APPROACH TO PEDIATRIC BRADYCARDIA – PART 2

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December 3, 2021

Introduction

Hello team,
My name is Damian Feldman-Kiss, and I am a medical student at the University of British Columbia. Today, we are going to discuss part 2 of an approach to pediatric bradycardia. This podcast was developed under the supervision of Dr. Karen Forbes, a pediatrician and medical educator at the University of Alberta.

Learning Objectives

This second part of our two-part series on pediatric bradycardia will focus on management of both the stable and unstable patient with bradycardia.

In terms of objectives, at the end of this podcast you will be able to:

1. Define high-quality cardiopulmonary resuscitation (CPR).
2. List two pharmacologic interventions used in the management of pediatric bradycardia with a pulse and poor perfusion.
3. List two rhythms that are shockable and two rhythms that are non-shockable in pediatric pulseless arrest.
4. List the three key investigations in the workup of pediatric bradycardia.
5. List three indications for pacing in chronic pediatric bradycardia.

Case: Review

Let's review the case from part 1. You're on an emergency medicine rotation in Victoria. You have just finished the initial work up of a previously well 16-year-old female named Adrianne who had syncopal episode while exercising. Her ECG demonstrated a third-degree AV block. On the way back to her room to discuss the results and next steps, you and your attending, Dr. Li, get called overhead to help out in the trauma bay. There is an incoming patient with bradycardia and signs of shock. Dr. Li thinks this patient will probably require resuscitation, unlike Adrianne who is hemodynamically stable with her bradycardia. While waiting for EMS to arrive, you decide to review Pediatric Advanced Life Support (PALS).

PALS: Introduction

Before we discuss the steps of specific algorithms, there are a few important points to consider about PALS in general. The steps of PALS are presented as if there was a single rescuer; however, it is important to understand that PALS is a team effort and actions are performed simultaneously.[1] Strong leadership, effective communication, organization, clear roles, and efficiency are integral to its success. Importantly, this podcast does not replace the need for formal training in PALS.

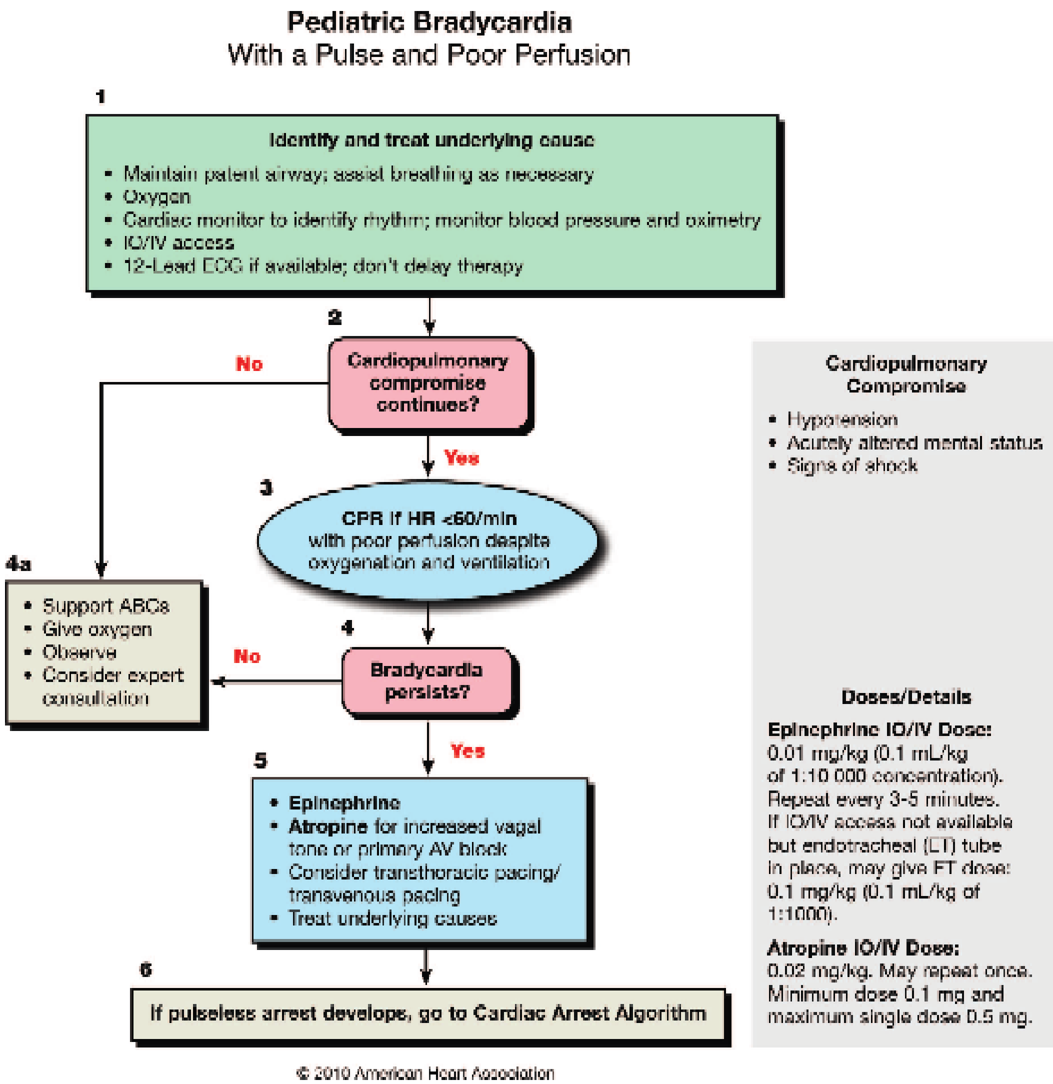
The most important part of PALS is high-quality cardiopulmonary resuscitation (CPR). The American Heart Association defines high-quality CPR as the following[1]:

