11. Induction of Hypothermia

Human metabolism is supported by biochemical processes that require a minimum temperature to function normally. When body temperature falls below that level, the person enters a state of hypothermia. If the temperature continues to fall, neurons in the brain will be unable to maintain their function and the person will eventually lose consciousness.

The following classifications of body temperature correspond with terminology often used in experimental and clinical literature:

Mild hypothermia:	32-36 degrees Celsius
Moderate hypothermia:	28-32 degrees Celsius
Deep hypothermia:	18-28 degrees Celsius
Profound hypothermia:	5-18 degrees Celsius
Ultra profound hypothermia:	0-5 degrees Celsius

While hypothermia is hazardous and potentially fatal to human beings, during cardiac arrest it can provide a therapeutic benefit. When the heart stops beating, lack of blood flow deprives cells of oxygen and glucose, leading to a toxic cascade of reactions that can ultimately result in destruction of the cell. Metabolism now becomes a life-threatening process instead of a life-sustaining process, and hypothermia can delay cellular injury by slowing the metabolic rate.

For this reason, when a standby team intervenes following legal death, the first priority is to cool the patient. *Unlike some other stabilization procedures, induction of hypothermia is not optional.* The primary goal of a standby team, after death is pronounced, is to reduce the patient's temperature as quickly as possible to a theoretical optimum approaching 0 degrees C.

Care must be taken not to go below that temperature until the patient has received cryoprotection, as ice formation will cause serious injury.

Figure 11-1 shows a comparison between different methods of cooling during an Alcor case. Surface cooling is much less effective than intravenous cooling, but it is still very important, especially because it can begin immediately and requires no surgical skills. Intravenous cooling, which typically occurs during blood washout, will be discussed in detail in Section 16.

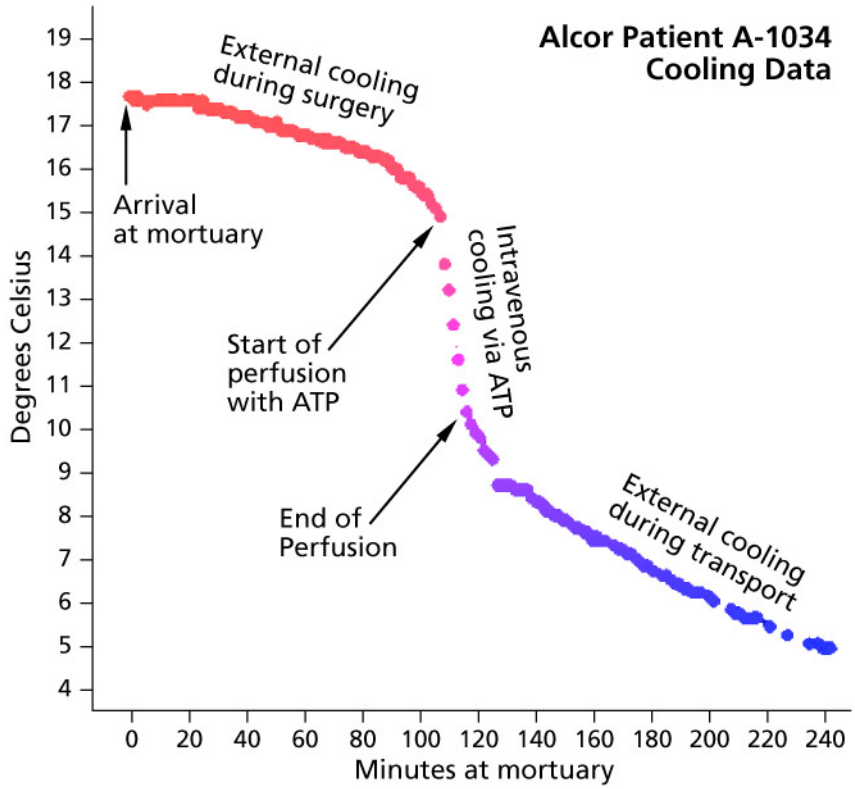

Figure 11-1. External cooling vs. intravenous cooling during an Alcor case. ATP refers to the Alcor Transportable Perfusion equipment that was used for many cases in the 1990s through 2000s.

The Physics of Cooling

To cool a patient effectively, team members must understand what cooling really means. When we "make something cold," what we are really doing is creating pathways for heat to flow out of the object.

If the object is warmer than its environment, heat from the object will tend to flow into the environment. The object will become cooler and the environment will become warmer until they reach thermal equilibrium. Heat always tends to flow from a warmer place to a cooler place, just as water tends to flow from a higher place to a lower place.

The flow of heat can occur in three ways:

- Convection (heat is picked up by a circulating gas or liquid)
- Conduction (heat travels through a solid object or liquid)
- Radiation (heat radiates from a warm object into its surroundings)

Imagine a patient resting on a bed in a room where the air temperature is 20 degrees Celsius. The patient's body temperature is 36 degrees, so heat will be transferred from the patient into the room. Currents of air will take some heat away through convection, and the patient's skin will lose some heat by radiation. Additional heat will be lost by conduction into the mattress of the bed, although this will not be very efficient, since a mattress is not a good thermal conductor.

All of the processes in this scenario will be relatively slow. Thus if a patient dies unexpectedly and remains undiscovered without intervention, the toxic cascade of harmful reactions in the brain will proceed in the absence of significant hypothermia, and will do a lot of damage.

A simple way to intervene is by immersing the body in very cold water. The patient will now cool faster, because

- The temperature difference between the body and the water is greater than the temperature difference was between the body and the air.
- Water conducts heat faster than air, by thermal conductivity.
- Water can also absorb more heat with less temperature rise, as it has greater heat capacity.

In fact, the ideal scenario for external cooling would be to arrange that every square inch of a patient's skin is chilled with water at a fraction above 0 degrees Celsius.

As heat in the patient's body is conducted into the water, the water will become warmer, especially in areas close to the skin. We can improve cooling by circulating the water with a pump, so that the warm boundary layer around the patient is disrupted and replaced with colder water.

We can also add ice. *As ice melts, it absorbs heat without increasing its temperature.* The heat that ice absorbs, known as the latent heat of fusion, loosens the atomic bonds that maintain its crystalline structure. Melting 1 gram of ice requires 80 times as much heat as raising the temperature of 1 gram of water by 1 degree Celsius.

A mixture of ice and water is ideal for a cryonics patient as it automatically maintains a temperature slightly above 0 degrees Celsius until all the ice has gone, and provides the fastest method of external cooling that is also consistent with safety. The patient cannot freeze, because the melting ice cannot make the patient colder than itself.

Note that the core of the patient will still contain heat, and this heat must travel outward through the patient's brain and body to the skin before it can be taken away. In fact the thermal conductivity of a person puts a limit on the effectiveness of external cooling, and a larger patient will take much longer to cool than a smaller one.

In some cases, the cooling process has been accelerated by introducing cold liquids inside the body. Internal cooling is more efficient than external cooling (as shown in Figure 11-1) because it reduces the distance that heat in the core of the body must travel to reach the cooling agent. On the other hand, all methods of internal cooling require some preparation or medical skill, while external cooling can be applied almost immediately by people with minimal training.

