Sleep Diagnosis and Therapy 2010; V5 N3 16–19 D. Bradley

Spotlight on Sensors

Shedding Light on the Subtle Differences in Sensor Technology that can Make or Break a Sleep Test

You may not know **Don C. Bradley**, but chances are you know his products or even worked with many of them. Before co-founding **Braebon Medical Corp**, (www.braebon.com) he created several sleep diagnostic products, including a well-known PSG system.

More than two decades of experience have helped Bradley shape Braebon's role as a single-source provider of accessories, portable monitoring/home sleep testing equipment, and PSG sensors for measuring thermal airflow, pressure airflow, respiratory effort (RIP), and body position. While all that sophisticated equipment has found a solid place in the market, Bradley is always looking to fine-tune Braebon's offerings. He and Braebon customer support are always there to assist sleep medicine professionals in their quest for the right sensor to obtain quality and accurate signals.

Obtaining Accurate Signals

At the base of all sleep units, the question is essentially the same: Is what you see on the screen an accurate reflection of what is physiologically going on with patients? The recorded and displayed signals have meaning to the trained eye, but are they reliable? If you can't trust your equipment, or know how to effectively use it, says Bradley, you have a fundamental problem. Sensors are the primary piece of equipment for obtaining signals and they must accurately reflect the physiological event being measured.

All sensors have limitations, and those limitations must be understood. Without proper understanding, you cannot expect to obtain accurate signals. The same type of sensor can use different technologies to give you a signal.

Accurately assessing the chest and abdominal effort of breathing is a basic function. When sensors are plugged into a PSG system, some technicians are simply *hoping* the filters and sampling rates are set right and that the sensor is working according to what they need. "The information comes up on the screen and you take that as gospel," says Bradley, who in addition to his role as founder also serves as chief technology officer at Braebon. "But is that really what is happening? Is there effort happening on the chest and abdomen? One cannot answer that question without having a basic understanding of the technology involved."

Quality Sensors Matter

There are many technologies and methods for measuring airflow: pressure sensors; thermal sensors; and esophageal balloons to name three. Whatever method is used, Bradley contends that quality matters. "I could go out and buy the cheapest pressure sensor, and then I could buy a more expensive one," says Bradley. "If you put a cannula on the patient and feed it simultaneously to both pressure sensors, you will see two totally different signals—yet people think if it is a pressure sensor, they are measuring accurately."

In fact, the signal from the lower quality unit will be heavily filtered, as well as baseline shifted, leading to inferior and possibly inaccurate information—which in turn can lead to a poor diagnosis. On the other hand, more expensive sensors may yield a more realistic representation, but require more initial effort to set up on the PSG system. "This isn't necessarily always the case," cautions Bradley. "It just goes to show that you need to understand the technology being used and see if you are getting the signals you want."

The effort could be worth it, because once the technology is understood better, increased accuracy will likely follow. Troubleshooting time will be reduced, and patient setup will be faster. That accuracy, says Bradley, will ultimately lead to better interpretations and improved patient outcomes.

Inaccurate data collection during the sleep study causes a domino effect that wastes the time of all concerned. Manufacturers can halt this chain reaction through renewed efforts to educate technicians about what is really going on with their devices.

In keeping with this philosophy, Braebon started offering courses to train people on the technology and show them simple techniques that can improve patient care. "For example, if you are measuring a breathing signal, don't set the low frequency filter at 1 Hz simply because it looks nice," says Bradley. "I've seen techs do that. We are also trying to improve the understanding of piezo-electric pressure sensors. The less expensive ones do not have the frequency response necessary to indicate UARS—that is, the sensor inside does not have the frequency response capability to give you an accurate signal. The signal will have premature decay because of the technology used."

