5 Bundle Branch Blocks and Hemiblocks

The conduction system of the heart is shown in Fig. 5.1. Under normal circumstances, the electrical activity of the heart arises from the sino-atrial (SA) node, whose intrinsic rate of electrical depolarization is normally faster than any other portion of the heart. The electrical impulse leaves the SA node, spreads across the atria, goes through the atrioventricular (AV) node, and enters the His bundle system at the inferior aspect of the AV node. The bundle of His bifurcates into the right and left bundle branches, and the left bundle branch divides again into two fascicles, the left anterior fascicle and the left posterior fascicle. Thus, by the time the electrical impulse reaches the end of the bundle branch conduction system it is running in three fascicles: (1) the left anterior fascicle, (2) the left posterior fascicle, and (3) the right bundle branch. Either of the bundle branches can have some process which interferes with conduction, thus leading to a bundle branch block, and either fascicle of the left bundle branch can have an impairment to conduction leading to a "hemiblock." It is important to emphasize that hemiblocks and bundle branch blocks may represent simply a *delay* in electrical conduction, rather than a total absence of conduction down the fascicle in question.

Bundle Branch Block

Two criteria must be met to diagnose a bundle branch block: (1) the QRS duration must be abnormally prolonged (0.12 s or greater) and (2) there must be a supraventricular origin of electrical activity. The other common situation in which one observes prolonged QRS complexes is ventricular rhythms; less common causes of prolonged QRS complexes are hyperkalemia and Wolff–Parkinson–White syndrome, so these must be ruled out in order to be sure that the QRS prolongation is from a bundle branch block. A supraventricular rhythm is documented if there are P waves with a consistent PR interval before each QRS complex (sinus rhythm) or if there are other evidences of supraventricular rhythms (see Chap. 7). Only on rare occasions is it difficult to distinguish a ventricular rhythm from a supraventricular rhythm with a bundle branch block.

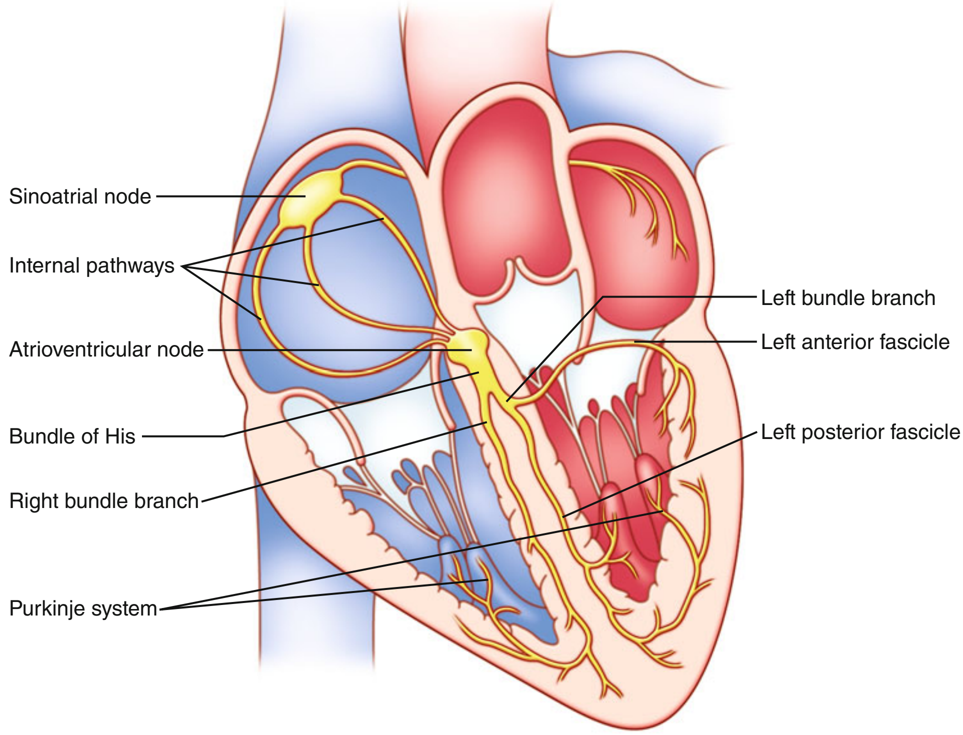
If the QRS complex is wide and there is a supraventricular focus of activation, then the most likely diagnosis is a bundle branch block. The issue then is whether it is a right bundle branch block or a left bundle branch block. The distinction is made by examining the QRS configuration in three leads: I, V_1, and V_6 (Fig. 5.2). With a left bundle branch block, there is a tall, broad R wave in I and V_6 and a QS or rS in lead V_1. With a right bundle branch block, the QRS configuration is markedly different, with a broad terminal S wave in leads I and V_6 and an rsR′ or a tall broad R wave in V_1.

The electrophysiology that creates these patterns may help you remember them. The key element of this electrophysiology is what is called the "terminal forces," or the last part of ventricular depolarization. With a right bundle branch block, the impulses go through the entire conduction system normally until the bifurcation of the bundle of His. At that point, the impulse continues normally (and quickly) down the left bundle, but it is delayed as it tries to traverse the right bundle. When the depolarization is complete on the left side, the wave of depolarization then sweeps towards the undepolarized tissue on the right, and the depolarization down the right bundle that had been delayed also may be able to finally get through. For either or both reasons, the terminal forces, those at the end of ventricular depolarization, are to the right (Fig. 5.3). Because leads I and V_6 have their positive directions to the left, the terminal forces in these leads are negative, leading to the typical "broad, terminal S waves" characteristic of right bundle branch block in these leads.

The changes in lead V_1 are likewise interesting in a patient with right bundle branch block. The normal QRS configuration in V_1 is a small r wave followed by a deep, narrow S wave as shown in (Fig. 5.4). Keeping in mind that the "right" side of the heart is not only to the right of the patient's body but also anterior, the terminal forces with a right bundle block are coming almost directly at V_1. Therefore, the normal rS pattern is altered by the substantial positive forces at the end of ventricular depolarization, causing the classic rsR′ in V_1 (and often in V_2).

