

Summer 2014

Reading

CEPCCF

Professional Development:
Hyperkalemia



Sunday Morning

If there is such a thing as karma then things like this should not happen. We were really trying to do a proper deep-clean. Not just a quick wipe down and mop job, but really clean the ambulance deeply. The contents of two of the cabinets in the back of the truck were emptied onto the stretcher so that we could clean out the cabinets properly. Rags and spray bottles also littered the back. That's when the karma of our hard work vanished with the piercing tones of the base pager. We looked at each other in bewildered disbelief. "Seriously? A code 3? Is there no justice?"

We quickly replaced all the cabinet contents, ditched the cleaning supplies and strapped the bags back on the stretcher. The drive to the nursing home was completely automatic. It is a trip made so often that some medics believe that if we pull the ambulance out of the bay, put the transmission in drive and jump out, it will actually drive itself there. The call information was just as run-of-the-mill. "82 year old female, vomiting, diarrhea, weak, difficulty ambulating".

It was just coming up on lunch-time as we entered the "secret" code on the keypad next to the back door. The code had not changed since the grand opening in the mid eighties and the digits on the used buttons were worn completely blank. Anyone wanting to gain unauthorized access would simply need to press the blank buttons in various combinations until the door slid open. Luckily there was not much of value to be had and the keypad seemed to be more of a formality than security.

The moist smell of steamed cafeteria food enveloped us as we walked past the kitchen and dining room towards the nursing station. After several minutes of confusion as to whether we were there for the transfer to go for CT scan or for the 'transfer to the ER' we were finally directed to Olga's room. Olga was laying in bed looking very unwell. A knitted blanket pulled up high and a tray with food, untouched, sitting on the nightstand, the vague smell of feces lingering in the air. "Hi there Mrs Volkman, how are you feeling?" "I feel, awful. Simply awful.", she exclaimed, with a slight German edge in her voice.

"I can't even get out of bed and I have to go a lot if you know what I mean."

Brandon, my partner for the day, was getting vital signs measured so I turned my attention to the envelope the nurse had handed us on the way in. A quick scan of the thick pile of paperwork revealed a fairly standard patient chart and MAR sheet for a patient her age. Hypertension, diabetes, chronic back pain. Taking enalapril, metformin and arthrotec. A quick scan of the sheet revealed that Olga had been on her arthrotec for three weeks and the rest of the medications for the entire MAR sheet (at least a month). The combination of elderly, female, hypertension and diabetes made a silent MI a real potential so I was glad to see Brandon snapping the electrodes onto the 12 lead harness.

The physical assessment revealed that Olga was very, very weak and seemed to lack sensation in her lower limbs. Her hands were very weak as well. There did not seem to be any difference from side to side which made a stroke less likely. Olga's blood sugar level was normal and it was beginning to look like a routine "generally unwell" call, until Brandon handed me the 12 lead. Suddenly it all made sense. "Brandon, let's get Olga loaded up and get going." Brandon looked surprised. He knew that tone in my voice and was clearly wondering why I was suddenly thinking that this was a high acuity call. "Ok, I didn't see any ST elevation.."
"Neither do I. Its not the ST segment that is the problem, its the T wave."

Winding the Spring in the Machinery of Life

If you ever want to cause a paramedic's eyes to glaze over and make them reach for their smartphone to check their facebook status, just mention the word 'electrolyte'. There are a number of reasons why electrolytes fail to spark the interest that can sometimes be observed in other topics.

1, Electrolytes are abstract. Unlike, for example, a heart attack with its clogged vessel that lead to starvation and death of tissue; an electrolyte imbalance is a bit harder to envision.

Potassium is depicted in textbooks as little Ks floating around, moved around by pumps embedded in cell membranes...by the way, why are they Ks instead of Ps? It is Potassium isn't it? Many medics cling desperately to the one concrete statement that they remember from the college electrolyte lectures. Lets see if you can finish this sentence "Where sodium goes..."(the answer is at the back of this reading package). Other than that, it is a slippery subject to grasp due to its theoretical, microscopic basis.

