Webinar Q&A Report
Invasive Blood Pressure: fundamentals and best-practices for preclinical research

1. **Does blood clot over the catheter? If so, how do you avoid this?**

   Dr. Tom Smith: If you have a solid-state catheter, this is less likely to occur. Fluid-filled manometric systems tend to have a certain amount of layering of blood into the catheter tip. As the catheter remains within the animal, each individual pressure pulse tends to move a few cells into the tip of the catheter. There is some layering of blood in the catheter which can eventually clot, attenuating pressure measurement. We routinely use a mild heparinized solution to flush catheters, but we try not to heparinize the entire animal.

   Another technique is to have a very slow infusion of fluid through the whole system, and the blood pressure waveform is superimposed upon that slight movement or gradual movement of fluid through the catheter. The rate of flow is so low that it does not generate a pressure that will artificially bias your recorded pressure. If you put in a chronic catheter and it is only intermittently opened, over time eventually that that will clot off, and there is not much you can do about it. Keep in mind that if you are doing a long term experiment during the day and the catheter system requires repeated flushing, additional fluid is being added to the vascular tree so that may or may not have an effect.

   Brandon Bucher: To some degree you will see a deposit on top of the sensing elements during recording on our solid-state system as well. The impact of that for an acute recording is relatively negligible, although the most important part is proper cleaning afterwards. Deposits make the most impact on your system if they are left over from sampling on a previous day. Dried or hard components will have a much larger impact on the quality of your measurements later on.

2. **What is shelf life of telemetry transducer?**

   Brandon Bucher: The typical shelf life for an implantable telemetry blood pressure transducer is 1 year.

3. **Can you comment on temperature sensitivity of pressure sensors? What issues should one consider, and how might they mitigate them?**

   Brandon Bucher: All pressure sensors are affected by temperature. However, because the fluid-filled catheter is external to the body at the site of measurement (continuously in the same environment), you should expect temperature fluctuations to be negligible in these studies. With solid-state systems, you should take care, to the degree possible, to calibrate these catheters at the same temperature they'll be used. This means warming them in saline at your animal's body temperature for ~30 minutes before use.

4. **In mice, we have issues with inconsistent and unstable blood pressure recordings due to anesthesia and fluctuations in core body temperature. What can we do to improve our recordings?**

   Dr. Tom Smith: Our lab has found that even isoflurane will cause a dramatic decrease in core temperature, particularly in mice. During experiments, we monitor core temperature using thermocouples and keep mice warm using a heated pad to maintain the animal at normal physiologic temperatures.

   Brandon Bucher: The best approach is simply to be aware of the effect that anesthesia has on body temperature, and compensate for that during your experiment. Most types of anesthesia will have this impact. In practice, this means monitoring body temperature and controlling that core body temperature with a warming pad or lamp. Commercial core temperature control systems are available to help in this regard.

5. **In our lab we have an issue with clotting in hard filled catheters, which can reduce the time of use of our catheters. What can we can do to improve the length of viability of our catheters?**

   Brandon Bucher: Blood clotting or deposits on a solid state catheter can be a minor issue. Typically, there is no need to use an anticoagulant during the experiment. The main approach to mitigating this is proper cleaning and care. First, never allow a catheter with deposits on the sensing elements to dry, this makes removal of those deposits much more difficult. Instead, when the catheter is removed from the animal, place it in saline directly and clean it when you have the time. A mild enzymatic agent, with a gentle approach (a Q-Tip does a great job) goes a long way to ensuring that deposits are removed before storage.

6. **What is the reusability of fluid-filled versus solid-state catheters for a typical lab, and what is the cleaning process to ensure reusability and a longer life?**

   Brandon Bucher: For the manometric system it is simple: if cleaning and reusability are a concern, you can use a new catheter each time because they are so inexpensive. With the solid-state catheter there is quite a bit of material that we provide [may want to link to this here], and your manufacturer or your supplier of your catheters can get you this information.

   The most important thing is to ensure that they're well taken care of. In terms of the reusability, solid-state systems greatly depend on how well you follow best practices, so do some reading ahead of time to get yourself familiar with the processes of cleaning and care during and after use. If you do a good job with that you will be able to reuse catheters to a certain degree. There is a wide range of success of that degree, and it really is dependent on the care and use aspect.

7. **What would you recommend for chronic LV pressure recordings in small and/or large animals?**

   Brandon Bucher: The answer here would depend greatly on the data analysis outcomes you desire. If a high fidelity signal is required (for example, systolic pressure in mice, or dP/dt), then a solid-state catheter would be highly recommended.

   For large animals, this consideration is lessened to a degree. The answer then becomes about the physical or geometrical impact of getting your catheter to the measurement site. In this case, a solid-state catheter, built with the proper material, may still be your best choice during a survival study. This is because introduction will typically be done through the femoral artery, and therefore will be better approached with a catheter that is fit for purpose, such as a larger solid-state catheter.