B.G. Petty, *Basic Electrocardiography*, DOI 10.1007/978-1-4939-2413-4_5,

Fig. 5.1 Conduction system of the heart



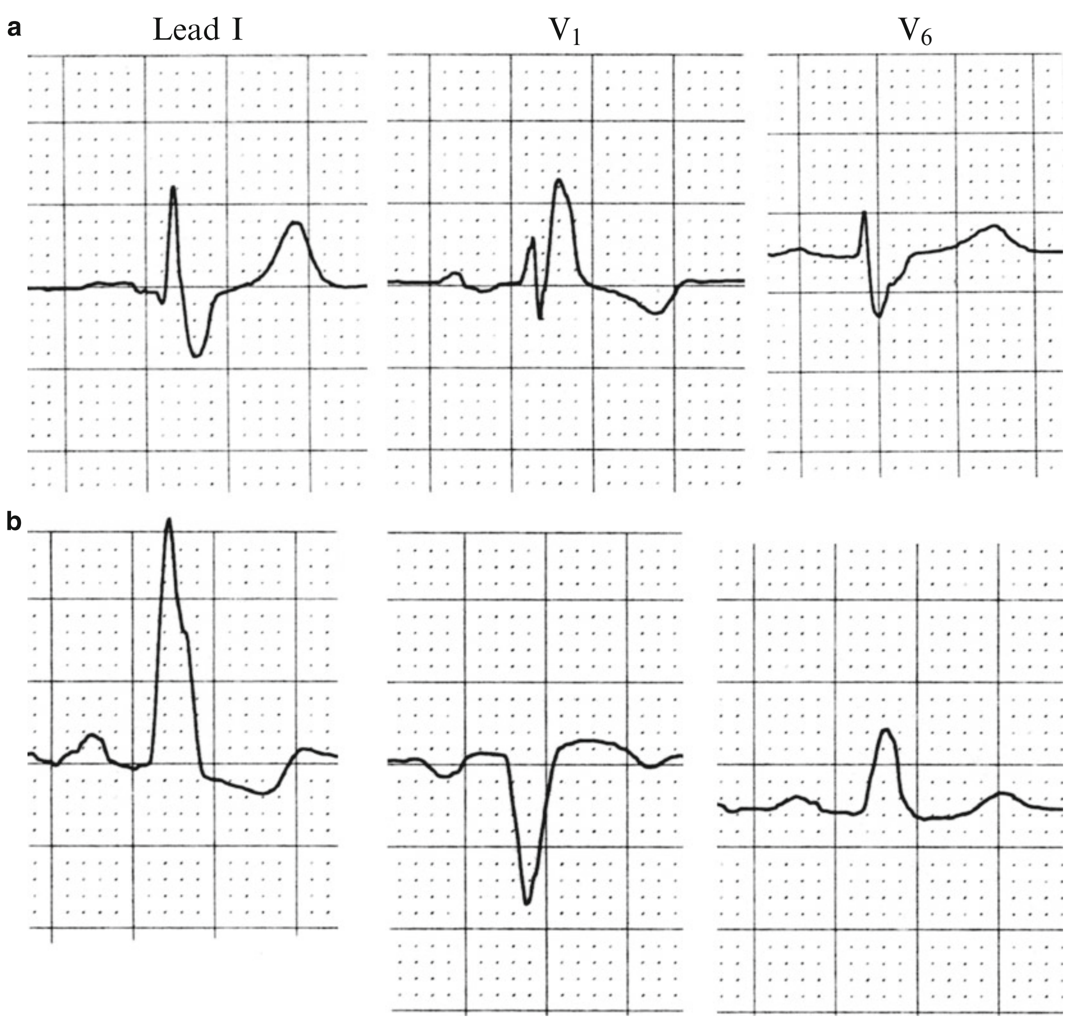


Fig. 5.2 Bundle branch blocks. (**a**) Right. (**b**) Left. For description, see text

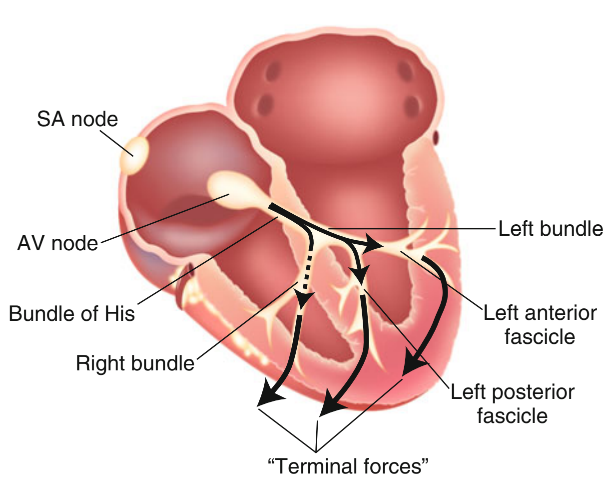


Fig. 5.3 Electrophysiology underlying the QRS configuration in right bundle branch block. The normal wave of depolarization originates in the SA node, goes through the atria, and then through the AV node into the bundle of His. It continues unimpeded down the left bundle branch (*arrow*), but is delayed going down the right bundle branch (*dotted arrow*). When the depolarization finishes through the left side of the heart, it then sweeps to the right side as that tissue is yet undepolarized because of the delay in the right bundle branch. When the delay in the right bundle branch is finally penetrated, the depolarization continues to the right. In both cases, the "terminal forces" (*large arrows*), which represent the last part of ventricular depolarization, sweep to the right, leading to the large "terminal S waves" in leads 1 and V_6 and the R′ in V_1

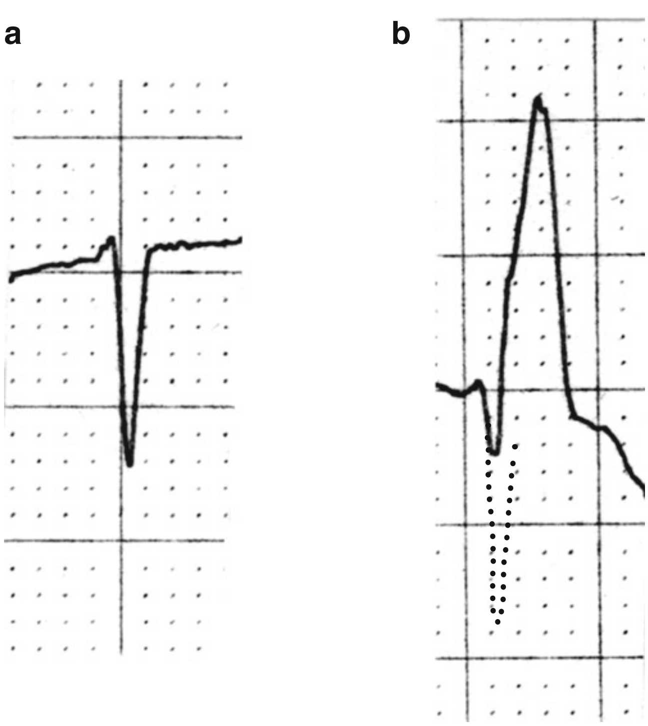


Fig. 5.4 QRS configuration in V_1. (**a**) Normal, with rS. (**b**) With right bundle branch block, where terminal forces anteriorly interrupt S wave and cause tall R′. Dotted lines indicate S wave appearance without interruption by terminal forces