Deploying an Ice Bath

Ice and ice-cold water are usually administered by immersing the cryonics patient in a portable ice bath while using a pump to recirculate ice-cold water

over exposed skin areas through perforated tubes. The portable ice bath is often referred to as a PIB, and the surface-cooling device may be referred to as an SCCD (Surface Convection Cooling Device) or, more often, a “squid.” Additionally, a helmet or face mask may be used with the SCCD to apply water to the head and face of the patient through perforations.

Figure 11-2 shows a mannikin that has been placed in an ice bath for training and demonstration purposes. The ice bath has a steel frame with a gray vinyl watertight liner. A battery-powered LUCAS device has been installed to apply chest compressions, the small gray box at right is an air compressor ventilating the patient, and the black helmet is cooling the head via recirculated ice water.

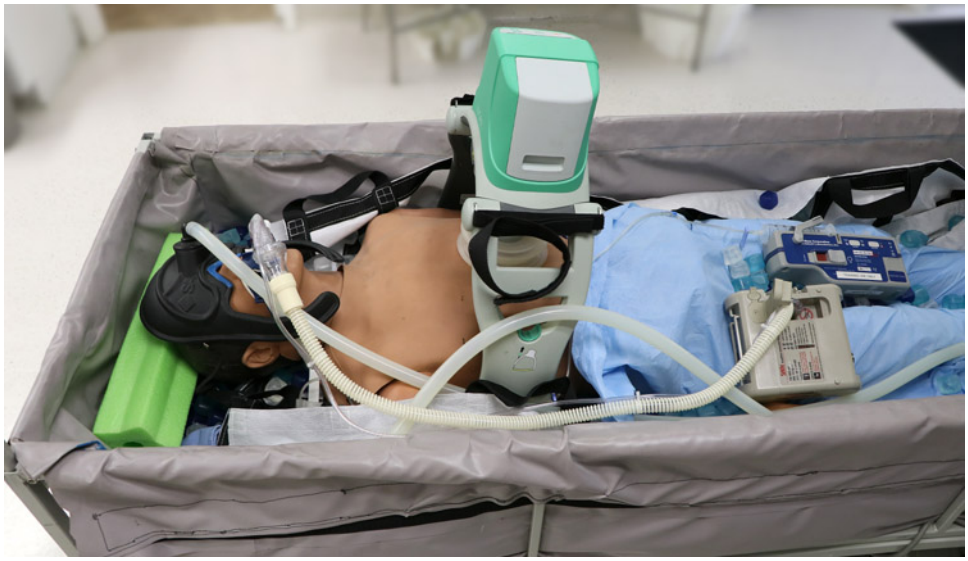

Figure 11-2. A mannikin in an ice bath at Alcor Foundation.

Many ice-bath designs are illustrated at the end of this section, all sharing the same design goal: to enable a patient to be cooled with at least 40 kg ice (about 100 lbs) and 20 liters of water (about 5 gallons) while cardiopulmonary support circulates blood and ventilates the lungs, and medications are administered. (Sections 9 and 10 have explained cardiopulmonary support. Section 13 will discuss medications.)

Some ice baths have been designed to collapse into a package that can be transported as baggage on an airline; others are noncollapsible, for deployment in a ground vehicle. Some have legs, for easier access to the patient; some rest at floor level, and can be transported in a vehicle where there is limited head room.

At the beginning of a standby, an ice bath should be placed as near to the patient as circumstances permit. This may require diplomatic negotiation with medical staff or relatives. Once the team has received permission for deployment, they must assess the area carefully to make sure that the ice bath can be removed when the patient has been moved into it with water, ice, and equipment. Stairs should be avoided, as they will require tipping the ice bath, which can release a flood of water. Elevators must be able to accept the full length of the bath, and it may have to negotiate corners in hallways. A few ice-bath designs have telescopic or hinged end sections that can reduce the length of the bath temporarily to make it more maneuverable.

A fully loaded ice bath generally requires at least three people to move it safely, especially if it must be lifted over steps or a curb.

After the ice bath has been placed near the patient, ice should be kept nearby in insulated picnic chests. Some melting is acceptable, but during a protracted standby an accumulation of water should be drained from each picnic chest and the ice should be refreshed once each day. As much as one-quarter of the ice will melt inside a picnic chest during each 24-hour period, if the chest is in a warm environment.

Using the Ice Bath

Any clothing on the patient should be removed after pronouncement, as it will inhibit cooling and may interfere with other procedures. If a lifting sling is available to facilitate transfer, the patient should be rolled onto one side, the sling should be spread out on the bed, and the patient is then rolled back onto the sling.

The patient will be most easily moved if the ice bath can be positioned end-to-end with the bed (not alongside the bed), and team members can line up on each side to raise the lifting sling.

An ice bath containing a lifting sling is shown in Figure 11-3.

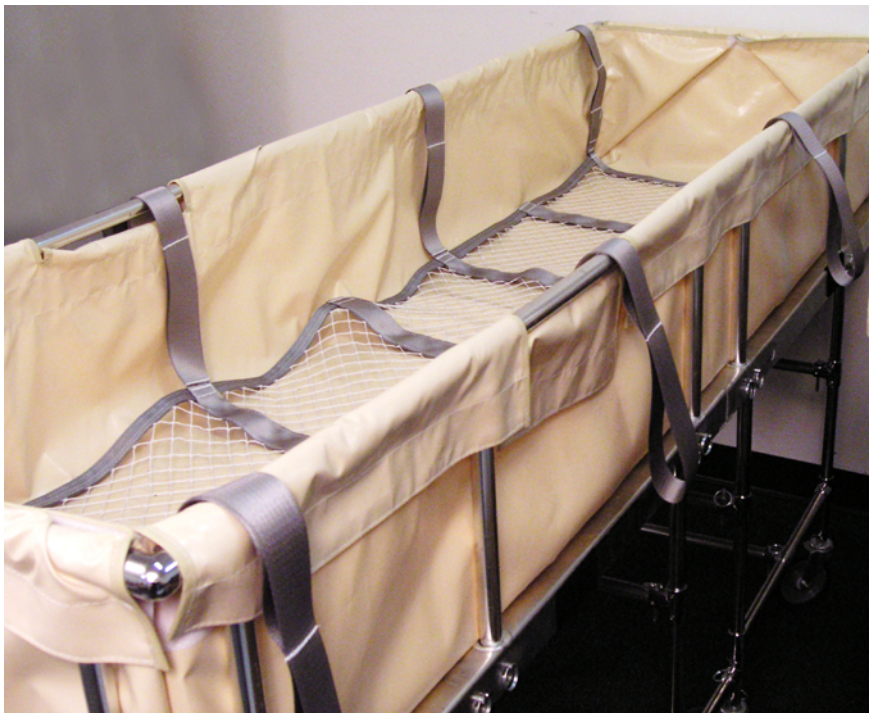

Figure 11-3. A lifting sling fabricated from nylon webbing and netting is shown in an ice bath at Suspended Animation, Inc.

