Solving the MRI Wait List

Welcome everyone to our latest Biotic Science Rounds. Chris is going to be presenting first about solving the MRI wait list with math. Go ahead, Chris.

All right, yes, very exciting, I know, as a topic. It is actually very exciting, and I hope to show you a couple ideas as to what we think we can actually make progress and why I've taken on some of this sort of a problem. I think a lot of you know of me as an MRI physicist, so a lot of my efforts are around the technical aspects of making an MRI scanner work, but that I think everybody would kind of appreciate is not fundamentally the biggest problem with MRI healthcare in Nova Scotia.

There's other factors at play, so I want to kind of get at that. So the MRI wait list, I think of it not as an administrative problem in terms of specifically management or a resource problem in terms of number of MRIs or a staffing problem and not having enough technologists. It's certainly all of these things, but I think there's a reason that of late with developments that have been happening around analytics in this province that we should be thinking of it as a math problem.

So I want to kind of break that down a little bit. So we have very simply a wait list equation. So there are two wait lists you can think of as a prospective wait list.

That means if I, Chris Bowen, get a requisition for an MRI exam of some type, like a shoulder exam today, how many days am I going to have to wait till I actually get that exam? Then what patients know when they show up and finally get an exam is the retrospective wait list. I got a scan today. I waited 378 days for that.

The website says it should have been 60 days. What's going on? So mostly I'm going to focus on the prospective wait list. This is the one involving planning and kind of give you some sort of sense for, in its simplest form, the wait list generally in the number of days you wait for an exam is the number of exams you have to do divided by your supply or the exams per day you can deliver with your MRI systems throughout the area where you have control.

But there's not really one wait list. There's really, I call it N sub I because there's roughly, and I'll get into this a bit more shortly, 140 different kinds of MRI exams you could have in central zone here. We have five different subspecialties, more really.

Neuro, body, MSK for shoulders and knees. We've got cardiac, we've got chest. So there's lots of different sections and each of them have dozens of protocols.

So it's about 140 in general. So N sub I, there's really 140 wait lists, one for each protocol. But it really isn't just 140 because the other thing when you get coded, when a doctor sends in a rec and the radiologist says, he needs a prostate MRI exam, they can put a priority, what we call P1, P2, P3 and P4.

So ostensibly that's how important is it to do this on a certain time scale. I almost forget what the actual priority specified times are versus what we actually deliver. I think in theory P1s are same day, P2s are kind of like same week, it might be shorter.

P3s are supposed to be a month, P4s like every two months, but in reality, it's grossly, grossly worse than that. But there's really 140 times four wait lists. And of course, the last part, a little bit of summation is we don't really have a constant supply of prostate MRIs that we do every day.

So if you want to know how many days you have to wait to deliver your supply, you have to integrate each day what your supply for each protocol and each priority is. So okay, so fair enough. Math, if you like math, that's pretty easy equation.

If you don't, you ask, why am I talking about this? It's because really the opportunity that's recently only come around in just the last few years is sort of analytics. And there's two types of analytic systems specifically that I'm going to draw attention to. And really the analytics is what gives us the numbers, lets us do any math.

The first one I'm going to show you is an analytic system called iCenter provided by GE. So what you're looking at here from GE's iCenter is our 3T MRIs efficiency. And it was for the month of April.

And I've done an analysis between 8am and 9pm. We operate from 7am to 10pm on this scanner clinically. And exams, definitions are important, are defined from when a tech first opens an exam to when the last series completes.

So if you kind of look, it's basically here we are in April, you can see the first day, Monday was a holiday, so I didn't include that. But white is when we're scanning, yellow is when we're not. So yellow is wasted dead time.

So you can kind of see, despite the fact that we are at a unique crushing MRI shortage in this province, the busiest MRI in the province doing the most work is idle 42% of the time. Now, that's not entirely fair in that you cannot instantly have a new patient appear where the other one was. So you have to give some reasonable sort of delay.

So I've had discussions with different radiologists at other sites have looked at efficiency, some say three minutes, some say five minutes is a suitable time to clean a bed and what they call flip a bed, clean it, change the coil, get it ready for the next patient. Even then, though, you can see the yellow bars, it's still basically 31 to 42%, still a third of the time the scanner is sort of empty. You can see some patterns in the middle of the day, there's a lot of yellow, gets better in the evening, kind of like where there's a little more white.