Sometimes the terminal forces totally obscure the normal S wave and one may see just a tall, broad R wave in V_1, which is just as good as an rsR′ in suggesting right bundle branch block. 'Incomplete right bundle branch block' is when the QRS duration is normal and there is a small r' in V_1; this finding is of little clinical consequence except that patients with incomplete right bundle branch block have a greater chance of developing complete right bundle branch block than other patients.

The electrophysiology of a left bundle branch block is, as one would expect, somewhat "opposite" of what is found with a right bundle branch block. The initial ventricular depolarization goes quickly down the unimpaired right bundle, with the terminal forces sweeping to the left. Because the left ventricle is so much greater in thickness and muscle mass than the right ventricle, almost all of the QRS complexes reflect the terminal forces. Therefore, one sees a tall, broad R wave in I and V_6 (as the terminal forces sweep towards the positive sides of these leads), and a QS or rS in V_1 (as the terminal forces sweep directly away from the lead). Especially in the QRS configurations in V_1, one can easily see the opposite appearance of the right vs. left bundle branch block.

The ST segment and T waves are affected by bundle branch blocks. The ST segment is downsloping and the T wave is inverted with left bundle branch block (see Fig. 5.2). The T wave is also opposite in direction in right bundle branch block relative to the predominant, terminal deflection of the QRS, but this generally makes for a fairly normal T wave configuration, i.e., upright T in I, inverted in V_1 and upright in V_6. These ST-T wave changes are secondary to the abnormal conduction pattern of the bundle branch block itself, not ischemia (Chap. 3) or strain (Chap. 6). Secondary ST-T changes do not indicate an additional process beyond the bundle branch.

Hemiblock

When either of the two halves ("hemi-") of the left bundle is not conducting properly, a hemiblock is the result. In contrast to bundle branch blocks, the QRS duration with hemiblocks is normal, i.e., less than 0.12 s. The primary indication of a hemiblock is an abnormal axis deviation of the QRS complex. For left anterior hemiblock, there must be left axis deviation beyond −30° to the left, and for left posterior hemiblock, there must be right axis deviation of +120° or more to the right. After the axis deviation criterion has been met, the limb leads are examined for characteristic QRS configurations. For left anterior hemiblock, a small q wave is present in I and aVL, and a small r wave is found in III. For left posterior hemiblock, the opposite is found, namely a small r in I and aVL and a small q in III (Fig. 5.5).

Bifascicular Block

Bifascicular block means that two of the three fascicles are conducting abnormally. There are three possible combinations for bifascicular block: (1) right bundle branch block and left ante-

