Introduction:

Each year, it is estimated that close to 400,000 people die from sudden cardiac death (SCD). A primary cause of SCD stems from rhythm disorders, or arrhythmias, where the normal electrical conduction system of the heart is disturbed. When the ventricles (bottom chambers) of the heart fibrillate, death is often the result. When the artria (top chambers) fibrillate, though death is typically not a result, many adverse health effects can follow. A common cause of either type of fibrillation is the existence of abnormal areas of conduction within the heart, which alters the normal "electrical circuit" of the heart. A standard treatment for atrial fibrillation has become radiofrequency (RF) ablation, in which thermal energy is provided through a long, string-like catheter, and the abnormal conduction area is burned.

Though RF ablation does have a high reported success rate, it can introduce its own variety of problems into the heart muscle. RF energy has been seen to induce damage to tissue surrounding the target area. In addition,

To counter many of these issues, cryoablation has become a preferred method of ablation to treat arrhythmias in humans. This method uses a similar catheter system to RF ablation, but instead of supplying heat to the tissue area, cryoablation removes heat from the tissue by freezing it. When cells in the heart are decreased to a certain temperature, ion channel activity decreases, which causes a decrease in the rate of depolarization in those cells, and thus reduces thier electrical activity. As long as the cell temperatures do not drop below certain a threshold, this process can be reversed, allowing the use of cryotherapy to be used as a diagnostic tool, known as cryomapping. This reversibilitiy at somehwat moderate temperatures provides one large advantage over RF ablation. The second main advantage is that cryoablation, though damaging to the target cells, leaves the extracellular components of the cells intact, therby minimizing the effects on actual heart structure.

Though cryoablation has certainly shown promising applications for clinical use, there are a number of unanswered questions that remain. Cryo-Console machines apply a complicated system of refridgerant phase-changes to remove heat from the target tissue. By the laws of cooling, the spatial gradient of cooling falls off in a linear manner from the point of the cooling source. As a result, we would expect the temperature mesured directly at the source of cooling, would not accurately represent regions in in the proximity of the source, even within millimeters. Because the cryo-console hardware's own temperature-sensing system is located within the tip of the catheter, we would then expect that the temperature will be significantly less than the actual temperature at the point of contact between the catheter and the tissue. In addtition, the presence of blood flow could amplify this difference by introducing convective warming around the target area. Further investigation is necessary to quantify this discrepancy.

Methods:

The model organism for use in this experiment will be the pig. Pig heart tissue will be prepared in roughly square-inch pieces, and perfused in a saline-containing bath, held at 37 degrees Centigrade, to model physiological conditions. Because standard thermometry equipment fails in the cryo-range, we will use custom fluoroptic probes, calibrated from minus 80 to 50 degrees Centigrade. The probes will be placed at varying depths, then inserted into the tissue directly underneath the point of contact between the cryo-catheter, and the tissue. The catheter will be placed directly on the surface of the tissue, and cryo-therapy will be run for either four or five minutes. A water pump will be introduced to simulate blood flow over the tissue at varying speeds, and the correspoding temperatures at different depths in the tissue will be imported into LabView for analysis. We will also import the temperatures from the cryo-console, for comparison with the probe temperatures. Finally, for each run we will measure the lesion-size created by freezing, and compare this data to previous studies using RF ablation.

Possible Results:

Preliminary tests show that the sensors within the catheter may read as low as -85 degrees while the tissue is only -50. Adding to this discrepancy, is the convective flow of blood which we would expect to cause an even more significant difference in the two measured temperatures. Measuring the tissue temperatures at various depths around the target site, we expect the probe directly near the catheter to drop to the lowest temperature, but also have the greatest response to increased saline flow rates. We also expect that the lesion size is reduced and less pronounced in appearance, versus RF ablation.