EKG Teaching Rounds

A Case-Based Guide

Lloyd Tannenbaum
Rachel E. Bridwell
Brannon L. Inman

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Lloyd Tannenbaum
San Antonio, TX, USA

Rachel E. Bridwell
Tacoma, WA, USA

Brannon L. Inman
San Antonio, TX, USA

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LT: Lloyd would like to dedicate this book to his wife, Jen, and his kids, Jacob and Mia, for being patient and supportive during all of his medical training and not scribbling all over too many of his EKGs.

RB: Rachel would like to dedicate this book to Mat Bridwell for being her endlessly supportive husband and her best friend.

BI: Brannon would like to dedicate this book to his wife, Rachael, for her love through an often time-consuming and demanding career.

We all would also like to dedicate this book to all of our students who have given us the privilege of assisting with their education.

Preface

Medicine shouldn't be that hard to understand. When we started writing this book, that was the central tenet guiding us. We firmly believe that the simplest approach to clinical pathology is the best. Our goal is to give you core EKG knowledge and a consistent, well-tested method to approach every EKG that you come across. To set you up for clinical success, we are going to spend today rounding with you. You'll see six patients with us: some in the clinic, some in the emergency room, and some on the wards. They will have a conduction block, a tachydysrhythmia, a bradydysrhythmia, an electrolyte imbalance, syncope, or acute coronary syndrome. In each chapter, you will start off by "Prerounding," where we introduce you to your patient and ask you a few questions to get your brain warmed up. Much like when you preround on your patients in the hospital, you do not need all the answers right now. You will still have time to look things up before rounding with the attending. After you've met your patient, you'll have "Study Time," which is your chance to review pertinent facts about your patient's condition and prepare for rounds. The information we give you in Study Time will not be specific to your patient; rather, it will relate to their presentation and EKG. For example, in the tachycardia chapter (Chap. 3), we discuss our approach to the tachycardic EKG and how to use this interpretation of that EKG to guide your management. You will not need all of the information in the Study Time section to figure out how to treat your patient that you prerounded on. The Study Time section is designed to give you a complete overview of the topic. Finally, we'll finish with a "Rounds" section where we explain to you our approach to manage the patient presented in the Prerounds section to answer any lingering questions. This textbook will be unlike any medical text you've read before as we have focused on readability and enjoyability, with an occasional pun. Use this book to help you transition from the student who runs away from EKGs to the resident and clinician who people turn to when they have a tricky EKG. We believe in you. Now hurry up, your first patient is waiting.

San Antonio, TX, USA — Lloyd Tannenbaum
Tacoma, WA, USA — Rachel E. Bridwell
San Antonio, TX, USA — Brannon L. Inman