Do not place any ice in the ice bath before moving the patient. You do not want ice under the patient during cardiopulmonary support.

As soon as the patient is in the ice bath, all available ice should be added, together with approximately 5 gallons of water, which should be sufficient to cover the base of the submersible pump that supplies the SCCD (assuming the ice bath is on a level surface).

Ice should be placed around the patient's head first, but be careful not to allow ice or ice-cold water to interfere with temperature readings from thermocouple probes that are inserted into the ears or nostrils.

Ice in bags is "less messy" than loose ice, but will not cool as effectively. Air pockets tend to exist inside the bags, and will act as an insulator. Also, water tends to gather inside the bags, and since the water will remain there without circulating, it too will slow the cooling process.

Bagged ice is necessary for packing patients when they are prepared for for shipping, to reduce the risk of water leaking from a shipping container. But bagged ice is not appropriate for initial cooling.

Cover the patient as thoroughly as possible. When in doubt, add more ice! Shaved or crushed ice may cool more effectively than cubed ice, but is not so widely available. Regardless of the form of ice that it used, team members should break up any large chunks before adding them to the ice bath. The contents of ice bags can be broken up by banging the bags against the floor before opening them.

As soon as the ice has been added, the SCCD tubing should be distributed over the exposed (upper) skin surfaces with a preference for head, neck, axilla, and groin. The submersible pump that supplies ice-cold water through the tubing should be placed under water at the foot of the ice bath, and should be switched on. Figure 11-4 shows a battery-powered SCCD kit that was developed at Suspended Animation, using sections of perforated tubing that are color coded to aid in plugging them together.

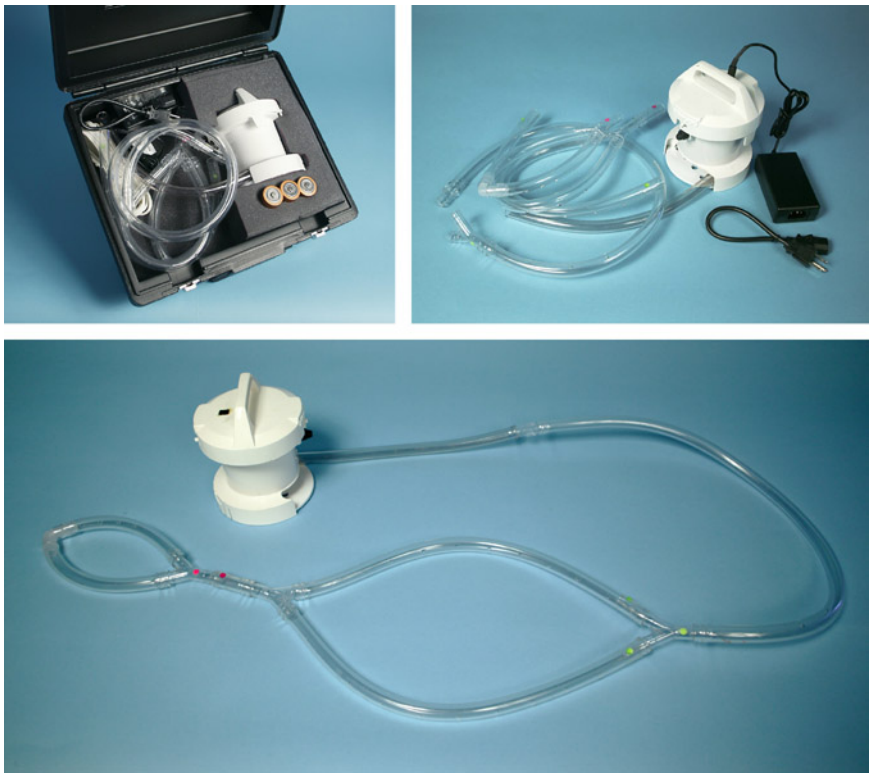

Figure 11-4. An SCCD device consisting of sections of perforated tubing that are supplied by a submersible pump. Although the pump is battery-powered, a socket for an external power supply has been added. The loops in the tubing are for the patient's head and chest, the larger loop fitting around the plunger on a chest-compression device.

A recent design of face mask is shown in Figure 11-5. It is a hollow shell with perforations in the interior surface.

Figure 11-5. A mask to promote cooling of the head. Water is introduced in the threaded bushing and is released via perforations underneath the mask.

The relative efficiency of different methods of external cooling is illustrated in Figure 11-6, which shows cooling curves for three Alcor patients. Patient A-1133 weighed 56.8 kg, patient A-1169 weighed 57.3 kg, and patient A-1049 weighed 36.4 kg. A smaller patient will naturally tend to cool faster than a larger patient, but still the use of an SCCD appears to have made a positive difference.

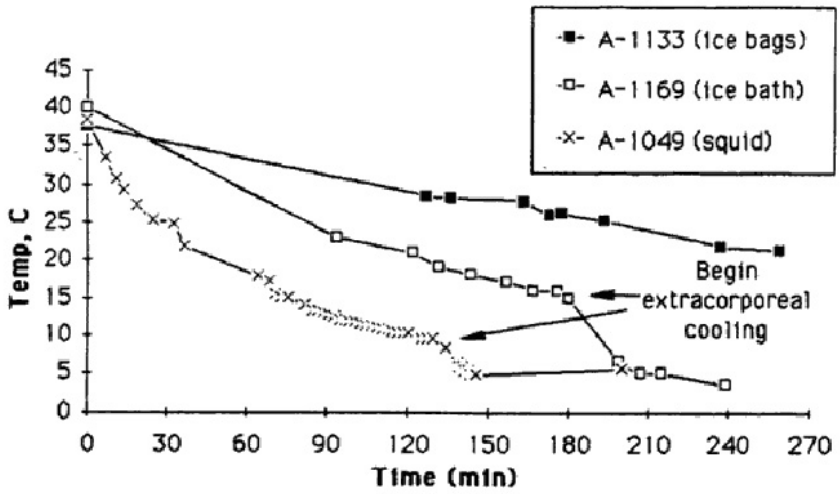

Figure 11-6. Comparison of cooling methods..

Chest compressions also accelerate the cooling rate, by circulating warm blood from the core of the patient to the capillaries near the skin where heat will be removed. Chest compressions should usually continue actively while external cooling is being applied.

Improvised External Cooling

If an ice bath cannot be used or is unavailable, team members may improvise a substitute by placing the patient inside a body bag (if one is available) before adding ice and water. Note that the bag will become difficult to move after large amounts of ice and water are added.

Body bags come in different weights, depending on their purpose. Lightweight bags are often found in mortuaries, and are not designed to hold heavy weights of ice and water in addition to the patient. However, this type of bag may be usable if it rests on a lifting sling.

If no body bag is available, the patient may rest on any hard, level surface, and under these circumstances ice may be applied in ziploc bags. Once again, cover the head first followed by areas where large vessels are close to the surface, such as the anterior neck, the axilla, and the groin. If only a limited quantity of ice is available, it should be applied to the head. Be sure

to shift and turn the ziploc bags frequently, to maximize contact with unmelted ice.

