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# Continuous veno-venous hemodialysis and suspected pacemaker malfunction on telemetry monitoring

Adam Oesterle, MD [a,*], Nora Goldschlager, MD [b,c]

[a] Division of Cardiology, Section of Electrophysiology, University of California, San Francisco, United States of America
[b] Division of Cardiology, University of California, San Francisco, United States of America
[c] Division of Cardiology, Department of Medicine, Zuckerberg San Francisco General Hospital, San Francisco, United States of America

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## Case

A 53 year old male with a past medical history of end stage renal disease (ESRD) on hemodialysis and intravenous (IV) drug use, who had had multiple hospital admissions for *Staphylococcus aureus* bacteremia with subsequent tricuspid valve endocarditis, was admitted for recurrent bacteremia. He was administered norepinephrine and vasopressin and developed a wide complex tachycardia that required electrical cardioversion (Fig. 1A). He subsequently developed a narrow complex tachycardia; he was administered adenosine IV without tachycardia termination, and was then started on IV amiodarone. Junctional bradycardia subsequently developed with heart rates of 30 beats per minute (BPM) that was associated with hypotension requiring IV dopamine (Fig. 1B). Given persistent hypotension and bradycardia after cessation of amiodarone, a temporary transvenous pacemaker was placed, programmed to VVI mode of function and base rate of 80 BPM. The cardiology service was consulted given concern for pacemaker malfunction seen on telemetry (Fig. 2) while the patient was undergoing continuous venovenous hemodialysis (CVVH).

## ECG interpretation

The ECG leads II and V1 in the telemetry strip demonstrate a ventricular paced rhythm at an interstimulus interval of 750 milliseconds (msec). There is an intermittent junctional rhythm (RR intervals 720 msec) with pseudofusion complexes, in which a pacing stimulus occurs during the intrinsic QRS complex, when the ventricular tissue is refractory. Pacing stimuli unassociated with ventricular depolarizations are present throughout the telemetry strip, raising concern for pacemaker malfunction that could lead to a stimulus-on-T occurrence (Fig. 3A).

The transvenous pacemaker was programmed to confirm normal sensing and capture thresholds. Telemetry artifact was considered; to confirm it the pacing rate was reduced to 30 BPM and the CVVH turned off (Fig. 3B). The patient's native underlying rhythm was sinus bradycardia with intermittent junctional rhythm and a premature ventricular depolarization. No pacemaker stimuli were present. Next, to document the nature of the artifact the pacemaker was programmed to VVI mode at 30 BPM and CVVH was turned back on. Multiple pacing “spikes” (pseudospikes) occurring at variable cycle lengths were seen (Fig. 3C). Given normal pacemaker function and presence of pseudospikes only when CVVH was turned on, the concerning extra stimuli on telemetry were diagnosed as benign artifact related to CVVH.

## Discussion

We describe a case of telemetry artifacts resembling pacing stimuli due to a CVVH machine in a patient with ESRD. Multiple types of medical equipment have caused various ECG artifacts. CVVH, in particular, has been associated with artifacts that resemble atrial fibrillation or atrial flutter [1,2]. CVVH pumps rotate at between 50 and 600 rpm and generate electrical currents. Two electrical effects have been attributed to CVVH: static and piezoelectric effects [3]. Piezoelectricity is created by plastic deformation, whereas static electricity is created by the plastics rubbing together; both electrical effects can present as artifacts on the ECG [3]. These electrical currents can enter the patient from the fluid in the dialysis tubing and be detected by the ECG electrodes [3]. ECG machines and telemetry monitors use differential amplifiers to increase the potential difference between two electrodes and reject background nose. If poor electrode contact is also present, signals from either piezoelectricity or static electricity sources can be picked up by the differential amplifier instead of being rejected as noise, and recorded on the EKG or telemetry strip [3].

Modern ECG machines convert the analog electrical signal to digital before processing. Pacemaker stimulus outputs are too short in duration

* Corresponding author at: UCSF Cardiac Electrophysiology, 500 Parnassus, MUE 434, San Francisco, CA 94143, United States of America.
*E-mail address:* adam.oesterle@ucsf.edu (A. Oesterle).

