# Hi Reddit! I am Andrew Zydney, a professor of chemical engineering at The Pennsylvania State University. Ask me anything about artificial kidneys!

AmerChemSocietyAMA [1] and r/Science AMAs[1]

[1]Affiliation not available

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Transplant anesthesiologist with a few questions (also former chemical engineer!)

1) will they still be piggy backed off the iliac artery? (I assume they'll still be drained into the bladder)

2) need for long term anti-rejection meds?

3) will they need to be on anticoagulants for the lifetime of the transplant or for any period of time?

4) how did you get around the native kidneys ability to actively transport certain electrolytes against their concentration gradient?

Thanks for doing this. I have a nephrologist sister that I'm sure is far more well informed in this than me!

Suicidal_pr1est

1--The device will be connected to the normal circulation, functioning as an arteriovenous shunt (with the urine draining into the bladder).

2--We don't believe that long term anti-rejection medications will be needed since the transplanted cells are immunoisolated.

3--The requirements for anticoagulation are still to be determined. We are trying to design the flow-path in such a way as to minimize the possibility of thrombus, with the hope that anticoagulation can be reduced or even eliminated.

4--Our device does use kidney tubule cells that organize and actively transport in much the same way that these cells function in the normal kidney.

Does using an artificial membrane obviate the need for HLA and blood type matching that currently exists when considering kidney transplant matches? I inherited my father's kidney disease and although he's had his sister's organ in him for almost twenty years now, it's been decades of catching a bad cold or some stomach bug every other week, and a kind of involuntary exile indoors to mitigate the risks all his immunosuppressants subject him to.

My dream has always been to only get sick in a day and age when it would be possible to grow my own kidney again anew so I wouldn't have to suppress my immune system. Where is the state of the art in artificial tissue for kidneys? What exactly is the approach to tissue matching, do you go for 100% fidelity in recreating the chemical structure of the kidney and it's nephrons, or are there efficiencies observed in other designs that give the kidney made greater interchangeability? Finally, how likely is my dream scenario fifteen years from now or so when I get sick?

Thank you so much for your time!

zzzbra

This is a great question. The membranes in the artificial kidney actually serve two purposes. First, they are a key component of the device functionality, filtering impurities out of the blood. But, just as importantly, they effectively "immuno-isolate" the transplanted cells so that they are "invisible" to the body's immune system (both immune cells and antibodies). The net result is that immune rejection of the artificial kidney is much less of a problem than one would think -- the device is recognized by the body as being "foreign", but it doesn't elicit the type of immune response that would occur from transplanting a mismatched biological tissue.

Can you perhaps do a "Explain like I'm 5" style explanation of how you create an artificial kidney? What do you start out with? How does the building process work?

dwiynwych

The goal of the artificial kidney is to "mimic" the biological kidney as best we can. Very quickly, the kidney removes impurities by first filtering the blood (retaining blood cells and proteins, but removing all small molecules) and then re-absorbing valuable components from the filtrate (things like amino acids, water, and sugars). The artificial kidney does the same thing. We use a synthetic membrane as the filter and then use cultured kidney cells to recover valuable components while concentrating the waste stream.

I'm a third year chemical engineering student. Membrane science and separations processes have been my favorite topics so far. How did you originally get into this field and what made you interested in it in the first place?

Do you think that something like an artifical kidney will ever be a common solution to kidney problems? My research is based on using an artificial medical replacement in patients. However, I can't help but feel like the simplicity of common methods will keep our solution from ever becoming common. Do you think your solution will ever be cost effective in comparison to dialysis or a kidney transplant?

Thank you!

ermin3

I'm delighted that you have enjoyed the material on membrane separations -- I'm obviously "biased", but I find this topic fascinating.

Hemodialysis is often referred to as the "artificial kidney" -- this approach for treating kidney failure has been around for decades. Developing an implantable artificial kidney is much more challenging. However, we are optimistic that this is a viable technology that will ultimately be cost competitive to both dialysis and kidney transplants.