To avoid the drawbacks of bagged ice, the patient's head can be immersed in a basin with water ice. Such a device can be made by cutting a neck-size groove in a picnic chest.

A major disadvantage of cooling only the head is that if chest compressions are applied, cooled blood will circulate from the brain down to the body, and warm blood from the body will circulate up to the brain. Since the need for chest compressions may vary depending on factors such as the patient's medical history, the availability of medications, and the time that has elapsed since pronouncement, the team should consult a medical advisor before reaching a decision regarding chest compressions when insufficient ice is available to cool the whole body.

Inducing even a relatively small drop in temperature (around 2 or 3 degrees Celsius) is worthwhile. This means that if a standby team is not present, a patient may still benefit if relatives or friends pack the head and, ideally, also the body in ice. Unlike other stabilization procedures, external cooling with water ice entails little risk of error—provided, of course, no one should attempt to intervene until after the patient has been pronounced.

Remember that while hypothermia is very desirable after pronouncement, it is dangerous to anyone who is still alive.

Internal Cooling

Methods of internal cooling include:

- Chilling large-volume medications before they are infused.
- Infusing chilled saline solution or ice slurry into the circulatory system.
- Gastric, colonal, or peritoneal lavage.
- Ventilating the lungs with a chilled breathable liquid ("liquid ventilation").

- Placing the patient on extracorporeal bypass and passing the blood (or a blood substitute) through a heat exchanger before it recirculates throughout the patient.

Chilled Medications

Unless this cooling method is complemented with others, the temperature drop that can be achieved is minimal.

Note that mannitol, which is used to prevent and reverse swelling of the brain and to protect brain cells from harmful free radicals, should not be cooled below room temperature as this will result in the formation of crystals. This is discussed in Section 13.

Infusions

Suppose we make a gross approximation, assuming that the patient possesses about the same specific heat as a saline solution (i.e. they both require the same amount of heat to increase their temperature by the same amount). Suppose we infuse 1 liter of fluid, weighing approximately 1 kg, into a patient weighing 70 kg with a body temperature of 36 degrees. In this example, a drop in temperature of 0.5 degrees in the patient will be sufficient to raise the temperature of the infused liquid by about 35 degrees. Therefore, even if a saline infusion is near 0 degrees Celsius and the patient is near normal body temperature, and even if the saline is circulated uniformly throughout the body, the most we can expect to achieve, from a one-liter infusion, is to cool the patient by half a degree.

If an ice slurry is used it will be much more effective, because the ice will absorb latent heat in the process of melting. However, the salinity of the slurry must be comparable to that of the body (i.e. pH and osmolality must be comparable). If pure water is introduced to the veins of the patient, the result will be edema—swelling of organs such as the lungs and the brain, and bursting of the cells

Ice slurries have not been used in any cryonics case at the time of writing.

Care should be taken to insure that the patient is not overloaded with fluids. The human body can accommodate some variations in fluid-to-mass

ratio without harm, but the team leader should consult the cryonics organization's medical advisor before attempting intravenous saline infusions.

Lavage

Derived from the French word for "washing," the term "lavage" is used in medicine to describe introducing a cold fluid into an organ of the patient. In gastric lavage, fluid is introduced to the gastrointestinal system; in colonic lavage, the colon is used; and in peritoneal lavage, fluid is introduced under the lining of the abdominal cavity. In a landmark CryoCare case in 1995, peritoneal and colonic lavages were used in conjunction with circulating ice-cold water to achieve unprecedented cooling rates. This is illustrated in Figure 11-7.

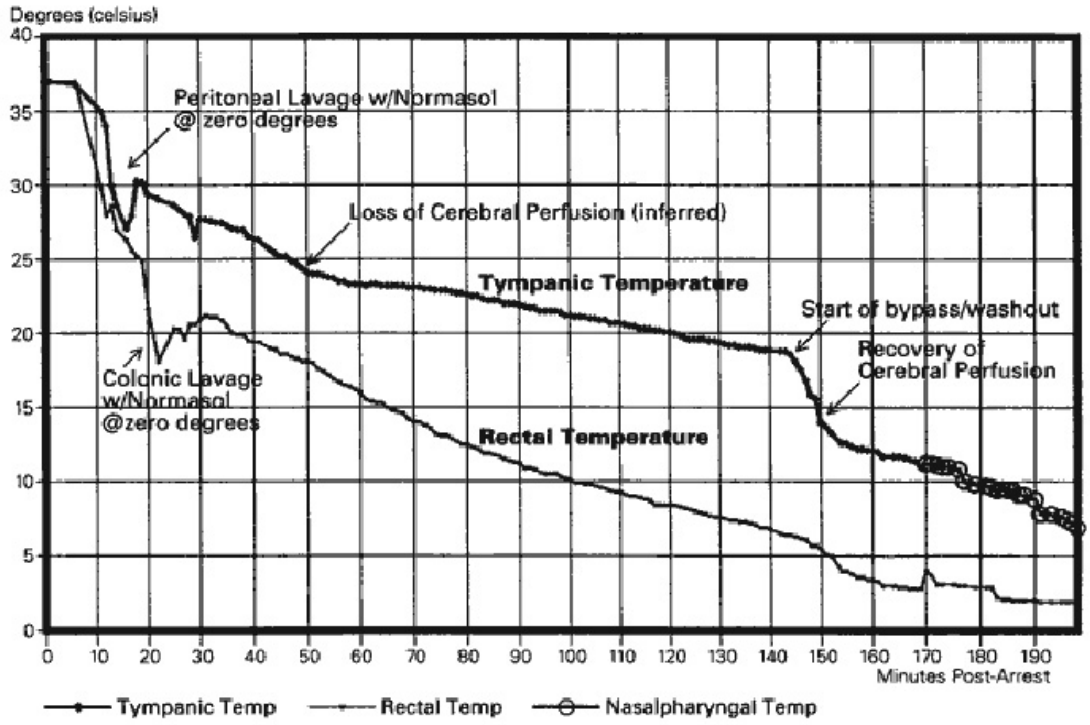

Figure 11-7. The effects of multiple cooling strategies on a CryoCare patient under the care of Biopreservation, Inc.

Lavage procedures should not be attempted by most team members because they require invasive techniques such as gastric intubation or surgery.

For example, during peritoneal lavage, a catheter is used to introduce a chilled solution to the peritoneal cavity through a small incision below the umbilicus. In gastric lavage, a gastric tube is used to introduce a chilled fluid to the stomach of the patient.

Liquid Ventilation

A special case of lavage is the infusion of a chilled breathable liquid into the lungs. Although commonly referred to as liquid ventilation, this procedure may or may not include oxygen dissolved into the liquid that enters the lungs.

See Section 12 for a detailed presentation on liquid ventilation.

Extracorporeal Bypass

In conventional medicine, during operations such as heart surgery where the patient must enter a state of cardiac arrest, a surgeon accesses the circulatory system so that blood can be piped through an external pump before being returned to the body. This procedure is known as extracorporeal bypass, and is often referred to as “placing the patient on bypass.” The process of introducing liquid into the circulatory system is known as perfusion, and the person who runs the bypass equipment is a perfusionist.

