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Cardiovascular Images

Preexcitation alternans in a dog[☆]



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Abstract Preexcitation alternans and orthodromic atrioventricular reciprocating tachycardia were diagnosed in a 3-month-old Boxer. The images described here show how conventional electrocardiographic techniques (12-lead surface electrocardiography, 24-hour Holter monitoring, and ladder diagram) can be interpreted to gain detailed information on presence of canine atrioventricular accessory pathways and their conduction properties.

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A 3-month-old 9-kg intact female boxer was referred to the Veterinary Hospital of the University of Bologna because of exercise intolerance and an arrhythmia. On physical examination, the dog showed phases of irregular cardiac rhythm and tachycardia with variable heart rates (HRs) (120–250 beats/minute). A moderate (3/6) systolic left basilar heart murmur was also detected. The rest of the physical examination was unremarkable.

Transthoracic echocardiography^c showed moderate left ventricular and atrial dilatation with preserved myocardial systolic function. Mild right ventricular and atrial dilatation was also evident. Doppler echocardiography revealed mild atrioventricular (AV) valve regurgitation, which was judged to be secondary to the ventricular dilatation. Left ventricular outflow tract flow velocity was normal. Twelve-lead surface electrocardiogram (ECG) was

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^c iE33 ultrasound system, Philips Healthcare, Monza, Italy.

Abbreviations Table

AV	atrioventricular
AP	accessory pathway
AVN	atrioventricular node
ERP	effective refractory period
HR	heart rate
OAVRT	orthodromic atrioventricular reciprocating tachycardia
VP	ventricular preexcitation

obtained with the dog positioned in right lateral recumbency^d (Fig. 1).

Image interpretation: Fig. 1 – Twelve-lead surface ECG: preexcitation alternans

A regular rhythm with a mean HR of 175 beats/minute is present. P waves are considered to be sinus on the basis of their mean electrical axis in the frontal plane (63°). Amplitude is normal in lead II (0.35 mV), while duration is mildly increased (50 ms), likely due to atrial dilatation or conduction disturbance. Each P wave is followed by a QRS complex, although there are two distinct QRS complex morphologies which can be seen to alternate on a beat-to-beat basis. The QRS complexes with normal configuration (e.g., first complex) are characterized by a normal duration (60 ms, narrow morphology), a normal mean electrical axis (81°), and an appropriate PQ interval (100 ms). The QRS complexes with bizarre morphology are instead wide (80 ms in duration), with a different mean electrical axis (51°), a rR morphology in the inferior peripheral leads, and a slurred upslope of the R wave in left precordial leads (arrowheads), compatible with a delta wave. The PQ intervals for these complexes were shorter and consistent (60 ms).

At this point, the presumptive diagnosis was a sinus rhythm conducted to the ventricle with a preexcitation alternans (preexcited complexes manifesting delta waves regularly alternating with normal QRS complexes) due to the presence of an AV accessory pathway (AP) capable of intermittent antegrade conduction [1]. As a differential diagnosis, a ventricular bigeminy associated with an isorhythmic AV dissociation with type 2 synchronization was also considered [2].

A 24-hour Holter monitoring was then performed using a non-corrected orthogonal 3-lead system^e.

Image interpretation: Fig. 2 – 24-hour Holter monitoring: bypass tract–mediated tachycardia or orthodromic atrioventricular reciprocating tachycardia (OAVRT)

During the 24 hours a narrow QRS complex tachycardia with a regular cycle length of 0.26 s (instantaneous HR: 231 beats/min) is identified. The onset and termination of runs of tachycardia occur suddenly (paroxysmal behavior), and they are followed by short pauses and well-defined sinus complexes (Fig. 2A). During tachycardia, a mild beat-to-beat variation of the R wave amplitude is evident (electrical alternans), while an apparent retrograde atrial activation, with negative P' waves, is visible in the ST segment. There is a 1:1 AV conduction ratio, with an RP' shorter than 50% of the relative RR interval (RP': 70 ms; P'R: 190 ms; RP':P'R: 0.37) (Fig. 2B left panel). On Fig. 2B right panel, a magnification of a normal sinus beat is attached. As evident, the ST segment and T wave appear remarkably different compared to the same tracts during tachycardia, suggesting absence of an inscribed retrograde P' wave. On the basis of these electrocardiographic features, OAVRT (bypass tract mediated tachycardia) due to retrograde conduction along an AP was strongly hypothesized [3]. Considering the findings detected during sinus rhythm and tachycardia, an AP capable of bidirectional conduction was judged to be the cause of rhythm disturbances in the puppy from this report. Ladder diagrams of both rhythms were created.

