[MUSIC PLAYING]

DAVID BINION: I'm in charge of the clinical nutrition group in gastroenterology. Nutrition has undergone a little bit of an evolution. GFLs used to rotate on nutrition in the past.

More recently, it's become primarily run by mid-level providers. But you should always reach out to the nutrition service. So when you have complex patients who have problems with massive weight loss, malnutrition, many times, it's going to be in the setting of surgery.

Just contact us. We have an inpatient TPN service that is running seven days a week, 24/7, 365. The attendings who are staffing that can definitely help when it comes to complex patients. In addition, we're going to start a complex tube feeding patient service this year. So we're going to expand with an additional mid-level console.

So these are patients who will have oftentimes surgically altered anatomy who would otherwise end up on TPN. And those individuals may be fed more successfully with J-tubes, but they're a little bit more tenuous. So just keep in mind that a person who would otherwise be a candidate for TPN-- we're really going to have to be watching them really closely when it comes to feeding their GI tract that's already damaged. And hopefully, that service will start up in the not too distant future. So these will be things that you can tap into and hopefully learn from.

So the purpose of this lecture is to give you guys a little bit of a background when it comes to TPN. TPN is-- actually, at this hospital, it's done in a fairly unique way. Every patient will have a customized TPN assessment and formulation. Many hospitals in the US don't have the staffing or perhaps the resources to do that, but we have the ability to really customize nutritional needs for our patients. And that actually is true on the inpatient side and those individuals that we follow on the inpatient side we will follow on the outpatient side. So we have about 70 patients on home TPN now that we are working with.

The only other service that is allowed to run TPN here in Montefiore Presbyterian is the small bowel transplant service. So they have an independent service for TPN. It's a little bit smaller. But we will handle the bulk of the patients. And this will include many of the individuals that you're going to work with who might be with inflammatory bowel disease. They might be with pancreatitis, problems like that.

So the lecture's just going to provide an overview, a few definitions of things. So when we think about protein energy malnutrition, protein calorie malnutrition, under-nutrition, and malnutrition-- so malnutrition is actually interesting, because in the US nowadays, we don't have underweight people as often as perhaps in the old days. So we're going to have patients who are actually obese but in many regards malnourished, which is this concept of an obese sarcopenic patient. And these are individuals who can do very, very poorly.

So we always have to think about the nutritional status of an individual and perhaps not just their BMI. This is very true when we think about things like Roux-en-Y gastric bypass. So we have a large cohort of people who have undergone bariatric surgery. Bariatric surgery is designed to really disrupt the ability to bring food and nutrition into the body effectively. And that's why weight loss ensues.

But then the disruption of the ability to digest and perhaps absorb nutrition's going to potentially lead to problems with protein malnutrition, vitamin deficiencies. And those individuals can get pretty darn sick. So malnutrition is going to include the extremes of underweight and overweight individuals right now. So keep that in mind.

It's very commonly encountered in individuals who are being hospitalized with acute or chronic illnesses, about 50% of hospitalized patients. In this current era of cost savings and being very conscious of health economics, if we are able to optimize nutrition in our patients who are admitted to the hospital for medical or surgical issues, we can lower the rate of readmission. And that's been definitively shown. So being cognizant of this, including it in our work-ups when we're thinking about our patients, trying to correct things when we have that opportunity on the inpatient side, is going to be a very important issue. And it impacts morbidity and mortality.

So a few more definitions-- so malnutrition-- unintentional weight loss of 10% of the usual body weight in the past three months. So as a quick calculation, if you have a person who is dropping 10% of body weight, that's someone with a red flag that you have to pay attention to. When body weight is now less than 90% of ideal body weight-- again, fairly rare, because we're talking about people who are dropping below body mass indexes of 18.5.

And I think everyone is familiar with how we calculate BMI. As it's actually in all of our records, so it's an automatic calculation that's in our EPI charts. And I think it's also in the Cerner chart. So when BMI start dropping below 18.5, it's really important for us to think about how that person got there and what we might be able to do to fix things.

Here's some more definitions. When we think about body mass index, normal's 18.5 to 25. Overweight is 25 to 30, but the obesity classes can be broken into class 1 is 30 to 35. 2 is 35 to 40, essentially, and class 3 is above 40. In the underweight groups, we have extreme underweight. And we do see patients, occasionally-- sometimes anorexia individuals coming over from WPIC. Occasionally, we'll see patients who have had that Roux-en-Y gastric bypass, and they have lost from 280 pounds to 200 down to 100, and they drop into the 80s, 70s territory. And those individuals we have to be very, very cognizant of, because the idea of trying to restore them with TPN-- we're extra careful in that regard, and we'll touch on the whole concept of refeeding in a minute.

All right, so starvation is going to have profound effects on the whole body. You're going to have decreased energy expenditure in general. Adipose tissue triglycerides are being used preferentially.

The brain slows. So when people have been starved or have had a starvation physiology, they don't think quite as clearly. Histories may not be quite as good.

The body really changes its ability to function. It's going into this survival mode of shutting things down. And if we think about this over across the organ systems, energy expenditure drops. Physical activity drops. Body temperature drops. People are hypothermic.