2, Electrolyte imbalances are listed as causing almost any condition you can dream of; seizures, chest pain, dizziness, weakness, twitchiness, death, dysrhythmias, nausea, abdominal pain, blurry vision and on and on. For medics this is good and bad. In paramedic school it was great: If ever asked for a differential diagnosis it was always safe to throw out 'electrolyte imbalance' as an option. On the road though, it doesn't help at all.

3, There is nothing we can do about an electrolyte imbalance. It is almost impossible to say for sure if there is an imbalance without blood work. Even if we did know, there are no treatments available in the drug bag. *If I can't treat it why should I care about it?*

All of these factors conspire to make electrolyte imbalances a real yawner of a topic. However, this is all about to change. There is a new medical directive in the works, there are no guarantees that it will be approved by all levels and put into effect, but the chances are pretty good. The directive outlines the treatment for hyperkalemia and includes a brand new drug (at least new to our drug bags).

This section of the reading package will provide a brief refresher on the topic of hyperkalemia. If you are part of a PCP only crew, don't dismiss the information that follows, recognition is huge on this and an early update to the ED, even if you are unable to provide any treatment, can be life saving to the patient.

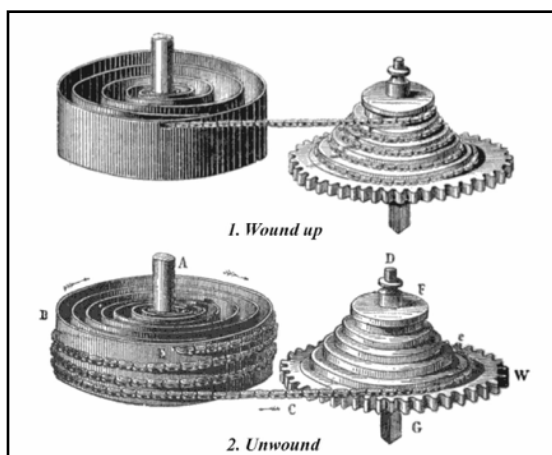
What is potassium?

Potassium is one of the main electrolytes that run the machinery of life. There are three main concepts regarding potassium that are critical to understand. We are going to go through them next. Take your time, reread sections if you need to. It is not overly complicated, in fact its kind of cool how it all works.

Diffusion can do work.

The law of diffusion states that substances will move from an area of high concentration to an area of low concentration. This statement may ring a bell but really think about it. Think about it like a hydro dam that uses the waters tendency to flow downhill to turn an impeller and create energy. If we can create a situation where we have a high concentration on one side of a cell wall and a low concentration on the other, held back from diffusing, then we have potential energy stored there. If we 'open the gates' the flow from high concentration to low concentration will create energy. And can potentially be used to do some 'work'.

It is like having a spring that has been wound tight. This kind of potential is sensibly called the diffusion potential.



Opposites attract.

The second concept is that positively charged particles are attracted to negatively charged particles. Anyone who has ever played with a magnet knows this. If you have two rod magnets and try to put the similarly charged ends together they will push apart. If you turn one the other way around they pull together. Truly in this case opposites attract. If we can place a bunch of positively charged particles (cations) on one side of a cell wall and leave some negatively charged stuff (anions) on the other side they will want to move across the membrane so they can stick together. There is potential energy stored now and as soon as the gates are opened they will flow across the membrane like iron dust to a magnet, creating current. With the potential to do so some 'work'.

By now you may be wondering how this concentration and electrical gradient is created to begin with. This potential has to use energy to be created if it has 'stored' potential to do work. There are pumps embedded in the cell wall actively pumping potassium into the cell. At the same time it is pumping sodium (out of the cell). In fact, the pumps stuff so much potassium into the cells that typically there is a concentration of 140 mEq/L inside the cell versus only 4 mEq/L on the outside! Since the pumps are moving things against the concentration gradient (up-stream) they need energy. The sodium potassium pump uses the energy that cells generate from oxygen and sugar (ATP).