Image interpretation: Fig. 3 – Ladder diagram: preexcitation alternans

Dots drawn at the top of the diagram are continued by vertical lines in the atrial tier (A), indicating that sinus impulses excite the atria in a normal fashion. In the AV node (AVN)/AP tier, slanted lines with a left-to-right direction represent impulses reaching the ventricles exclusively through the AVN (e.g., first beat). In this moment, the AP produces an antegrade unidirectional block (short parallel bars perpendicular to truncated lines in the AVN/AP tier), likely due

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^e Cube Holter, Cardioline S.p.A., Milan, Italy.



Fig. 1 Twelve-lead surface electrocardiogram. A consistent beat-to-beat alternation of normal and preexcited QRS complexes (asterisk) is evident in each lead. Note the left precordial leads (V2–V6) where delta waves have typical slurred upstroke contour (arrowheads). Notice also the stable duration and constant morphology of delta waves as well as their fixed relationship to the preceding P waves. All these features support the diagnosis of preexcitation alternans. Paper speed = 50 mm/s; amplitude = 5 mm/mV.

to its relatively long antegrade effective refractory period (ERP). The vertical lines in the ventricular tier (V) indicate normal ventricular depolarization. Accordingly, a normal QRS-complex configuration is observed electrocardiographically. In contrast, sinus impulses reaching the atrial insertion of the AP when the excitable state has been recovered can propagate simultaneously through the AVN and the AP (e.g., second, fourth, and sixth complexes). In this case, vertical lines indicating rapid antegrade conduction through the AP are also drawn in the AVN/AP tier. In the ventricular tier, connection between the

two distinct lines indicates fusion of the two routes of AV conduction within ventricles, resulting in delta waves on the ECG.

Image interpretation: Fig. 4 – Ladder diagram: bypass tract–mediated tachycardia

This image represents the ladder diagram of the OAVRT (bypass tract–mediated tachycardia)