Cardiac output goes down. Kidney function-- if a person has body mass index below 18.5, their creatinines should be 0.1. If you see a creatinine of 0.8 or 1, it may be in the normal range, but in someone who's massively underweight or malnourished, that really reflects renal failure. And that's part of the organ system shut down.

And when we see these individuals, you can just click off the organ systems. They're going to bone marrow failure. They're going to have kidney failure. Their livers are shutting down.

People who are malnourished are going to have a much harder time with drug metabolism. So just keep in mind that some of our IBD patients-- we're not going to be able to start drugs like methotrexate in someone who's malnourished because their liver's already very, very compromised, likewise azathioprine. So these are all part of the calculation. So those might be fantastic drugs, but it might be a great drug a month or two months down the road once we've restored nutritional basal status.

Immune system is going to be shutting down in these individuals, which puts them at a markedly increased risk for infections and the infections being much more severe. So this is an upper GI barium study on a patient who has had calorie deprivation marasmus. And what we're seeing here is, really, I think, a snapshot of many of the things that go wrong.

So we have a massively dilated stomach, so a gastroparesis-like picture. Tells us motility is being deranged. The small bowel folds are actually separated by these nice black rims. And when you see separation or if you see these areas of darkness on contrast studies, it's actually telling you something about the tissue being edematous.

So think about those patients that you've seen who are incredibly ill, in the hospital for too long. They have that horrific pitting edema and edema to the dependent parts of their body. This is actually occurring on the inside as well. So if you see a person who's albumin is drifting down below 3, perhaps into the 2 range or onto the 1 range, they're going to have edema, not only in their periphery but also in their internal organs, particularly the GI tract. And when the GI tract becomes edematous, it's going to compromise its function.

So you're in this horrific spiral where you need to restore nutrition, but the GI tract may not be reliable. So this same patient who has been treated for one month-- this is the appearance of the upper GI small bowel follow-through. So what we have here is a much more normal appearance of the plicae circulares, the little folds in the small bowel. That separation, that tissue edema that we see on the left side of the X-ray picture, is resolved, and the barium is not pooling in the stomach.

So this is a study that was done by Trevor Winter a few years ago which actually looks at the impact of malnutrition on digestive function, specifically pancreatic function. So the pancreas has important jobs to do. Obviously, it's going to produce insulin and regulate glucose.

But the exocrine pancreatic function-- we're actually producing digestive enzymes. Please keep in mind that the GI tract has an important function, and we should always understand that and think about that in the context of our patients who are suffering from malnutrition. So we digest our food in our duodenum. That's where the pancreas inflow comes in, and it's going to meet, basically, the small particles of broken-down food that exit the stomach.

When a person is malnourished, they simply don't have the protein reserves to make these enzymes. So you have to, again, perhaps supplement the patients or think about other strategies to bridge them so that they then become well enough to start having a normal digestive function. In terms of tube feeding, it gets complex because there are so many different products out there. And you have to try to remember which is which.

I keep it really simple when we think about tube feeding. There's two big groups. There's polymeric tube feeds. Polymeric tube feeds-- Ensure, Boost, over the counter or Jevity in the hospital, Glucerna for the diabetic patients.

Basically, it's blended food. Polymeric tube feeds are blended food. You still have to digest it in order to break it down and then absorb the nutrition.

The other big group of these are called elemental tube feeds. Elemental tube feeds are predigested, so you don't need pancreatic enzymes to break the food down to have it absorb. It's going to get absorbed passively, essentially across the mucosa.

So in someone who's really compromised and someone who's in deep trouble, just remember that elemental tube feeling may actually work quite nicely. Sometimes when we're feeding distal to the pancreas, we're feeding down into the deeper parts of the jejuno, there's not going to be reliable pancreatic enzymes in proximity. So that might be someone who would do better with elemental tube feeds.

So interesting thing about elemental tube feeds. It was actually created by NASA. It was actually created by the space program, because they didn't want astronauts having to go to the bathroom in space capsules.

So they came up with foods that would be almost entirely absorbed, and there would be less waste being processed through the GI tract. So pancreatic function is going to be compromised in patients who have malnutrition. And it improves as patients are being restored. So two big categories for malnutrition-- we have marasmus. So marasmus is a deprivation of calories-- all food groups, all calories.

And these are going to be individuals who have had an inability to eat but also a person who might have had disrupted digestion. And we see marasmus fairly regularly in individuals who have had that overshoot with bariatric surgery. Actually, it's common for us to see all of the classic malnutrition syndromes that you read about in textbooks.

So we see scurvy a couple of times a month. You just have to look for it in a physical exam. We'll go through those in a minute. We see pellagra with regularity.

If you have a patient who has heart failure, who has a history of a Roux-en-Y bypass procedure 10 years earlier with no vitamin supplementation, heart failure, wet beriberi. I mean, just keep this in mind because these are fixes. You can fix this stuff. You just have to get the vitamins on board, and then hopefully they just the function starts to improve.

I keep talking about Roux-en-Y gastric bypass, because that operation is so good at breaking the ability to digest and then absorb nutrition. Actually, our colleague Steve O'Keefe, who's one of our incredibly accomplished nutrition investigators in the whole world, who's on our faculty, just published a paper this month in *Clinical and Translational Gastroenterology* where he looked at the Roux-en-Y gastric bypass cohort who had had that overshoot. They had lost weight but then kept going into deep trouble.

