volume of nonactionable alarms, increasing the risk of longer response times that may delay care or result in missed critical events.

The bedside monitor used in this study has 3 configurations for audible alarm levels: crisis (3 beeps), warning (2 beeps), and advisory (1 beep). At our institution during the primary study, AVR alarms were configured as warning-level alarms, with the monitor sounding 2 beeps constantly until the user silenced the alarm. This constant beeping can result in nurse frustration if the alarm is false or, even if it is true, clinical action is not required. This situation may desensitize nurses to other arrhythmia alarms that are clinically important, placing patients at risk for adverse events in the case of missed alarms. Adjusting AVR alarms to an inaudible text message alarm may be a better configuration strategy, reducing alarm burden and thus helping to prevent alarm fatigue. Patient outcomes are unlikely to be affected given that AVR is associated with high rates of false alarms and that true AVR alarms are generally not associated with a change in clinical care. It could be argued that even the inaudible message alarm configuration might pull a nurse's attention away from patient care unnecessarily, and that AVR alarms should not be turned on at all. However, additional research, including prospective studies, is needed before this recommendation can be made with total confidence.

Our study has several limitations. First, it was a retrospective study based on EHR review, which limits our ability to gather detailed information about clinical management, nurses'

clinical thoughts at the time of the alarm, and patients' conditions during the actual alarms. Second, the study included only 23 patients with 223 true AVR alarms in the ICU setting. Whether similar results might be obtained in other hospital units (eg, emergency department, telemetry) is unknown. Third, our findings may not be applicable to other types of bedside monitors whose algorithms might define AVR differently. Nevertheless, the results of our study provide important information about the clinical relevance of closely monitoring AVR. Prospective clinical trials with larger sample sizes, involving different brands of monitors, and an assessment of patient safety, are warranted to shed further light on the questions addressed in our study.

Conclusion and Implications for Practice –

Accelerated ventricular rhythm alarms are common false alarms in ICUs and may contribute to alarm fatigue. In our study, the vast majority of true AVR alarms were not documented in the EHR. None of the true AVR alarms were clinically actionable, and none were associated with adverse patient outcomes. We propose that hospitals reevaluate the need for close monitoring of AVR and consider adjusting this alarm to an inaudible text message setting in an effort to reduce alarm burden and help prevent alarm fatigue.

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SEE ALSO

For more about managing alarms, visit the *Critical Care Nurse* website, www.ccnonline.org, and read the AACN Practice Alert, "Managing Alarms in Acute Care Across the Life Span: Electrocardiography and Pulse Oximetry" (April 2018).