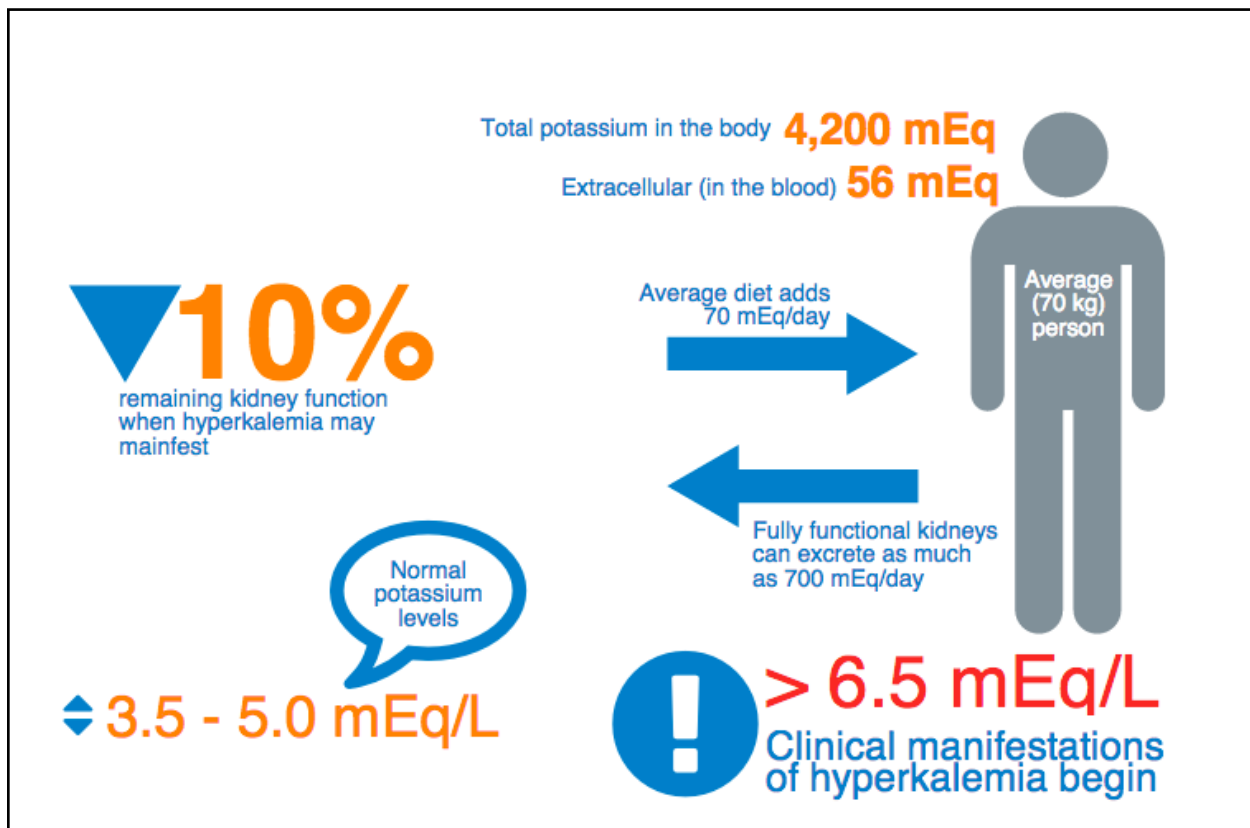
Since the pumps move sodium out at the same time as they pump potassium in, the pumping of sodium in the opposite direction sets up an opposite gradient for sodium. Basically there are two wound springs at this point with sodium wanting to flow into the cell and potassium wanting to flow out. Lots of potential for stuff to happen! What about the electrical potential? With both sodium and potassium being positively charged is there any electrical charge across the membrane? Yes there is. The sodium-potassium pump actually pumps more sodium out than it pumps potassium in. So it is left with less positive charge on the inside of the cell (-

