On the Relationship Between Impedance, Site Size, and Unit Activity

We are often asked by customers how impedance relates to unit activity. For example:
"Does NeuroNexus offer probes similar to the standard ones we usually buy but with higher impedance? Would increasing the impedance make a smaller sampling region (i.e., less cells which would increase the chance of spike discrimination?)."
Or
"What is the impedance of the probe? Based on my previous experience with (tungsten) single channel wire electrodes, an electrode with impedance of XX works well."

A common misunderstanding for new users (coming from the wire electrode technology) is to request probes based on impedance. Impedance values are used by wire electrode manufacturers to approximate the exposed tip area, which is the main factor in determining the suitable type of signal that may be recorded. Since NeuroNexus probes are fabricated using microfabrication techniques, the exposed site area is precisely controlled, and impedance alone does not necessarily determine the ability to discriminate units. If you had two electrode sites with the exact same surface area, and one had higher impedance, your ability to discriminate units would actually be less in the higher impedance site due to the increase in thermal noise.

$$\upsilon_n = \sqrt{4k_B T R \Delta f}$$

The RMS υ_n (the voltage due to thermal noise) increases as the square of the impedance (R above). For a 1 MΩ electrode the voltage due to thermal noise is ~10 µV, whereas for a 200 kΩ electrode the voltage due to thermal noise is ~5 µV.

If you are getting multiunit activity and would like to discriminate more single unit activity, we suggest using a probe with a smaller site size. The smaller conductive surface area will result in a higher impedance; however, this can be ameliorated by surface modification of the electrode site with deposition of an iridium oxide layer (called "activation" by N2T). Since the electrode sites are smaller, the "listening sphere" is smaller, you may record from a smaller number of units, and thus your unit discriminability will be higher. The "listening sphere" is smaller ONLY because recording from a dipole (neuron) is a function of distance; the electric field for a dipole falls as a square of the distance from the source ($1/r^2$). A large electrode site is closer to more dipoles (neurons) than a small electrode site simply because the large electrode site has a greater surface area and thus exposed to more neural tissue. Larger electrodes sites (1250 um^2) are generally better for chronic (weeks to months) recording, whereas smaller electrode sites (177 um^2), are generally better for acute experiments trying to get only single unit activity (with only one-two neurons recorded on a given site).

For microstimulation, the relationship of impedance to charge carrying capacity is VERY IMPORTANT. See accompanying document: Intracortical Microstimulation with Microelectrodes.

[1] IEEE Trans Biomed Eng. 2000 Jul;47(7):911-8. Chronic neural stimulation with thin-film, iridium oxide electrodes.Weiland JD, Anderson DJ.

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