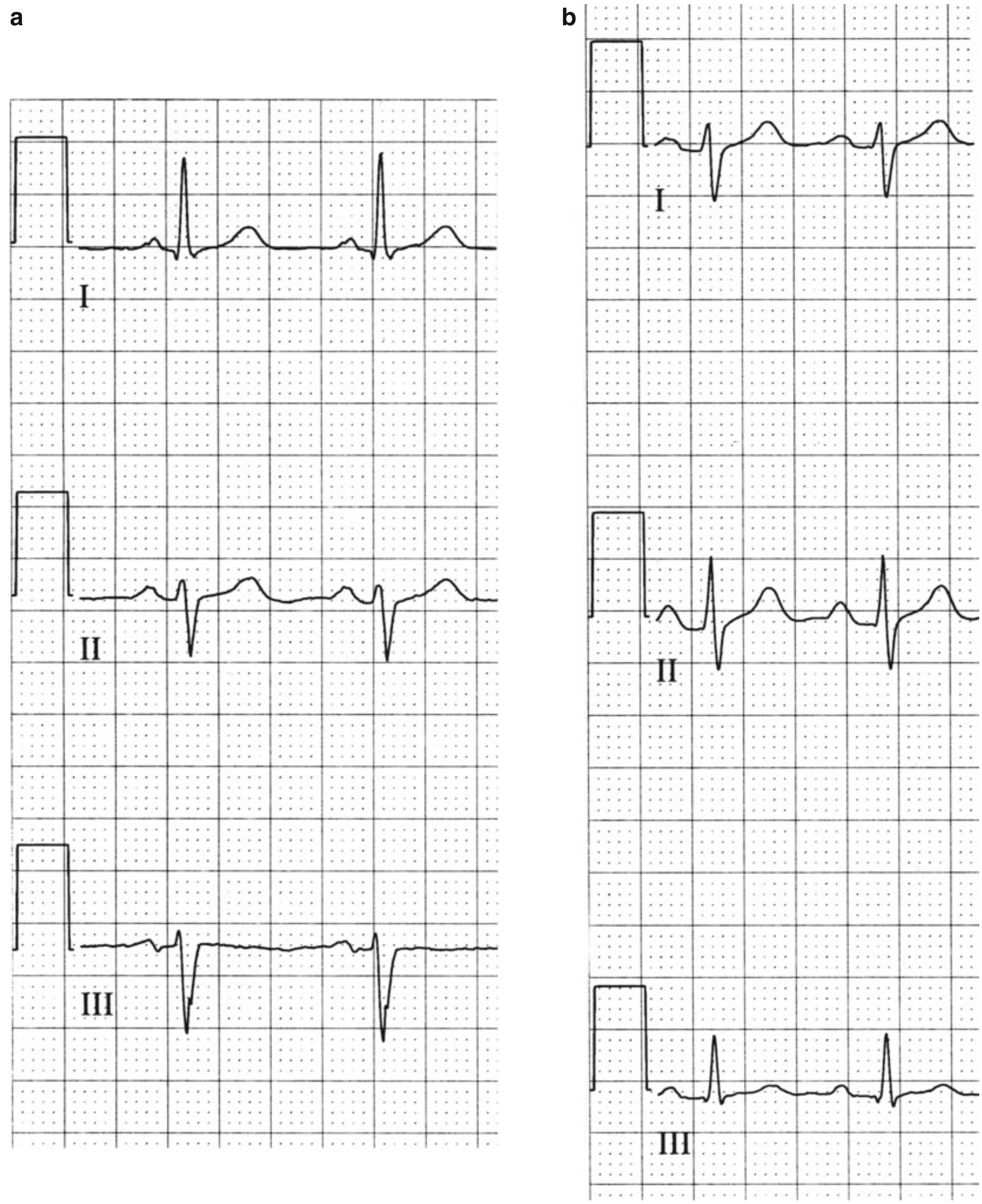


Fig. 5.5 Hemiblocks. (**a**) Left anterior hemiblock. (**b**) Left posterior hemiblock. For description, see text

rior hemiblock, (2) right bundle branch block and left posterior hemiblock, and (3) left bundle branch block. Even though the point of conduction abnormality may be proximal to where the left bundle branch divides into the two fascicles, left bundle branch block constitutes bifascicular block because if conduction down either fascicle were normal there would be at most a hemiblock. In the setting of right bundle branch block, an appropriate axis deviation, with or without associated q's and r's as described above, is adequate to denote block of a second fascicle. In the case of right bundle branch block and sufficient axis deviation, the bundle branch block may obscure the typical q's and r's that would otherwise be seen in the hemiblock.

Trifascicular Block

Sometimes there is a fairly diffuse process that impairs conduction in all three fascicles. If the process is severe, the electrocardiogram (EKG) may show complete heart block, indistinguishable from that which is due to severe, AV node conduction block. In fact, invasive electrophysiological studies ("His bundle studies") show that complete heart block is more often related to trifascicular block than to AV nodal dysfunction. Other manifestations of trifascicular block include alternating left and right bundle branch block (very rare) and bifascicular block with a prolonged PR interval. As shown in Fig. 5.6, the conduction system below the AV node is responsible for the last portion of the PR interval, so a delay in conduction through those parts of the conduction system could prolong the PR interval. This last manifestation of trifascicular block cannot be distinguished on the regular 12-lead EKG from bifascicular block with a concurrent first-degree AV block. Invasive electrophysiological conduction studies are required to definitively establish which process is involved. It is not unreasonable to assume, however, that if two of the fascicles are conducting abnormally, then the third may be affected as well. If the third fascicle is affected to a lesser degree than the others, the EKG would not show complete heart block but would instead show bifascicular block with a prolonged PR interval, which would reflect the relatively less complete blockage of conduction through the third fascicle.

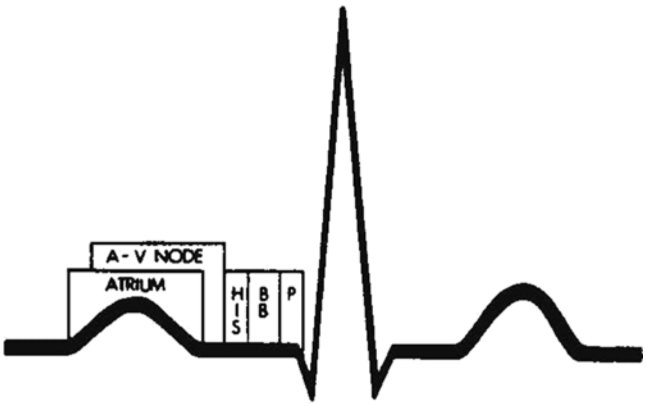


Fig. 5.6 Components of the PR interval. This diagram indicates the multiple portions of the heart which contribute to the PR interval, including the bundle of His, the bundle branches ("BB"), and the distal Purkinje fibers ("P")

It may be useful to approach bundle branch blocks and hemiblocks in the fashion outlined in Fig. 5.7. When one has an EKG with prolonged QRS complexes and a supraventricular focus of activation, then a bundle branch block is likely present. If it is a right bundle branch block, one should next examine the QRS axis because if deviated to more than −30° to the left or +120° or more to the right, a hemiblock is also present, and this is a bifascicular block. If the bundle branch block is a left bundle branch block, then by definition a bifascicular block is present. If one has a bifascicular block, the next question is whether a trifascicular block may be present. If the PR interval is prolonged (>0.20 s), then a trifascicular block *may* be present (vs. bifascicular block and first-degree AV block), and this should be mentioned in the interpretation.

1. Wide QRS Complexes
+ 2. Supraventricular rhythm
= Bundle branch block

RIGHT OR LEFT?