90 mV). So you can imagine the sodium, not only is there a steep concentration gradient but it is also being pulled inside by the electrical gradient. The only thing that is stopping the sodium from being magnetically and chemically yanked downhill and into the cell is the sodium channels that are usually closed. What happens when they open can be the topic of a whole other reading package. The important thing to clearly be able to imagine is that most cells are stuffed to the brim with potassium ions and that this concentration gradient is like a wound spring waiting to do some work.

So, what is this 'work' that the wound springs and electrical gradients have the potential to do? The work is most of the work done by the machinery of life: A thought, a heartbeat, a muscle contraction, a sensation transmitted through a nerve, they are all dependent on action potentials made possible by the gradients of sodium and potassium created by the sodium potassium pump. Pretty important stuff! If the delicate balance is not maintained things can go horribly wrong in a hurry.

The Ins and Outs of Potassium

So where does the potassium come from? Potassium is present in food (healthy food at least) and is rapidly absorbed from the small intestine into the blood stream. An interesting (and unsettling) fact is that if the potassium is not quickly moved into the cells our potassium levels will rise to lethal levels really fast. Once it is stuffed into the cells it can be slowly released and excreted by the kidneys over time. From now on anytime I eat a banana it will be with a little prayer that my bodily functions are all up to snuff lest I die a quick death from hyperkalemia. The cells basically act as a buffer mechanism, able to store some potassium until the kidneys can process it out, ensuring that the free floating potassium in the blood is maintained within a very narrow range required for things to work properly.



In summary, potassium comes in through foods, is buffered by cells and is excreted by the kidneys (mostly). This is helpful when figuring out what may cause levels to increase. Too much intake in the form of food or potassium supplements may overwhelm the buffer and elimination system causing levels to accumulate. Or, if the cells break open through a crush injury or other cell damage the potassium will leak out of the cells and into the blood increasing the free-flowing levels. And finally, if the kidneys are unable to excrete the potassium due to damage, or some medications, the levels will obviously rise. More on that later.

Too Much of a Good Thing

The signs and symptoms associated with hyperkalemia are related to the failure of the concentration gradients required for cells to do the work they normally do. As you can probably appreciate from the discussion above, the sodium / potassium gradients are established in a very

precise, intricate balance. If there is too much potassium outside of the cells (hyperkalemia) the balance fails and all sorts of weird things start to happen. It is not unlike having brown-outs in a power grid. The lights dim and your electronic appliances start to act up.

Muscle contractions and nerve conductions are very dependent on cell membrane potentials and hyperkalemia can cause muscle twitchiness, cramps and numbness and tingling. Within the central nervous system it can cause irritability and anxiety. In the GI tract it often causes cramping and diarrhea. Hypotension is also a common sign that can become life-threatening. However, the most important sign is the ECG abnormalities that occur as potassium levels rise. The ECG signs can provide a clue that a patient with otherwise vague symptoms is in fact hyperkalemic.



How does hyperkalemia happen?

In order to catch that your patient has hyperkalemia it is important to understand all the factors that can contribute to causing it. Because the symptoms are very vague, it requires an astute paramedic that clues in to the past medical history, medications and other complaints to catch the hyperkalemia and get on top of treating it. It is uncommon for one single factor to lead to hyperkalemia, it is usually a combination of things. For example, increasing potassium intake because no-frills had a sale on bananas will not cause most of us to become hyperkalemic despite an increase in potassium intake. The kidneys can excrete 10 times the typical daily intake of potassium so there is a wide safety margin there. With such a wide margin we can argue that a patient with partial kidney failure should also be relatively safe from hyperkalemia, unless the function drops below 10%. However, if we add those two factors together and put someone with marginal kidney function in a no-frills with a banana sale it could spell trouble.

