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Blinded by the height: A case of telemetry T wave overcounting

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ABSTRACT

High grade atrioventricular (AV) block, defined as 2 or more non-conducted P waves, is a common indication for permanent pacemaker implantation and can be a cause of syncope or presyncope. A 61 year-old male presented to the emergency department with presyncopal symptoms and high grade AV block confirmed on electrocardiogram. Continuous cardiac telemetry monitoring did not trigger any alarm notification during episodes of AV block, due to T wave overcounting. The limitations of telemetry monitoring are rarely recognized and even more rarely reported in the literature.

Introduction

High grade atrioventricular (AV) block suggests infra-AV nodal conduction system disease. It comprises both Type II second degree, fixed ratio AV block (3:1, 4:1, etc.), and is distinguished from complete AV block where there is total absence of AV conduction. It can have several etiologies including ischemia, cardiomyopathy, myocarditis, electrolyte disturbances, postoperative state, medication-induced, or idiopathic [1]. In the absence of reversible causes, high grade and complete AV block are treated with permanent pacemaker implantation in accordance with guideline-based recommendations [2]. We present a case of a man admitted to the hospital with lightheadedness in the setting of high grade AV block in which the resulting bradycardia was not recognized by telemetry monitoring.

Case presentation

A 61-year-old man with past medical history notable for essential hypertension, type 2 diabetes mellitus, and end-stage renal disease developed lightheadedness and near syncope during dialysis. His vital signs revealed a blood pressure of 157/51 mmHg, respiratory rate of 16 per minute, and pulse rate of 39 beats per minute (bpm). He was transported to the emergency department. He denied any prior history of near-syncope, or frank syncope, recent fevers, chills, changes in medications, chest discomfort, or palpitations. Admission electrolytes were within normal limits aside from a chronic elevation in serum creatinine. His medication regimen was notable for the absence of AV nodal blocking agents. A 12-lead electrocardiogram (ECG) was performed (Fig. 1) demonstrating high grade AV block, and he was admitted to acute care with telemetry monitoring with plans for observation and inpatient permanent pacemaker implantation. Surface echocardiogram was within normal limits. Telemetry review the following morning revealed episodes of high grade AV block (Fig. 2) that were not detected by the telemetry's bradycardic algorithm (Philips Healthcare, Cambridge, MA) [3]. The patient underwent dual chamber permanent pacemaker implantation.

Discussion

Of the 10 most common admission diagnoses reported by the Agency for Healthcare Research and Quality, telemetry is recommended for seven. ED presentations for syncope, pre-syncope, and lightheadedness account for up to 2% of all visits to ED's annually [4]. The volume of syncope and pre-syncope presentations leads to costly diagnostic testing including continuous telemetry monitoring and hospitalization admissions that are usually of low diagnostic yield. Therefore, these common chief complaints require risk stratification based on validated clinical criteria. In a prospective analysis of 1400 ED patients presenting with syncope, an abnormal ECG at presentation was the most prevalent risk factor in those who suffered poor outcomes [5]. The American Heart Association endorses a Class IC level of recommendation ("should be performed, consensus of expert opinion") for telemetry use in hospitalized patients, symptomatic AV block [6]. High grade AV block, defined by the American College of Cardiology/American Heart Association/Heart Rhythm Society as Mobitz Type II second or third degree AV block, receives a Class IB recommendation ("should be performed, moderate-quality of evidence") for permanent

