SCIENTIFIC POSTER PRESENTATION AWARD

Evaluation of Extracorporeal Blood Heat Exchanger Devices

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Keywords: Extracorporeal circulation, heat exchanger, efficiency

Abstract

An accurate and easy to use test circuit has been developed for the performance evaluation of the heat exchangers used in cardiac surgery during extracorporeal circulation. The water part of the heat exchanger is fixed at a flow rate of 15 l/min and at a temperature of 40°C. In the blood side, the flow rate is varied from 1 to 6 l/min and the temperature is 30°C. The use of a precise thermometer (precision 0.01°C) and of a microcomputer permits efficiency with a good reproducibility. The results obtained show a real improvement in the efficiency of the new extracorporeal blood heat exchangers devices.

Introduction

A heat exchanger is a system used in extracorporeal circulation (ECC) that lowers the patient blood temperature during the ECC and increases it at the end of the operation.

It consists of a water circuit separated from the blood circuit by the surface of the heat exchanger, where TWO represents temperature of the water out, TWI represents temperature of the water in, TBI is the temperature of blood in, and TBO is the temperature of the blood out.

A great number of heat exchangers are available with a very wide range in efficiency. The principle behind heat exchangers has been defined by Galetti (1), Peirce (2), Reed (3), and Riley (4).

New heat exchangers have been recently developed and have been tested in order to evaluate their relative performance.

The main parameters that must be taken into account are:
- the material (metal or plastic)
- the thickness of the heat conductor
- the thermal conductance in cal/sec/cm/°C
- the heat conductor area
- the heat lost to environment
- the priming volume
- the mean blood path thickness
- the blood and water path resistances
- the effect of water flow variation on efficiency
- the efficiency of the heat exchanger

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To be precise, a comparison must take all these parameters into account. The evolution of ECC has led to the development of different kinds of heat exchanger devices, integral to the oxygenator or otherwise. In such conditions, it is difficult, even sometimes impossible, to isolate the heat exchanger for proper tests.

One very important parameter that can be tested in all cases is the heat transfer efficiency, which is defined as:

Efficiency = (TBI-TBO) / (TBI-TWI)

TBI - blood input temperature
TBO - blood output temperature
TWI - water input temperature

Material and Methods

For the measurements (Figure 2), the flow rate in the water circuit is fixed to 15 l/min and varied from 1 to 6 l/min in the blood circuit. It is through this protocol that the effect of flow rate variation in the water circuit was not tested.

The three temperatures are measured with Yellow Springs Instruments (a) (YSI) thermistors, matched in order to be reliable with 0.01°C. To ensure comparable values, the same electronics were used to measure the three temperatures. A multiplexer is used to connect the probe to the electronics, thus ensuring the same measurement error is done on each temperature signal. A Cole-Parmer (b) portable thermistor thermometer (Model 8502-16), with three channels and one analog output was employed. Because there is only one analog output, the signal corresponding to this output is the one displayed by the liquid-crystal display of the device. In order to change the channel display to change the analog channel output.

The thermometer is coupled to an Apple (c) microcomputer, in order to achieve more easily the calculation of the efficiency. A 10 bits analog to digital converter is used with a full scale of 0.41 volt corresponding to a range of 41°C for the analog output of the device.

In order to maintain absolute reliability between all heat exchangers, water was utilized on both sides of the heat

a. Yellow Springs Instruments.
b. Model 8502-16, Cole-Parmer.
c. Apple II, Apple Computers, Inc.

Figure 1

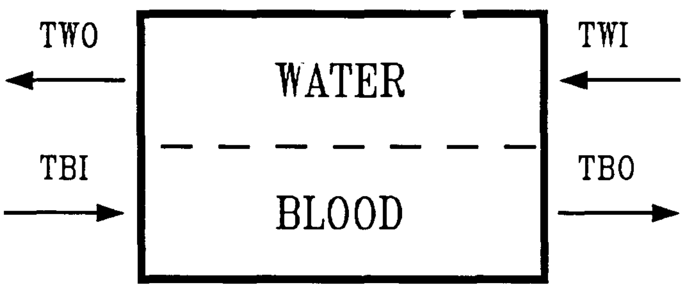
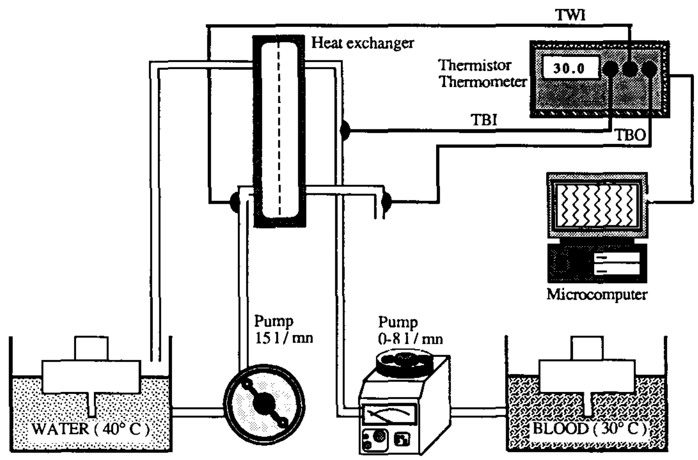