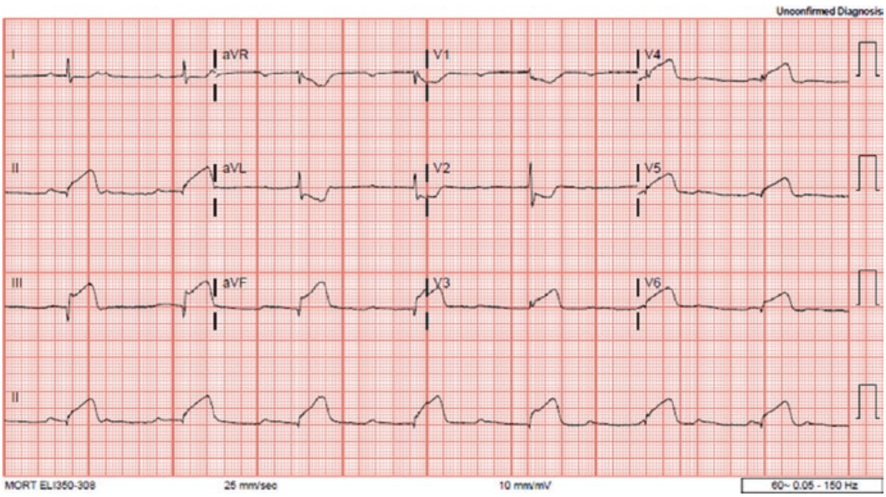
Acknowledgments

This book started as a small project to help our residents get better at EKG interpretation. We intended it to be a small handout and it rapidly morphed into this textbook. Without the encouragement of multiple people, this book would never have come to fruition. First, we would like to thank Dr. Amal Mattu for his help and guidance. Without his support and advice, this book would likely still be just a dream. We'd also like to thank the entire Springer team for their dedication, suggestions, and support. Specifically, without Michelle Tam and Vinodh Thomas, we would still be lost. Thank you both for believing in us and this project. An especially large thank you goes to Robert Low for his guidance and insight into the publishing world. Thank you for helping us navigate this exciting new journey! Additionally, we could not have made this book without the support and guidance from our friends and colleagues. Specifically, we'd like to thank Drs. Samuel Cochran, Jared Cohen, Laura Methvin, Jesse Wray, John Patrick, Daniel Merrill, James Kimber, Maggie Moran, Seshi Tekmal, Stephen Chong, Jordyn Janes, Glen Olsen, Zac Baker, Anil Gehi, Matt Figlewicz, Eric Chin, Eric Ball, and Rebekah Riordan for helping us to collect the EKGs used in this book. We also appreciate the hard work of our friends who took the time to edit and review our work, including Drs. Brit Long, Andrew Muck, Amber Cibrario, Matt Figlewicz, Zac Baker, Danica Cutshall, Sarah Mongold, Alec Pawlukiewicz, Josh B. Lowe, Chris Belcher, Cayla Fappiano, Mike April, James Kimber, Cody Newell, Dan Weidner, and Ilya Ryaboy. We'd also like to thank emdocs.net for allowing us to reproduce some of their EKGs in our book. Finally, we would like to thank our families for their love and support as we spent many hours typing.

Contents

Chapter 1
The Basics

Prerounding Mr. McNeil is a 52-year-old male with a 40-pack-year smoking history, hypertension, and diabetes who presents with crushing substernal chest pain. He is pale and complains of nausea and vomiting. Vital signs show a heart rate of 42 beats per minute, blood pressure of 110/87 mm Hg, SpO2 of 95%, and temperature of 98.6 °F. You are handed the following EKG by your senior resident who asks you to read it.



You are not sure what your senior is going for, but you hand it back to her and tell her that it is an obvious STEMI and she should activate the cath lab.

She gives you a knowing smile as if to say, “I’ve been in your shoes before,” as she prepares to walk you through this EKG and explain what you missed by just focusing on the obvious STEMI.

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Study Time
You need a standardized approach to every EKG that you read. You are much less likely to miss things when you approach every EKG the same way. In this section, we will introduce you to a systematic approach to EKG interpretation which will help you miss less and pick up on some of the more subtle aspects of reading an EKG. While there are several ways to interpret EKGs, we recommend assessing the following elements in this order:

1. **Rate**
2. **Rhythm**
3. **Axis**
4. **Interval**
5. **Morphology**

These are the primary elements of interpreting an EKG and, regardless of the system you ultimately develop to read EKGs over your career, the most important thing is that you read each EKG the same way every time. Let's dive a little deeper into each component.

1.1 Rate

The rate is the number of times the heart beats in a minute. It is often reported as "beats per minute" or bpm. To determine the rate, you will need to have a basic familiarity with the standard EKG grid. The enlarged image of the classic EKG grid is shown in Fig. 1.1.

Notice that going across the bottom, each large box is 0.2 seconds (200 ms), which means that five large boxes are one second in a standard EKG. A standard EKG is a 10-second strip.

Now, let's practice:

Case 1 You are handed the following rhythm strip for an 18-year-old female in the waiting room presenting with 2 days of fever, cough, and shortness of breath. She has no past medical history, takes no medications, and has normal vital signs.

What is the rate on this patient's EKG?

As we alluded to above, you can use the EKG paper to count out the rate for patients with a regular rhythm. If there were to be a QRS complex on every thick line, the rate would be 300. How do we know that? It's a 10-second strip and each thick line shows up at 0.2 s (200 ms). So, that's five beats every second, 50 beats every 10 seconds, and, since there are 60 seconds in a minute, multiply 50 beats by 6 seconds.