You Get What You Pay for

In sleep medicine as in life, price typically goes up with quality. More expensive pressure sensors have batteries and the technology inside to give accurate signals. "As an example, if there is constant flow as in UARS, then you should see a plateau or flattening in the signal," explains Bradley. "In the piezo (non battery) type pressure sensors, you will not see this flattening. You will see a significant decaying of the signal to the zero baseline. This is due to the poor frequency response of the sensor technology used with respect to the physiological event being measured. In the end, paying a bit more for higher quality technology may be worth it."

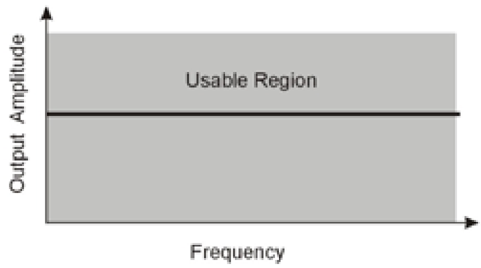

Fig. 1. Frequency response graph of what we want every sensor to be like.

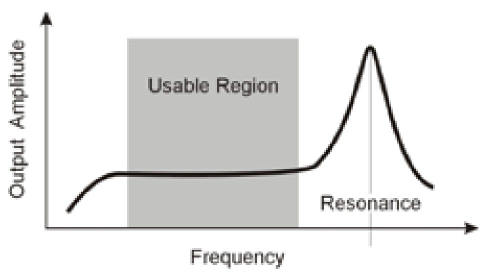

Fig. 2. Frequency response graph of a typical piezo-based sensor.

Technicians typically want sensors to have a frequency response similar to that shown in Figure 1. In this illustration, the sensor is able to output the entire input signal at all frequencies. However, Bradley points out in Figure 2 that typical piezo sensors only output signals in a specific frequency band. There is a usable region for this type of sensor, and this is why piezo sensors make good snoring sensors and poor respiratory effort sensors.

If a patient inhales and holds his breath, we want to see that signal. A piezo-based sensor will show the signal decaying to zero fairly rapidly. This is why they are not the greatest for measuring UARS. Figure 3 shows the outputs from a piezo-based pressure sensor and a Braebon PT1 pressure sensor. Both sensors were simultaneously connected to the same patient. One can see the decay in the UARS, the poor quality in the snoring signal, and the shifted baseline in the Piezo-based sensor compared to the PT1 signals.

Merely paying attention to these differences is often a foreign concept, and that can also be the case with snoring. In determining snores per hour, Bradley again casts a skeptical eye on much of the industry's existing technology. If you have the number of snores per hour, asks Bradley, then what about the effect in magnitude i.e. volume? Is it not important to know the actual change in volume when a patient undergoes therapy? That is one reason why Braebon developed the Q-Snor, as well as placing this technology within the MediByte portable sleep screener.

Within the three main types of technologies used to determine snoring, technicians can access sensors that qualitatively measure vibrations on the neck, or *qualitative* auditory signals, or *quantitative* auditory signals. "The vibratory signal may contain movement artifacts such as cardiac pulses or head movements," explains Bradley. "The qualitative or quantitative audio sensor may contain external artifacts such as talking. It is the quantitative audio sensor that can give us the most valuable information related to snoring in the patient. The quantitative audio sensor (Braebon Q-Snor) allows you to do a proper pre- and post-comparison of *both* snoring indices and change in overall volume in patients. This is paramount if one is to assess the effectiveness of certain types of therapies."

Bradley explains that understanding sensor technology is paramount in ensuring the collection of accurate signals. As an example, piezo technology cannot measure events with low frequency content. At 10 Hz or higher, a piezo sensor responds acceptably well to what is going on. "If, however, you are looking to measure respiratory effort in patients with breathing rates of between 6 to 30 breaths per minute, and look for relative amplitude changes for each breath, a piezo sensor cannot give you what you need." explains Bradley. "An accurate signal refers to not only the sensor's ability to react quickly enough to the physiological event being measured, but to also output a signal that should be linearly proportional to the physiological event being measured.