We know what these are. These are not a surprise to techs or administrators who kind of do that. But, you know, essentially, what we want to look at here, and I just have a little bit of a cartoon, essentially, of what an organization that prioritizes this minimizing dead time or wasted time is.

So this is a Mercedes double pit crew, where they basically have one car in, other car out. And you can see the everybody here has a specific job and a specific purpose. It's deeply organized, guys change tires, some have the jacks, some have the bolts and the lug nuts.

Nobody's on the phone, nobody's doing administrative tasks, nobody's wondering why the other car didn't show up. Nobody's wondering, I thought we were doing trucks today. Like, you know, there's a mission oriented, isolated focus on what is the critical rate limiting step to efficiency.

And in this case, there's millions of dollars involved. But of course, our healthcare system spends about six billion a year in Nova Scotia. So like efficiency is important, and we know waste is a big part of it.

So this is one aspect, what I call the Formula One problem. How can we reduce the sort of dead time? And by the way, it's not entirely all of anyone's fault. It's a function of the systems and the design of the facilities we have.

And I'm going to get into that in a few minutes, how that'll be improved. But the other thing analytics can do is look at the exact exam. So what exams are we doing? And how long are they taking? So what you're looking, again, on the 3T, and this is, again, April, I've got here the number of exams by description, and how many I did.

So we did 139, what we call MR brain non-enhanced. That basically means brain scans without contrast. And then combined is brain scans with contrast.

So these are, unfortunately, with the GE analytics, they organize around what we feed into the system, which is really a billing code. So you can think of each of these not as a specific single protocol, but they're a envelope of protocols that fit the same billing code. So non-enhanced could be an MS brain scan.

It could be a routine brain scan. Somebody bumped their head. They're just generally trying to get a first glance at what's going on.

It's an envelope. And unfortunately, that kind of spoils our ability to very precisely understand how long protocols are taking. But you can see the potential.

The MR brain non-enhanced, although that is an envelope of protocols, it is mostly MS brain, by the way. It just happens to be that's what we run a lot of on the 3T. We consumed 53 hours of time, and the average protocol was 23 minutes.

So you can see there's information here. There's other information, too. Although there's 140 protocols, five of them were two-thirds of the exams and 86% of the scan time.

So they're the big elephants in the room that if you focus on to start with, there's low-hanging fruit. If you make those go fast, various ideas to do that, you're probably going to get a pretty quick return on investment. The main issue, as I alluded to here, is that I need to have sorting by protocol with the average exam length, the idle time pre and post, and the number of exams monthly to design efficient measures.

It's not good enough to have billing codes. I need protocols. So fortunately, we have that opportunity.

One of the strengths of Nova Scotia, which is unique in North America as far as I can tell, is we have a single database, PACS, that is every MRI, CT, ultrasound that every patient in Nova Scotia largely has their imaging on. So we have a single accessible database, and we have the ability to attach analytics to that so we can make measurements. So let me give you a little example of what you're looking at just for fun.

So here's the 10 MRIs in the province. HIMR2 is the code for our 3T. This is the trailer MRI, just to give an example.

And this is sort of monthly. You can kind of see exam counts, and we've ramped up with the trailers. We got desperate, basically, and shut down some of the other.

So you can get snapshot views of how many exams you're doing monthly. And this is easy to program. This is in a program offered by Google called Looker.

And BI for business intelligence is something that Agfa, the company that provides our PACS, has made available to us. So you can create dashboards without coding experience rather quickly. So I just put these together in just a few minutes, just on quick things I was interested in.

But it's very powerful. It can reproduce kind of what GE did, which is by billing code for each of the three scanners, how many exams do we did. So the 3T did a whole lot of MR brain non-enhanced.

Whereas on the trailer, we can see we do a lot of GAD brains, and we do a lot of abdomen scans as well, liver scans. So you get that kind of, but this is what I'm really after. I can pull specific tags that maybe people don't realize when they look at an MRI image, but there's a huge, rich header that's associated with it, which has the obvious patient names, weights, but what protocol the tech run, what tech ran it, when the order came in to do it.

There's all kinds of information that if we can customize, pull these tags, we can sort as we want and make all kinds of measurements. So in this case, I've started to sort how many exams do we do on the 3T, the trailer and the VG as sorted by prostate. So for example, we did 67 prostates on the 3T in April.