And he actually did a formal study analyzing pancreatic secretions. And when they were malnourished, they had a loss of pancreatic function, but the problem with the Roux-en-Y gastric bypass is that food does not go into the GI tract in a normal fashion. So you have the pancreaticobiliary limb meeting the Roux limb downstream, and you're hoping that the pancreatic juices and the enzymes are going to meet up with the food in an efficient manner that will allow for digestion to have some absorption of nutrition in that last segment of the small bowel.

So what he did in this study was basically supplement patients with Roux-en-Y gastric bypass with enzymes, and he salvaged. So just keep in mind that you can save someone's life by just getting a little bit of Creon or one of the other pancreatic enzyme products onboard. So starvation patients with marasmus are going to typically have edema in the setting of malnutrition.

Kwashiorkor is the other big category for severe malnutrition. And this is a word that's from an African language, the Ga language. And so this was first described in 1935 in *The Lancet.* And it was the syndrome of a swollen abdomen and the displaced child.

So the oldest child was breastfed, and then a second baby shows up when the child's about two years old. The first child is no longer breastfed and develops protein malnutrition because diet is primarily carbohydrates. So this is a selective loss of protein. In all honesty, what we typically see is a combo of kwashiorkor, marasmic malnutrition. So it's not pure categories.

So who's malnourished? I think both of these people are. Marasmus the left. Kwashiorkor on the right.

So there are ways to objectively assess malnutrition. We don't typically use many of these. We don't use hand-grip strength routinely.

But if you do a physical exam, you can see loss of muscle. You can see, obviously, temporal wasting, and we'll comment on this. Percentage of usual body weight-- again, that loss of acute body mass in a rapid time period. There are these anthropomorphic measures, such as mid-arm muscle circumference.

Albumin is criticized for not being an effective short-term marker of nutritional status, but it's actually an important marker, just in terms of the overall status of the patient, particularly in the context of surgical risk. And the surgeons know that when albumins start to become low, again, there's this tissue edema that happens. And patients can have this, like we saw on the X-ray before, this edema in their tissues that makes surgical anastomosis much more problematic to hold.

All right, nutrition assessment-- determine who is at risk, and provide a means to monitor for effectiveness and nutritional support. So we talked about the nutrition history. Anthropomorphic measures.

Biochemical measures-- prealbumin is the test that we will routinely use in the short term. The problem with some of these markers is that when a person becomes septic, there will be a vascular leak where all serum proteins drop acutely. So there's a little bit of confounder where all these numbers may look terrible.

And you can also just think about this in the context of c-reactive protein. So CRPs are going to elevate in many of our individuals who are infected or perhaps having surgical complications that are septic complications. These numbers will drop. If the person is in a little bit more stable status, perhaps in the outpatient realm, these markers are going to be much more reliable.

And then we talked about creatinine in the context of malnutrition. You always have to put it into the context of that individual. What's the expected result, and what's going to be abnormal?

All right. We have a couple of questions. Serum protein markers are used sometimes as indicators for nutritional status. These proteins which turnover rapidly are most sensitive to changes in nutritional status. Which plasma protein has the shortest half life, will be the best marker of acute nutritional status? Shout out. And the answer is-- prealbumin.

OK, so the half-life of the proteins-- prealbumin is a two-day half-life. Albumin is a 20-day half-life. So as they all start to drop, that's trouble. But prealbumin's going to be the best indicator. And when we actually put people on TPN, and you'll see the prealbumins change fairly quickly.

So nutrition assessment-- we have the history, body composition, serum proteins, immunologic test, muscle function prognostic indices. And on the right side is basically taking a look at the patient, getting a history and physical. So that's subjective global assessment, which is basically how we do this. So we have all of the components, and we basically categorize things as someone who's appropriately nourished, someone who has moderate malnutrition or severe malnutrition.

So malnutrition is going to be a product of all these factors-- age of the individual, the degree of energy deficit, the length and duration-- is this an acute process or a process that's been going on for multiple years in a downward spiral? If the person is going to be massively stressed, that's a big part of this.

Again, a person who's been through an acute injury, perhaps a burn-- that's a person who is going to lose their ability to maintain certain proteins, simply because they have a leak that's occurring across the injured skin. And that's where the metabolic stress is massive. And that's where we're going to use incredibly high levels of support. We're going to give much more protein than usual, simply because there's a weeping that comes through the skin.

The GI tract can also suffer from similar problems. So GI tract is a massive, massive surface area. And even a low-level injury across the tract can result in a loss of proteins that will become a major problem for the individual. So if we think about surface area of the skin-- 1.5 to 2 meters squared-- surface area of the intestinal tract, the GI tract, if you flatten out all the villi and crypts, is the equivalent of a tennis court with both doubles [INAUDIBLE].

So a low-level inflammatory injury across that surface can result in a constant oozing of serum proteins, hemoglobin, and these enteropathies that we see in patients who have had these kind of chronic processes over multiple years. We're going to have to supplement those people more. And psychosocial stress-- sometimes people, for mental health issues-- we talked about anorexia nervosa-- 50% premature death in those individuals. So these are serious problems. Psychosocial stress in the context of people who are not able to access appropriate food.