"If I inhale and then exhale quickly, you won't see the proper signal with a piezo-based sensor," continues Bradley.

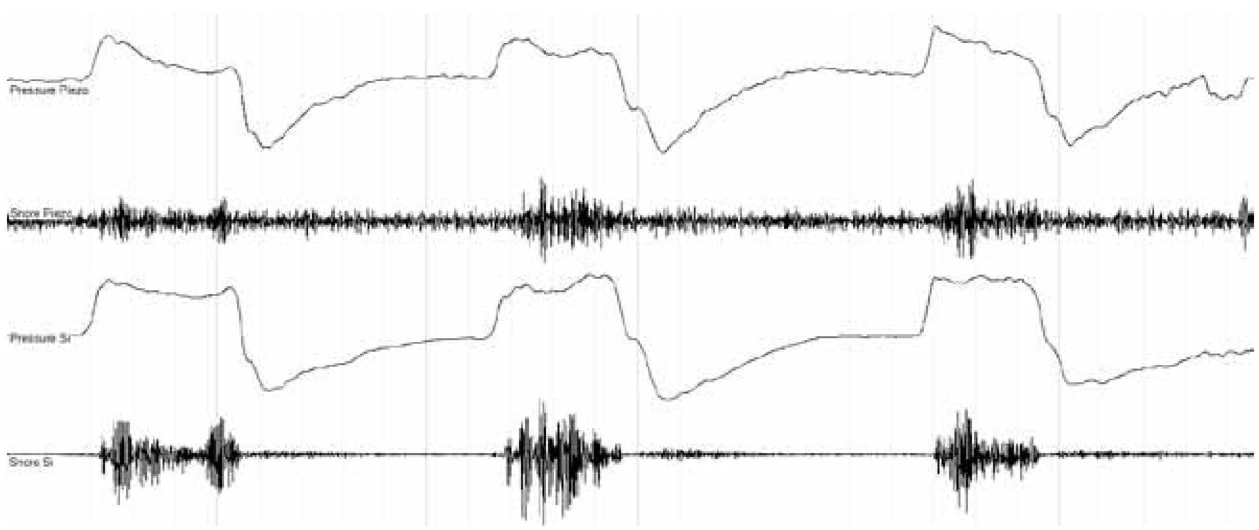

Fig. 3. Four pressure sensor showing signals from the same patient. Top two waveforms are from a piezo based pressure sensor. The bottom two waveforms are from a Braebon PT1.

"There will be a slow decay because of the filtering that has been added by the manufacturer to generate signals in the low frequency band that do not really exist. Properly developed sensors ensure that the sensor technology used generates an accurate signal. Some technologies are better than others. One must also consider the fact that just because a manufacturer states a type of technology is being used, it is not a guarantee that the sensor will accurately reproduce the physiological signal being measured."

Respected organizations such as the American Academy of Sleep Medicine (AASM) are always concerned with accuracy standards for things such as oral hypopneas. Bradley points out that the AASM did in fact come out with guidelines on oral hypopneas. Calling them "a great first stab" he laments that the guidelines could only go so far since there has not yet been enough research to substantiate measuring oral pressure.

Problems with Pressure

There are several different types of cannulae used to measure airflow to gauge the nasal and/or oral breathing component. "You've got the thermal side, so you can measure nasal and oral apneas because you've got a thermal sensor," says Bradley. "However, you don't have the oral component on the cannula, and that is something Braebon looked at and worked out. We have the PureFlow and PureFlow Duo cannulae, These cannulae have a big scoop designed to give you an accurate, almost 1:1 relationship between the nasal breathing and the oral breathing—as well as give you a reliable signal. The PureFlow combines both the nasal and oral component into one signal where as the PureFlow Duo, when working with the Braebon PT2 Dual Pressure Transducer, gives you separate oral and nasal signals. This family of cannulae will allow you to now look into oral breathing and be able to determine oral hypopneas or other phenomena that may be present in the oral signal and not in the nasal signal."