1 Terminal S in I and V_6
+ 2 rSR′ or tall R in V_1
= Right bundle branch block

1 Tall broad R wave in I and V_6
+ 2 QS or rS in V_1
= Left bundle branch block

+ Left axis deviation
= Right bundle branch block and left anterior hemiblock

+ Right axis deviation
= Right bundle branch block and left posterior hemiblock

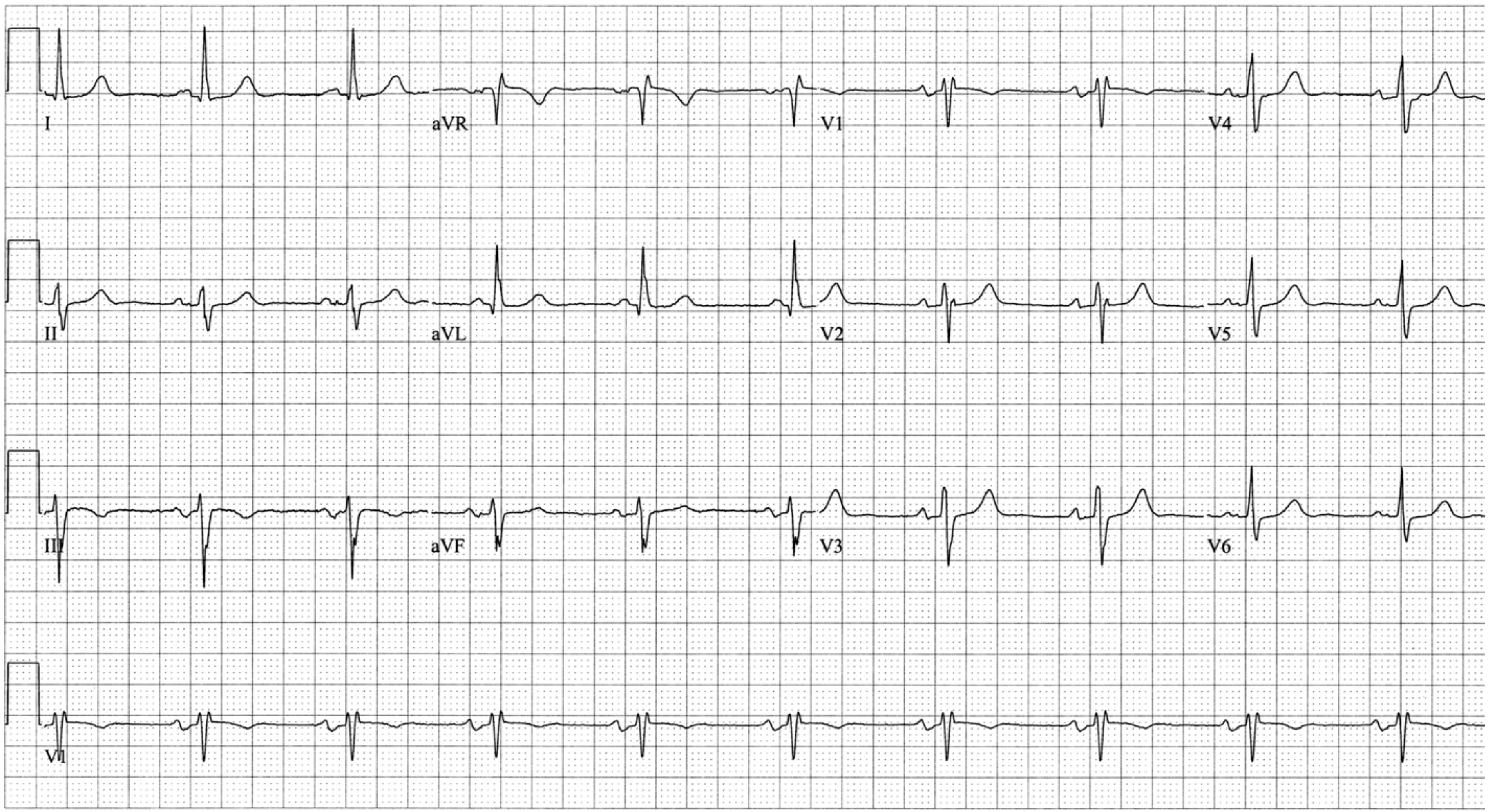
= Bifascicular Block

+ prolonged PR interval
= Trifascicular Block (vs. Bifascicular block and first degree AV block)

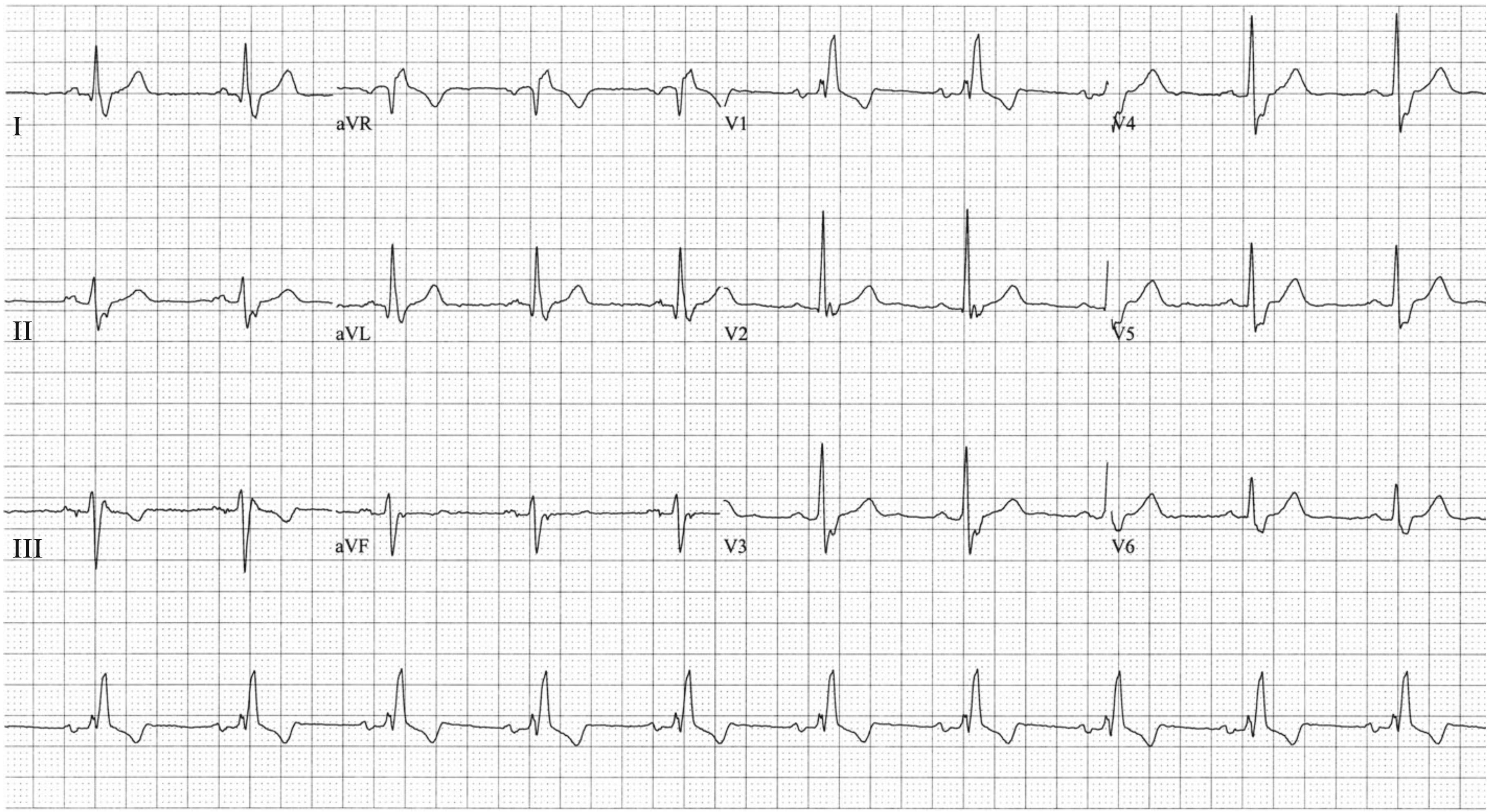
Fig. 5.7 An approach to bundle branch blocks