How far are we from phasing out dialysis?

qatanah

We have done animal testing of all of the key components of the artificial kidney, with very promising results. The plan is to start animal testing of the full device sometime this year, with actual clinical trials probably targeted for 2018. It will still be quite some time before this becomes a widely available option for treating kidney failure -- dialysis won't be phased out for quite a while.

Professor Zydney,

I am an "expert" in this particular research field, having authored a couple of modest publications on it. I've noticed that there's a lack of discussion in the literature about implantable versus wearable artificial kidneys. An implant is obviously a "sexier" proposition, but not being able to replace the filter cartridge is a hugely challenging engineering problem, as it requires the membrane to remain intact and unfowled for many years of continuous use, with the cost of failure being emergency surgery. Obviously vascular access poses its own issues, but doesn't it seem that an externally-worn, continous-use device is a much more tangible, safer goal at this stage? In other words, why jump straight to the highest goal rather than solving the slightly easier problem first?

UmiNotsuki

This is a very good point -- we have considered options for both an implantable device as well as a wearable system based on the same technology. I agree with you completely that a wearable system has some real practical advantages. On the other hand, I think it has been easier to "sell" the concept of an implantable device to various funding organizations.

In the future if you can get this down, do you believe artificial kidneys will replace the need for human transplants at some point? If so, how far off do you imagine this will be?

Endless_Vanity

This is very much the goal. Although it is very difficult to design an artificial device that performs as well as the human organ, the reality is that we simply do not have enough organ donors to provide transplants for even a fraction of the patients who would benefit. The artificial kidney would hopefully eliminate that problem.

What is it about being on dialysis that reduces someone's lifespan? Are the machines just not as efficient as an actual kidney or is it simply that the ordeal involved in getting it makes it hard for people to do it as frequently as would be necessary to fully replace working kidneys?

ChicagoBoy2011

There are many complications from dialysis. One of the key issues is that the human kidney functions every minute of the day, 7 days a week. In contrast, hemodialysis is typically done only 3 times a week for approximately 4 hr per session. The net result is that hemodialysis can never do as good a job as the human kidney. This is one of the primary drivers for the artificial kidney -- as an implanted device, it will function continuously to purify the blood, just as the normal human kidney does.

Good Afternoon Professor Zydney, and thank you for doing this AMA.

I was wondering if you could please answer two questions for me about the future of your work?

1. What level of artificial kidney function are your team hoping to achieve in the next, say, 10 years?
2. What would you expect the lifetime of the medical devices to be? Having a device that is capable of lasting long enough to be cost effective and worth the trauma of surgery must be an enormous challenge.

CompleteNumpty

These are excellent questions. Our hope is that we will have a device (within the next 10 years) that functions equivalently to the natural kidney. It is hard to guess how long such a device would last -- we just don't have enough clinical experience to make that type of prediction. Our goal is to have a minimum of 1 year -- anything less than that would probably be impractical given the challenges of implantation / removal. However, there are other options that could help. For example, it might well be possible to develop a wearable artificial kidney using the same approach, but where the device removal / replacement would be relatively straightforward.

This is awesome! Several questions.

1. What do you think might be the next artificial organ?

2. Are artificial kidneys created with the same structure besides the size?

3. When is a time, if any, that dialysis would be better than artificial kidneys.

Thanks for your work and time!

tsmooov3

There is exciting work being done on numerous other artificial organs, like the artificial liver and pancreas. In most cases, these artificial devices combine biological tissue (transplanted cells) with some type of synthetic device / system -- this is a synthetic membrane in the artificial kidney. The artificial kidney would be designed for long-term use where a transplant is not available. You would still prefer to use dialysis for acute (short-term) kidney failure.

How do you think artificial (non-living) kidneys will stack up against lab-grown kidneys in the coming years?

CrateDane

The artificial kidney that we are developing does use living cells. However, we don't try to recapitulate the entire complex design of the full organ. Instead, we take advantage of our engineering expertise to use synthetic membranes (in place of the glomerulus in the kidney) in combination with the living kidney cells. It may well be possible to grow full kidneys in the lab at some point in the future, but we definitely aren't there yet.