- A compression rate of at least 100 compressions per minute
- A compression depth of at least one-third of the anterior-posterior (A-P) diameter of the chest (~4 cm in infants and ~5 cm in children)
- Allowing complete chest recoil between compressions
- Minimizing interruptions in compressions, and
- Avoiding excessive ventilation

It is recommended to only interrupt chest compressions for ventilations (until an advanced airway is in place, like an endotracheal tube), to check the rhythm, and to deliver a shock.[1] In addition, rescuers should rotate giving compressions at least every 2 minutes to prevent fatigue and maintain high-quality CPR.[1]

PALS Bradycardia Algorithm [1]

Let's start with the PALS Bradycardia Algorithm. This algorithm is indicated for both infants and children with bradycardia, poor perfusion, and a palpable pulse. If, however, your patient no longer has a pulse at any time throughout the resuscitation, you must switch to the PALS Cardiac Arrest Algorithm. Also, throughout the entire algorithm, you must try to identify and treat the underlying cause of the bradycardia. Okay, let's get started. If you would like to follow along visually, see the script of this podcast for a picture of the algorithm. The PALS Bradycardia Algorithm contains the following steps.



PALS Bradycardia Algorithm, 2010 American Heart Association [1]

Step 1: Upon recognizing a patient with bradycardia, poor perfusion, and a palpable pulse, call a code and send for the crash cart. Then, assess the airway and keep it patent (e.g., you could use a head-tilt/chin-lift or jaw thrust). Administer 100% oxygen and, if necessary, support breathing. Once the crash cart arrives, attach the defibrillator pads so you can monitor the rhythm. It is very important to note that in this algorithm, these pads are used for monitoring purposes only and not shock delivery. A regular cardiac monitor may be also be used if the crash cart is not readily available. Next, place a blood pressure cuff and pulse oximeter. Obtain intravenous (IV) or intraosseous (IO) access and obtain a 12-lead ECG if available.

Step 2: Reassess your patient. Is the monitor still showing bradycardia despite supporting their airway and breathing? What do they look like? For example, are they showing signs of cardiopulmonary comprise such as altered mental status? Do they appear shocky? Are they hypotensive?

If their ABCs are improving, further emergent treatment is not indicated, so skip ahead to step 4a.