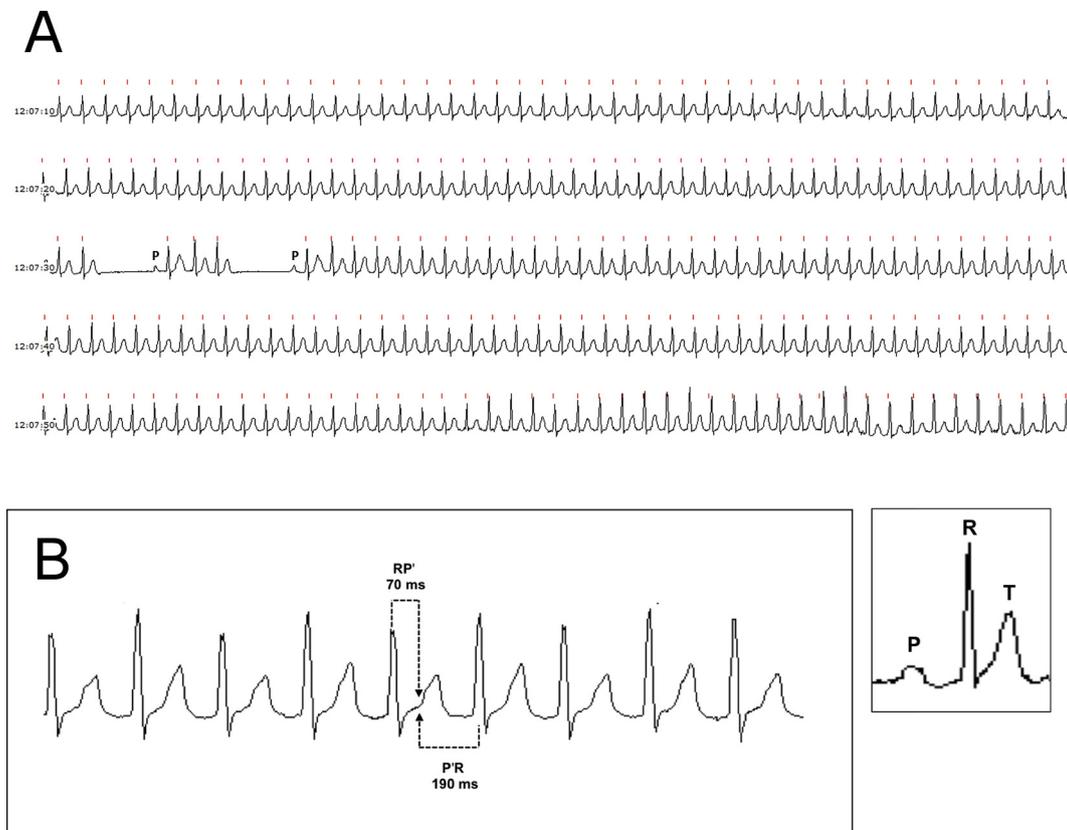


Fig. 2 Selected portions of 24-h Holter monitoring. (A) Panel A helps to study the behavior of narrow QRS complex tachycardia overtime: note its abrupt termination followed by a sinus beat (P); notice also its sudden restart with the same cycle length. Channel = X axis; paper speed = 44.3 mm/s; amplitude = 5 mm/mV. (B) Left panel represents a close-up of (A), and it helps to appreciate additional features of the tachycardia, including the retrograde atrial activation inscribed in the ST segment with a constant and short RP'/P'R ratio (RP' = 70 ms, P'R = 190 ms; RP'/P'R = 0.37) (dotted arrows) and the electrical alternans. On the right panel, a normal sinus beat of the same dog is shown. Notice the different presentation of the ST segment and T wave, indicating absence of a retroconducted P' wave during this phase of normal rhythm. By means of all these features, a bypass tract-mediated tachycardia (orthodromic atrioventricular reciprocating tachycardia) due to retrograde conduction over an atrioventricular accessory pathway can be hypothesized. Channel = X axis; paper speed = 88.6 mm/s; calibration = 10 mm/mV.

observed during 24-hours Holter recording. A slanted line with a left-to-right and up-to-down direction is drawn in the AVN/AP tier to show orthodromic conduction through the AVN. Here, two different routes of conduction occur. The first one spreads orthodromically activating the ventricles through the normal pathways. This depolarizing wave front is depicted by a vertical line in the ventricular tier and leads to a narrow QRS complex on the ECG. The second route of conduction propagates retrogradely along the AP toward the atria. This depolarizing wave front is illustrated by a left-to-right and down-to-up oriented arrow (dotted arrows), which is directed from the ventricles to the atrial-AVN/AP junction and then to the A tier. The upward oriented arrow in the atrial tier represents the following retrograde atrial depolarization, evident as a negative deflection inscribed in the ST segment on the

ECG. From the atria, the impulses reach the AVN (short obliquely up-to-down and left-to-right oriented line) and then, once again, conduct both orthodromically to the ventricles and retrogradely via the AP, thus reestablishing the reentrant circuit.

Outcome

Echocardiographic findings, interpreted in the context of the electrocardiographic abnormalities, were considered most likely compatible with an arrhythmia-induced cardiomyopathy [4]. Further diagnostics and therapeutic options (including radiofrequency catheter ablation of the AP) were offered to the owners, but these were refused. Medical therapy with oral sotalol was initiated, and the patient was then unfortunately lost to follow-up.

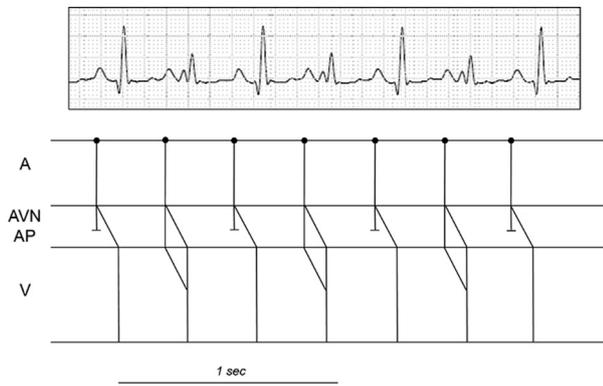


Fig. 3 The electrophysiologic phenomena depicted in Fig. 1 are represented on a ladder diagram to better elucidate their temporal relationships. Note that the intermittent conduction along the AP consistently occurs every second beat, creating the characteristic bigeminal pattern on the electrocardiogram. Slanted lines with a left-to-right direction are drawn in the AVN/AP tier to depict the orthodromic conduction along the atrioventricular node. For every other beat, the antegrade conduction along the AP pathway is drawn as a vertical line in the AVN/AP tier continued with a slanted line in the ventricular tier. Accordingly, in the surface ECG, ventricular preexcitation occurs. Short parallel bars perpendicular to truncated lines in the AVN/AP tier are used when unidirectional block in the accessory pathway occurs. A, atria; AVN, atrioventricular node; AP, accessory pathway; V, ventricles.

Discussion

An AP is an abnormal shaft of conductive fibers that directly connect atria and ventricles bypassing the AVN and physiological AV delay [4,5]. Electrophysiologic study represents the gold standard technique to assess AP anatomical features, such as their number and location and functional properties, such as their ability to conduct antegradely, retrogradely, or bidirectionally. Moreover endocardial catheter-based ablation of the arrhythmic substrate can represent a definitive treatment for the AP-mediated arrhythmias [4,5]. However, in veterinary practice, this approach is still limited to a few specialized centers. Therefore, the surface ECG often remains the main diagnostic tool in dogs [3]. Based on AP conduction properties, different electrocardiographic features are expected. In case of antegrade conduction, two parallel fronts of depolarization coexist: a faster one that travels along the AP and activates prematurely a portion of the ventricle without passing through the AVN and a slower one traveling through the normal conduction system and, thus, subject to the physiological AV delay.