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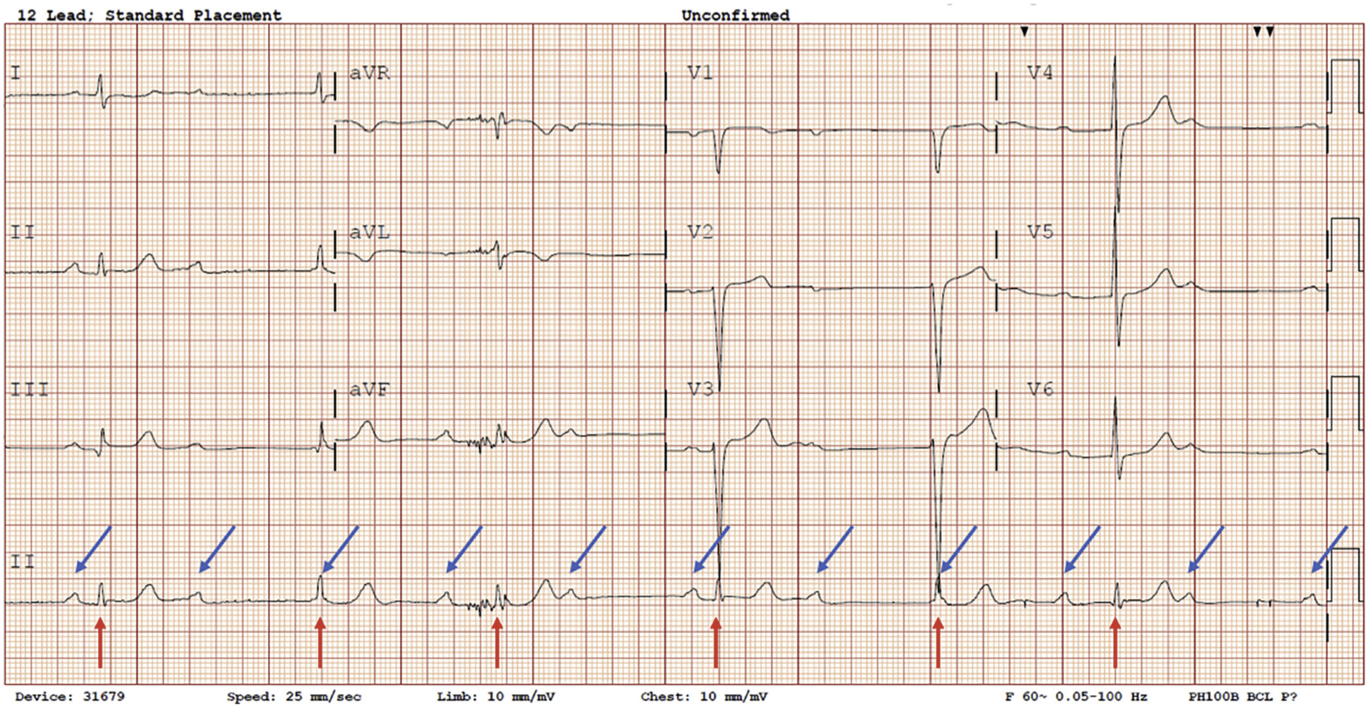

Fig. 1. Admission 12-lead electrocardiogram demonstrating high-grade atrioventricular block with a regular sinus rate (blue arrows) and intermittent AV conduction with junctional escape complexes (red arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