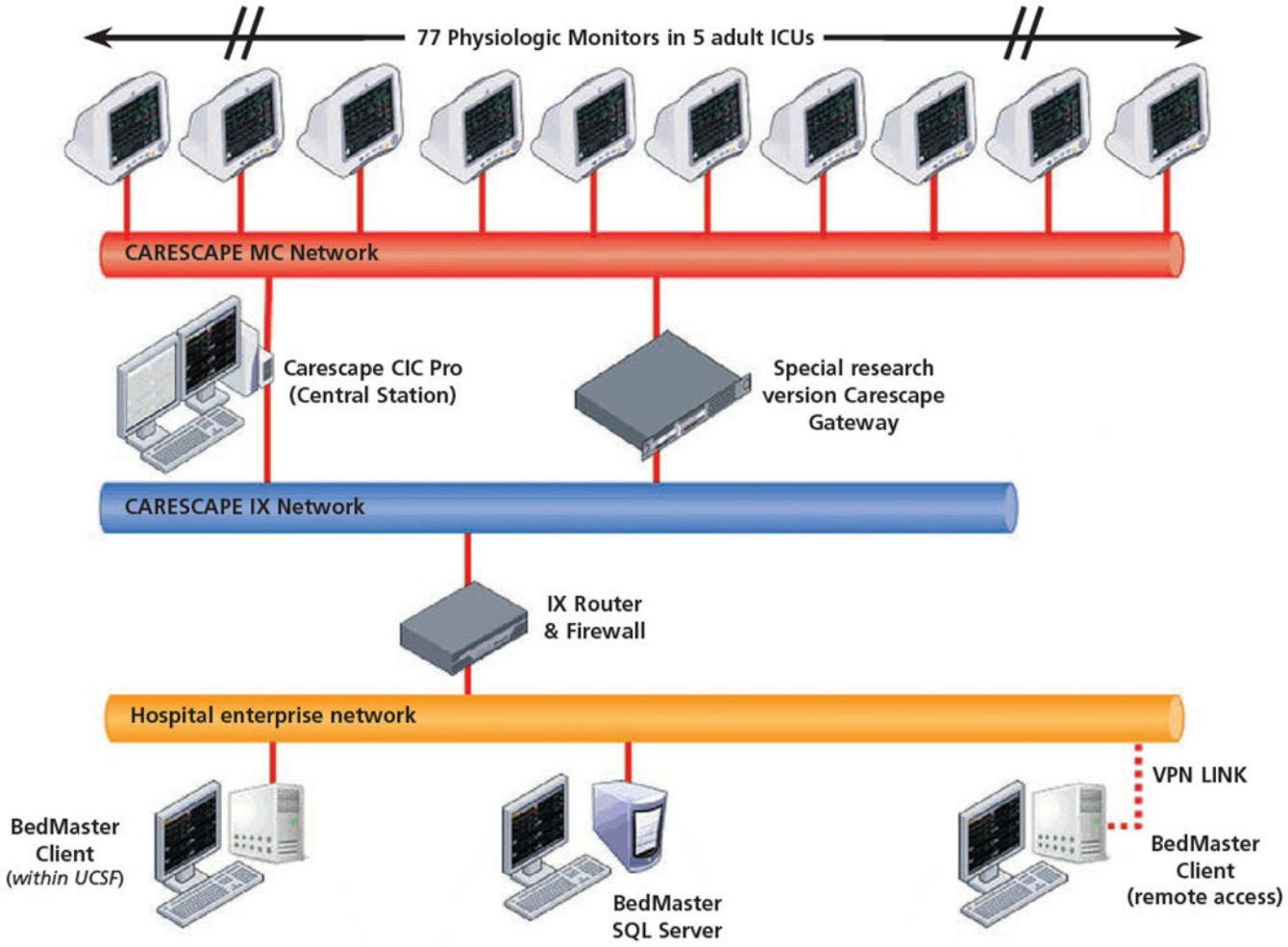

Figure 1.

Hospital infrastructure used to collect physiological waveform and alarm data from bedside monitors in the primary study.

Abbreviations: ICU, intensive care unit; UCSF, University of California, San Francisco; VPN, virtual private network.

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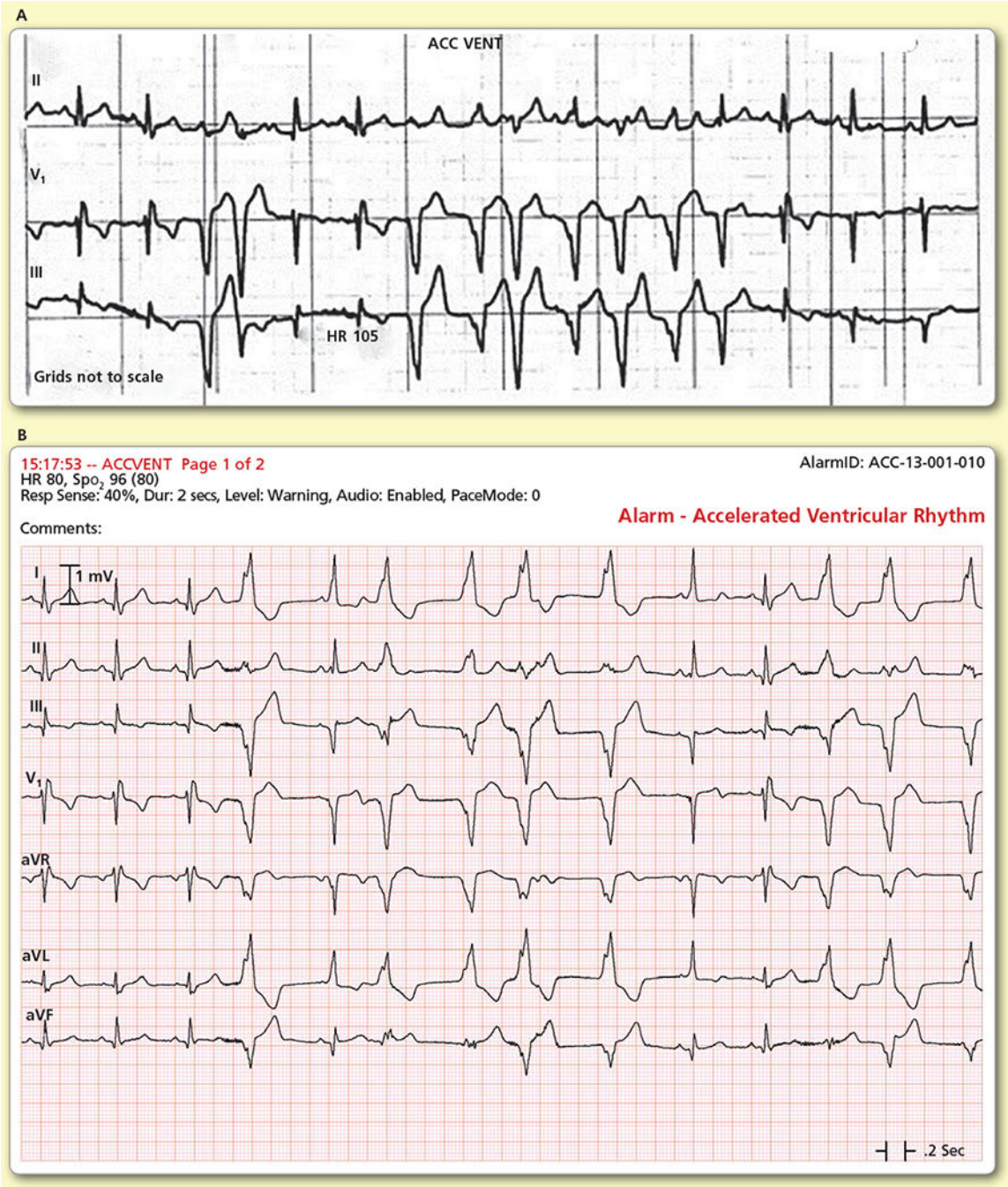

Figure 2.