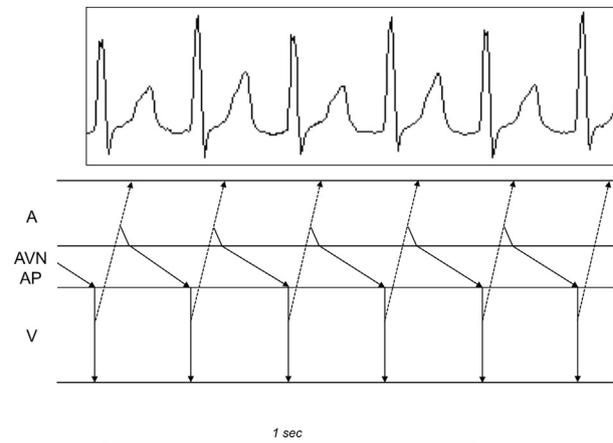


Fig. 4 The electrophysiologic phenomena depicted in panel B of Fig. 2 are represented on a ladder diagram to better elucidate their temporal relationships. Note that the ventricular activation is always the result of an orthodromic conduction over the normal conduction system (slanted arrows with a left-to-right and up-to-down direction drawn in the AVN/AP tier followed by vertical lines in the V tier). In contrast, atria are depolarized in an abnormal fashion due to retrograde conduction over the AP. Dotted arrows, directed from the ventricles to the A-AVN/AP junction and A tier, are used to depict this depolarization wave front (the arrowheads indicate the direction of conduction). The different lines drawn within the A tier represent the different fronts of depolarization moving into the atria: one completing the depolarization of the atrial myocardium and another one reaching the atrioventricular node antegradely. A, atria; AVN, atrioventricular node; AP, accessory pathway; V, ventricles.

Electrocardiographically, the premature activation of the ventricles shortens the PR interval, while the summation of the two routes of AV conduction creates a hybrid, wide QRS complex with a notch in the upstroke of the R wave (delta wave) [4,5]. Ventricular preexcitation (VP) may manifest continuously or intermittently. Intermittent VP can show episodic unpredictable behavior or regular patterns, including preexcitation alternans, a rare ECG entity characterized by beat-to-beat alternation of normal and preexcited QRS complexes [1]. Phase 3 or phase 4 blocks in the AP, concealed conduction through the AP caused by premature ectopic complexes, and supernormal conduction often explain intermittent VP with irregular rhythm [6–9], whereas intermittent VP without HR changes can be due to regular antegrade block of AP with relatively long antegrade ERP [10]. Regarding the latter, it is interesting to note that human APs often have an antegrade ERP longer than the retrograde ERP at a comparable cycle length [11], likely as a consequence of

impedance mismatch at the point of insertion of the AP into the ventricular muscle [12]. This can help to explain why antegrade conduction over APs might fail more easily than retrograde conduction at similar HR [11]. In addition to intrinsic anatomic and electrophysiologic properties of APs, additional factors able to prolong their ERP have been proposed in human medicine, including transiently increased vagal tone during respiration due to a greater vagal effect on APs than the AVN [13]. In the case of preexcitation alternans, the bigeminal pattern can raise suspicion for ventricular bigeminy. In this report, preexcitation alternans was diagnosed because ventricular ectopic QRS complexes usually vary in shape, degree of widening, and relationship to the previous P waves over the same tracing, while delta waves normally have constant duration, stable morphology, and typical contour at least in one lead [14]. In the case of an AP capable of retrograde conduction, properly timed ectopic depolarizations can initiate OAVRT, a macroreentrant tachycardia where the AVN acts as the antegrade slower limb of the circuit and the AP as the retrograde faster one [4,5]. Electrocardiographically, OAVRT is typically characterized by sudden onset and termination, rapid ventricular response with constant cycle length and 1:1 AV conduction, retrograde P' inscribed in the late part of ST segment with a RP'/P'R ratio <1, narrow QRS complexes, and high incidence of QRS alternans and ST segment deviation [3]. Concurrent detection of VP and OAVRT on electrocardiographic tracings obtained from the same patient indicates AP capable of bidirectional conduction [4,5], as in the case presented here. In conclusion, this report illustrates how conventional electrocardiographic techniques can be interpreted to gain detailed information on presence and conduction properties of canine AP. Additionally, a unique pattern of intermittent VP, namely preexcitation alternans, is illustrated for the first time in a dog.

Conflicts of Interest Statement

None of the authors have a conflict of interest.

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