Step 4a: continue to support their ABCs, monitor for any changes in status, and consult pediatric cardiology.

However, if supporting their airway and breathing do not improve the bradycardia and restore perfusion, proceed to step 3.

Step 3: Start high-quality CPR and perform for 2 minutes. For single-rescuer CPR, the compression to breath ratio is 30:2. For two-rescuer CPR, the compression to breath ratio is 15:2.

Step 4: After 2 minutes, reevaluate your patient. Again, what do they look like and what's on the monitor? Are they altered, shocky, hypotensive, or bradycardic? Also, take this opportunity to ensure that their airway and breathing are being managed adequately and that high-quality CPR is being performed. Don't forget that CPR is exhausting, and rescuers must rotate giving compressions at least every 2 minutes.

If their ABCs are improving, further emergent treatment is not indicated so, again, move on to step 4a—continue to support their ABCs, monitor for any changes in status, and consult pediatric cardiology.

However, if they are still compromised, continue airway management, ventilation, oxygenation, and high-quality CPR and proceed to step 5.

Step 5: The next step is to administer epinephrine. Epinephrine induces vasoconstriction and increases aortic diastolic pressure, which, in turn, increases coronary perfusion pressure. The dose is 0.01 mg/kg IV or IO and can be repeated every 3 to 5 minutes.

If you've determined that the bradycardia is due to hypervagatonia or primary AV block, administer atropine. Atropine increases sinus and atrial automaticity and increases AV conduction velocity. The dose is 0.02 mg/kg IV or IO with a minimum dose of 0.1 mg and a maximum dose of 0.5 mg. In summary, the two medicines that can be used here are epinephrine and atropine. Importantly, shock delivery is NOT indicated in the bradycardia algorithm. Remember, the patient has a pulse and an organized rhythm; the rhythm is just not sufficient to provide adequate cardiac output.

At this point, if none of your interventions have improved your patient's status, the next step is emergency transcutaneous or transvenous cardiac pacing. The transcutaneous method involves pacing the heart via chest pads, whereas the transvenous method involves pacing the heart via wires inserted into the venous system and advanced to the right heart. These temporary pacing techniques may save your patient's life if the bradycardia is secondary to sinus node dysfunction or complete AV block. At this point, consulting pediatric cardiology and pediatric critical care would be essential.