Since the blood can pass through a heat exchanger in addition to the pump, bypass is a very efficient way to reduce the temperature of a patient. In fact, it can achieve faster cooling rates than any other method. In a cryonics case, bypass is also used to substitute an organ presentation solution or, if neuro-vitrification is the chosen strategy, a vitrification solution.

Typically in a whole-body cryonics case, access is obtained via femoral vessels in the upper thigh. Raising and cannulating these vessels requires surgical skill and may take half an hour or more, during which external cooling should continue. Almost always, the patient will be moved from a hospital, hospice, or home setting to a suitable location where surgery can be performed, such as the prep room of a mortuary or a specially equipped vehicle. For these reasons, other cooling interventions should be used initially, and bypass should be reserved as the last step before transport of the patient to the cryonics organization.

If neuro-vitrification is done, access is via the carotids.

Other Methods of Cooling

Just as ice absorbs heat in the process of melting, water absorbs heat in the process of evaporation. In fact, the quantity of heat that will change a liter of water into vapor is about seven times the quantity required to melt a kilogram of ice. In military medicine, patients suffering heat stroke have been cooled by spraying them with water which is then evaporated by fans or helicopter rotors. However, body temperature and ambient temperature must be high for this procedure to be effective, and it is generally not practical in cryonics applications.

Non-invasive brain cooling techniques include cooling through the sinus cavity. Although these techniques could slightly increase the cooling rate of the patient, the practice of placing the patient in circulating ice water and surrounding the head with ice should incorporate most of the benefits of such cooling methods.

One approach that is gaining in popularity in contemporary medicine is the use of endovascular cooling, in which the temperature of a patient is dropped by directly cooling the blood through an endovascular catheter. Instead of circulating the blood outside of the body (as in extracorporeal cooling), a catheter with circulating coolant (cooled saline) is placed into the patient's blood stream through central venous access. The efficiency of such endovascular cooling catheters can be increased by careful attention to design, materials and operating principles. For example, heat exchange can be increased by circulating the coolant countercurrent to the flow of blood. Despite the encouraging advances of these technologies for the induction of hypothermia in a clinical setting, these technologies are not practical during cryonics stabilization because they invariably come with a bulky control and heat exchange unit.

Temperature Measurement

Measuring and recording temperatures during stabilization procedures is important, because the rate of cooling is an excellent indicator of success in protecting the brain from injury. It also yields data that we can use to compare the effectiveness of different cooling techniques in different cases.

The skin temperature of the patient is of little interest, since the skin should be covered in ice or ice-cold water and therefore should be near 0 degrees Celsius. Our primary concern is the "core temperature" of the patient. To obtain this noninvasively (i.e. without inserting a probe into the brain itself) we have two options:

- Nasopharyngeal probe: A thermocouple wire inserted into the sinus cavity.
- Tympanic probe: Measures the temperature of the ear drum.

Swimmer's wax is used to secure these probes and prevent ice-cold water from entering the nostrils or the ears.

In addition, for comparison, it is useful to have another record of internal body temperature, and for this purpose we use a thermocouple wire mounted in a rectal plug. The plug is inserted into the rectum as soon as the patient is placed in the ice bath, and an inflatable collar around the plug prevents it from being dislodged. The collar also helps to prevent leakage of fecal matter into the ice bath, and should prevent ice-cold water from entering the rectum and creating a false temperature reading.

The output from each thermocouple probe is plugged into a temperature logging device, which should be enclosed in a waterproof box that will accompany the patient through subsequent stabilization procedures and during transport to the cryonics organization. This is especially important when the patient is shipped before cooldown has been completed, or when the patient travels as air cargo during summer or winter months and may be in a high-temperature or low-temperature environment for sustained periods.

Quantifying the Benefits of Cooling

Regrettably, if we assess case histories during the past decade or more, we find that good temperature data often have not been recorded. Typical problems include:

- Probes were incorrectly placed.
- Probes were not securely placed, and became dislodged.
- Probes were contaminated with ice-cold water.
- Probes were never plugged in to a data logger.
- The data logger was not set up properly.
- The data logger was never started.
- The data logger was left out of the shipment.
- The batteries in the temperature logger failed.

These errors are understandable in that personnel may be fully occupied with procedures for intervention, during which data logging may seem a low priority. Still, data is essential to evaluating the outcome of a case.

Let us suppose that we do obtain good temperature data showing the rate of cooling during the stabilization. To make sense of this data, we need to know:

- What is an acceptable cooling rate?
- What would be an optimal cooling rate?
- What conclusions can we draw regarding brain preservation?

In ideal circumstances we want to cool so fast that energy will not be depleted and the brain remains viable by contemporary criteria. In reality, such cooling rates cannot be achieved through external cooling. However, one of the authors (de Wolf) has found that a cooling rate of about 0.18 degrees Celsius per minute is sufficient to inhibit the development of the so called

"no-reflow phenomenon" in the rodent model. This cooling rate is within reach when aggressive external cooling is combined with vigorous cardiopulmonary support.

Because there are no known adverse effects of high cooling rates, there is no limit on the rate that cryonics organizations should strive for. The faster the patient is cooled, the better. The calculation of an optimum cooling rate, using very conservative assumptions, is shown below.

Even the combination of rapid cooling and mechanical cardiopulmonary support may not be sufficient to prevent energy depletion of cells, especially when stabilization is followed by long transport times (cold ischemia). In such cases the best that can be hoped for it to prevent structural injury to the brain so that there will be little guesswork necessary as to the patient's memory and identity in the future.

The Q10 Rule

A very simple rule suggests an approximate relationship between temperature and metabolic rate. This is the "Q10 Rule," which states:

For every 10 degrees Celsius drop in temperature,
the metabolic rate decreases by 50%.

We can think of this as meaning that the rate of damage to cells in the brain decreases by a factor of 2 for every reduction by 10 degrees. A simple table will show this more clearly:

Patient Temperature (degrees Celsius)	Metabolic Rate (1=normal)
35	1
25	1/2
15	1/4
5	1/8

This rule may vary between species and in different organs and cells, and may not tell the complete story, because even modest reductions of brain temperature can have profound neuroprotective effects. Still, the Q10 rule is very useful for evaluating the benefits of cooling in cryonics because of its simplicity and its conservatism.

Other Systems of Measurement

Two authors have attempted to develop formulas to evaluate brain injury more accurately when hypothermia is induced.

In *Cryonics* magazine (2nd Quarter, 1996) R. Michael Perry contributed an article titled "Toward a Measure of Ischemic Exposure." Perry's Measure of Ischemic Exposure (MIX) calculates how long the patient has been at a given temperature, with a higher weighting used for higher temperatures. For example, using an exponential rule, one hour at 0 degrees Celsius corresponds to a MIX of 1, 1 hour at 10 degrees Celsius corresponds with a mix of 2, 1 hour at 20 degrees Celsius corresponds with a MIX of 4, and so on.

Steve Harris, MD has proposed a similar metric, the Equivalent Homeothermic Ischemic Time, which he abbreviates as the "E-HIT." In an incomplete and unpublished manuscript, Harris uses the E-HIT formula to calculate the equivalent normothermic ischemic time for different cryonics case scenarios and real cases.