So here are going to be some shout-outs. What are we looking at here? Malnourished child, older person in the hospital, and a young person by on the bottom right. Any ideas? Not edematous. Severely malnourished, calorie deprived little bit of edema. I apologize. Pitting edema. What's that? Kwashiorkor predominant malnutrition. Cracks in the corner of the mouth. Kylosis. Magenta tongue. Riboflavin deficiency.

Here, we have, I think, kylosis in the corners of the mouth, angular stomatitis. Here's kylosis with fungal. Changes [INAUDIBLE], which is iron and B vitamin deficiencies. Rash on the skin, dermatitis, pellagra, diarrhea, dermatitis, dementia, and death. Here's magenta tongue.

All right, any ideas? Corkscrew hairs? Scurvy, loss of dentition, perifolllicular hemorrhage, corkscrew hairs, hyperkeratosis, dental loss. So part of the problem is that when we order some of these vitamin levels, it'll come back in about two to three weeks. So it's important to pick up on these things when a person is being admitted to the hospital, because giving intravenous vitamins, again, can turn this around fairly quickly. Vitamins by mouth when the GI tract is broken may not be quite as effective.

All right, here we have hemorrhage in the skin. Any ideas? With vitamin deficiency? Vitamin K, bruising.

All right, poor outcome-- weight loss greater than 10% in the past six months. If they have a low serum albumin anergy immunologic testing, abnormal muscle function. And when people have malnutrition and they're going to be dealing with challenges in the hospital, mortality rises dramatically. Readmission rises dramatically.

So when we think about intervention, you have to do this calculation. Are we going to wait for things to become a problem? Or do we want to intervene a little bit earlier? And I think, really, the key is to get the history of how long that process has been going on.

If the person's been really in a decline for a long time and their GI tract's not going to be effective for replacement, that might is a setting where we want to intervene with something like TPN a little bit earlier. This is very, very relevant in the context of surgery. So a person who has a postoperative ilius may not be able to have nutrition.

We'll wait for a while. We'll wait for five days, seven days, to give that person a chance to have some recovery of gut function. If there was profound malnutrition coming into the surgery, we're not going to wait that long. So this is that balance that we have to strike when we make these assessments. And the goals of nutrition are to improve immune function, again, restore homeostasis as norms of organ function, wound healing in the context of surgery.

So I think the key indications for TPN are going to be patients who have such high metabolic requirements-- we talked about burns. We don't have a burn unit in this hospital. The burn unit is over at the Mercy Hospital.

But the amount of protein supplementation that's required in these individuals is much more than would typically be available to enter via the GI tract. Patients who have inability to swallow-- again, the thoracic surgery colleagues will have individuals who have had esophagectomies, leaks. They're in discontinuity. Will sometimes have to struggle with fistulas from surgical wounds-- enterocutaneous fistula, intestinal failure for a variety of reasons, loss of bowel acutely.

One of the big problems with intestinal failure-- and this talk is focused mostly on TPN-- but intestinal failure in the individual who has lost perhaps the second half of their GI tract, eating is going to cause a massive increase in diarrhea. And we have to be careful. We have to basically balance the oral intake with helping that person get adaptation of the surviving bowel.

But again, keep in mind the physiology. The GI tract is going to handle approximately 10 liters of fluid on a daily basis. It's not from eating and drinking. That's not where the 10 liters of fluid come from.

If we think about the secretions that come into the luminal GI tract, saliva's 2 and 1/2 liters. Stomach juice is 2 to 2 and 1/2 liters. The duodenum secretes a bicarbonate-rich fluid that helps to neutralize stomach acid. So you have a couple of liters from that.

Pancreatic juice is 300 to 500 CCs. Bile coming in from the liver or the gallbladder-- 300 to 500 CCs. If you don't have your gallbladder, bile actually is higher because the bile would typically be concentrated in the gall bladder. And a person might eat one to two liters. So if you add up that fluid, you're usually in excess of 10 liters per day.

Normal stool output-- the medical definition of diarrhea, 200 CCs. Above 200 CCs per day-- you're starting to meet criteria for diarrhea. So normal stool output is 200 CCs. 10,000 CCs are handled by the GI tract.

So most of the secretion is going to be in the first half. The second half is going to all be absorption. You absorb the majority of that 10 liters by the time you reach the colon. So the colon usually receives about 1 liter of fluid per day. And you're going to absorb another 80% of that fluid to ultimately make 200 CCs of output.

So when a person has had a massive resection. They've thrown an embolus that's taken out the SMA. They have not had a chance to adapt. They have not had a chance to optimize the absorptive function from remaining GI tract. We can't use their gut reliably, because it actually stimulates further loss, and you get into this horrific spiral of dehydration.

We saw this yesterday on a TPN console of a 75-year-old lady who's a vasculopath, who basically lost 2/3 of her small bowel. And acute care surgery had to remove gangrenous intestine. She has an [INAUDIBLE] jejunostomy.

This is someone who's, is in all likelihood, not going to be able to eat for a while. Colon is intact, so we'll hopefully be able to reanast most of the remaining small bowel to her colon to improve absorptive capacity. But we now have a new medication that has become available that actually improves and enhances the adaptation of the surviving small bowel. And that drug is delegated. It's a GLP-2 agonist. It's been available on a routine basis for the past five years.