Hi Dr. Zydney! When I took 497C a few years ago, it helped me figure out what I'd like to do in Chem E post-undergrad. I just wanted to say thanks for the outstanding class and for being one of the best educators I've ever had the pleasure to meet.

Hensroth

Thanks for the very nice note!

First off, I'd lIke to say "hello" as I am a current Penn State undergrad.

My question is simple. What do you find the most challenging, yet most intriguing about what you do?

cgs5198

I find projects like this to be fascinating. They combine my love (and expertise) in chemical engineering with the challenges of dealing with the complexity of biological systems. And, if successful, the work has a chance to have incredible impact on people's lives.

The abstract says that the membrane performed well for 72 hours. What happened after that? Does it get clogged up or dissolve or something?

macenutmeg

The membrane does have a tendency to foul over time (although I believe in this case we simply decided to stop the study after 72 hr). We are working on a number of surface modifications of the membrane that would reduce issues associated with fouling.

Hi Professor, thanks for taking the time to answer some questions. It's awesome to be able to talk to someone who is contributing research to the field that I'm interested in.

One of the great problems with implantables, especially something involving fine filtration structures such as your kidney membranes, is biofouling by protein deposition. What, in your opinion, are the 'future' developments that we might see coming in the next few years that could help solve this problem?

AppleCrumpets

You are absolutely correct -- biofouling by plasma proteins is a major issue. The silicon membranes that we are using have an inherent advantage in that the upper surface of the membrane is very smooth (in contrast to polymer membranes). In addition, we have been examining a number of surface modifications to reduce membrane fouling. We have made considerable progress on this, but fouling may well end up being the critical factor determining the viable life of the artificial organ.

A few questions:

1) How much will an average transplant + operation cost? Will the artificial kidney have a "shelf life" in the body?

2) When will this be available for real patients? Which countries?

3) Does this technology have bigger implications for artificial organs in general? What do you think the future of membrane based technology in the next decade?

Much appreciated, Professor!

the3rdfloorguy

It's too early to estimate costs given that we haven't even done any human clinical trials.

The clinical trials are planned for the U.S., but we certainly hope that the technology is adopted worldwide once it proves to be successful.

I do think that some of the strategies that we are employing could have implications for other artificial organs as well as for other applications of membrane technology.

Are there enhancements you get with with artificial kidneys. Like once you have an artificial kidney does it do its thing better and more efficiently than a perfectly healthy normal kidney?

f_bastiat

At this point, we are simply looking to replace kidney function in individuals whose kidneys are no longer working. It is very difficult to design a device that would actually be better than a perfectly healthy normal kidney -- our kidneys are amazingly effective at what they do.

Hi Professor Zydney, Thank you very much for doing this AMA, I actually interacted with you before through paper I submitted to JMMS and your feedback led me to find better membrane fabrication method for hemodialysis membrane. Now I have defended and I want to know the latest research progress out there. I have several questions:

1) What's the major challenge you are trying to solve with your membrane, why your membrane will be better than the membrane out there in the market?

2) Is your membrane mainly for dialyzer that used externally? Are you also considering making implantable kidneys in your lab?

3) To the best of your knowledge, what methods have been proposed to improve protein-bound toxins' clearance level? Which one of them do you think is more promising?

Lisse02

The membranes that we are using in this work are made using a combination of nanolithography and MEMS techniques. They have two distinct advantages over currently available membranes. First, the pores are slit-shaped, which is actually very similar to the pore structure in the natural kidney. Second, the pores are incredibly uniform -- they are all nearly identical in size. This provides the membranes with much better selectivity than what you find in more traditional membrane materials.

Hi Prof Zydney, thanks for taking the time to do an AMA!

When creating an artificial membrane, how do you ensure it mimics the semi permeable nature of biological membranes? I presume pores must be created in the material you use to make the membranes. If this is the case how do you ensure that the membranes allow selective passage of molecules rather than allowing every molecule of a similar size through?

Pondglow

Fortunately, there is a lot of excellent data on the selectivity of the natural kidney -- we use that information to guide the design of the semipermeable membranes that we are making for the artificial kidney. Our goal is to recapitulate the function of the natural kidney as best we can.