8. Can a small animal catheter be used in large animals?

Dr. Tom Smith: It depends on the system you're using. If you're using a catheter manometer you can lose certain degrees of fidelity by going with a smaller system; in a larger animal, a larger catheter will improve fidelity. However, you don't want to have a catheter that's so large that it occludes the blood vessel. Usually you want to have something less than fifty or sixty percent of the blood vessel's diameter. You need to think about that when you're selecting a catheter system for a large animal. If you had a solid-state device, a small or large diameter wouldn't really matter: they both would be accurate within that application.

Brandon Bucher: While this is technically possible, there are two issues to consider. First, you should consider the site of introduction and where in the vascular tree you wish to make a measurement. The smaller catheters, due to the flexibility and length of the catheter, will not be able to be introduced to any distance through the vascular tree. Second, if the catheter is much smaller than the vessel of interest, you may introduce movement artifact as the catheter is allowed to move from side-to-side, impacting the walls of the vessel. It is best to use a catheter fit for purpose in terms of size for your application.

9. In your experience, what is the effect of circadian rhythm when making blood pressure recordings? What are some ways to keep things consistent?

Brandon Bucher: There is a circadian rhythm to blood pressure in rodents. Rodents sleep during the day, and therefore have a corresponding drop in blood pressure. Best practice is to measure blood pressure from your animals at the same time during the day.

Dr. Tom Smith: The circadian cycle has a dramatic impact on arterial pressure and cardiac output in rodents, particularly rats. Lab animals are usually nocturnal, so from about 4:00 pm until 6:00 am their activity increases along with their heart rate, blood pressure and cardiac output. If one is really concerned about measuring arterial pressure in conscious animals, it is probably best to do a reverse light-dark cycle and to do all your studies in the dark. Otherwise, make your measurement at the same time of day and be aware that animals brought down during the day were sleeping.

10. Do you have any successful experience with mouse femoral artery when using the micro-tip catheter? The average weight of mice is around 25g.

Brandon Bucher: The smallest solid state catheters (1F) should be more than suitable for a mouse femoral artery. Once you begin getting larger on the scale (>1.4F), this will become more difficult.

11. Does direct measurement using a transducer inside the vessel make the maintenance of the catheter better, or is there no difference?

Brandon Bucher: Maintenance between a manometer system vs a solid-state catheter system is just different all together. Solid-state sensors introduce a necessity for cleaning and care that just isn't a requirement for a manometer based system. The reason being that a PE catheter can easily be replaced, with very little cost.

12. Do we need to continuously infuse saline to avoid fluid loss in rodents? Does it affect blood pressure response?

Brandon Bucher: The best way to avoid fluid loss is a solid surgical technique. Through careful vessel exposure, and a good technique for the introduction of a catheter into a blood vessel, you should be able to minimize fluid loss to a degree that it is negligible to the measurement.

13. How does the surgical or experimental procedure of acquiring data change between manometer/catheter systems?

Brandon Bucher: There is very little difference in procedure between manometer-based blood pressure systems and solid-state catheter systems. Both are introduced using the same surgical procedure, and generally follow a similar calibration procedure as well. The major difference will simply be in preparation. Manometer systems will need to be physically prepared, filled with saline, and attached to the transducer. Solid-state catheters are best prepared by soaking in body temperature saline before 30 minutes before calibration and use.

14. In your experience is it possible to obtain measurements of BP in a conscious (without anesthesia) but restrained mouse with a solid-state catheter?

Brandon Bucher: While this is technically possible, this would not be a recommended method. The reason being that keeping an animal wired for a duration that allows recovery from surgery, and avoids physical stress on the site of introduction of the catheter is an incredible challenge. It would be best to consider the trade-off for your experiment. If conscious recording is most important, then choose a telemetry system for your experiment.

15. What type of measurements require the higher fidelity you talked about offered by solid state catheters?

Dr. Tom Smith: If you want to measure an accurate systolic and diastolic pressure, you should use a solid-state system. It's really asking a lot of a catheter manometer system to be able to accurately measure systolic and diastolic pressure in the mouse. I think your first clue whether you have adequate fidelity is whether or not you can see a dicrotic notch within your waveform, particularly if the mouse is conscious.

If the animal has a high basal heart rate or if you are testing a drug which causes an increase in heart rate, you may want to use a tether or something similar. If you're testing a sympathomimetic drug causing an increase in both heart rate and arterial pressure, that could be very difficult to measure on the manometer catheter system, and you really would require a solid-state pressure transducer.

Brandon Bucher: The best way to know which pressure measurement system is right for your procedure is to try it first. Acquire some data, look at the outcomes you desire from the experiment, and decide whether or not the data produced from the lower quality systems is sufficient for your experimental aims. In general though, anything that requires a high fidelity in either amplitude or timing will benefit from a solid-state system. It is asking a lot of a manometer to acquire systolic and/or diastolic blood pressure with any degree of accuracy.

If you have additional questions for ADInstruments regarding content from this webinar or wish to receive additional information about their instrumentation for invasive blood pressure measurement, please contact them by phone, or click here to make a general inquiry.

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