Cooling Device for Transesophageal Ultrasound

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Abstract
The purpose of this design was to create a cooling device for a Philips X7-2T 3D transesophageal ultrasound probe. The device should be small enough to fit into the esophagus of a swine model when attached to the probe, and should keep the internal probe temperature at a steady state value below 42 degrees Celsius. A prototype of this device was fabricated using vinyl tubing, low-density polyethylene (LDPE) and Tygon tubing, and was tested both in vitro and in vivo. The prototype successfully held the internal probe temperature below 42 degrees Celsius in each test by holding the temperature at a steady state value. An unexpected device at the end of the probe requires our device to be smaller than originally designed. However, the design is easily modifiable and has shown great promise as an external cooling device of the Philips X7-2T probe.

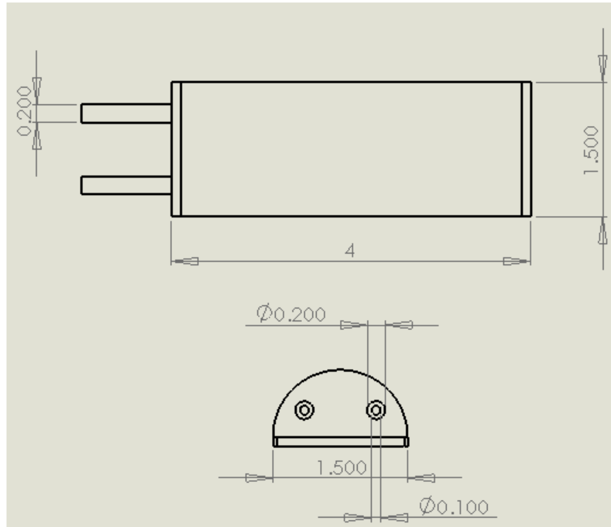
Introduction
The UW Department of Medicine is conducting research to determine if direct injection of mesenchymal stem cells, isolated from bone marrow, can be used to regenerate dead heart tissue and cardiovascular disease. A typical procedure begins by inducing heart attacks in swine models, which creates regions of dead tissue in the heart. Then a catheter is used to inject stem cells into the regions of cell necrosis in the heart.

During this process an ultrasound imaging device is used to determine the location of the catheter in the heart. Currently a Philips X7-2T ultrasound machine is utilized. However, each procedure is very time consuming due to large areas of dead myocardial tissue requiring numerous injections.

Due to the long duration of the procedure the ultrasound machine shuts down due to overheating. This is due to a safety mechanism which turns off the ultrasound machine if the internal probe temperature reaches 42.5 degrees Celsius. Therefore, a device was created to keep the ultrasound probe at a steady state temperature below 42 degrees Celsius.

Materials and Methods
The materials used to build the cooling device were 2mm diameter Tygon tubing, 1.5cm diameter polyvinyl tubing, and low density polyethylene film. The polyethylene film was cut into a 6cm by 6cm square, the polyvinyl tubing was cut in half and then cut down to a length of 4cm. Two pieces of Tygon tubing were cut to 1m in length. The Tygon tubing was then attached to the polyethylene film using polyethylene spray adhesive. The two pieces of Tygon tubing were placed approximately 1cm apart from each other. These two tubes will serve as the inlet and outlet tubes of the reservoir. The polyvinyl tubing was then attached to the polyethylene film using polyethylene spray adhesive. The polyvinyl tubing was placed around the outside of the inlet and outlet tubes. The polyethylene film was then wrapped around the polyvinyl tubing and sealed shut with polyethylene spray adhesive. This formed a reservoir around the polyvinyl tubing. The final dimensions of the reservoir are 4cm length, 1.5cm width, and 0.5cm height as shown in Figure 1.

Figure 1. Schematic of reservoir design. The input and output tubes control the flow of saline as the saline fills the reservoir and cools the probe.



The cooling device was attached to the back of the ultrasound probe using surgical tape. The entire reservoir was wrapped in surgical tape to ensure secure attachment. In order to achieve flow through the device, adapters were used to connect a saline bag to the inlet tube. The saline bag was then elevated on an IV stand and gravity caused the saline to flow through the reservoir.