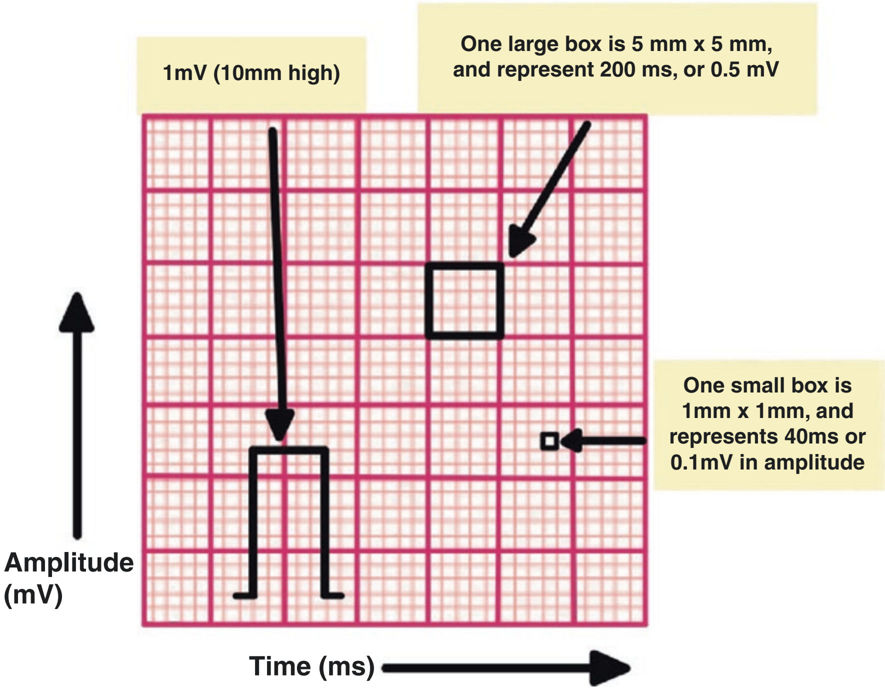


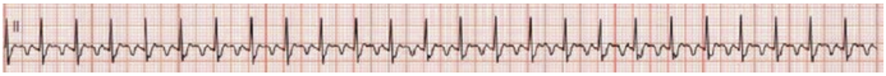
Fig. 1.1 Example of an enlarged EKG grid

That's 300 beats per minute. In this rhythm strip, we see a QRS complex approximately every five thick lines, giving us a rate of about 60 beats per minute (bpm).

Effectively, you divide 300 by the number of thick lines between QRS complexes. In the patient above, there are roughly five thick lines between each QRS complex. So, her heart rate is roughly 300 divided by five, which is 60 beats per minute.

Chart 1.1 will help you calculate the rate on an EKG with a regular rhythm.

Case 2 The following rhythm strip is electronically transmitted to your emergency department from an incoming EMS. The patient is a 34-year old otherwise healthy female with a past medical history of asthma who has been taking more of her albuterol lately. This morning she began having palpitations and called 911. Per EMS dispatch, her vitals showed a heart rate of 150 beats per minute, blood pressure 110/82 mm Hg, SpO2 100%, and temperature of 98 °F. Before moving forward, double-check the rate that EMS reported:



Notice here that the QRS complexes fall on every other thick line. Thus, using Chart 1.1, the rate would be 150 beats per minute (300 divided by 2 is 150).

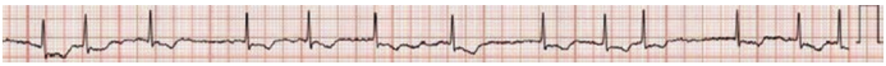
Thick Lines Between QRS Complexes	Heart Rate
1	300
2	150
3	100
4	75
5	60
6	50

Chart 1.1 For a regular rhythm, the number of thick lines between a QRS complex will let you determine the patient's heart rate

Remember, even if the QRS doesn't fall perfectly on the thick lines, you can use this method to approximate the rate. So, if the QRS complexes are falling every 3.5 lines, you know that the heart rate is somewhere between 75 and 100 bpm.

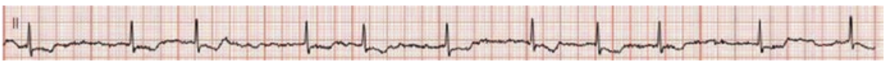
This method works pretty well, but what if your patient's rate is irregular?

Case 3 Mr. Sanchez is a 64-year-old man with a history of atrial fibrillation. He is presenting to the emergency department with a chief complaint of palpitations that started 3 hours ago. The following rhythm strip is obtained:



Looking at this rhythm strip, there are two thick lines between the first two QRS complexes and almost four thick lines between the second two QRS complexes. Irregular rhythms will not work with the thick line method of determining a rate. Luckily, there is another way.

Remember, each EKG that you read is a ***10-second clip in time***. So, if you count the number of QRS complexes you see along the rhythm strip on the bottom of the EKG and multiply by six, you'll get the number of beats per minute. Let's practice on this rhythm strip below:



There are 11 QRS complexes seen across the rhythm strip. So, the rate would be 11 × 6, which is 66 beats per minute.

