PEDIAPOD JANUARY 2022 TRANSCRIPT

Geoff Marsh
Hello and welcome back to Pediapod for January 2022. This month, a new technique for estimating respiratory rates in preterm infants.

Most very preterm infants experience apneas of prematurity. It is a common comorbidity of prematurity, and therefore reliable real-time monitoring of respiratory rates is key in these infants. The conventional method is to use chest impedance measured with electrodes on the surface of the thorax. However, this method is known to be unreliable, as it is prone to motion artifacts. For this reason, indirect measurements such as oxygen desaturation or bradycardia are often necessary to identify apneas. In this episode, we meet this month's featured Early Career Investigator, Dr. Kirsten Jost at the Karolinska Institute in Stockholm, Sweden. She describes a recent study of a novel technique using a commercially available nasogastric feeding tube that measures esophageal signals and uses customized software to identify the respiratory rate of non-ventilated preterm infants.

Kerstin Jost
I was born in Switzerland and attended medical school at the University of Basel, I started my clinical education at the University Children's Hospital in Basel. At the beginning, I had a rotation to the neonatal intensive care unit, and there I had the chance to do a PhD in Biomedical Engineering. We were conducting a clinical study about the mathematical characteristics of vital signs in preterm babies. I had the luck to have very enthusiastic and motivated mentors and supervisors. So Professor Schulzke and Professor Frey who really encouraged people to link research and clinical activity and really supported new ideas. And additionally, I had the chance to visit the Department of Biomedical Engineering at Boston University, at Professor Béla Suki's lab, and I learnt a lot about signal analysis of vital signs. And through these experiences, it was toward the end of my PhD that this collaboration with the Institute for Human Centered Engineering from the University of Bern in Switzerland, was started and we then started the project that is described in the manuscript here.

Geoff Marsh
So you talk about the problem with the standard monitoring of vital signs, what can be difficult about monitoring vital signs?

Kerstin Jost
If you think about newborns, they move a lot and they have to be taken care of a lot, so nurses, doctors, parents are touching them, turning them around and that makes a lot of motion on the wires of the sensors. All these motion artifacts are really hard to be filtered out. Actually, heart rate is probably the easiest vital sign to measure because it's a very clear action, but respiration is much more difficult to capture because it has a lot of overlying frequencies that can interfere with it. So everyone in daily clinical care that works with newborns really knows that you shouldn't trust the respiration signal.

Geoff Marsh
So what is the current kind of gold standard in the NICU for assessing the respiratory rate?

Kerstin Jost
The current gold standard is surface electrodes that measure the chest impedance, which is kind of an easy method because you can use the same electrodes as you use for the ECG monitoring. But it's a very unreliable measurement because you measure a lot of motion.

Geoff Marsh
So the gold standard has got issues…

Kerstin Jost
Yes. And it has so many issues that actually, the alarm for an apnea that you want to detect is not triggered by the respiration signal itself, but by proxy signals like the decreasing heart rate, which is a secondary sign of the apnea, or decreasing oxygen saturation level.

Geoff Marsh
The manuscript that we are here to talk about today describes a new tool for measuring the respiratory rate. Tell me where this idea came from.

Kerstin Jost
The idea came from the NAVA ventilation, so the 'neurally adjusted ventilatory assist'. It's a special technique where you have this gastric feeding tube with electrodes in it and you use it in babies that are normally on a ventilator. What we did was we used this tube, but we didn't use the software and the ventilator but we built our own customized software for the project and we had non-ventilated preterm babies. We took advantage of the fact that there is a tool that is safe to use in those babies but then we built our own software to enhance the signal that we get in a different way.

Geoff Marsh
Before we get to the signal processing aspect of this work, why did you think that these esophageal electrodes would be better placed than something on the chest?

Kerstin Jost
It's really close to the diaphragm, which is the main respiratory muscle, and it doesn't have all the skeletal muscles in between. You have kind of a stable field because it's inside. And the other advantage is that if you think about it from the baby's perspective, if you don't need the surface electrodes, it will be so much nicer.

Geoff Marsh
And the second part of this study was looking at how you could improve the signal processing. Tell me first of all, about the difficulty of these kinds of signals and what your solution was.

Kerstin Jost
The difficulty is that if you imagine you have several electrodes in a feeding tube, in a very small baby, you get a lot of signals. So in this specific case, we had 10 electrodes in this feeding tube and then you get one summation signal out, which, of course, has breathing components in it, but also has a lot of other signals like the heart rate and all the normal background noise that you have on a NICU, then also skeletal muscles and swallowing, so a lot of different things are happening. The difficult thing is to really filter out the signal of interest.

Geoff Marsh
Tell me about this Kalman filtering then. How do you filter that signal?

Kerstin Jost
The advantage of an extended Kalman filter technique is that it's a model that is estimating a signal that can vary a lot, which is perfect for physiological signals. Additionally, it can integrate different signals at the same time - so as I said, we had 10 electrodes and the Kalman filter is able to take all of these simultaneously into account and then really estimate where is the signal closest to what I would assume is the diaphragmatic activity.

Geoff Marsh
And just before we hear about the results, this was a prospective, observational study, wasn't it?

Kerstin Jost
Yes this was a prospective single-center study at the University Children's Hospital in Basel, Switzerland. We enrolled 13 preterm infants, all rather stable, non-ventilated, but in need of a gastric feeding tube. And with these, we captured over 400 hours of esophageal signals, synchronized with the current standard monitoring from the NICU.

Geoff Marsh
First of all, did they successfully identify their respiratory rate? And how did you measure the success of that?

Kerstin Jost
The way we could prove if what we estimated with a Kalman filter was right or not, wasn't so easy, because the very motivation of this project was that the standard monitoring from the NICU is actually problematic, so we had to come up with another way of comparing what we thought would come closest to the truth. So we took the esophageal signals after we processed them to really highlight the respiratory activity, and visually went through them and labeled them in a customized software with inspiration and expiration peaks. Those visually annotated segments were then compared to the results of the extended Kalman filter and to the results of the synchronized NICU monitoring.

Geoff Marsh
So how did this new technique compare?

Kerstin Jost
We had a very good agreement between the extended Kalman filter estimation of respiration and the visually annotated signals so it was almost overlapping. When we compare it to the standard monitoring, there we actually saw more of a difference.

Geoff Marsh
So overall, it was closer to what we assumed to be the truth and there was less variability in the signal?

Kerstin Jost
That's perfectly said, yes.

Geoff Marsh
What further evidence would you like to gather in support of this new technology?

Kerstin Jost
I think one would have to add additional information to really find out because even if we have more babies it would give us the same information. So we would either have to have more sensors in the esophagus that could give us more information about the respiration to prove if this is actually measuring the right thing, or we would have to have another way of an getting an assured respiration detection synchronized, which is very difficult in babies, because either they're on a ventilator- then it's really easy to detect when they're breathing in and out but then that’s not natural breathing because they're on a ventilator. There are ways to measure natural breathing in babies but that means that you need a very large study setup and then you measure 10 minutes, 15 minutes so it's also not over a longer time and clinically applicable. So that's the very difficult part about this study, I would say, to actually prove that we are right.