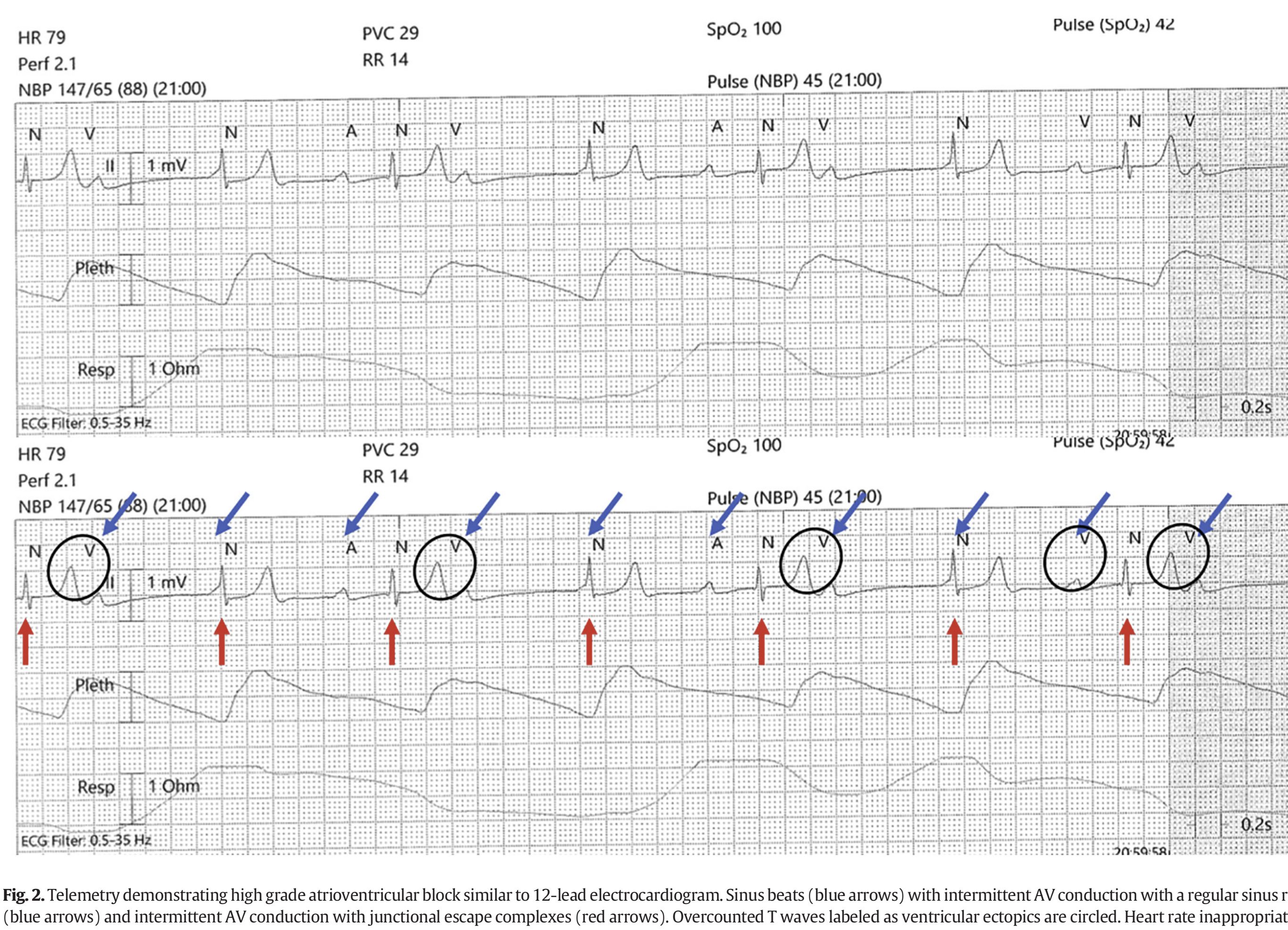

Fig. 2. Telemetry demonstrating high grade atrioventricular block similar to 12-lead electrocardiogram. Sinus beats (blue arrows) with intermittent AV conduction with a regular sinus rate (blue arrows) and intermittent AV conduction with junctional escape complexes (red arrows). Overcounted T waves labeled as ventricular ectopics are circled. Heart rate inappropriately calculated at 79 bpm. ST/AR algorithm definitions: “A” artifact, “N” normal sinus, “V” ventricular ectopic. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

pacemaker implantation, irrespective of symptoms, as untreated patients are at risk for recurrent syncope, heart failure admissions, and possibly decreased survival in comparison to those treated with a pacemaker [2].

Telemetry monitoring remains a diagnostic tool subject to its inherent accuracy and precision in determining its sensitivity and specificity for reporting heart rate, measuring conduction intervals, or diagnosing heart rhythm disturbances. Telemetry monitoring utilizes specific algorithms to determine cardiac arrhythmias, ST segment changes, and QT intervals. In this case, the patient was monitored using the Philips Healthcare IntelliVue MX40 wearable monitor with a Philips proprietary MX40 standard 5-lead cable and continuously analyzed with Philips' ST/AR (ST and Arrhythmia) ECG algorithm. This algorithm has an internally validated QRS and PVC detection with positive predictive accuracy of >99% and >96%, respectively, for both single-lead and 5-lead performance [7].

The Philips' ST/AR ECG analysis is performed in a stepwise process [3]. The initial step is sample filtering at a sample rate of 125–250 Hz for QRS detection in order to remove low frequency signals such as baseline noise and wander, and thus isolate the QRS complexes from surrounding frequencies. The second step entails QRS detection at a threshold of ≥0.15 mV per the Association for the Advancement of Medical Instrumentation (AAMI)/American National Standards Institute (ANSI)/International Electrotechnical Commission (IEC) requirements for the basic safety and performance of electrocardiographic monitoring equipment [8]. Therefore, when telemetry is initiated on a patient, Philips recommends selecting a monitoring lead with an identified QRS amplitude of ≥0.5 mV. The algorithm locates candidate QRS complexes based on an integrated ECG signal which, in turn, is based on the highest amplitude waveform detected after an absolute refractory period from the previous highest amplitude waveform. This refractory period has a nominal setting of 184 milliseconds for adult patients. QRS complexes with an amplitude <1/5 of the maximum detected candidate R wave or at an absolute values <0.15 mV are rejected to avoid overcounting of P or T waves. In addition, the algorithm assesses the QRS waveform features to help classify into various templates ('normal,' 'ventricular-in-origin,' 'ventricular-paced,' or 'unclassified') during the "learning" phase when arrhythmia monitoring commences. In sum, the algorithm utilizes the waveform features, timing, template matching, and morphology in comparison to neighboring complexes, and pacing artifacts associated with complexes (if present) to label a beat as N 'normal', S 'supraventricular ectopic', V 'ventricular ectopic', P 'paced', or ? 'questionable'.