Unfortunately neither Harris nor Perry reached a final, definitive conclusion, and the development of a formula to express brain injury as a function of temperature reduction over time remains a work in progress. The issue is complex because in an ideal cryonics case, pronouncement of legal death is followed by three interventions, all of which may contribute simultaneously to the inhibition of injury:

- Restoring oxygenated blood flow to the brain via cardiopulmonary support.
- Administration of neuroprotective drugs.
- Induction of hypothermia.

Moreover, in some cases these procedures may begin very soon after cardiac arrest, while in others, an hour or more may elapse before legal death has been pronounced and intervention may begin.

An ambitious program of research would be required to establish the degree of brain damage that is likely to result from different combinations of these factors—for instance, if cooling is applied but medications are unavailable, or if medications are administered rapidly but for logistical reasons, an ice bath cannot be used.

Another complicating factor is that oxygenation in combination with low perfusion pressures might produce more injury than "anoxic cardiopulmonary support" (chest compressions without ventilation).

In an effort to reach some tentative conclusions, one of the authors (de Wolf) has collaborated with R. Michael Perry. They began with the following simplifying assumptions:

1. The patient is not ischemic prior to pronouncement of legal death.
2. Cooling is initiated immediately after pronouncement of legal death.
3. There is no cardiopulmonary support or administration of neuroprotective agents.
4. Brain injury starts at 5 minutes of warm ischemia.
5. We assume that the Q10 rule is valid.
6. No other forms of injury occur, other than ischemic injury.
7. Ischemic injury is completely eliminated at the glass transition temperature of the vitrification agent M22 (-123.3 degrees Celsius).
8. A constant cooling rate is assumed.

With these assumptions, Perry calculated that to stay ahead of the brain injury that would normally begin after 5 minutes of warm ischemia, a cooling rate of 2.89 degrees Celsius per minute is necessary. Such a rate cannot be achieved by any known intervention. Therefore, cooling alone is insufficient to enable optimum brain preservation. This strengthens the case for

administering cardiopulmonary support (CPS) to maintain metabolism and homeostasis as best as possible during cooling rather than ischemia or anoxia.

Even so, it may not be possible to maintain complete viability of the brain in a cryonics case, even under optimal circumstances. However, we must emphasize that complete protection should not be necessary.

Numerous case studies describe successful resuscitation of patients who have endured an hour or more of accidental hypothermia in "natural" conditions, such as immersion in snow drifts or ice-cold river water. Even more impressively, hospital patients have been revived successfully after half an hour of hypothermic surgery during which there is no pulse, no respiration, and no measurable brain activity.

We may reasonably hope that cryonics patients can be revived in the future at a time when ischemic injury is much better understood than it is today, and injury can be reversed either pharmacologically, or by nanotechnology, or both. Since this issue remains speculative, we must simply try to do the best we can to minimize injury, and rapid cooling is the most important method to achieve this.

Thermoregulation in Cryonics Patients

Even after cardiac arrest and the pronouncement of a patient, the human body may attempt to resist the induction of hypothermia via reflexes that would constitute a survival strategy under normal circumstances. This is known as *thermoregulation*.

Vasoconstriction

By constricting blood vessels near the skin, the body attempts to retain as much heat as possible at its center. This, of course, is precisely the opposite of what we wish to achieve during cooling. Chest compression-induced vacuum vasodilation of the surface capillaries of the arms and legs may be effective in reversing this vasoconstriction

Shivering

The purpose of shivering is to sustain metabolism via rapid muscular contractions. This phenomenon is controlled by the hypothalamus, and is the body's second line of defense, after vasoconstriction has occurred. If we achieve some success in protecting the brain, it may induce shivering after death, leading to the paradoxical conclusion that the more effectively we intervene, the more likely we are to find the patient's reflexes attempting to defeat our efforts.

Shivering is highly undesirable during patient stabilization as it consumes the remaining reserves of energy in the body. Fortunately, general anesthesia impairs thermoregulation, and thus can be mitigated by the administration of propofol.

Shivering can also be inhibited by neuromuscular blockers. One major disadvantage of using such agents is that their ability to depress spontaneous respiration can make a cryonics organization vulnerable to suspicions of hastening death prior to pronouncement. Another limitation of such agents is that their ability to inhibit shivering may not necessarily prevent the increase in metabolic rate that precedes shivering. Most importantly, the need for additional agents to inhibit shivering in cryonics patients should be reduced, if not eliminated, when general anesthetics are used to depress cerebral metabolism and to prevent the recurrence of consciousness during cardiopulmonary support. It should be reiterated once more that concerns about defeating thermoregulatory defenses may be only applicable to a small portion of "ideal" cryonics cases that do not feature age related, agonal, and ischemic-induced impairment of thermoregulation.

Benefits of Hypothermia

One of the strengths of rapid induction of hypothermia in cryonics patients is that its benefits resemble those that can be gained by employing more complex interventions such as active compression-decompression cardiopulmonary support and multi-modal medications administration. As has been discussed in the section about quantification of cooling, very rapid core cooling rates would be able to prevent injury associated with ischemia even in

the absence of cardiopulmonary support and administration of medications. In this section we will review some of the technical benefits of hypothermia on the ischemic brain.

The finding that even mild decreases in brain temperature can confer long term benefits during ischemic insults raises the question of whether hypothermic neuroprotection can buy delays in energy depletion (depolarization) alone. For example, ischemia induced at hypothermic temperatures can inhibit the release of excitatory amino acids like glutamate into the extracellular space. At normal body temperature, ischemia produces a significant increase of these neurotransmitters; initiating glutamate receptor activated intracellular calcium influx and the start of a series of harmful consequences. Hypothermia can attenuate these excitotoxic events to a degree that exceeds what would be expected based on reductions of metabolic rate alone. Conversely, even modest cases of hyperthermia (about 39 degrees Celsius) increase the release of harmful neurotransmitters many times over what would be expected based on metabolic rate calculations alone. For this reason, the temperature of terminal cryonics members should be carefully monitored and, if possible, attempts should be made to persuade hospital staff to control the temperature of the patient to avoid hyperthermia.

Similar observations have been made about other elements of the ischemic cascade such as the formation of free radicals, inflammatory molecules, altered gene expression, apoptosis, proteolysis, and disruption of the blood brain barrier (BBB). Since increased permeability of the BBB is associated with increased edema during cryoprotective perfusion, maintaining the integrity of the BBB appears to be preferable in cryonics. As a general rule, progressive cerebral edema is observed in patients with progressive (warm) ischemic down time.

As can be seen from this brief discussion of the benefits of hypothermia, the benefits of rapid cooling exceed simple reduction of metabolic rate alone. From a physics perspective this observation is not completely satisfying because what else is a decrease of temperature than a decrease of average kinetic energy. The findings about the effect of hypothermia on biochemical events such as neurotransmitter release indicate that these processes should not be approached as ruled by a linear relationship with temperature but as

requiring a critical activation temperature. This explains why some adverse biochemical events following ischemia do not just decrease after moderate temperature drops but are inhibited altogether. As our understanding of the effects of temperature on biochemical processes grows we should expect a more individualized classification of how various biochemical pathways are affected by temperature.