Testing was performed in vitro by using a water bath kept at 37 degrees Celsius to simulate body temperature and placing a container filled with beef inside the water bath to simulate tissue. The container with beef was left in the water bath until it maintained a constant temperature of 37 degrees Celsius. The ultrasound probe was then inserted into the beef and temperature measurements were taken every 30 seconds. On the ultrasound machine, it is possible to set different patient temperatures, affecting the temperature response of the probe. The above procedure was used with a set patient temperature set of 39 degrees Celsius for a control. The same procedure was then repeated twice, but with the cooling device attached to the tip of the probe using room temperature saline. Drip rates of 108 drips/min and 48 drips/min were for the two tests. Temperatures vs. Time graphs from the above testing were obtained to see how the cooling device affected the temperature of the probe at each drip rate.

Results

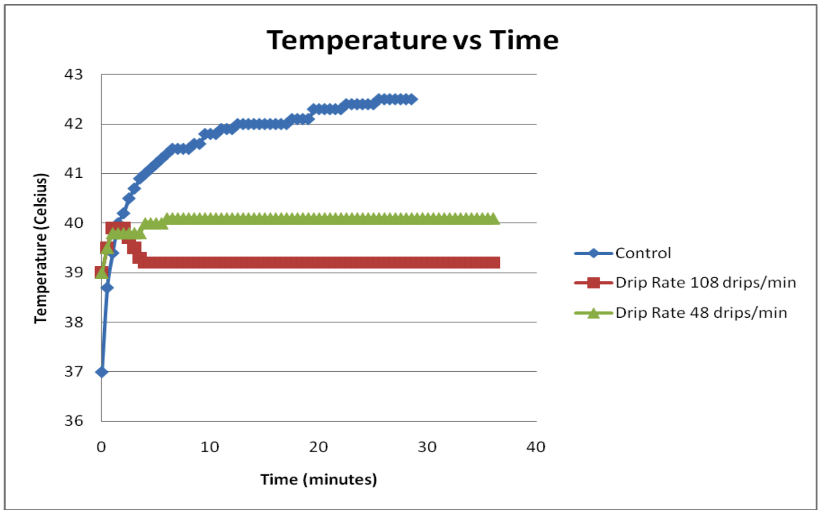


Figure 2. Probe temperature over time without the cooling device, and with the cooling device set at two different drip rates.

As displayed in Figure 2, the control shut off at 29 minutes due to overheating. At a drip rate of 108 drips/min, the cooling device was able to keep the probe at a steady state temperature of 39.2 degrees Celsius after 4 minutes. When the drip rate was 48 drips/min, the cooling device was able to keep the probe at a steady state temperature of 40.1 degrees Celsius after 6 minutes.

Discussion

The testing revealed that, with the cooling device, the probe is able to reach a steady state temperature below the 42.5 degrees shutoff point. Therefore, one would be able to perform the lengthy procedure with live 3D imaging without the potential of the probe overheating with this device.

Although the cooling device was able to maintain a steady state temperature in vivo, more work is necessary due to a few remaining design flaws. First, the prototype was not fully watertight, and minor leaks were observed during testing because the polyethylene spray adhesive did not fully seal the LDPE around the tubing that enters and exits the reservoir. Solvent glues or other adhesives are unlikely to work for this due to the flexibility of both the tubing and LDPE and the chemical resistance of their surfaces. In the future, it would be desirable to have a seal that allows the user to manipulate the device without fear of leaking. The best approach to solve this problem would be to use a heat treatment to seal the device, using an open flame or other heat source to melt the LDPE to the tubing.

Another complication that occurred during testing was due to an EM tracking device that was attached to the probe in addition to the cooling device. With this additional device attached to the probe, the probe tip was larger than specified and damaged some of the esophageal tissue. In addition, the surgical tape used to attach the prototype seemed to have rough edges when wrapped around the tip. This could be potentially harmful when used on a live subject. Thus, a new method of taping the device to the probe may need to be found or a smoother tape may need to be used. With these modifications and a method for mass production, this design could potentially be produced as a disposable cooling device for ultrasound probes or other devices with cooling needs.

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