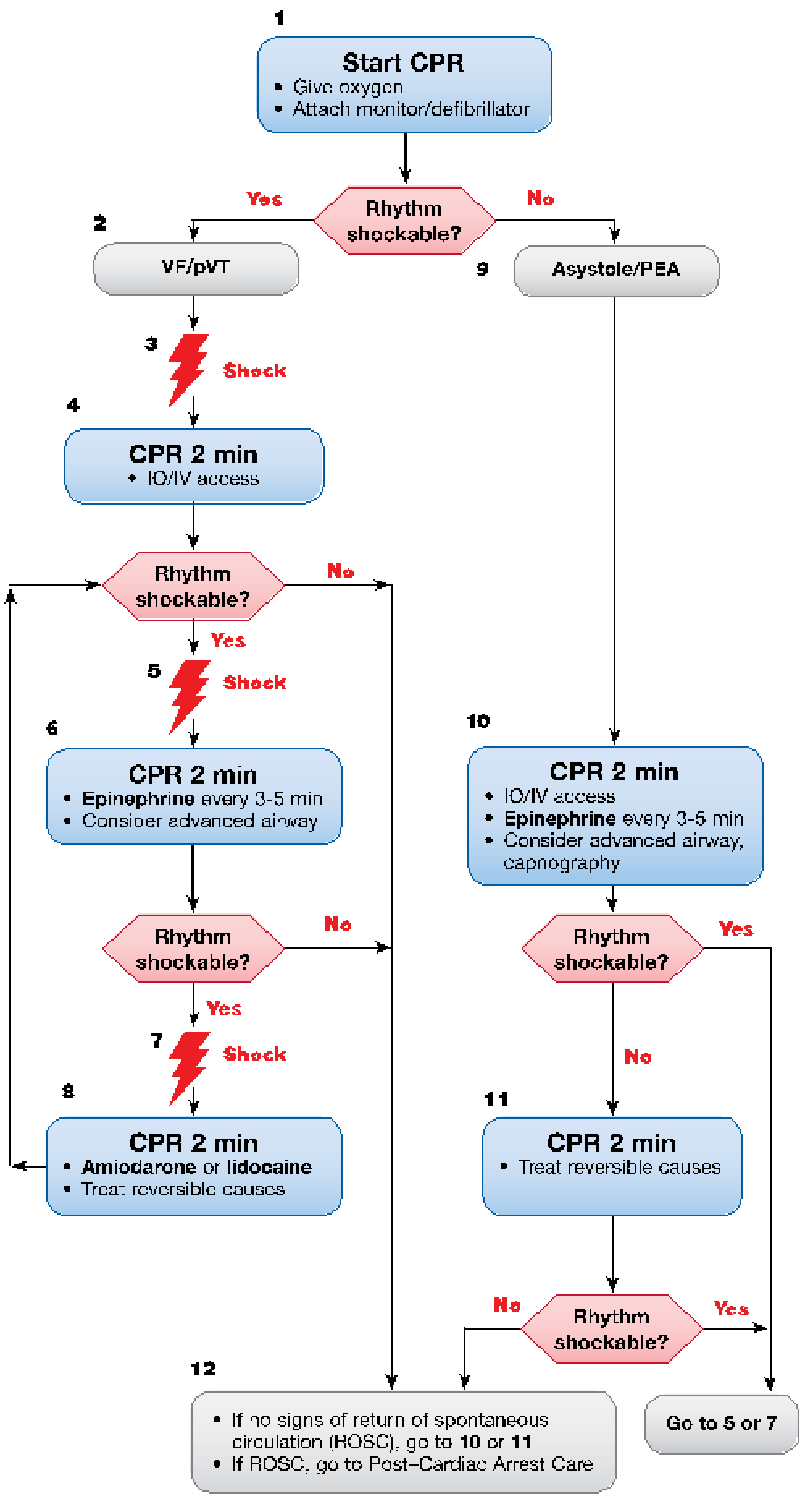
PALS Cardiac Arrest Algorithm [1,2]

Okay, let's move on to the PALS Cardiac Arrest Algorithm. This is the algorithm to follow if your patient does NOT have a pulse. It is slightly more complicated than the Bradycardia Algorithm because it contains two arms. The decision of which arm to follow depends on whether the rhythm is 'shockable'. If the rhythm is shockable (i.e., the rhythm is ventricular fibrillation [VF] or pulseless ventricular tachycardia [pVT]), follow the steps on the left arm. If the rhythm is non-shockable (i.e., the rhythm is asystole or pulseless electrical activity [PEA]), follow the steps on the right arm. If at any point throughout this algorithm, a non-shockable rhythm becomes shockable, you must switch to the left arm and vice versa.

A key point that simplifies the decision of which arm to follow is that you do NOT need to differentiate between VF and pVT. If you see either of these rhythms, the rhythm is shockable. Likewise, you do NOT need to differentiate between asystole and PEA. However, this distinction will likely be more straightforward as asystole is a flatline and PEA is any organized electric activity without a palpable pulse. PEA most commonly has a slow rate and wide QRS complex.

Okay, let's get started. Again, if you would like to follow along visually, see the script of this podcast for a picture of the algorithm. The PALS Cardiac Arrest Algorithm contains the following steps.

Pediatric Cardiac Arrest Algorithm—2018 Update



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CPR Quality

- Push hard (≥1/3 of anteroposterior diameter of chest) and fast (100-120/min) and allow complete chest recoil.
- Minimize interruptions in compressions.
- Avoid excessive ventilation.
- Change compressor every 2 minutes, or sooner if fatigued.
- If no advanced airway, 15:2 compression-ventilation ratio.

Shock Energy for Defibrillation

First shock 2 J/kg, second shock 4 J/kg, subsequent shocks ≥4 J/kg, maximum 10 J/kg or adult dose.

