We've been doing in my lab trying to understand this link between obesity and cancer and how we might be able to intervene.

So we're doing this work because as likely everyone in this room is aware there's a strong link between obesity and several tumor types. The CDC has now associated 13 tumor types with an increased risk and a poorer prognosis occurring with obesity and it seems that there may be others on the horizon and with rising obesity rates in the US and really worldwide. This is meant that obesity has now become the second leading cause of preventable cancer deaths in the United States second only to smoking.

So that means that we really need to understand what causes this link between obesity and cancer so that we can intervene.

So there have been a number of potential tumor promoting factors that have been associated with obesity. And here are just a few inflammatory cytokines glucose insulin fatty acids. IGF one at a connect and leptin and sex hormones and many others.

And realistically it's probably all of these factors converging but the work that my lab has been doing focuses on understanding the link between obesity insulin and cancer and how that might be mechanistically promoting tumor growth.

It turns out that tumor insulin signaling is dynamically regulated in this study, we performed an oral glucose tolerance test, giving mice a dose of glucose that mimics what happens under postprandial conditions. So if you ate a very high carbohydrate meal and then we looked at a readout of insulin signaling asked phosphorylation in implanted subcutaneous colon adenocarcinoma tumors and we find that the time course of plasma insulin concentrations, they as you might predict they go up quite quickly and then fall off.
Normalizing by 2 hours and asked phosphorylation in the tumor follows that pretty closely indicating that over the course of the day there might be dynamic changes in tumor insulin signaling that could contribute to tumor growth in Katy is certainly a growth factor and so this could be 1 read out of insulin being linked to tumor growth.

So based on that we performed this study, the inaugural paper for my lab published last year to test the hypothesis that hyperinsulinemia, resulting from insulin. Resistance would drive colon tumor growth in obese high fat fed mice.

In this study to test that hypothesis. We first treated animals with metformin. The most commonly prescribed anti diabetes drug worldwide and not surprisingly, we found that it lowered fasting plasma glucose and insulin concentrations to test the relevance of this reversal of hyperinsulinemia. We also took a group treated with metformin and gave them back replacement insulin by subcutaneous insulin pallet. This would allow us to dissociate plasma glucose concentrations, which of course were lowered when we gave insulin from plasma insulin?

Which is normalized with the insulin subcutaneous insulin infusion?

And what we see is that while high fat feeding has a profound impact to accelerate tumor growth metformin treatment reverses that through an insulin dependent pathway. So when we treat with metformin tumor growth rate slow to about 1/4 of what they were simply on a high fat diet and growth rates are way back up when we restore hyperinsulinemia, suggesting that this is an insulin dependent effect of metformin to slow tumor growth. Unfortunately metformin is a bit of a messy agent.

To use to test this hypothesis because it does accumulate in tumors as you likely are aware. There have been a number of studies over recent years, giving metformin primarily in vitro and actually showing a direct effect of metformin to slow tumor cell division. But the important point about that is that to get that effect to slow cell division. You have to give very, very high millimolar concentrations of metformin concentrations that would never be measured in plasma or likely tumor of patients who are treated and so to test the relevance of.
Pharmacologically relevant doses of metformin we measured metformin concentrations in plasma and tumor by mass back and find them to be quite low around 100 micromolar and when we put those pharmacologically relevant doses of Metformin. An MC 38 cells in vitro. We have absolutely no effect on cell division again, suggesting likely not a direct effect in this context.

So our alternative hypothesis that we pause. It is that instead of acting directly on the tumor that metformin is likely slowing tumor growth in high fat. Fed mice by an effect on glucose metabolism by reducing insulin responsive tumor glucose uptake and oxidation to test that hypothesis of course, we measured these parameters and we find that glucose uptake is indeed hormone responsive. It’s reduced by 50% by reversing hyperinsulinemia with metformin treatment and restored when we give back insulin.