Exercise Tracings

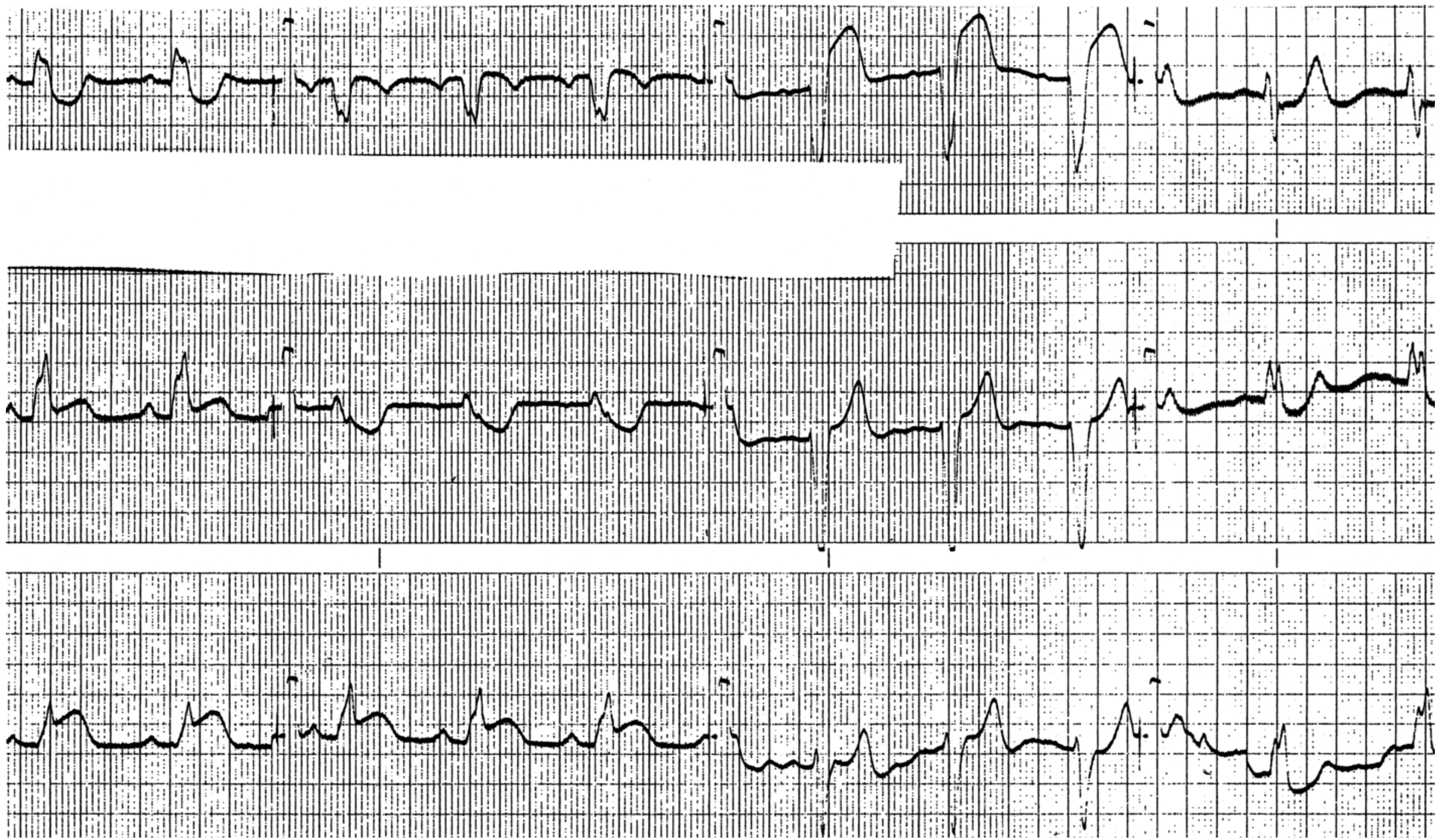
Exercise Tracing 5.1



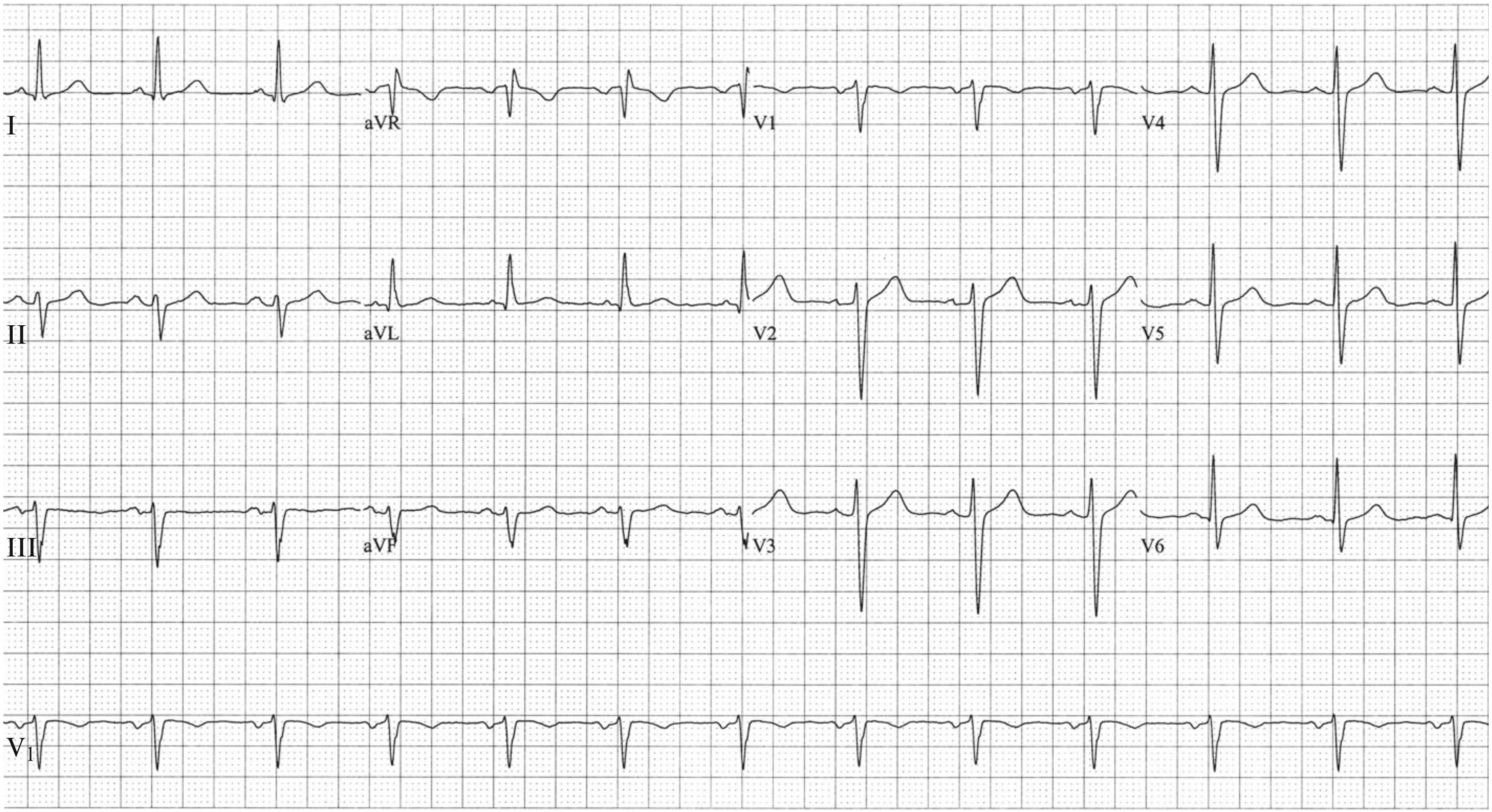
Exercise Tracing 5.2



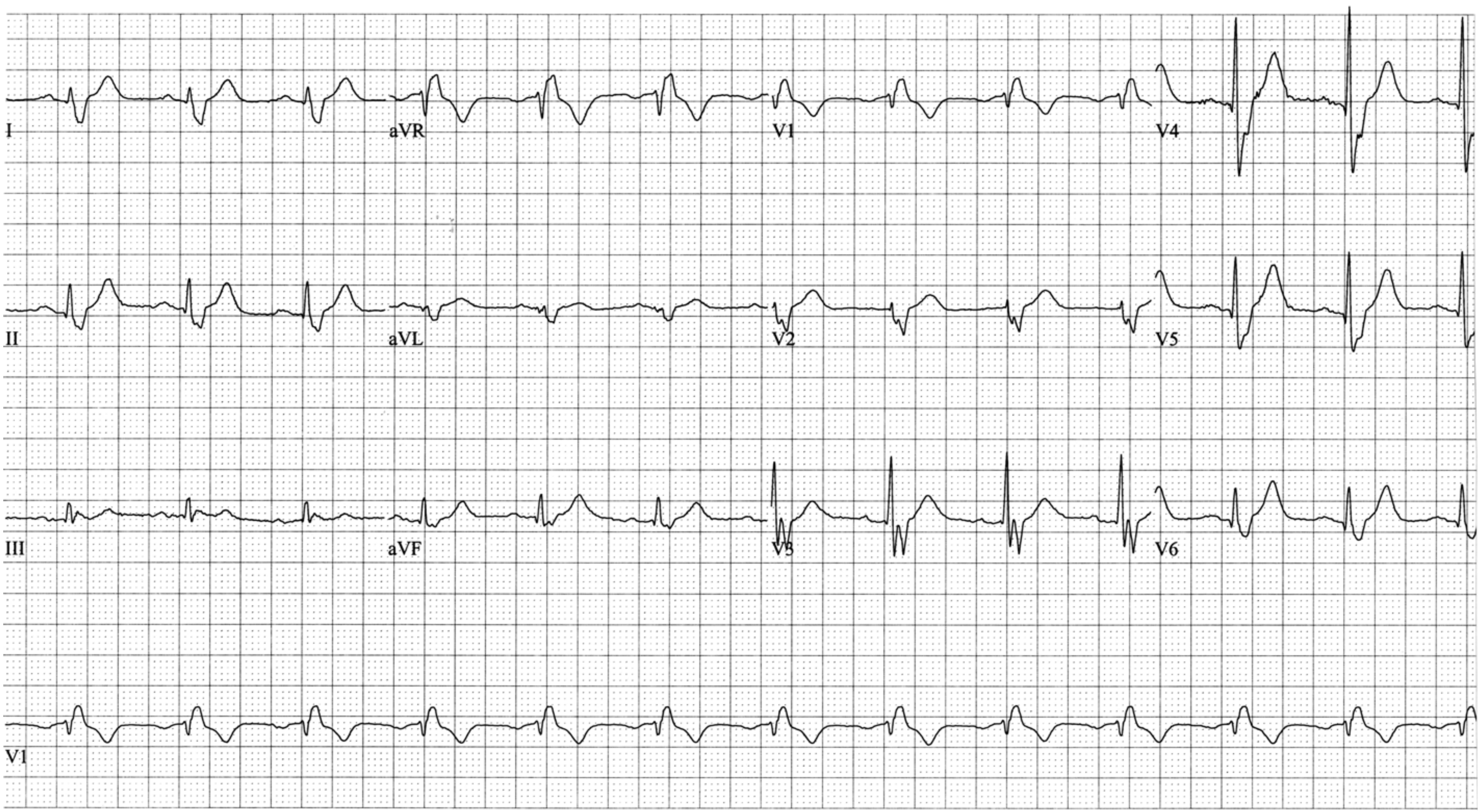
Exercise Tracing 5.3



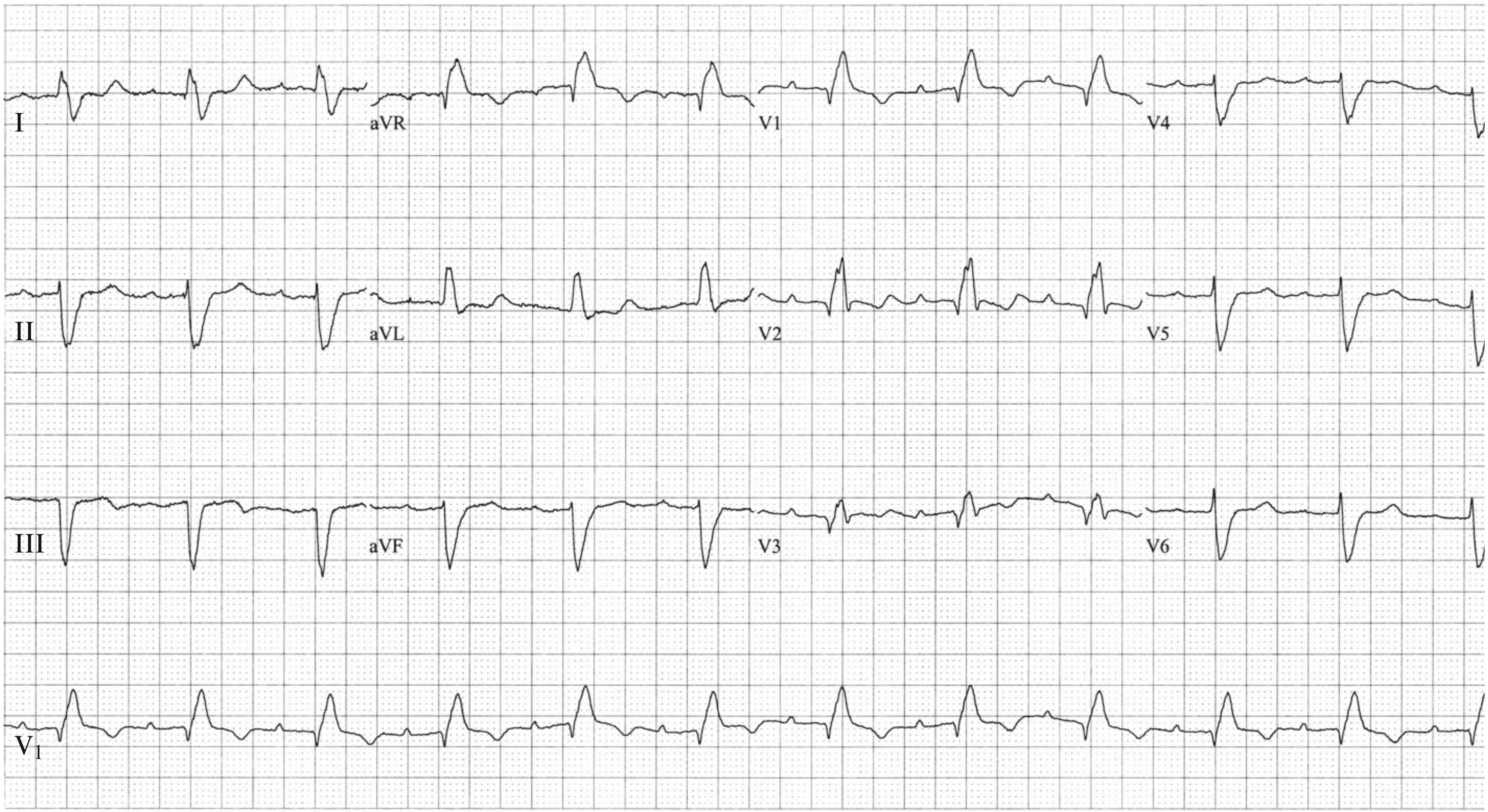
Exercise Tracing 5.4



Exercise Tracing 5.5



Exercise Tracing 5.6



Interpretations of Exercise Tracings

Exercise Tracing 5.1	
RATE:	A 62 V 62
RHYTHM:	Normal sinus rhythm
AXIS:	–40°
INTERVALS:	PR 0.17 QRS 0.10 QT 0.39
WAVEFORM:	q in I and aVL, r in III; rSr′ in V_1
SUMMARY:	Abnormal due to left anterior hemiblock, incomplete right bundle branch block

Exercise Tracing 5.2	
RATE:	A 64 V 64
RHYTHM:	Normal sinus rhythm
AXIS:	–40°
INTERVALS:	PR 0.17 QRS 0.15 QT 0.39