Drug Therapy

- **Epinephrine IO/IV dose:** 0.01 mg/kg (0.1 mL/kg of the 0.1 mg/mL concentration). Repeat every 3-5 minutes. If no IO/IV access, may give endotracheal dose: 0.1 mg/kg (0.1 mL/kg of the 1 mg/mL concentration).
- **Amiodarone IO/IV dose:** 5 mg/kg bolus during cardiac arrest. May repeat up to 2 times for refractory VF/pulseless VT.

  -OR-

  Lidocaine IO/IV dose: Initial: 1 mg/kg loading dose. Maintenance: 20-50 mcg/kg per minute infusion (repeat bolus dose if infusion initiated >15 minutes after initial bolus therapy).

Advanced Airway

- Endotracheal intubation or supraglottic advanced airway
- Waveform capnography or capnometry to confirm and monitor ET tube placement
- Once advanced airway in place, give 1 breath every 6 seconds (10 breaths/min) with continuous chest compressions

Return of Spontaneous Circulation (ROSC)

- Pulse and blood pressure
- Spontaneous arterial pressure waves with intra-arterial monitoring

Reversible Causes

- **H**ypovolemia
- **H**ypoxia
- **H**ydrogen ion (acidosis)
- **H**ypoglycemia
- **H**ypo-/hyperkalemia
- **H**ypothermia
- **T**ension pneumothorax
- **T**amponade, cardiac
- **T**oxins
- **T**hrombosis, pulmonary
- **T**hrombosis, coronary

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PALS Cardiac Arrest Algorithm, 2018 American Heart Association [2]

Step 1: Upon recognizing a patient in cardiac arrest (i.e., they are unresponsive, not breathing, and do NOT have a pulse), call a code, send for the crash cart, and begin high-quality CPR at 30:2 for single-rescuer CPR or 15:2 for two-rescuer CPR. Once the crash cart arrives, attach the defibrillator pads, and administer 100% oxygen.

Next, determine whether the rhythm is shockable. If the rhythm is shockable (recall that means, VF or pVT) follow the steps on the left arm. If the rhythm is non-shockable (recall that means asystole or PEA), follow the steps on the right arm.

Let's discuss the right arm first.

Step 9 to 11: Once you've decided that the rhythm is non-shockable, do not shock, of course, and continue high-quality CPR for 2 minutes. During this time, obtain IV or IO access, and consider an advanced airway (e.g., endotracheal intubation) and capnography to monitor respiratory CO_2 levels. Administer epinephrine IV or IO at 0.01 mg/kg (max dose of 1 mg) and repeat every 3 to 5 minutes.

Once an advanced airway is obtained, compressions need not be interrupted for ventilations. Compressions should then be continuous at a rate of at least 100 compressions per minute with the only interruptions for checking the rhythm and rotating the compressor role every 2 minutes or earlier to prevent fatigue. Ventilations should be given at a rate of 1 breath every 6 to 8 seconds, which is approximately 8 to 10 breaths per minute.

After 2 minutes of high-quality CPR, stop to check the rhythm. If the rhythm is non-shockable, continue cycles of high-quality CPR, epinephrine, and checking the rhythm every 2 minutes. Continue until spontaneous circulation returns (termed "return of spontaneous circulation" or ROSC), which is noted by a palpable pulse, or your team decides to stop the effort. During this time, you should also be searching for and treating reversible causes, which are the so-called H's and T's. These include hypovolemia, hypoxia, hydrogen ions (i.e., acidosis), hypoglycemia, hypo or hyperkalemia, hypothermia, tension pneumothorax, tamponade, toxins, and thrombosis of the lungs or heart.

However, if at any point the rhythm identified is shockable, meaning VF or pVT, charge the defibrillator to 2 J/kg, deliver a shock, and switch over to the left arm.

Now, let's discuss the left arm.

Step 2: If, after attaching the defibrillator pads, you've decided that the monitor is showing a shockable rhythm, continue high-quality CPR, and charge the defibrillator to 2 J/kg.

Step 3: Deliver a single shock at 2 J/kg.

Step 4: Immediately after the shock has been delivered, resume high-quality CPR and continue for another 2 minutes. Also, obtain IV or IO access if not already established.