Another factor that affects potassium levels is a patient's acid base balance. Acidosis causes potassium to leave the cells, increasing potassium levels in the blood. Acidosis on its own will not

likely render somebody hyperkalemic but let's add a few other factors. Take a patient who has suffered multi-system trauma perhaps. Their blood-loss lead to acidosis compounded by a period of hypoxia. In addition they suffered injuries, injuries that ruptured cells causing the potassium to spill into the blood. Now we again have those multiple factors that inch the potassium levels up towards the red zone.

One really strong connection that must be recognized by all paramedics is the dialysis patient and hyperkalemia. If a patient has a recognized, significant problem with their kidneys they will usually be on hemodialysis. The hemodialysis takes on the functions of the kidneys and will get rid of excess potassium. It stands to reason that potassium levels will gradually climb after a dialysis session until the next one. Consider this fact in someone who has missed a dialysis appointment or that are getting close to their dialysis appointment.

There are many combinations of factors that can lead to hyperkalemia, take a look at the list of factors that increase potassium levels and beware if one or more of them are present. Remember that your biggest clue is the ECG strip.

Factors that can lead to hyperkalemia:

- Acidosis
- Insulin deficiency
- Rhabdomyolysis
- Increased potassium intake
- Kidney failure
- ACE inhibitors
- Angiotensin Receptor Blockers
- NSAIDs
- Beta blockers

Treatment

Calcium gluconate is the first-line treatment in the emergency management of hyperkalemia, and is one of the drugs that Ontario paramedics may soon be carrying. Calcium gluconate does not work to lower the potassium level, but it does prevent the ECG from deteriorating into ventricular fibrillation. It accomplishes this by stabilizing the cell membranes. Hence it can be life saving and time critical. Calcium gluconate is relatively safe and the only real contraindication is giving it to someone who is on digoxin. Because calcium gluconate affects the ECG and is given for the sole purpose of treating the rhythm abnormality it should only be given if the ECG is affected badly enough that the QRS is starting to widen. It should be administered slowly with a close eye on the monitor and the printer running.

The other treatment option available to paramedics is salbutamol. Remember those pumps that were mentioned earlier that pump potassium into the cells and sodium out? It turns out that giving salbutamol increases the speed of those pumps. By stuffing the potassium into the cells, less of it is floating around in the blood, hence the level of potassium is lowered. The dose of salbutamol required to move the potassium into the cells is typically double that given to treat bronchoconstriction. However, please be aware that this is NOT part of the medical directives as of yet but MAY be so in the future.

Insulin has the same effect but is not very pre-hospital friendly since dextrose would need to be given as well to counteract the sugar lowering effects of insulin.

Another treatment option that should work in theory, but is not proving to be all that helpful when studied, is sodium bicarbonate. Because there is no real good evidence behind it, it will probably not make it into the medical directive for paramedics to use. However, when patching regarding a suspected hyperkalemia you may get the order for sodium bicarbonate so don't be surprised if that happens.

Back to Olga

As we were loading Olga in to the back of the ambulance I was beginning to put the pieces together. Olga's long standing history of diabetes had most likely reduced her kidney function. She was also on an ACE inhibitor which increases potassium levels. The last straw was the NSAID (arthrotec) that she had been on for three weeks now. NSAIDs are also known to increase potassium levels.

Olga's symptoms of nausea, diarrhea, weakness and numbness all fit that of hyperkalemia. However, the tall, peaked T-waves are what really caught my attention. As we were pulling up to the ER doors the QRS was markedly wider than when we were on scene. I printed another 12 lead and we hustled to get inside.

Although (due to PHIPA) there is no way we would be able to find out how Olga made out, suffice it to say that her potassium level 'may' have been 9.49 mmol/L. And let's ,in theory, say that she may have been taken off her NSAIDs in a hurry! Luckily the calcium gluconate she may have been given within minutes of our arrival worked to narrow the QRS, flatten the T-wave and saved her life.