What I'm missing is the scan time. So I don't actually know how long it is. So I'm working essentially with the Agfa Looker people to do that.

We were also exploring other options. We now have cloud-based with Microsoft Azure rich analytics systems that also can access PACS and other databases. It's a whole separate conversation, roll out systems for our AI tools in that cloud, but we also have very powerful analytics offered by Microsoft Azure as well.

So we may be developing that there as well. So it's not sure which system we're going to use, but we are getting full support. We've had meetings with all the relevant parties to kind of do this.

So we're going to get there on this. So let's say we do, what can we do with this? So I just wanted to, one of the obvious things that seems painfully obvious as we could start by seeing if the time we actually do a protocol matches the times we actually book a protocol. So you can kind of see, this is an example of the cheat sheet, an Excel file, and here are the body exams that are shown.

And you can sort of see like adenal mass protocol. That's one of the 33 protocols that you can run on body. So there's also tabs for cardiac, MSK, neural, and vascular, and the billing code is here.

And you can sort of see how MR abdomen combined can be various different protocols, and they're not always the same length of time. This is the amount of time to book them. So we very manually just book in these kinds of very coarse slots.

And it's way too coarse, 15 minute granularity when we're looking for five minute or three minute bed flips. And we know that it's 23 minutes. So what you observe is a mismatch between the time it takes to book, between the booking time and the operation time, what I call a bleeding to death kind of problem.

We've got 10 or five spare minutes at the end of every exam that sometimes the techs use to catch up because they're late, because they have too many administrative tasks to do. But oftentimes they don't. It's lost time.

You can't do anything with six extra minutes. So we need to, but the first step to do any of this is to measure. You have to measure, then you can think about how can I organize myself better around that.

So the main thing about this protocol is, this sort of system is, we need to match booking to protocol time, but we also have constraints. I have five MRIs in this central zone area. They don't all do all of the same exams, like cardiac's not done at Bear's Lake, and they don't all take the exact same amount of time to run the same protocol.

Advanced technologies make some scanners operate faster to deliver, say, a routine brain than other ones. So it's a complicated problem as to how to sort of sort this out. So I wanted to kind of show you a little bit like, in addition to matching protocol length to booking length, which seems somewhat obvious, is we are about to, in one month with the 1.5 and in two months with the 3T, unveil a completely new sort of arrangement.

This is the floor plan for the new Siemens 1.5T and the 3T, where we'll be doing a lot of research. So some of you may know the old corridor, which has been inaccessible for a while. This is the public corridor.

This is a modern design two-bay suite. We have none of these in the province. The advantage of these side by side is we can share what we call zone two and three between the two magnets and find lots of efficiencies.

So if you're an outpatient coming for your knee exam, you come in through this door, you sit here. What's labeled as a change room will be an administrative area where we can have people who sort of run the floor, more or less, and look at things. You've got a couple of change rooms, a couple of bathrooms, and then you've got three essentially prep rooms where patients can come in and get changed into gowns.

After they've been changed into gowns, they can maybe get an IV set up, have a safety screen. So they can sit and wait for their exam. Right now in the 3T, one of the reasons for all the yellow bar is we are a one patient per zone three operation.

We have no privacy. So if we're doing an inpatient, complicated support required from anesthesiology, for up to two hours, the entire magnet's tied up. We can't do anything else, even though the scan might be only 20 minutes, 30 minutes.

We have the ability to plan around all of that. That patient could be in holding transfer, using one of our spare beds where they're transferred off their hospital bed onto that. I don't want to get into too much details of the workflow.

My main point of the analytics is we can separate, we can actually measure these workflow changes that we might propose. And we can separate what techs are doing now, way too much administration, by providing this kind of administrative support. An ideal system in my mind is a tech does not even know that there's a patient ready for them until they're gowned, sitting, filled out their forms.

Then a tech comes out, does their part that's mandatory safety screening, and gets them into their magnet. They're not calling, negotiating when patients can come down from the floor. They're not wondering why the porter's not there.

So anyway, there's a lot to be thought of. And I think separation of an administrative boss for the floor from the techs is a key part to anti-deficiency. So the other part is, instead of the bleed-to-death model, more like safety valve model.

Run flat out for three hours with tightly booked protocols, then give an hour gap where you can do whatever is required. Catch up because you're running late. You can use other patients that are low priority that have come into, who have agreed to kind of wait and sit around.