Step 5: After 2 minutes, briefly interrupt CPR to check the patient's rhythm. If the rhythm is still shockable, recharge the defibrillator to 4 J/kg and deliver a second shock. Remember that you should continue compressions while the defibrillator is charging.

Step 6: Immediately after the shock has been delivered, resume high-quality CPR and continue for another 2 minutes. Administer epinephrine IV or IO at 0.01 mg/kg and repeat every 3 to 5 minutes. At this point, you should also consider an advanced airway.

Step 7: After 2 minutes, briefly interrupt CPR to check the patient's rhythm. If the rhythm is still shockable, recharge the defibrillator to 4 J/kg, and deliver another shock.

Step 8: Immediately after the shock has been delivered, resume high-quality CPR and continue for another 2 minutes. If an advanced airway has been obtained, compressions need not be interrupted for ventilations, just like in the non-shockable arm. During this time, administer amiodarone or lidocaine and search for and treat those reversible causes like hypovolemia, hypoxia, and toxins.

Quick side note, amiodarone and lidocaine are antiarrhythmic drugs used in the setting of refractory VF and pVT. You can think of the action of these drugs as slowing down the heart to disrupt the tachyarrhythmia. Amiodarone is a potassium channel blocker that decreases AV nodal and ventricular conduction velocity and increases the AV nodal refractory period and QT interval. The dose is 5 mg/kg, which can be repeated twice during cardiac arrest. Lidocaine, on other hand, is a sodium channel blocker that decreases ventricular conduction velocity, the QT interval, and the excitability of ventricular cells with automaticity. Lidocaine is administered by loading dose and maintenance dose. The loading dose is 1 mg/kg, and the maintenance dose is an infusion of 20 to 50 mcg/kg per minute. You can repeat the loading dose if the infusion is started over 15 minutes after the initial loading dose. Okay, back to the algorithm.

After 2 minutes of high-quality CPR, stop to check the rhythm. If the rhythm is still shockable, recharge the defibrillator to 4 J/kg, and deliver another shock. If defibrillation restores an organized rhythm, check for a pulse. If a pulse is present, start post-resuscitation care. If defibrillation is successful but VF returns, resume high-quality CPR for another 2 minutes, and administer a second dose of amiodarone. Continue cycles of high-quality CPR, epinephrine, rhythm checks, shocks, and searching for and treating reversible causes until you get ROSC, or your team decides to stop the effort.

PALS: Summary

In summary, the most important part of PALS is high-quality CPR. The PALS Bradycardia Algorithm is indicated for both infants and children with bradycardia, poor perfusion, and a palpable pulse.[1] It focuses on reversing bradycardia. The PALS Cardiac Arrest Algorithm is indicated for patients who are unresponsive, not breathing, and who do not have a palpable pulse.[1,2] It contains two arms. The left arm focuses on reversing VF or pVT, and the right arm focuses on reversing asystole or PEA. Remember that if you're following the steps on the right arm and the rhythm becomes shockable, you must switch to the left arm and vice versa. For more information on PALS, check out the PedsCases Podcast, "Pediatric Advanced Life Support". Even better, sign up for a PALS provider course if it is within your scope of practice or training.

Case: Resuscitation

After you finish reviewing PALS, EMS arrives and brings the patient into the trauma bay. The patient is a 14-year-old male with a past medical history significant for ADHD who took a toxic dose of his clonidine. He is bradycardic at 20 and has hypotension, respiratory depression, altered mental status, and weak pulses. Dr. Li assumes the team leader role and asks a respiratory therapist to assess the airway while two nurses set up the monitoring equipment and obtain IV access. Given the bradycardia, Dr. Li asks you to begin high-quality CPR. You and the respiratory therapist alternate 15 compressions and two breaths with a bag-valve-mask. After two minutes of CPR, you and a nurse switch the compressor role, and the second nurse administers epinephrine. The bradycardia persists after two doses of epinephrine, so Dr. Li orders transcutaneous pacing. While the transcutaneous pacing is set up, Dr. Li reminds you that since the patient had a palpable pulse throughout the resuscitation, you did not need to switch to the cardiac arrest algorithm and, therefore, did not need to consider shock delivery. The transcutaneous pacing restores the patient's heart rate and perfusion, and you and Dr. Li consult pediatric critical care.