And that’s all well and good, but unfortunately just measuring glucose uptake only tells half the story. It doesn’t tell us what the cell does with glucose once it takes it up and so to figure that out, we developed a stable Isotope, Mass. Spec method to be able to measure the ratio of tumor glucose oxidation to total mitochondrial oxidation and we find that again metformin treatment reduces that parameter by 50% and insulin restores. It importantly this is evidence against the Warburg effect being the only important.

Parameter of glucose metabolism, contributing to tumor growth because we show here that not only glucose uptake, but also oxidation is dynamically regulated by insulin.

So we believe that these data show that metformin is slowing tumor growth by an indirect effect to improve to lower plasma insulin levels. But because it is a messy agent and as I said does accumulate somewhat in tumors. We wanted to use an alternative insulin lowering agent that might be a bit cleaner and Fortunately we developed such an agent. A couple years ago and insulin sensitizer hepatic insulin sensitizer, which we call controlled release. Mitochondrial protona 4 or CRMP. This is simply a controlled release version of the classic mitochondrial.

Cortana, 4, two fourth dinitrophenol with a controlled release coding.
Because it’s an unpopular it increases hepatic mitochondrial oxidation increasing it. About 2 fold in high fat fat animals and it does so safely because of the altered pharmacokinetics when we compare the peak plasma concentrations of the toxic dose of unaltered DNP to the effective dose of CR MP. We find that peak plasma concentrations are about 100 fold lower whereas the half life of the drug is much longer. We find that the toxicity of uncouplers relates to their peak plasma concentrations in the efficacy relates to the.

Area under the curve and so this would predict that this drug would be much safer and more effective and in fact that is what we see a 500 fold improvement of the toxic to effective dose ratio simply by putting that controlled release coding and EMP.

And it works when we give it to animals mixed up in a little bit of peanut butter. It increases hepatic mitochondrial fat oxidation.

Reverse is non alcoholic fatty liver disease by burning liver fat improving hepatic insulin sensitivity, lowering gluco. Neo Genesis and reducing fasting flat, fasting and postprandial plasma insulin concentrations and of course, it’s this reversal of hyperinsulinemia. That’s most important for testing the insulin hypothesis here.

So we hypothesized of course, that controlled release. Mitochondrial Cortana for would also slow tumor. Growth in high fat. Fed mice in an insulin dependent manner by reducing tumor glucose uptake and oxidation when we treat MC 38 tumor bearing mice with this controlled release. Mitochondrial Cortana for we find that it does indeed reverse non alcoholic. Fatty liver disease and also normalizes skeletal muscle triglyceride content. Now that might be a little bit of a surprise because I told you that this agent is functionally liver targeted it.

Only increases fat oxidation in the liver and it turns out that this reversal of the diet induced increase in skeletal muscle triglycerides is also due to that reversal of Nafld. When you reverse non alcoholic. Fatty liver disease. You have a reduction in hepatic. VLDL export and that reduction in liver triglyceride export leads to this normalization of skeletal muscle content. So the Uncoupler CR MP is doing all the right things, normalizing liver and skeletal muscle fat? What does it do to plasma glucose and insulin?
Doing all the right things their CR MP reverses the high fat diet induced increases and fasting plasma glucose and insulin concentrations.

And again to test the physiologic impacted this reversal of hyperinsulinemia. We also took a group of CR MP treated mice and gave them back insulin by subcutaneous pellet when we measure tumor size. We find that high fat feeding only accelerates MC 38 tumor growth. But this is reversed by CR MP treatment in an insulin dependent manner. When we restore hyperinsulinemia. We reverse the effect of CR MP to slow tumor growth.

It also has the hormone dependant effects that you might expect and tumor glucose metabolism. We find in this model also glucose uptake and oxidation are hormone driven increased with obesity normalized with CR MP and restored by replacement hyperinsulinemia.

So CRP works and metformin works in MC 38 tumor bearing mice. What about a second model of colon adenocarcinoma here. We studied APC. Min heterozygous mice. This is a mouse model of familial adenomatous polyp. Oasys, a condition that is also exacerbated with diet induced obesity and we find in this model again. CR MP normalizes fasting plasma glucose and insulin.