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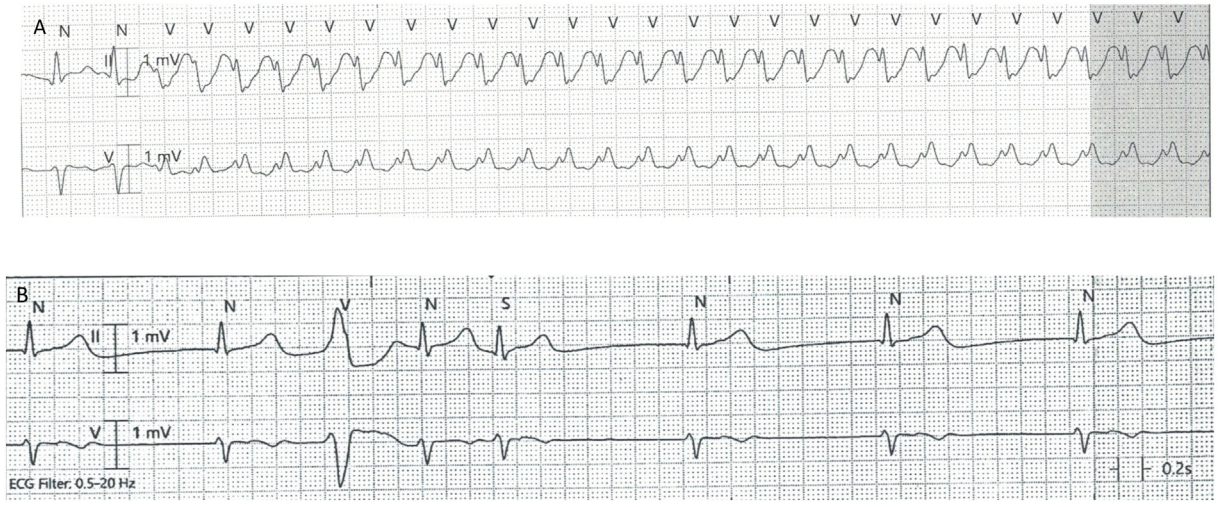


**Fig. 1.** A: Telemetry strip leads II and V1 showing a wide QRS complex tachycardia with right bundle branch morphology that was hemodynamically unstable and required external cardioversion. Given the hemodynamic effects and the correlation with vital signs, the wide complex tachycardia was thought to represent ventricular tachycardia related to vasopressor use, although an electrocardiogram was not obtained to confirm the diagnosis. B: Telemetry strip showing an underlying junctional rhythm occurring at 1600 msec intervals, an interpoplated ventricular depolarization follows, and a premature narrow QRS complex (origin uncertain) resets the junctional focus. The junctional rhythm was not hemodynamically tolerated and required dopamine for hemodynamic support. N – normal; V – ventricular; S – supraventricular.

(e.g., generally 0.3–0.6 msec) to be detected by ordinary ECG signal processing. Therefore, to detect pacemaker stimuli, digital ECG processing algorithms "oversample", and the initial sampling rate during the analog-digital conversion is higher than the upper frequency cutoff that is used for processing other ECG signals [4]. The Philips telemetry system (Royal Philips, The Netherlands), was used in this case. It oversamples at 500 samples/s to detect narrow pacing stimuli (which occur at the point of care device prior to other filtering) and uses a sampling rate of 125 to 250 samples/s for analysis of the QRS complex [5]. The Philips system assigns the marker 'to mark a paced beat (Fig. 2 – seen before or after the letters denoting the beat classification), which in this case happened with both true pacing stimuli and artifacts from CVVH (Fig. 3C). The Philips beat classification algorithm classifies paced beats within set windows; from 600 to 150 msec before the QRS complex it searches for atrial pacing spikes and for 150–48 msec before the QRS it searches for ventricular pacing spikes [5]. If the spikes occur at random intervals the algorithm does not classify them as it assumes they are not related to the rhythm.

Given that the telemetry system detects the pacing stimuli prior to any filtering, the artifact seen in this case must be due to electrical activity from an external source (in this case, CVVH). Close inspection of the telemetry strip in Fig. 2 shows clear paced depolarizations that are 750 msec apart, which indicates correct pacemaker function since the device was programmed to VVI mode at 80 bpm. The additional pseudospikes do not show consistent timing intervals, which should raise suspicion for artifact.

Artifactual telemetry pacemaker pseudospikes have been reported to occur from ambient radiofrequency interference, transcutaneous electrical nerve stimulation units, an IV fluid warmer that is improperly grounded, and peripheral nerve stimulators [6–9]. It is important to remember that any electromagnetic field can be seen on a telemetry strip or surface ECG and appear similar to a clinical condition. Troubleshooting should first involve making sure the electrodes are appropriately attached and then systematically disabling or removing possible sources from the area to identify the source. Since static electricity may occur randomly, it is not necessary that an electrical artifact on ECG or telemetry occur at constant intervals (most commonly 60–100 Hz for electrical equipment).

It is important to always consider electrical artifacts when evaluating an abnormal telemetry strip or ECG. Systematically eliminating potential sources of electrical interference can avoid inappropriate treatment and lead to the correct diagnosis.