Case: Sharing Results and Next Steps

After helping out on the resuscitation, you debrief at the workstation and then visit Adrianne in her room. You explain that her ECG demonstrated a problem with her heart's conduction system, which is the most likely reason for the syncopal episode. You explain that she will need to be admitted to the hospital and see a pediatric cardiologist.

Back at the workstation, Dr. Li asks if you would like to practice your SBAR by calling pediatric cardiology. She reminds you that SBAR is a communication tool that stands for situation, background, assessment, and recommendation. It is an organized approach to communicating with your attending or a consultant over the phone. Before calling pediatric cardiology, you briefly review how the cardiologist might workup and manage pediatric bradycardia in a stable patient.

Workup

The approach to pediatric bradycardia from a cardiology perspective includes a history, physical exam, 12-lead ECG, an ambulatory ECG or Holter monitor, echocardiography, and possibly an exercise stress test and invasive electrophysiology.[3]

The history focuses on answering two questions.[3] The first is whether the bradycardia is symptomatic.[3] So, ask about clinical features such as feeding difficulties and lethargy in infants, and fatigue, exercise intolerance, and syncope in older children. The second question is what is causing the bradycardia.[3] As discussed in the first podcast of this series, we want to rule in and rule out possible etiologies including extrinsic causes like enhanced vagal tone, drugs, and hypothyroidism and intrinsic causes like complications from cardiac surgery, congenital heart defects, and heart disease. For hypervagotonia, does the patient have a history of endurance training, anorexia nervosa, obstructive sleep apnea, or vasovagal syncope? Recall though that hypervagatonia can be completely normal in children. For drugs, has the patient taken or have they been exposed to any drugs known to cause bradycardia like fentanyl, clonidine, metoprolol, or verapamil? For hypothyroidism, is there any history of weight gain, dry skin, constipation, or cold intolerance? For the intrinsic causes, does the patient have any history of cardiac surgery or heart disease? Also, inquire about a family history of early pacemaker insertion or septal defects as they can be suggestive of inherited arrhythmias.[3]

The physical exam is often not particularly helpful in determining the etiology of bradycardia [3], but a set of vitals is nearly always helpful to ensure that the patient is hemodynamically stable. Important features to look for on physical exam include a murmur, an irregular heart rate, signs of hypothyroidism, such as dry skin and muscle weakness, and signs of anorexia nervosa, such as a low BMI and soft, downy body hair.[3]

As discussed in part 1 of this podcast series, the ECG is the key first line test in the workup of bradycardia as it evaluates the rate and rhythm over 10 seconds. However, as noted earlier, it can miss intermittent arrhythmias. If an arrhythmia is found, it can help narrow the list of possible underlying etiologies.

An ambulatory ECG or Holter monitor further characterizes heart rate and rhythm. It gathers data on the maximum, minimum, and average heart rate and any pauses in heart rate over 24 or 48 hours.[4] While wearing the Holter monitor, patients can also keep track of when they are feeling symptomatic. In this way, the Holter monitor can be helpful in determining whether the bradycardia is symptomatic by establishing a correlation between bradycardia and the occurrence of symptoms.[3]

Echocardiography is a formal ultrasound of the heart that assesses its structure and function. It is used to rule in or rule out structural causes of bradycardia such as congenital heart defects.
An exercise stress test and invasive electrophysiology aren't always required for diagnosis, but they're good to know about. An exercise stress test is used to assess the heart's response to increased demand. The appropriate response to increased demand includes increasing automaticity at the SA node and conduction velocity at the AV node. This test can help differentiate hypervagatonia from dysfunction of the cardiac conduction system because hypervagatonia responds appropriately to increased demand, while the latter does not.[4] Invasive electrophysiology is used to assess various physiologic parameters of bradycardia and can be used to diagnose a syndrome called sinus node dysfunction.[3]