WAVEFORM:	Broad terminal S wave in I and V_6, rsR′ in V_1
SUMMARY:	Abnormal due to right bundle branch block and left anterior hemiblock (bifascicular block)

Exercise Tracing 5.3	
RATE:	A 70 V 70
RHYTHM:	Normal sinus rhythm
AXIS:	+60°
INTERVALS:	PR 0.22 QRS 0.14 QT 0.43
WAVEFORM:	Tall, broad R in I and V_6, rS in V_1; ST elevation in II, III, aVF; ST depression in I, aVL, $V_{4–6}$
SUMMARY:	Abnormal due to acute inferior ST elevation myocardial infarction with reciprocal changes in anterolateral leads, left bundle branch block with prolonged PR interval suggesting either trifascicular block or concurrent first-degree AV block

Exercise Tracing 5.4	
RATE:	A 78 V 78
RHYTHM:	Normal sinus rhythm
AXIS:	–50°
INTERVALS:	PR 0.16 QRS 0.10 QT 0.36
WAVEFORM:	q in I and aVL, r in III; delayed R wave progression $V_{1–5}$
SUMMARY:	Abnormal due to left anterior hemiblock, delayed R wave progression $V_{1–5}$

Exercise Tracing 5.5	
RATE:	A 80 V 80
RHYTHM:	Normal sinus rhythm
AXIS:	+120°
INTERVALS:	PR 0.18 QRS 0.14 QT 0.40
WAVEFORM:	rsR′ in V_1
SUMMARY:	Abnormal due to right bundle branch block and left posterior hemiblock (bifascicular block)

Exercise Tracing 5.6	
RATE:	A *73* V *73*
RHYTHM:	Normal sinus rhythm
AXIS:	–80°
INTERVALS:	PR 0.26 QRS 0.17 QT 0.44
WAVEFORM:	Broad S in I and V_6, tall R in V_1; Q waves in $V_{1–3}$
SUMMARY:	Abnormal due to right bundle branch block, left anterior hemiblock, and prolonged PR interval compatible with trifascicular block; old anteroseptal myocardial infarction