Basically, it's a peptide growth factor that'll cause the villa to double in length. And if we start this process, not usually in the immediate acute setting, but when patients are transitioning into the home-- TPN parental nutrition, IV fluid support setting-- we can enhance the ability to absorb fluids so that they're not going to be struggling with the horrific fluid needs overnight. So if you're giving a person 6 liters of IV fluid per day, just the rate of fluid going through their central access becomes a problem, because you're running 150, 200 CCs an hour, and the lines can't even handle that pressure. So we have to craft a plan and then hopefully allow these people to stabilize moving forward.

This center, University of Pittsburgh Medical Center, is the world's leading center for small bowel transplantation. So when a person has been on parenteral nutrition and they're experiencing too many challenges, too many line infections, loss of central access, perhaps liver failure as a result of being on parenteral nutrition for a decade, those patients actually become the candidates for small bowel transplant or multivisceral transplant, combined liver and small bowel transplant. So we have these resources available, and we will see people from throughout the country for these reasons.

So perioperative support-- there's an increasing push to actually use TPN on the cancer patients to enhance nutrition. When we re-establish nutrition, chemotherapy is better tolerated, so we can actually improve outcomes. HIV patients are not quite as much emphasized because we have effective heart therapy. And then the ICU patients over in Hillman Cancer Institute.

So the history of starvation-- from normal status, fatigue, bedridden, developing decubitus ulcers, pneumonia because of an inability to clear secretions, and then death. So we don't want this to happen. And we're to try to intervene before things become too late.

So as we've talked about a couple of times already, the immune status becomes severely compromised in patients with malnutrition, and their ability to clear infections is going to become problematic. And the timing-- parenteral nutrition. It's not an algorithm. It's on a case-by-case basis.

But when you think about a person who is not going to be able to have recovery of nutritional status through the gut because of impaired function because they've been attempting to eat but have had progressive weight loss, these are individuals where we have to think very carefully about the reasons that are contributing to weight loss and then early intervention, particularly in the setting of surgical intervention. So early TPN in that setting is appropriate. The person who comes in in a relatively strong nutritional status but has an ilius that's persisting beyond day five-- that's a potential situation where we will give TPN to effectively jumpstart their gut and get them back on track.

One of the nice things about the TPN service here is that we have complete control of electrolyte replacement, too. So we can give amino acids, again, optimize the electrolyte concentrations. We give vitamins routinely. And as we restart many of the surgical patients on TPN, the gut wakes up. The ilius resolves on sometimes a very short course of TPN to actually get them over the hump.

We don't like to overfeed our patients. So philosophically, we will not use massive amounts of dextrose and lipid in our patients. When we get people transferred in from the outside, sometimes we'll see patients receiving incredibly high concentrations of dextrose. And it's challenging for patients to have-- again, we're giving direct infusions of dextrose.

We'll see 300 grams, 400 grams of dextrose per day, which is more than people would ever need. And that can potentially have negative effects on immune function and also liver function. So we will typically underfeed our patients here. We will emphasize protein, because protein's going to be essential for wound recovery. Vitamins, electrolytes for optimizing electrophysiology of gut motility.

But we will try really hard to cut back on dextrose. And lipids are needed to provide some support. But our goal is really to provide nutrition in the setting of protein.

Now, what we have here is a way to think about protein supplementation with metabolic stress. And it's gram per kilogram per day. And we're usually thinking about grams per kilogram of ideal body weight, remembering two out of three patients in the United States are over their ideal body weight.

On the surgical patients, 1.5 grams per kilogram amino acid supplementation is pretty common. Because of the wound healing issues, when we're dealing with enterocutaneous fistula and patients who have increased losses, we may have a need to go above and head towards the 2 grams per kilogram category. In terms of calories, ballpark-- most people need something in the neighborhood of around 1,500 to 1,600 kcals per day. When we're giving TPN, those calories are going to come largely from dextrose and fat.

Again, we will accept that reduction in total calorie support if we're trying to balance these issues. The lipid that we use in TPN can stress the liver and can lead to some problems in the setting of sepsis. So we will cut back on calorie support as needed.

There are formulas for calculating ideal body weight that are gender-dependent. So women-- these are things that you can definitely find on the internet so you don't have to memorize these formulas. But if you want to think about ideal body weight, basically a five foot height in a woman starts with 100 pounds. And for every inch above that is an additional five pounds.

And then their frame is going to impact that by 10% above or below. So this is a very quick formula for ideal body weight. And then you start with 106 pounds for five foot and every inch over five foot gets six pounds. And again, that small or large frame is the adjustment.

So we have to make these calculations for ideal body weight, actual body weight, usual body weight. That gives us a sense of where we are. Total energy expenditure-- again, these are the bomb calorimeters. We don't have access to these technologies for our patients on a routine basis. We'll use objective assessment.

Keep going. When determining a patient's traditional formula, we must know the nutritional needs for calorie, protein, and water. Indirect calorimetry is a bedside tool that we don't typically use because of the cumbersomeness of it. That could be used to measure which of the following.

So here, we're basically looking at the metabolic activity in the body and respiratory quotient. So I don't think you'll see this on the board exam, but this is the basis for understanding the energy needs of the patient. So respiratory quotient on the body is basically how foods are being burned and how CO2 is being generated.