Long Term Management

First line therapy for chronic bradycardia in children under 19 years old is implanting a permanent pacemaker.[5] According to the American College of Cardiology, the American Heart Association, and the Heart Rhythm Society, the indications for pacing can be broadly classified as the following [5]:

- Symptomatic sinus bradycardia
- Symptomatic sinus node dysfunction, and
- Advanced second-degree AV block or third-degree AV block

The Class 1 recommendations in which the benefits of permanent pacemaker implantation greatly outweigh the risks include the following five scenarios [5]:

1. Advanced second- or third-degree AV block that is associated with symptomatic bradycardia, ventricular dysfunction, or low cardiac output.
2. Sinus node dysfunction with symptoms occurring during periods of bradycardia.
3. Postoperative advanced second- or third-degree AV block persisting for at least 7 days after cardiac surgery.
4. Congenital third-degree AV block with a wide QRS escape rhythm, complex ventricular ectopy, or ventricular dysfunction.
5. Congenital third-degree AV block in an infant with a heart rate below 55 or with congenital heart disease and a heart rate below 70.

The complete list of indications and contraindications and specifics about pacemaker generators and leads is beyond the scope of this podcast. For more information, see the references of this podcast.

Case: SBAR

After reviewing the investigations and indications for pacing, you are ready to call pediatric cardiology. Your phone consult is as follows:

- Identification: Hello, my name is Damian*,* and I am a third-year medical student working with Dr. Li in the emergency department (ED).
- Situation: We have a patient with what appears to be cardiogenic syncope.
- Background: The patient is a previously well 16-year-old female named Adrianne van Beek. She presented to the ED after an episode of exertional syncope today at school. She described it as 'blacking out' and didn't experience prodrome, vertigo, or a loss of balance. This is her first episode. Her only other symptoms are vague fatigue over the last few months and a mild decrease in exercise tolerance. She has bradycardia with a heart rate of 30, but the rest of her vitals are within normal limits. Cardiac exam revealed an innocent murmur. She also has some mild tenderness of her left shoulder from her fall, but otherwise, her exam is unremarkable. Her blood glucose is normal, but her ECG shows a complete AV block. She is currently on a continuous cardiac monitor.
- Assessment: This appears to be her first presentation of symptomatic bradycardia associated with a complete AV block, and I think she might need a permanent pacemaker.
- Recommendation: We would like to admit her to pediatric cardiology for further investigations and management. Are you able to see her this evening? Is there anything else that you would like to know, or you would like us to do before you take over her care?

After getting off the phone, you head back to Adrianne's room to give her an update. You let her know that the pediatric cardiologist is going to see her shortly and take over her care. You wish her the best and ask if you can visit her after your next shift to see how she's doing. Adrianne says yes, and she thanks you for your hard work. You say a final goodbye before going to grab another chart.

Conclusion

Alright team, that wraps up part 2 of this PedsCases podcast. Before we finish up, let's review the learning objectives.

1. **Define high-quality CPR.** High-quality CPR is defined by the following characteristics: a rate of at least 100 compressions per minute, a depth of at least

one-third of the A-P diameter of the chest, allowing complete chest recoil between compressions, minimizing interruptions in compressions, and avoiding excessive ventilation.

2. **List two pharmacologic interventions used in the management of pediatric bradycardia with a pulse and poor perfusion.** The two pharmacologic interventions used in the management of pediatric bradycardia with a pulse and poor perfusion are epinephrine and atropine.
3. **List two rhythms that are shockable and two rhythms that are non-shockable in pediatric pulseless arrest.** In pediatric pulseless arrest, the two shockable rhythms are VF and pVT, while the two non-shockable rhythms are asystole and PEA.
4. **List the three key investigations in the workup of pediatric bradycardia.** The three key investigations in the workup of pediatric bradycardia are an ECG, a Holter monitor, and an echo.
5. **List three indications for pacing in chronic pediatric bradycardia**. The indications for pacing can be broadly classified as symptomatic sinus bradycardia, symptomatic sinus node dysfunction, and advanced second-degree AV block or third-degree AV block.

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