1.2 Rhythm

At this point in your training, for rhythm, we really only care about one question:

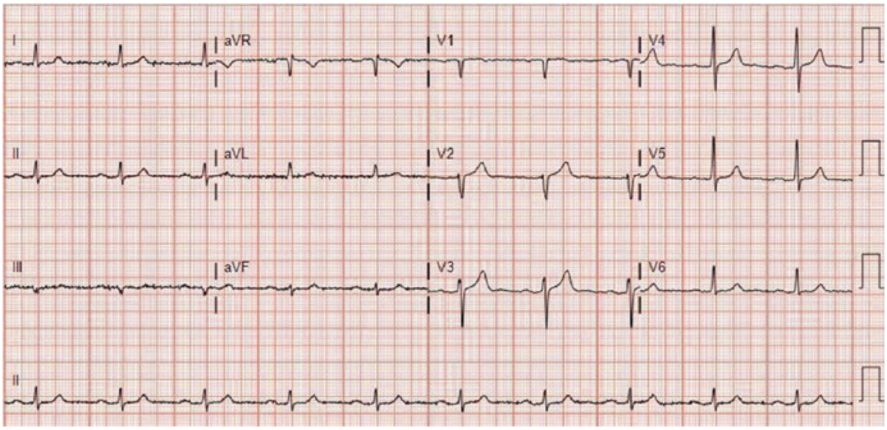
"Is this normal sinus rhythm?"

There are a lot of rhythms that can be represented on an EKG, but we always start by assessing if the patient is in sinus rhythm. If the answer is yes, we move on to the next step. If not, we spend a little time trying to figure out what the rhythm is. For now, let's just focus on normal sinus rhythm. To be considered normal sinus rhythm, you need:

1. A P wave before each QRS.
2. A 1:1 ratio of P waves: QRS complexes.
3. An upright P wave in lead II.
4. Regular rhythm—i.e., the amount of time doesn't change between beats.
5. Rate between 60 and 100 beats per minute (for an adult).

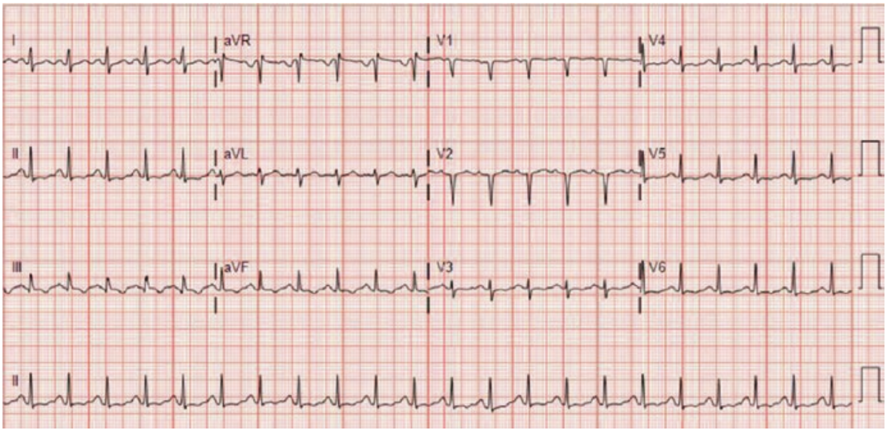
Let's take a look at an example of normal sinus rhythm:

Case 4 The following EKG is from an otherwise healthy teenager you are seeing as part of a sports physical. He is asymptomatic:



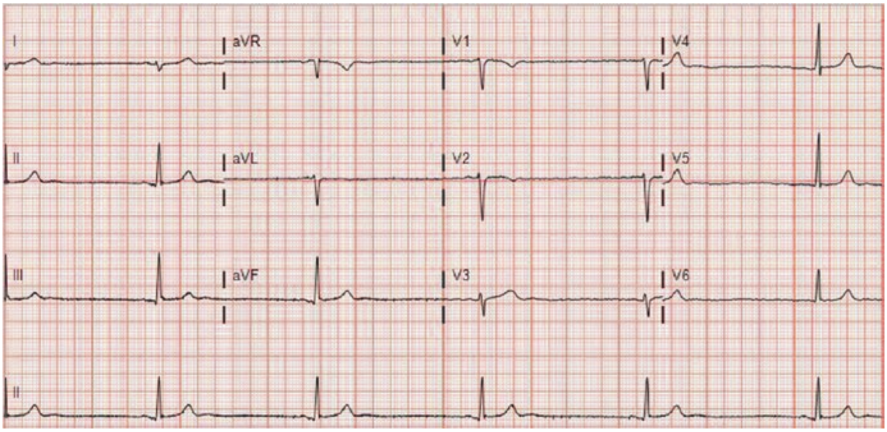
Notice that the patient has a P wave before each QRS, a 1:1 ratio of P waves to QRS complexes, an upright P wave in II, and a rate between 60 and 100 bpm. Lastly, note that there is a regular rhythm (QRS complexes are roughly the same distance apart). This patient is in normal sinus rhythm.

