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Concentric ion selective microelectrodes for accurate measurement of dynamic volume changes of the extracellular space during epileptiform activity

During neuronal activity, the brain's extracellular space (ECS) undergoes fast, dynamic volume shrinkages. When measuring such changes, slow detection can underreport ECS shrinkage. To detect volume changes in the ECS, an ion selective microelectrode (ISM) is used to quantify the concentration of an ECS specific probe introduced into the ECS. Detection of an increase in the probe's concentration by the ISM reflects a shrinking of the ECS volume. ISMs require the use of an ion exchanger to detect the probe. This ion exchanger possesses inherent high resistance properties that slow the detection of the signal and undercut true measurement values. Recently, while observing post-traumatic epileptiform activity in the neocortex of ex-vivo brain slices in rat, we have reported a phenomenon of rapid volume pulsation of the ECS volume with shrinkages as high as 26%. However, these measurements used traditional double-barreled ISMs that require the signal to traverse the entire length of the exchanger column in the ISM. These initial observations using traditional ISMs may therefore underestimate the true magnitude of ECS shrinkage during epileptiform activity.

To accurately capture the amplitude and time course of ECS volume shrinkages during epileptiform activity, I am implementing concentric ISMs which have shown response times twice as fast as traditional ISMs due to their unique design. Concentric ISMs use an inner barrel which is advanced through the exchanger to within a few micrometers from the outer barrel tip. This enhances response time in two ways. First, minimizing the distance the signal must travel through the exchanger also minimizes the resistance by the exchanger. Second, the inner barrel adds distance from the surrounding bath, reducing capacitance of the electrode. The use of concentric style ISMs is expected to provide more accurate measurements of ECS volume shrinkages and better report ECS dynamics occurring during epileptiform activity.