There are a lot of technical issues in trying to grab oral pressure and accurately represent it, because engineers are not dealing with an enclosed system. "You've got leaks everywhere as well as the changing shape of the oral orifice," laments Bradley. "The nasal one is a little easier because you design prongs that go in and they act like pitot tubes so you can measure the pressures and infer airflow fairly accurately. Even though people have different diameters on their nose, there is not that much of a change. But the mouth really changes shape throughout the night plus, it has been shown, people change their breathing patterns throughout the night between nasal and oral. They have even had studies showing that the person will actually change their breathing between left and right nostrils throughout the night. It is almost like we are just getting into the science of these types of things and it is all coming down to how can we easily and accurately measure the amount of air moving in and out of the patient."

Determining the inherent truth in any testing scenario can be hampered by complacency, and Bradley believes that technology has been taken for granted for too many years. The answer is a deeper understanding and a renewed focus on issues such as filters, or even the positioning of sensors. "A tech may say the body position sensor does not work, but if you have a well endowed lady and you're putting a body sensor on, then you have to be careful about how you put it on," cautions Bradley. "Many body sensors out there will report standing when the person is lying down when the sensor is not within a few tens of degrees of horizontal."

The upside of better understanding is that correcting problems during sleep tests can suddenly become easier. If a signal on the PSG goes flat, for example, it could be something as simple as sensor positioning, but all too often the problem does not get addressed as going in to fix something will take too long. "The technologist or physician may think s/he can't interrupt the patient's sleep, and I understand that," says Bradley. "But if you need accurate quality information, you can go in and fix it—and get out quickly—if you know exactly what to look for. I would rather have somebody come in and wake me up for five minutes to fix something, so I know that we are going to have accurate data at the end of the night."

It all goes back to knowing what you are working with. As another example, Bradley says he has visited a couple of labs were the filters were set so that they would get a nice looking waveform on their respiratory effort signals. The people in the lab wondered why at times there was almost no movement on the effort signals, yet they had flow and no desaturations. Ultimately, understanding the tools is critical to ensuring accurate data collection.

Speaking of Signals

As an inventor, Bradley is keenly aware of how signals are collected, interpreted, and represented. Variations in breathing, such as hyperventilation, can wreak havoc on some systems and these problems must be addressed. Indeed, with some manufacturers, hyperventilation will cause the signal to be completely filtered away. A good technologist wants to see that hyperventilation on the screen, but these limitations are often unknown until the equipment is sold and returns are a hassle.

As someone who has actually written many programs on RIP calibration, Bradley knows that unexplained signal changes can happen in some RIP systems when the output recalibrates on its own. "We take the actual output and recognize it as a one-to-one calibration," says Bradley. "You take the chest and abdomen, add them together, and look at the sum. When you use our system, you can see what is going on and get an accurate indication of what is happening. You can know whether to trust the signal or not. In other words you know when you have adjusted gain on poor effort signal and can then make a properly informed decision to ignore or fix it."

Tracking the nuances of human sleep is one thing, but predicting the future is an endeavor that Bradley and his colleagues rarely indulge. Admittedly reluctant to reveal Braebon's plans, Bradley will concede that smarter sensors are likely on the horizon. "This is something we developed with our titration sensor for manufacturer Fisher and Paykel, where you have 'brains' inside the sensor and it operates like a mini PSG system, digitizing the signal and processing the signal that is taken in," reveals Bradley. "If you are measuring a pressure, you may translate it into an accurate flow signal that comes out. This is done within PSG systems, but I think you are going to see sensors start to build up and get real time information to the technicians."

