TRANSIENT WARMING RATES OF 250ML CRYOPRESERVATION BAGS
OBJECTIVES

1. Characterize the temperature profiles of 250mL blood bags filled with 70mL of liquid during sample extraction using automation and manual methods.

2. Quantify the warming rates for non-targeted cassettes in a shared rack or frame.

3. Compare and contrast the temperature profiles of samples extracted manually to those extracted with automation.

METHODS

Omega brand Thermocouples were placed inside of Chronen CS250 cryopreservation bags. The bags were filled with 200mL of colored water using a syringe to simulate blood or other biological fluids. The thermocouples were then sealed inside of the fluid-filled bags using hot glue. Each bag and thermocouple were then placed inside a Custom BioGenics ZC021 cassette. All probes were plugged into a data logger and temperature data was taken every second for the duration of each test.

A sample preservation cart was created by placing an aluminum plate and frame into a larger, insulated freezer. The plate was raised by the frame below it from the bottom surface of the freezer. The freezer was then filled with LN2 such that the bottom surface of the plate was in contact with LN2, but the top surface was dry. This cart served as a staging location during manual extraction. Automated extraction did not require a staging location.

Manual Extraction:
5 samples were placed into a Custom BioGenics 9-place frame for ZC021 canisters. The frame with samples was then placed into a Chart MVE 1800 freezer filled with LN2 and allowed to habituate overnight.

Automated Extraction:
One sample was placed into the second from the top shelf of an automation-friendly rack and placed into a Chart MVE 1800 freezer and allowed to habituate overnight. This shelf was chosen to characterize the thermal experience of all other samples in the rack because it is the shelf second furthest away from the targeted shelf and will thus spend a greater amount of time exposed to ambient temperature while being further away from the large metal top plate of the automation friendly rack. Preliminary testing found that the top shelf of the rack experiences a small decrease in warming rate when compared to the second shelf due to the large thermal mass of the top plate. The times when: the lid of the freezer was opened, the frame was removed from the freezer and placed into the sample preservation cart, the frame was lifted from the sample preservation cart to return to the freezer, and when the freezer lid was closed, were recorded. The sample rack was lifted from the freezer manually and held in ambient for approximately 30 seconds. The time to examine the rack was chosen to simulate how a worker might search for barcodes or labels to ensure the correct rack has been pulled from the freezer. The rack of samples was then placed into a fully charged sample preservation cart. An additional 30 seconds was allowed in the cryopreservation cart to account for a worker searching for the targeted sample, which was then removed from the frame and left in the sample preservation cart. The remaining samples and frame were then lifted from the sample preservation cart and placed back into the freezer. Temperature data was logged until the sample temperatures were within approximately 10°C of their starting temperatures.

RESULTS

Manual Extraction:
A plot of the temperature over time during a manual-extraction shows that the non-targeted sample in the frame is exposed twice to ambient temperatures: Once when the frame is first removed from the freezer and placed into the sample preservation cart, and once more when the frame is removed from the preservation cart and replaced into the freezer (Fig. 3). From the time the freezer lid was opened to when the samples were placed into the sample preservation cart, there was a rise in temperature of 16.3°C. From the time the samples were removed from the cart and the lid was closed, there was an additional ΔT of 9.0°C. After the samples were returned to the freezer and the lid was closed, there was a final rise in temperature of 1.1°C due to elastic warming. In total, there was a maximum ΔT of 26.9°C from the moment the freezer lid opened to when maximum temperature was reached.

Automated Extraction:
A plot of the temperature over time of a sample in the top shelf of an automation-friendly rack during an automated extraction shows a single exposure to ambient temperature (Fig. 4). From the time the freezer lid was opened to the time it was closed after extracting the targeted sample, the non-targeted sample experienced a rise in temperature of 1.1°C. The sample experienced an additional ΔT of 2.9°C due to elastic warming after the lid had closed. The total ΔT experienced by the non-targeted sample was 4.0°C.

This was experimentally determined to be the time required for the automation to eject a sample and for a waiting user to remove the sample from the system. Temperature data was logged until the sample temperature was within 10°C of its starting temperature.

CONCLUSIONS

Temperature Profiles:
As shown in figure 5, the total change in temperature for a non-targeted sample extracted using automation in an extreme use case was approximately 80% lower than that of a non-targeted sample extracted using standard manual methods. This is likely due to the second exposure of non-targeted samples during the return to the freezer from the preservation cart and to the increase in time required to extract the rack manually. It was also found that the elastic warming of a non-targeted sample was greater using automation than using manual methods. This is likely due to the difference in the two styles of racks. The manual frame has a much lower thermal mass due to its smaller size and lower number of shelves. The greater thermal mass of the automation-friendly rack led to an increased elastic warming, but also a decreased total ΔT for the sample.

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