It normalizes the increases in Pollock glucose uptake and oxidation that we see with diet induced obesity and this is in an insulin dependent manner because restoring hyperinsulinemia. Abrogates these effects, so these data really speak to the hormone responsive AT of tumor glucose uptake and oxidation indicating that glucose uptake and oxidation aren’t constituent if Lee High, but may actually be regulated by hormonal and or dietary factors.

But what effect does it have on the polyps well the Histology really tell the story. The polyps we can see here in Brown with this beta catenin stain. You can tell they’re much smaller in the Chow and CR MP treated animals than they are in high fat fed animals and those treated with replacement insulin.
So we’re very excited about these data. But Unfortunately our uncoupler. CR MP is not in the clinic. Yet it has just published a study in nonhuman primates. It’s looking like it’s likely to move that way or at least a derivative of this uncoupler, but it’s not there yet. So we wanted to say what could we do with an insulin lowering agent that is already in the clinic. We’ve done it with metformin, but the concern about metformin is that it acts primarily as an inhibitor of gluconeogenesis. So it will lower fasting plasma glucose concentrations and have some effect on postprandial.

But it’s not a glucose waster what we really want to do is give a drug that has a profound effect on both fasting and postprandial insulin glucose and insulin concentrations and that could just be dhapakhel flows in or another. SG LT2 inhibitor. SG LT2 Inhibitors. Of course cause. It’s pretty significant glyco Syria and so the individual gets rid of a whole lot of glucose through the urine and has a larger reduction in glucose and insulin area under the curve over the course of the day at least in mice, then we see with met Foreman and so when we give.

This SG LT2 inhibitor to MC 38 tumor bearing mice, we find again that tumor glucose uptake and oxidation are normalized in high fat. Fed Mistah Chao said rates and this corresponds to a large impact on tumor size, whereas high fat feeding accelerates tumor growth. Dappa slows it to what we measure in the Chow said mice through an insulin dependent pathway.

So we’re very excited about these this impact of insulin lowering agents and colon cancer but are these findings going to translate to other obesity associated tumor types as I showed you there are 13 tumor types. So far that have been associated with obesity and so we want to know if we may have an impact in more than just colon cancer.

And so very talented student I had working with me. Aviva did this in vitro study where she took several different tumor cell lines. Some associated with obesity on the left colon cancer breast cancer and prostate cancer and others, not associated with obesity. Melanoma B cell lymphoma and small cell lung cancer and she finds that when she incubates. These cells in physiologically relevant concentrations of insulin. There is an impact to increase the ratio of glucose oxidation to total mitochondrial oxidation.
Only in those obesity associated tumor types, but no relationship in the obesity independent ones, and what’s most important is this impact on cell division. We see a dose dependent effect of insulin to accelerate tumor cell division in the obesity associated tumor types, but not in the obesity independent.

These findings may actually translate to humans, so an excellent MD, PhD student. I have working with me. Brooks Leitner did this analysis of publicly available PET images where he compared tumor types that are associated with obesity versus not and he finds that in both head and neck, squamous cell carcinoma and soft tissue sarcoma, which are not associated with obesity. There’s no relationship between body mass index and tumor glucose uptake, whereas in small cell lung cancer, which several reports have suggested.

Obesity may actually be protective in that cancer, although that certainly still up for debate. There was a negative correlation between BMI and tumor glucose uptake, whereas in breast cancer, which has one of the strongest associations between obesity and tumor cell division. We see a positive correlation between BMI and tumor glucose uptake now. Obviously, what we’d really like to do is have plasma insulin concentrations on the X axis here and so, if there are any clinicians in the room interested in collaborating on that study. I’d love to talk to you afterward.

But these data. We think are at least suggestive of a relationship between some parameter related to obesity and tumor glucose metabolism.