Hypothermia and the "No-Reflow" Phenomenon

When we think of the effects of oxygen deprivation on the brain we usually think of the injury to the cells or even the danger of autolysis. There is another risk associated with cerebral ischemia, and that is perfusion impairment in the brain. Researchers dating back to the 1960s have found that successive interruptions of blood flow to the brain result in increased areas of the brain that are never perfused, as evidenced by experiments performed with ink perfusion or modern imaging technologies. The development of no-reflow in cryonics is detrimental for a number of reasons including:

1. Incomplete circulation of cerebroprotective medications
2. Reduced metabolic support of the brain during cardiopulmonary support
3. Reduced cooling of non-perfused areas in the brain
4. Incomplete washout during remote blood substitution
5. Sub-optimal perfusion of the brain with cryoprotective agents

To mitigate the development of no-reflow the most important consideration is to establish immediate metabolic support of the brain through cardiopulmonary and vasoactive medications. Laboratory experiments have shown that the no-reflow phenomenon can be mitigated through high perfusion pressures and the administration of volume expanders with rheological effects such as Dextran 40.

There is in an ongoing debate between scientists and clinicians about the mechanisms involving no-reflow, but the correlation between energy

depletion, cerebral edema, and the development of perfusion impairment points in the direction of vessel constriction produced by ischemia-induced water movement. This is further evidenced by the finding of many researchers that drugs that prevent or dissolve blood clots, such as heparin and streptokinase, are not able to prevent or reverse the no-reflow phenomenon.

Further evidence for the hypothesis that energy depletion (as opposed to blood coagulation) is the main factor behind the no-reflow phenomenon comes from the finding that rapid induction of hypothermia after cardiac arrest eliminates the no-reflow phenomenon. No gross indications of cerebral no-reflow have been observed in rodent brains that have been rapidly cooled (~ 1 degrees C per minute) down to zero degrees Celsius. As mentioned earlier, experiments with cooling rates that can be achieved in human cryopreservation cases (~ 0.18 degrees C per minute) showed the same result. If these results hold, this means that the development of perfusion impairment in the brain can be prevented in cryonics by a combination of prompt cardiopulmonary support and placing the patient in an ice bath with circulating ice water.

Induction of hypothermia can slow down energy depletion and its consequences but cannot eliminate it. This applies to the development of no-reflow during cold ischemia as well. Research in rodents shows that the beneficial effects of hypothermia on no-reflow start to disappear around 5 hours of cold circulatory arrest (without blood washout). Since the tolerable limits for the benefits of hypothermia to prevent perfusion impairment fall in the same range as the documented records for whole body hypothermic resuscitation and isolated brain resuscitation (3-5 hours) attempts should be made to keep the time between pronouncement of legal death and start of cryoprotectant perfusion under 5 hours until there is conclusive evidence that viability and vascular potency can be maintained for longer periods of time. Successfully cryoprotectant perfusions of humans have often been performed after longer than 5 hours of cold ischemia, sometimes even after 24 hours or more. However this is clearly not desirable, and the effects on brain structure of such long delays are not well-understood.

Adverse Effects of Hypothermia

Unlike other cryonics interventions such as cardiopulmonary support and administration of medications, the lowering of temperature constitutes the essence of cryonics. Therefore, if there are any disadvantages associated with cooling per se (as opposed to ice formation), attempts can be made to mitigate them, but cooling cannot be avoided. What can be done is to reduce the time that a patient must spend at hypothermic temperatures, prior to cryoprotection, by increasing the cooling rate and decreasing transport time. Strictly speaking, long transport times do not constitute an adverse effect of hypothermia, but it is important to be aware of the fact that extended periods of cold ischemia (more than 5 hours) will lead to energy depletion-induced movement of fluids between the vessels, the interstitial space, and cells, which can produce perfusion complications during cryoprotectant perfusion. The ideal non-technical solution to these problems is to minimize the time between pronouncement of legal death and start of cryoprotectant perfusion by good logistical planning and encouraging members that are critically ill to relocate to areas that are close to cryonics facilities while they are still alive.

Some of the adverse effects of hypothermia are not important in cryonics. Examples of such adverse responses include physical discomfort associated with lower core temperatures or the development of arrhythmias and cardiac arrest at low temperatures. Other effects are of a mixed nature such as the vasoconstriction associated with cooling of the extremities. Vasoconstriction improves blood flow to the core organs but decreases the rate of cooling of the core of the body.

The adverse effects of hypothermia pertain to the effect of low temperatures as such on the structure and functioning of cell membranes, proteins, energy generation and membrane-embedded pumps that regulate fluid balance.

Of greatest concern in cryonics is the fact that, as temperatures decrease, biochemical reaction rates decrease more than physical diffusion rates. As a consequence, cold-induced inactivation of cellular pumps can lead to an undesirable influx of water into cells. To prevent or delay such cellular edema, the blood of the patient can be replaced with a universal organ preservation

solution such as MHP-2 which includes impermeant agents designed to prevent such passive water movement.

Another adverse effect of hypothermia is increased viscosity. Increased viscosity will limit the speed at which cryoprotective agents can be equilibrated with cells. As a general rule, cryoprotective agents are perfused at temperatures close to zero to decrease toxic effects. In the case of cryoprotective agents like glycerol, however, such temperatures are highly impractical because permeability of glycerol at zero degrees Celsius is neglible, necessitating perfusion at higher temperatures, resulting in increased dehydration of the brain. It is important for team members to be aware of the effects of temperature on viscosity and permeability of cryoprotective agents and the trade-offs of perfusing at higher temperatures.

As a general rule, decreasing core body temperature produces increasing adverse effects in human beings. Unlike some hibernating organisms, decreasing the temperature in humans will not produce a corresponding drop in heart beat and respirations until the danger of ice formation presents itself. The human heart will stop beating toward the lower end of the deep hypothermia spectrum. In clinical medicine, however, induction of deep hypothermia is utilized for complicated surgical procedures that require complete cessation of circulation. In these procedures great care is taken to protect patients against the adverse effects of lower temperatures. Despite the obvious advantages of rapid cooling to the temperatures of water ice, it should be kept in mind that currently no human beings are routinely resuscitated from profound or ultraprofound hypothermic temperatures as an elective procedure in contemporary medicine.

A Pictorial History of Portable Ice Baths

The MALSS

The Mobile Advanced Life Support System (MALSS) was designed for Alcor Foundation by Jerry Leaf and Mike Darwin during the 1980s. Its objective was to enable rapid cooling, femoral cutdown, and blood washout in remote locations such as a mortuary or even a private residence. It utilized an ice bath consisting of a vinyl liner supported by a frame of PVC pipe, mounted on top of a Ferno-Washington collapsible gurney. Hugh Hixon of Alcor recalls that the longitudinal frame was reinforced with chrome-molybdenum 4140 tubing, while a DC power system was added to drive a 24-volt Sarns roller pump for perfusion. Provision was included for a side-mounted Michigan Instruments Thumper, and the unit was still in use as late as 1995 in a case performed by Biopreservation, Inc. for CryoCare Foundation.