Case 5 The following EKG is from a 77-year-old female who lives in a nursing home and was brought in for evaluation of a fever and a blood pressure of 78/59 mm Hg



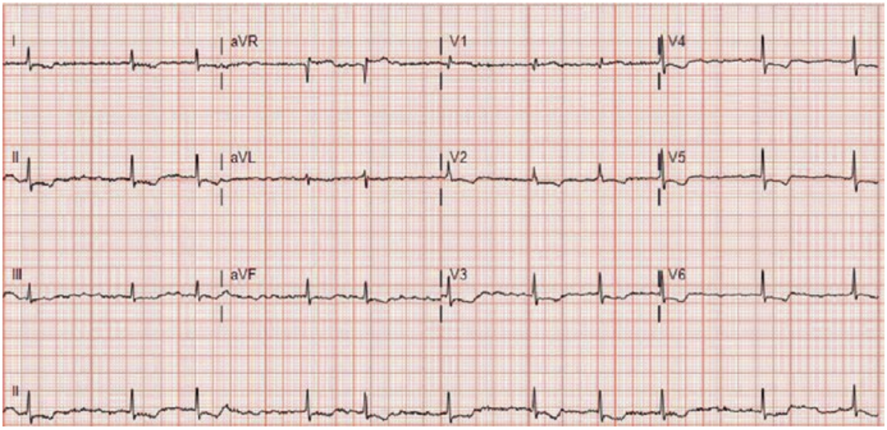
Notice that the patient has a P wave before each QRS, a 1:1 ratio of P waves to QRS complexes, and an upright P wave in lead II. Note that there is a regular rhythm (QRS complexes are roughly the same distance apart). The rate, however, is close to 150 bpm. When all other criteria are met for sinus rhythm except the rate, we refer to this as sinus tachycardia (if over 100 bpm) or sinus bradycardia (if under 60 bpm). This patient is in sinus tachycardia.

Case 6 The following EKG was obtained from a 58-year-old female presenting with altered mental status. On arrival, her vitals showed a heart rate of 30–36 bpm, blood pressure of 90/77 mm Hg, core temperature of 93 °F (33.8 °C). She was ultimately determined to have myxedema coma. Let's look at her EKG:



Notice that the patient has a P wave before each QRS, a 1:1 ratio of P waves to QRS complexes, and an upright P wave in lead II. Note that there is a regular rhythm (QRS complexes are roughly the same distance apart). The rate is very slow, close to 30 bpm. This patient is in sinus bradycardia.

Case 7 The following EKG is from Mr. Tilton, who has a history of heart failure with reduced ejection fraction and is presenting to the emergency department for weakness.



Rhythm can often be a challenging portion of EKG interpretation, as there are so many options to choose from. Just remember your first decision branch point is: *sinus rhythm* vs *not sinus rhythm*. In order to be considered sinus rhythm, this EKG would need to meet the criteria above. Remember, in sinus rhythm there needs to be a P wave before each QRS complex and these P waves must localize to the sinoatrial node, meaning the P waves are upright in lead II. Notice that this patient has no discernable P waves. Next, the rhythm would have to be regular. Notice how this patient's rhythm is irregular (QRS complexes are not roughly the same distance apart). Rhythms that are not sinus rhythm are called arrhythmias or dysrhythmias, as they are technically pathologic. Arrhythmias frequently encountered and considered while evaluating EKGs include but are not limited to: atrial fibrillation, atrial flutter, supraventricular tachycardia, and ventricular tachycardia, all of which will be discussed in depth throughout this book. Looking closer at this EKG above, note the QRS complexes are irregular. In fact, it's hard to predict when a QRS complex might be expected on this EKG. That feature is often called "irregularly irregular" and is a hallmark of atrial fibrillation, which was this patient's diagnosis.

1.3 Axis

There is actually an axis for all waves and complexes on the EKG. There is a P wave axis, a T wave axis, and so on. However, when we talk about an axis in medicine, we are talking about the QRS axis in almost all instances. The official method to calculate the QRS axis is to look at something called the isoelectric lead and then calculate the vector that would be 90 degrees from that lead.