Figure 2



EFFICIENCY MEASUREMENT SYSTEM

Figure 3

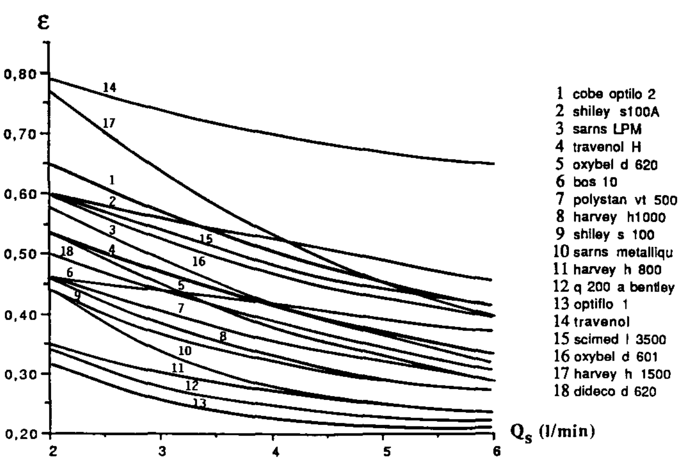
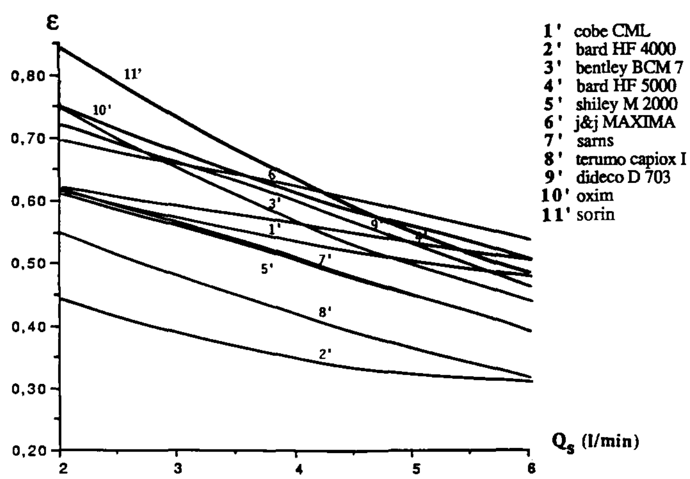


Figure 4



exchanger instead of water to blood. Since the conditions are the same for all the heat exchangers tested, the relative values are the basis for comparison.

The test circuit includes (Figure 2):

- a stand for tubing, valves, mounting of the heat exchanger to be tested.
- a 100 liter tank of water regulated at 40°C for the water part of the heat exchanger
- a 60 liter tank of water regulated at 30°C for the blood part of the heat exchanger
- four-probed thermistor thermometer with display and analog output
- an Apple II microcomputer for the calculation and the display of the procedure.

During the test procedure, the water pump flow rate is fixed to 15 l/min for the water part, and the water pump (blood) is varied from 1 to 6 l/min.

The measurement procedure is as follows: the temperature of the inlet water as measured by the thermistor thermometers is displayed and validated by the user on the microcomputer keyboard. Then the same process is repeated for the water (blood) inlet temperature. The display of the outlet water (blood) temperature is recorded in real time and the efficiency of heat exchange is obtained by calculator.

Currently, only static efficiency in a steady state position is being measured. This is accomplished in the following manner: TWI, TBI and the water (blood) flow rate are selected and allowed to stabilize before the measurement begins. In this way, the time response of the heat exchanger to varying blood flow rates can be taken into account. The efficiency is measured for different flow rates varying from 2 to 6 l/min. The advantage of our measurement system is its great precision and stability.

Results

The results show that in the normal range of blood flow rate which is from 4 to 6 l/min,, the heat exchangers of the previous generation performances than the ones of the new generation (Figure 4). In addition, the new ones have closer performances than before.

Conclusion

Great improvements have been made in the design of heat exchangers, such that they now really present values which are quite similar in efficiency. We have now an operational test circuit, which is easy to use and tests all the new heat exchangers, with ease, accuracy and good reproducibility.

References

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