So we did in the final part of the talk. I’ll show you data where we hypothesize that both of our insulin, lowering agents would slow obesity associated tumor growth in a second cancer type breast cancer in an insulin dependent manner. So here we studied mice in a mouse model of triple negative breast cancer and we treated them with CRMP and and find that again in this model of breast cancer tumor glucose uptake and oxidation are hormone responsive accelerated with diet induced obesity reversed.
And what impact does that have on tumor size well again in this mouse model of triple negative breast cancer high fat diet accelerates tumor cell division, but it’s normalized by normalizing hyperinsulinemia with CRMP.

And brought back up when we get back insulin to restore hyperinsulinemia in this model.

And Secondly with Dappa again. We find an insulin dependent effect on tumor glucose uptake and the ratio of tumor glucose oxidation to total mitochondrial oxidation that is insulin mediated.

Translating to an effective dappa to slow E0771 tumor cell division that again is insulin dependent.

And finally I’ll end with exercise, which is an intervention that we know is insulin sensitizing there have been a number of trials done both at Yale and elsewhere to look at the impact of exercise in breast cancer as well as several other cancers and we know epidemiologically that exercise is protective reduces the incidence and improves the prognosis of those with breast cancer at just about any stage but we really don’t fully understand what the mechanism for this is and to what extent it’s driven by the insulin sensitizing effect of exercise.

So I took some mice and gave them access to voluntary running wheel so that they could run anytime. They wanted it’s very impressive a mouse will run about 7 kilometers if you give it access to a running wheel, which is many thousands of kilometres of inhuman if we were to do that based on body size and this clearly isn’t insulin insulin sensitizing intervention plasma insulin concentrations are reduced by more than 50% in the exercising mice.

And so that’s a question, we’re addressing in future studies. So I took some mice and gave them access to voluntary running wheel so that they could run anytime. They wanted it’s very impressive a mouse will run about 7 kilometers if you give it access to a running wheel, which is many thousands of kilometres of inhuman if we were to do that based on body size and this clearly isn’t insulin insulin sensitizing intervention plasma insulin concentrations are reduced by more than 50% in the exercising mice.

And this slows tumor growth rates if anything, the tumor growth is looking even a little bit lower than the child fed animals. Even in these high fat fat animals that are exercising and so the next series of studies will be in my sweetie. E0771 tumors that lack the insulin receptor and so we can see to what extent this effect of exercise to slow tumor growth may or may not be insolent dependent so with that. I hope I’ve convinced you in this talk that hyperinsulinemia is indeed driving tumor growth in mouse models of breast.
And colon cancer.

And that insulin lowering agents may be beneficial in slowing tumor growth at least in part by a reversal of insulin stimulated increases in tumor glucose uptake and oxidation.

And with that I’ll close I’d like to acknowledge the folks in my lab have done a lot of this work. Our collaborators as well as our funding sources and I’d be very pleased to take any questions, you may have.

So I’ll start Rachel, the effects of the glucose and insulin lowering treatments seemed to bring it back down to baseline of the high non high fat diet. One could imagine that it could have actually gone beyond that, like the exercise any thoughts or explanations for that. It sort of reverses the high fat diet right. You know it’s never going to get it down to 0. I mean insulin doesn’t go down to 0, either when we give these interventions, it would be an?

Actually, uh the next series of studies will be to combine potentially curative therapies with these insulin lowering agents. Both immunotherapy and chemotherapy to see if we can actually cure. These animals because that’s certainly what we really want to do and it seemed like also your folks in really on the insulin affect specifically in these models exactly as well.

Your data suggests that glucose oxidation might be the important metabolic driver in this system do you have you ruled out all other metabolic pathways? Now certainly not the glucose oxidation metabolism? Is associative data? I think realistically we probably have increased or decreased glycolysis at that also tracks with increased or
decreased oxidation. There are inhibitors and activators of pyruvate dehydroge-
nase and so giving those agents in combination with these metabolic therapies
would would really be the best way to test.

NOTE Confidence: 0.859322845935822

00:19:28.340 --> 00:19:39.400 The impact specifically of oxidation have you used
other inhibitors of the DC cycle to see if you got a similar effect. Not yet but
that's that’s a great experiment and we’re certainly planning to thank you.
Thank you.