And this is something, if you're actually overfeeding patients, which we typically don't do in this setting, in this hospital, you'll actually see the rest of the respiratory quotient starting to change as a result of lipogenesis. So again, we've learned over the past several decades that overfeeding patients in the setting of parenteral nutrition support is really not a good idea. So we avoid these problems. All right, so protein intake we touched on a little while ago. One gram per kilogram is a typical ballpark for most patients in terms of protein need, but under the setting of hospitalization and stress, we're going to go above that and again, optimizing for the patient in front of us.

All right, so when we think about feeding the GI tract versus feeding via intravenous, it's always better to use the GI tract if possible. We talked about the types of tube feeding that could be used. Elemental tube feeding is sometimes the key ingredient to have success. And elemental feeds have a better chance of being absorbed across the mucosa that's injured or the person who has that marasmic picture that we talked about previously with the edema component.

Again, these don't need to have digestion. It's just a passive absorption. Parenteral nutrition is guaranteed delivery. So if we feel that the GI tract is not yet able to do its job in terms of absorbing nutrition, parenteral is going to be the right way to go.

So the clinical indications for parenteral nutrition or section for short bowel that we touched on-- pseudo obstruction, when the motility in the GI tract is not effective, and feeding basically results in distension and then fermentation. So example would be scleroderma, systemic sclerosis. If there's a malabsorption, patients who've been through radiation in the past-- enterocutaneous fistula-- again, the patients in the perioperative setting who have had a leak that's, again, short-circuiting the GI tract. Obstruction, clearly an indication.

When you can't get to the GI tract-- many of our patients, particularly in the surgical services, are in discontinuity and we don't have access to the GI tract. And when enteral nutrition has failed. So this is a laundry list, but it's not completely comprehensive.

So when we're going to give TPN, we have to think about vascular access. Peripheral IVs cannot be used for the high osmolar concentrations that we're going to use in TPN. Basically, we'd sclerose the veins. It would be incredibly painful.

So the blood flow in peripheral veins is approximately 100 mls per minute, and the blood flow in the central veins, the subclavian, where we will usually try to place the catheters, is 10 times more. And that is going to allow us to put in a very hyperosmolar concentration. The patients who have been on long-term TPN, or patients who have been through multiple admissions in the hospital, will sometimes start to lose vascular access. And our interventional radiologists here have been able to help us by placing additional lines that are lumbar lines in certain settings.

So we have this algorithm for keeping the central access available. Subclavians and internal jugulars are obviously used first. We have lumbar lines, femoral lines that are tunneled. We actually put a huge emphasis on not having our patients develop line infections.

So we've come up with protocols where we actually teach our patients how to clean the lines. They will use chlorhexidine prep pads as opposed to alcohol. We ask them to time the debridement of the catheter tip. So just cleaning the catheter for 30 seconds, allowing it to air dry for 60 seconds, maximizes killing and then repeating that before they hook up their catheter on a nightly basis.

We actually have more problems when health personnel access these lines, because they may not be as fastidious. They may not be as careful as the patients are. These are lifelines for our patients.

All right, so peripheral solutions are very low calorie. The dextrose concentrations are typically quite low. The amino acids are quite low.

We don't typically give peripheral hyperalimenation for a couple of reasons. If a person is sick enough to need parenteral nutrition, they're going to potentially have refeeding. And refeeding is going to need a central access in order to give enough potassium, magnesium, and phosphorus to prevent complications.

So peripheral supplementation is not routinely done in our patients. We really make an attempt to get central access so that we can potentially deal with complications of IV nutrition. So the TPN order-- we have critical care dietitians on our service that staff on a daily basis-- again, every day of the year.

And we'll come up with a customized formula. So when we write the TPN order, the first thing we try to think about is protein requirement. And then we'll try to supplement calories with a combination of carbohydrate and fat. And then we'll get to a ballpark of approximately 1,500 to kcals per day. In smaller patients, it might be lower, in the 1,200 kcal range.

Vitamin supplementation-- thiamine is essential in the early time period to prevent refeeding issues and neurologic damage in that early time period. And if we think about patients who-- their metabolic activity's depressed due to malnutrition, and then we suddenly provide nutrition guaranteed via the intravenous, they're going to have this incredible ramping up of metabolic activity in their cells. They're going to have this big shift of potassium and phosphorus and magnesium from the extra set of that compartment. Intracellularly, they're going have big drops in their blood chemistries.

And that can actually result in problems with electrophysiology. It can result in problems with arrhythmias, seizures. Vitamins are going to be rapidly wiped out, and that can lead to the neurologic issues with Wernicke-Korsakoff. So big emphasis on vitamin supplementation early on.

And the adjustments that occur in those first few days-- as we are dealing with refeeding, we'll typically see a big drop in potassium. But then because we have central access, it's relatively easy for us to provide additional supplementation. We write the TPN formulas in the morning. They are actually formulated in the afternoon, and they're hung at six o'clock. So there's a hard cutoff of about 1 o'clock in the afternoon. And we can't write a TPN order after that, simply because the formulas are already being created.

Other vitamins that we pay attention to-- I personally think B12 is something that is under appreciated in terms of malnutrition. Many of our patients have, again, altered anatomies, where they're going to have disturbances in B12 absorption. So just to refresh your memory, intrinsic factor comes from parietal cells in the stomach.