There's different ideas you can imagine using. You could run somebody who is a last minute inpatient and pull them down, have a porter bring them down. Point is, I think running flat out and having a system, because if you don't have any of these safety valves, what happens is the techs get behind, they get frustrated, and essentially like this quench here, everything kind of blows up.

It's just a very bad day. It creates a lot of sort of stress. The other part, no-show management.

There's been a lot of discussion around how do we make people not show. And you know, electronic systems where you get texts and reminders, those are all great, but it's been proven over and over again anywhere from the hairdressers who have these systems for a decade, our hospitals just now getting to some of this in some areas. People, it doesn't matter if you're like Taylor Swift and George Clooney show up in a chariot, you're just not going to get some people to show up in their exams.

There's just no way to kind of avoid this problem. So what you need to do is define a system that accommodates it. So for example, this is an example of a picture at Whistler of the main wait list.

Essentially it's pretty good analogy to our health care system waiting for the gondola, but you also have a shorter list, the singles line. So these are people who may have no guarantee of ever getting on a chair if group eight after eight kind of keep showing up. But in reality, of course, that's the fastest line everybody who skis know is the singles line because you're going to have incomplete groups.

So if you were a person, and some of you have probably been in this situation where you have a knee exam, it's a priority four, you know you're going to wait two to three years. Would you be willing to come in in a month, sit for up to four hours, wait your turn and look for one of these gaps? Because they know you have a simple exam, no GAD, 12 minutes table time. That's the kind of thing.

We have now a floor where we could sit you out in this waiting, and when the floor boss kind of identified it was your turn, guess what? You're in, you're gowned, and you're ready to go on a short list. These are ideas rather than fight the no-show, live with it. And it's amplified when you have a two-bay, twice the probability that somebody's not going to show.

So when you look at this kind of a problem, there's lots of work to be done administratively. I just want to give a sampling of what kind of ideas you might explore. But mathematically, what is it from an optimization standpoint? It's basically a scheduling system that you require optimized around waitlist.

So what are the constraints? So for those of us who do sort of minimization, the constraints are in central zone, I have five MRIs. There's two of them are new. Bayer's Lake just opened, Dartmouth a few months ago, the new Siemens 3T HI here for 3T and 1.5, and then of course we have the VG.

They're each, we know in advance, usually two months in advance, they know what their staff is based on how frustrated or angry the techs are, how many have quit or found new jobs in IT, that basically how it kind of goes from month to month to figure out. But they come up and plan eight-hour shifts on each of the magnets. And each of those magnets also has constraints.

You can't run every type of exam. You can't run every exam for certain hours. Daytime, you could run stuff with RAD support that you can't run at night.

And each magnet in theory has different protocol length. So it's kind of, these are constraints and values. And what do we want to do? We want to optimize.

Fundamentally, we want to optimize the waitlist. That's the target, minimize it. So you can have essentially these 140 protocols with these different priorities and minimize.

So for example, if cardiac P3s are 500 days and the target is, you know, you want to make it say 300 days or something for all P3s, then you can have the various 140 protocols drive towards 300 days with a square penalty. So it's a very common cost function to kind of make sure the outliers are prioritized and jammed towards the mean. And so you can think a lot about how you want to set your priorities.

You can customize priorities. Say I just come hell or high water, cardiac's got to get down. You could make that a goal.

Point is you have control. If you have a constraint optimization problem, you can set that up. So I just give an example here.

I don't want to get into the details of how one might do it, but Matt, there's a lot of scheduling software out there. I looked into some of it for this problem, but it's kind of, in some sense, I almost think it might be better for us to in-house some of this with MATLAB. It's very easy.

So this is a classic mixed integer constraint minimization. It's sort of where you have, it's kind of hard to see, and I don't intend for people to sort of see, but if you want to create alloy of metal and you got like four different lumps of metal or ingots, which have a certain proportion of carbon and molybdenum, and you also have alloys, which are mixed, and you got some scrap metal, which is its own carbon, and you need to make a certain mass with a certain mix as cheap as possible. Then you just basically set up the optimization problem with what variables.

In our case, our variables are not metals, but they are like how many prostate exams are you going to do, that are P3. And our constraints are what is the wait list for that specific exam using our input data of our supply and demand balance, which comes from our analytics. So it's pretty simple, really.