Electrocardiographic (ECG) examples of a true accelerated ventricular rhythm from a 38-year-old woman with multisystem dysfunction. A, ECG rhythm strip in leads II, V_1, and III from bedside monitor that was scanned into the electronic health record and thus considered to be “acknowledged” by the nurse. B, Seven-lead ECG obtained from the BedMasterEx software system (Excel Medical Electronics, Inc) used in the primary study. Note the vital sign information indicating heart rate (HR) of 80/min with oxygen saturation (Spo_2) of 96%. Both represented the same alarm event.

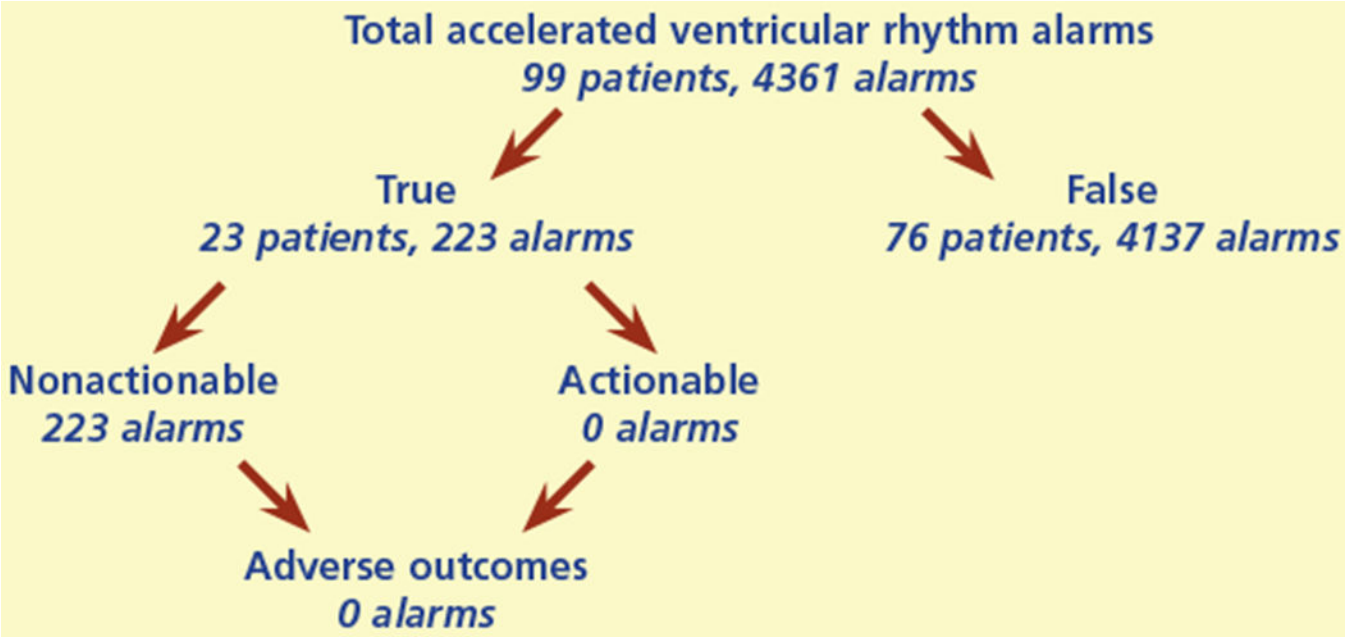

Figure 3.
Flow chart showing whether true accelerated ventricular rhythm alarms were actionable or led to an adverse outcome for the patient.

Table

Characteristics and alarm statistics of 23 intensive care unit patients with 223 true accelerated ventricular rhythm alarms

Characteristic	**No. (%) of patients**
Age, y	
18-64	9 (39)
≥ 65	14 (61)
Sex	
Female	9 (39)
Male	14 (61)
Race/ethnicity	
White	14 (61)
Asian, African American, Hispanic, Hawaiian	9 (39)
Intensive care unit	
Neurologic/neurosurgical	4 (17)
Cardiac medical or surgical	9 (39)
Medical/surgical	10 (43)
Mechanical ventilation	
Yes	10 (43)
No	13 (57)
Alarm statistic	**No. of alarms**
Range	1-123
Mean	9.70
Median	1
Mode	1
Standard deviation	25.76