People who have been disconnected with a Roux-en-Y gastric bypass will never absorb B12 effectively again. Terminal ileum in the distal small bowel is where the intrinsic factor B12 complex is absorbed. Patients who've been through TI receptions-- again, marked defect in their ability to absorb B12.

During inflammation, there's going to be increased nitrogen radicals, NO. Nitric oxide gas is created during inflammatory stress. That destroys B12 in the body.

So many, many of our patients are going to come in with B12 deficiency. Easily fixed. We recommend an injection strategy.

Some of our patients, not too many, but are going to be vegetarians. And they're just not going to have access to the animal protein which is the substrate for B12. So we think about where the problems can lie-- again, anatomy and surgical changes are going to be one of the big issues.

Bacterial overgrowth is also going to contribute if a person's lost their ileocecal valve. An example would perhaps be a patient with the TI resection. A patient might have had a J-pouch reconstruction where the TI has now turned into a neo colon.

There's going to be substantial bacterial overgrowth. That's going to contribute to B12 deficiency, because bacteria will break apart the B12 intrinsic factor complex. The blood testing for B12 is not particularly accurate. It's about a 50% accuracy.

So we've actually come to learn in the past few years that there are other blood tests that are more effective, that are just not available on a routine basis. There's something called a holotranscobalamin level. We can't order it in the United States right now. That's a much better marker of B12 status. So based on surgical history, based on problems with physiology, we may just start supplementation in these individuals.

We look for megaloblastic changes. MCV's going to rise. But many of our patients are going to have neuropathies.

So when a patient has had surgical history and has got a peripheral neuropathy, that's a clue to remember. B12 could be a contributing factor. So before we send that patient to a pain clinic for gabapentin, try to go through that checklist of nutritional issues that could be corrected.

And subcutaneous replacement more frequently is actually more comfortable. Many patients are capable of doing this. IM injections into the tricep, a little difficult to achieve. In some of our malnourished patients, it's just hard because the tricep step is, again, very, very-- there's been a loss of muscle mass.

Iron replacement-- again, this is something that we can administer very easily in the hospital setting. We have a number of compounds that are now available. Iron dextran was the original compound but has a very high rate of anaphylactoid reactions. You'd have to give a test dose.

Nowadays, we have this second and third generation of supplements that have a different carbohydrate moiety. So iron sucrose, ferrogluconate-- this is Venofer and Ferrlecit-- are routinely available. For patients who are allergic to those, we do have an additional agent that's become available in the past two years, which is carboxymaltose.

We can restore iron very quickly and efficiently in the inpatient setting. And the effects are not just in the blood counts. Iron is very important for cytochrome functions, cytochrome P450s. It's important for generating ATP, mitochondria. It's important for motility. So when you see a patient who has problems with gastroparesis, and their GI tract's not working particularly well, and their hemoglobin is 8.5 and setting a normal renal function, think about replacing intravenous iron if they are not dealing with the infection at that time.

Overfeeding is bad we. We try not to do that. I don't think we ever have issues with overfeeding in the formulas that we typically work with here. But again, liver toxicity's is the big issue that we are concerned about.

So hyperglycemia is problematic when we give TPN. We have a glucose level of 180. That's our threshold. We try not to get above that.

We will add insulin to the TPN, and we'll work with endocrine to help with glucose control. Again, some of our patients are very edematous. insulin delivery may not work effectively. So we just put it into the TPN. Some of the problems that can occur with long term TPN-- micronutrient deficiencies. If we don't keep an eye on zinc and copper, we can see disturbances emerge over time.

L-carnitine is another nutrient that will become deficient. It's not routinely in the TPN amino acid supplementation. We have to add it. And L-carnitine deficiency can emerge in patients. It's oftentimes not reimbursed on the outpatient's side but people are in the hospital will actually make a point of checking and administering.

So different types of catheters that are used for TPN-- we have infusaports, metaports that are subcutaneous, that have to be accessed with the Huber needle, tunneled catheters that come across the skin, typically Hickman catheters are what we'll use in this hospital. PICC lines are really easy to put in. They can be put in at the bedside.

The problem with the PICC line is obviously it's a long line. It travels up through the brachial vein up into the subclavian. And it can lead to a much higher rate of clotting. It's about 10 times higher clotting risk in the arm and the subclavian, compared to the dedicated subclavian lines.

So the PICC-- very convenient. Patients oftentimes like it because it's easy to control. It's easy to control for bathing and showering. All of our PICC lines at this hospital are dual lumen PICCs. So you have to flush the line that's not being used for TPN. Every time you manipulate the line, there's an increased risk of infection.

The other problem with the PICC line is if a person lives alone, they're not going to be able to manipulate the line with the hand that has the catheter. So we have to make sure extenders are available, because it's just not able to control things. The Hickman catheters are much easier to have two hands available. So those are questions that we will ask in the home setting.

One of our patients, a few years ago-- she was being transitioned from a surgical team to us. I knew she lived at home by herself. She had a PICC line. I asked her, how does she flush her line? She said, it's no problem. She just put the cap into her mouth. And, I can do it no problem.

So the next question is, well, do you brush and floss before you flush your lines? And she would come in with repeated line infections. So just figuring out how people can do these mechanics on a daily basis.