In the realm of pressure sensors, improved amplitude response could be on the horizon to accurately output a qualitative flow signal. Bradley laments that many sensors are not linearly proportional and lack a linear relationship between

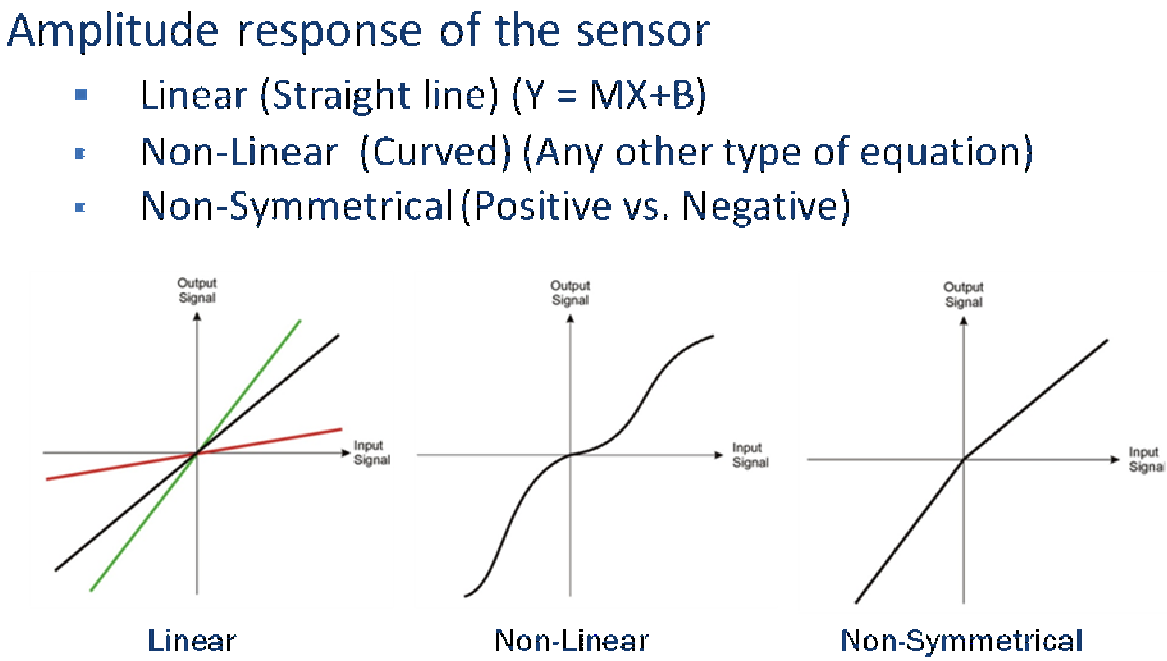

Fig. 4. Amplitude response graphs Input signal vs. Output Signal

the input signal being measured and the output signal (what the sensor is sending out [See Figure 4]). This can cause issues when trying to make decisions based on relative amplitude comparisons.

Some sensors are linear on the positive scale, but when they go negative they may end up changing the equation which equals a change in flow. "In that case, you would have a sensor that does not report on both the positive and negative side accurately," says Bradley. "This is something that nobody really goes into and asks: What is the amplitude response of your sensor? How does it work compared to the physiological conditions I am trying to measure? How does the sensor's output respond to the input? If I hold a constant flow, what is the amplitude output of the sensor? Is it linear? Is it a quadratic equation? Is it an equation that I can't even define?"

The quality of the oral/nasal cannula can directly influence the usability of information. For example, pressure loss due to a common chamber between the nose and the mouth can compromise the signal. While some techs may not understand these nitty gritty details, Bradley believes they can comprehend enough to help patients and make better choices when it comes to selecting equipment. "The bottom line is that if patients are going to undergo a medical test, they want to make sure that the person giving the test is using the best possible equipment," says Bradley. "The best equipment is also the most accurate, and that means fewer misdiagnoses."

Don Bradley is founder and chief technology officer for Braebon. He has worked in the sleep diagnostic industry for over 19 years. He has designed and developed many medical devices included PSG systems and sleep sensors and authored several articles in technical and research publications as well as given talks on technology in sleep.