If excessive noise in the signal is present, waveforms are labeled with A 'artifact'. Although a simplified letter labeling system, it is not universally used or readily adopted in clinical practice and may be a source of confusion upon telemetry review. In our patient, false identification of the T waves as V 'ventricular ectopics' due to the high amplitude (0.5 mV) and post-QRS timing of 340 ms, well beyond the nominal refractory period, led to failure to diagnose bradycardia. Moreover, given the regularity in the arrhythmia, it is possible that the telemetry algorithm binned the repetitive abnormal T waves into a stored PVC template. This resulted in overcounting of ventricular complexes, both sinus and false 'ventricular ectopics,' with the algorithm determining a heart rate of 79 bpm, and thus not triggering the telemetry definition of AV block alarms, which includes "bradycardia," "pauses," or "missed beat" (telemetry algorithm definition of AV block). Fortunately, the managing service was aware of the patient's high grade block present on the initial ECG.

Otherwise, without judicial review of the telemetry tracings, the high grade AV block may not have been diagnosed due to T wave overcounting. We recommend careful review of initial telemetry tracings to determine if cardiac rhythm is being accurately analyzed by the algorithm. Our patient may have benefited from selection of different ECG monitoring leads without high-amplitude T waves or alteration in lead placement to prevent T wave overcounting.

Telemetry use is increasingly common during inpatient hospitalizations; however, its effectiveness in patient cost and care is debated. Telemetry alarm fatigue is a well-studied phenomenon in which physicians and ancillary staff ignore monitoring alarms as most do not require medical attention or treatment and generate sensory overload [9]. Similarly, we hypothesize that many healthcare professionals review only telemetry-generated alarm events as part of an information overload. In this case, telemetry alarm events would not have identified the pathologic rhythm disturbance. To our knowledge, this is the only reported case of underdiagnosed AV block on continuous cardiac telemetry.

In conclusion, physicians should recognize the limitations of continuous telemetry monitoring and its utility as a diagnostic test. Understanding the basic concepts of telemetry algorithm-based learning can help avoid the pitfalls of either under- or overdiagnosis of cardiac arrhythmias.

Competing interests

The authors declare no competing interests.

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References

[1] Zoob M, Smith KS. The aetiology of complete heart-block. Br Med J 1963;2:1149–54. https://doi.org/10.1136/bmj.2.5366.1149.

[2] Kusumoto FM, Schoenfeld MH, Barrett C, Edgerton JR, Ellenbogen KA, Gold MR, et al. 2018 ACC/AHA/HRS guideline on the evaluation and management of patients with bradycardia and cardiac conduction delay. J Am Coll Cardiol 2018. https://doi.org/10.1016/j.jacc.2018.10.044.

[3] Arrhythmia monitoring: ST/AR algorithm; application note. K Philips NV; 2017.

[4] Patel PR, Quinn JV. Syncope: a review of emergency department management and disposition. Clin Exp Emerg Med 2015;2:67–74. https://doi.org/10.15441/ceem.14.049.

[5] Francisco S, Francisco S, Rule S, Rule S, Patients P, Patients P, et al. Derivation of the San Francisco Syncope Rule to predict patients with short-term serious outcomes. Ann Emerg Med 2004;43:224–32. https://doi.org/10.1016/mem.2004.430.

[6] Sandau KE, Funk M, Auerbach A, Barsness GW, Blum K, Cvach M, et al. Update to Practice Standards for Electrocardiographic Monitoring in Hospital Settings: A Scientific Statement From the American Heart Association. vol. 136. 2017. doi:https://doi.org/10.1161/CIR.0000000000000527.

[7] Assessing arrhythmia performance: ST / AR algorithm; application note. K Philips NV; 2015.

[8] IEC 60601-2-27: 2005. Medical electrical equipment—part 2–27: particular requirements for safety, including essential performance, of electrocardiographic monitoring equipment. 2016. doi:https://doi.org/10.5594/J02961.

[9] Drew BJ, Harris P, Zègre-Hemsey JK, Mammone T, Schindler D, Salas-Boni R, et al. Insights into the problem of alarm fatigue with physiologic monitor devices: a comprehensive observational study of consecutive intensive care unit patients. PLoS One 2014;9. https://doi.org/10.1371/journal.pone.0110274.