So PICC line-- PICC lines can be controlled. These are devices. There's something called DRYPro, where you'll basically have a sleeve that goes over this. You'll have a bulb that can provide a pressure, like a sphygmomanometer, that'll allow a person to take a shower and have things remain dry.

This is a Hickman catheter. These are the tunneled subclavian lines. So the image on the left-- the line goes across the skin. What we have here is a person who's got a necklace, and the necklace is taped to the end of the line. And that is being pinned up or held up. So if a person has an ostomy, it's really important to give that person some suggestions about how to keep those two hubs away from the ostomy appliance, because they typically are going to be in close proximity under the clothing.

Some of our patients will pin it up to their clothing. Some of the patients will wear a necklace and pin things up. And just keeping those caps away from an area of the body that's going to have a heavy gram-negative and interior contamination.

Some of the lines will travel into the subclavian, sometimes will track up into the IgA. Our interventional radiologists will tunnel and then go up into the IgA as a first approach. Subcutaneous ports are actually really nice for patients who have lost peripheral access. We'll do this for some of our patients who need infusion drugs on a regular basis and they simply don't have IV sites available.

And the photo on the right-- you see a little bump under the skin. Nurses who are part of the IV team and the infusion clinic nurses-- they just palpate. They know exactly where you're going to go with that Huber needle.

Huber needle has this right angle. It has to be changed once a week. So the needle has to be removed and re-accessed. Some of our patients can actually access themselves. They're good enough. Their health care people, their nurses-- they have expertise. They can access the device without a problem.

The devices have a lifespan-- every time you access, you puncture that membrane, and it's going to need to be replaced at some point. But this is nice for a person who may not need to be on daily support. If you need daily support, we typically go with a line that crosses the skin.

And then the lines have to be appropriately positioned. So we want to see them right at the atrial. Cable junction again if they're a little bit too high or something, they'll migrate into the azygos vein, which can become problematic. So we pay a lot of attention. The hyperosmolar concentration can sclerose veins. And we don't want that to occur.

So the complications-- mechanical problems, the thrombotic complications, infections. Air embolism can occur. It's a very rare phenomenon. Because the lines are capped, they have clamps, but occasionally there have been problems where patients have had an air embolus.

All right, peripherally inserted central catheters PICCs, as compared to centrally place catheters for parenteral nutrition and installation have the following association. Increase thrombotic complications, tenfold higher. So our preferred line for someone who's going to be on long term-- single lumen silicone Hickman. The reason is that silicone allows us to use an alcohol lock. It gives us an additional way of preventing line infections.

So the number one bug that we will see for a line infection is staph epi. So staph epi is coag-negative staph. Basically, it's skin flora. Patients will hook up their TPN in the evening, and they'll start their run. It's usually a 10 or 12 hour run, starting in the evening, finishing overnight. They'll sleep with their TPN while it's running, and they'll start to get chills.

They don't have overwhelming temps of 104. They just don't feel well. They have some chills when they do the hookup. That's usually a clue that we're dealing with staph epi. It's about 70% of our line infections Staph epi creates a biofilm on the inside of the catheter. It lives in that environment. If

We use an alcohol lock or an antibiotic lock, we can sometimes sterilize the catheter. And we will sometimes, again, make an attempt to salvage a line. If it's a lumbar line or one of our more fancy lines, we're definitely going to try to salvage in that setting.

Some of the other bug-- Staph aureus, temp of 104. It's not subtle. Candida, gram negatives. We're not going to be able to salvage those lines as effectively. So they're going to have to remove that Hickman and replace. But Staph epi is something we may make an attempt to make better.

All right, we're talking about refeeding syndrome. Touched on it a few times. Refeeding is associated with which of the following-- hyperkalemia, hypophosphatemia, hypermagnesemia, hyponatremia, hyperglycemia. So phosphate levels drop.

So we said we essentially learned about refeeding syndrome after World War II. There were concentration camp survivors and Pacific POWs who were liberated who had been systematically starved. And when these individuals were given food for the first time in, literally, years, many of them died as a result. And they died from seizures and arrhythmias, respiratory failure.

So you have this profound drop of electrolytes in the bloodstream as intracellular metabolism revs up. And you'll have hypophosphatemia, which is acute, hypomagnesemia, problems with vitamin deficiencies across the board. And we can be cognizant of this and give additional vitamin supplementation early on.

And the patients who are obviously at risk for refeeding syndrome-- individuals with really profoundly low BMIs, with anorexia. The individual with kwashiorkor or marasmus. But we can see this in people who have not been fed for five to seven days. We see the hypophosphatemia arise. And it's something we, again, are very acutely aware of because it's a preventable problem.

So on the first day, in a person high risk for refeeding, we give about 50% of the goals of calories. So we don't use very high concentrations of dextrose. Actually, pretty similar to D5 levels. Over the first two days, we'll have extra phosphorus, magnesium than typically needed, extra thiamine, other MVIs. And we'll ramp up slowly over the course of several days, which is why when we start TPN in one of these individuals, they plan to be in the hospital for the next five to seven days, and daily electrolytes are mandatory.

Again, we have to just monitor all parameters. So key issues-- just be cognizant, and remember too much nutrition, acutely, in this type of a setting can be very dangerous.