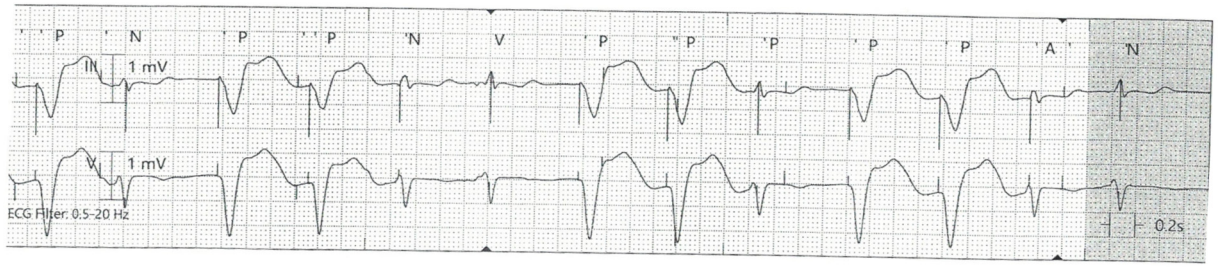


**Fig. 2.** ECG leads II and V1 telemetry strip concerning for inappropriate stimulus-on-T occurrences with pseudofusion in the native complexes that follow the paced complexes. Baseline pacing mode and rate were programmed to VVI 80 BPM. Letters at the top of the strip are automatically noted by the telemetry system. N – normal beat, V – ventricular ectopic, P – paced beat, A - artifact.

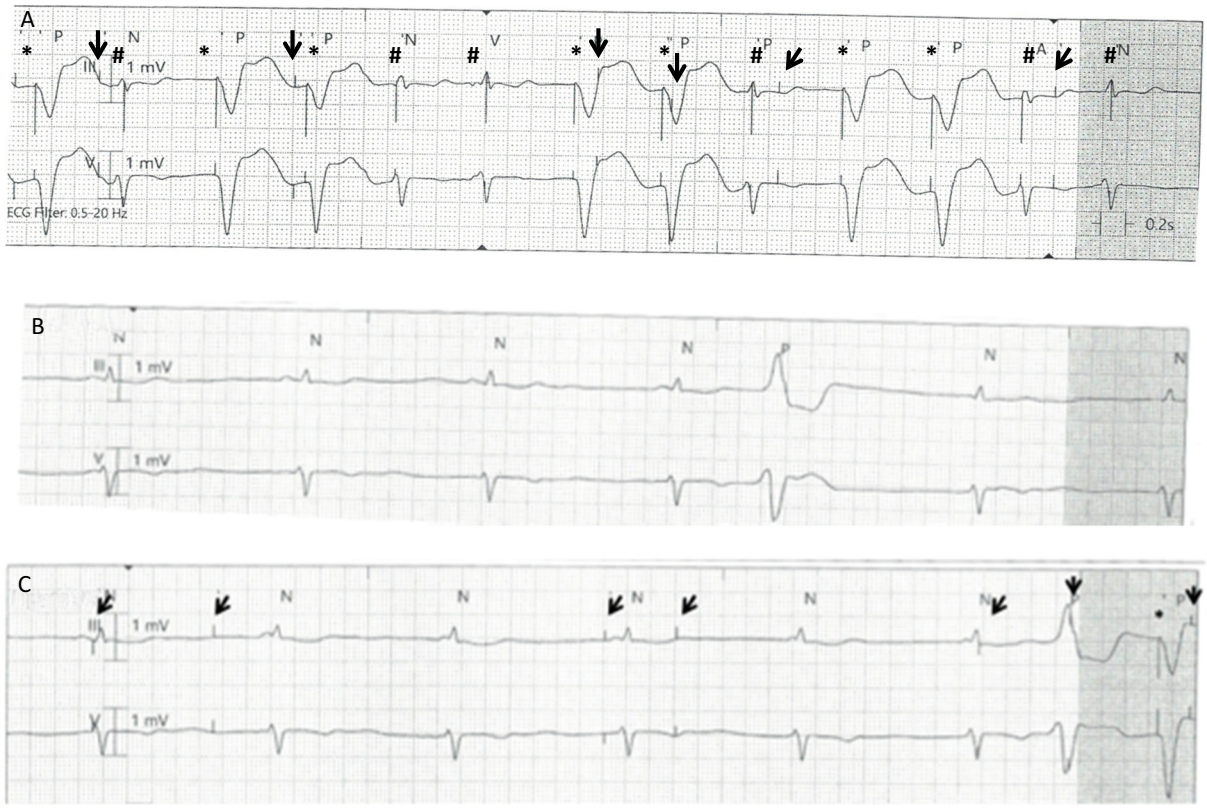


**Fig. 3.** A: The same telemetry strip as Fig. 2. * denotes an appropriately paced ventricular depolarization, # denotes a junctional complex with a 'spike' within, suggesting pseudofusion, ↓ denotes a non-capturing pacing pseudospike. 3B: The underlying rhythm with the pacemaker programmed to VVI mode at 30 BPM and CVVH turned off. The underlying rhythm is sinus bradycardia with an intermittent junctional escape rhythm and a premature ventricular depolarization. The premature ventricular depolarization is incorrectly labeled as a paced beat (P) by the telemetry system. 3C: The pacemaker remains programmed to VVI 30 BPM and CVVH is turned on. The underlying rhythm remains sinus bradycardia with intermittent junctional rhythm. One (*) fully paced depolarization is present at the end of the strip. Multiple ↓ non-capturing pacing pseudo spikes with irregular cycle lengths are present, now documented to be CVVH-induced artifact.

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