What are the main differences between membranes for usage in kidneys vs. a desalination membrane?

Do you get much scaling or fouling with membranes?

moosedance84

Desalination membranes are designed to retain salts while allowing just water to pass through the membrane pores. In contrast, the membranes used in the kidney are designed to remove water, salts, urea, creatinine, small toxins, etc. Thus, these membranes have considerably larger pores than what you find in a desalination membrane.

Scaling isn't a problem (that's typically due to retention of minerals in desalination), but fouling by the proteins in blood is definitely an issue. A lot of the work that we have done has been focused on reducing membrane fouling by modifying the membrane surface.

How can you make a synthetic membrane that is impermeable to certain chemicals but permeable to other ones. e.i make an artificial membrane that works exactly like a biological one. Is there a synthetic na/k pump or a similar technology?

Xxslash

Although there are groups that are working on artificial membranes that "pump" (similar to biological membranes), the glomerular membrane in the kidney is actually just a filter, with no complex pumping or active transport. So, the membranes that we are using in our artificial kidney are "passive" -- they retain all of the blood cells and key plasma proteins while allowing smaller components to pass into the filtrate.

One of the most remarkable things about the human kidney is the countercurrent exchange mechanism within each nephron, allowing for concentration gradients to be formed along the tubules, creating anatomically distinct driving forces for absorption of different aspects of the filtrate.

Is this something which bioartifical kidneys are trying to mimic? Maybe before answering that, looking from a more bird's eye view, are bioartifical kidneys attempting to mimic the nephron anatomy at all? I'd love to hear what your team is trying to accomplish on a structural/mechanical level!

Cptpat

This is a difficult question to answer in this type of format. We are trying to mimic the function of the nephron, which is the functional unit of the human kidney. However, our approach is to use a synthetic membrane in place of the glomerulus, and then use functioning kidney cells to transport water (and key nutrients) out of that filtrate and back into the blood. We aren't able to mimic the details of the countercurrent exchange mechanism in the tubules, but we are able to provide comparable overall functionality.

Hi there! My background is in Physics and Electrical Engineering and I am currently studying a Master in Biomedical Engineering.

Current implantable technologies (pacemakers, Vargas nerve stimulators etc.) have a limited battery life and have to be replaced several times over patient lifetime. You mention early in your linked paper that the current RAD requires peristaltic pumps to provide driving pressure for hemofiltration. If your work using MEMS technology allows for sufficient miniaturization of the device to be implantable, how would you seek to make either the power last a long time or the device be easily replaceable? Will the membranes need replacing too, and which would come first?

So far it looks like the RAD is of purely passive design. Has there been any work towards active monitoring of blood chemistry in order to check on patient well-being? An example is a modern pacemaker that has the capability of communicating out of the patient while implanted.

Thanks!

B-Dawgy

Our goal is to eliminate the pumps altogether and drive the blood through the device using the natural pressures in the circulation (basically, using the heart as the pump just as the normal kidney does). This would effectively eliminate the need for any type of power source -- the membrane is "passive" and the kidney cells will function based on the nutrients present in blood.

maybe 15 years ago pigs were being modified genetically to make spare parts for humans that would not be rejected. any idea what the current status is of pig kidneys for transplant?????

sgtpinback

There are still groups that are pursuing the use of xenotransplants (tissues from other animals) as a replacement for human transplants. I'm not intimately familiar with all of the work in that area -- the FDA does provide an update on this field (https://www.fda.gov/BiologicsBloodVaccines/Xenotransplantation/)

In addition to the technical challenges, there are also a number of ethical issues regarding the use of animals as a source of "spare parts" and on the possibility of transmitting animal viruses into the human population.

As someone who is hopefully going into graduate school to pursue a doctorate in chemical engineering, is there any career advice that you would give?

Also, what is the time scale for projects that relate to the human body like yours?

SuperGoodLookingMan

The timescale for projects like this is quite long -- we've already been working on various aspects of the artificial kidney for over a decade, and our work built on work done by others that dates back many years earlier.

In terms of graduate school, my best advice is to find a project that really excites you and an advisor who can provide the support and mentorship that you are looking for.