It takes less than a second to run these things, but this is what I envision might be a useful idea. Have MATLAB set up a constraint minimization for our 140 protocols, our four different priorities, feed the data from the analytics into it, and design a schedule as an output that is optimized across the five magnets based on the staffing. That's so hard for a single person to do.

We had Dylan just trying, who's the lead MR tech here, trying to schedule just techs for a month, and it takes him up to 20 or 30 hours a month to schedule, because there's so many vacation requests. It's just very complicated to schedule. So scheduling is a big problem.

So I'm just going to kind of close out by stating some of the challenges that I kind of see going forward. So first of all, wait lists, they are a balance between MRI supply, that's the exams you deliver monthly, and the MRI demand, that's the requisitions that come in monthly, and accounting for backlog. So I'm going to get new exams, and I'm going to have unfinished exams I didn't get to last month.

That's basically the supply demand balance. The supply analytics are fantastic, probably some of the best in North America. We are the only place I know where province wide there's a single database PACS, and we now have some analytic tools to access it so we can pull data.

We're going to have a pretty good handle how many MRI exams we're doing, and all the magnets, and how long they're taking. What is catastrophically bad is our understanding of demand. It's because we are in a fax environment where paper recs are faxed and faxed again, because I don't, they didn't know if the first fax went in, and they send them to Truro, Halifax, they shop around to all the different zones with recs, because whichever one gets in first, that's great, and all the rest, whatever, that's a no-show, that's something they can deal with.

We need an electronic system, and we have one. Ocean has been adopted, but unfortunately only about 15 percent of recs that are currently in our system are in Ocean, but we're getting there. We're going to have a full electronic system, so the demand side will improve.

I think, though, one thing I have looked at looking at this horrible system is the actual number of recs that they have tracked for the six months prior to decommissioning the 1.5T and the HI, and the six months after, it's less than one percent variable. It's actually, so they thought for some purposes that there was a spike in our demand for recs, but really not. It's actually pretty stable.

The problem that's made our waitlist go a little haywire lately is our supply has gone way down. Instead of having an efficient in-hospital MRI, we have a trailer. We take 15 minutes to walk a patient to and from it.

I'm not going to get into the details, but our demand has gone down 18 percent, our supply has changed not at all, but we can assume demand is stable until we get better systems coming in to build waitlist models. The other challenges are administrative adoption. It's constantly a discussion with leadership, and I've had these conversations with Pearl and James and others who are supportive in general of this, but they're leery.

Obviously, whenever you do something big like change how we handle and manage our clinical floors, there's a lot of potential for people who are set in their ways of being concerned about what you're going to break, and we will break things. There's no doubt this is going to have problems. We're going to need to have continuous support and evaluation to find and fix as we go.

I think the other big piece, and I've talked to Judy, who's essentially a radiologist in charge of a lot of the IT infrastructure for the province, we need scheduling. We can't have Dylan spending half his time scheduling, but we need linkage between the schedules of the RADs, the techs, and the scanner itself, so we can coordinate such that if I want to fix a prostate protocol, I have the right radiologist, like Sharon, who is capable of evaluating whether there are good changes, the tech that's responsible for body MR exam, protocol development, which I believe is going to be Xena, and also some scan time given to them so they can actually book eight prostates in a row and kind of look at that. So that's just so impossible to manually do to coordinate that.

You'd spend all day just setting that up. So I think scheduling and AI scheduling is part of it, but I think there's a real appetite for this. Obviously, waitlists is a very topical problem.

We've tried to fight it with raw horsepower, with all these MRIs opening, but efficiency, as you can see, can probably produce a greater return on investment than one. If I could have an efficient system or one more MRI, I would take an efficient system in central zone, and I think the analytics support that. So I'm going to leave it there, just if there's any questions, but my problem is I need to, I can handle telling the story as to why this is important and understanding what analytics are there, but I will probably need to resource how we, I think this could be a great student project, honestly, a constraint minimization problem if they're given the right data and the right analytics support from data engineers like Jeff can really help to kind of feed analytic system information into these models.

And then a lot of it's around management, who's going to administer the floor to be the floor boss, run the schedule, follow the rules to fix things as we trial. There's a lot to be done here, but I think there's an appetite to try. Okay, that's it for me.

Thanks.