The MALSS was extremely important conceptually, since it introduced the concept of an all-in-one device for rapid cooling and blood washout. It was not air-transportable, and its weight made it difficult to move in any vehicle lacking a lift gate.

The Pizer Bath

In collaboration with Mike Darwin, long-time Alcor member David Pizer conceived of a simplified ice bath, similar in construction to the bath on top of the MALSS. A vinyl liner was supported by a frame of PVC pipe mounted on a sheet of 3/4" plywood, with wheels enabling the bath to trundle along at floor level. The vinyl liner was supplied by Pizer, who at that time owned a business selling replacement automobile seat covers.

The Pizer Bath allowed use of a Thumper but offered no capability for blood washout. It satisfied the need to carry a patient securely with at least 100 lbs of ice, and was used in several cryonics cases. Its great advantages

were low cost and simplicity, enabling regional groups to make their own copies. For many years, a Pizer bath was part of the standard equipment in the New York chapter of Alcor Foundation, and was stored at the home of cryonics pioneer Curtis Henderson in Sayville, Long Island. Henderson is shown beside the ice bath in Figure 11-8.

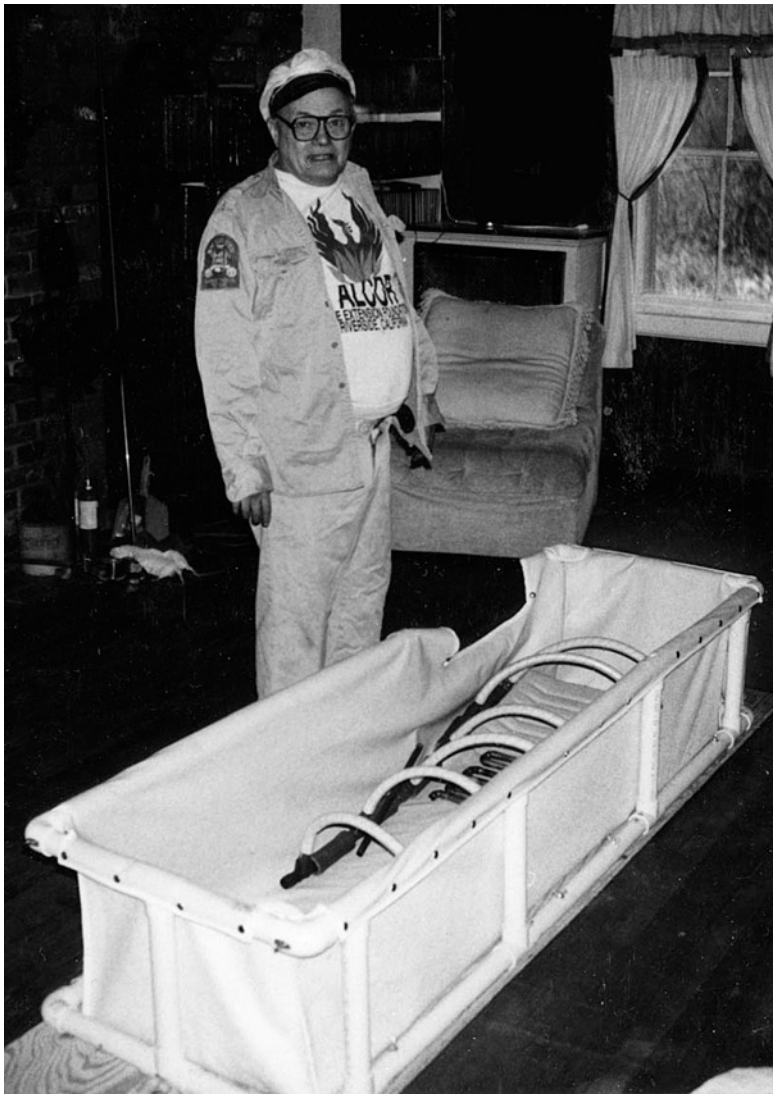

Figure 11-8. Curtis Henderson with a Pizer Bath.

The Pizer Bath could not be disassembled for air transport, and its choice of materials gave it a home-made look which would not help team members seeking respect and acceptance from medical personnel.

An SCCD was added, consisting of a 115-volt AC sump pump circulating water from the bottom of the ice bath through lengths of perforated hose that were draped over the patient. Figure 11-9 shows a couple of loops of hose with Henderson, who enjoyed posing for photographs of this type.

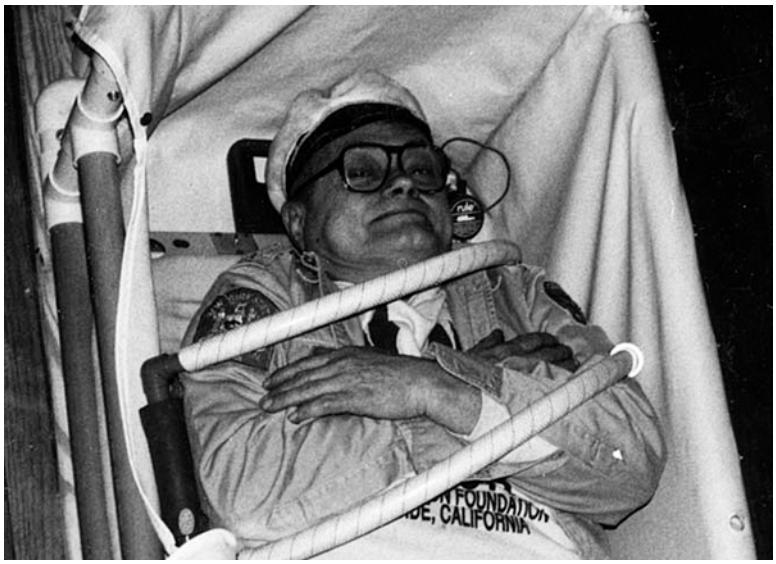

Figure 11-9. Curtis Henderson with the SCCD.

The MARC

Hugh Hixon developed the Mobile Alcor Rescue Cart, or MARC, at Alcor in the early 1990s, using lessons learned from the MALSS. Hixon's design was highly ambitious, incorporating not only the pumps needed for blood washout but also a pair of oxygen cylinders, everything being installed in a custom-welded frame of gray-painted square-section steel tubing. In Hixon's words: "It was designed to be completely autonomous; all you had to do was get it there."

The MARC was used in several cryonics cases but was not air-transportable, and was so heavy, merely raising it to traverse a curb at the side of the road was a challenge. It could not be moved up or down a flight of steps, and could not be taken across soft ground. Two photographs of it are shown in figures 11-10 and 11-11.

The ambulance owned by Alcor for many years was fitted with a lift gate capable of raising or lowering the MARC, and a similar lift gate was installed for the same purpose on Alcor's rescue vehicle purchased in 2003. The MARC remains at Alcor but its future remains uncertain, since an intermediate-height ice bath was installed in the rescue vehicle in 2009.

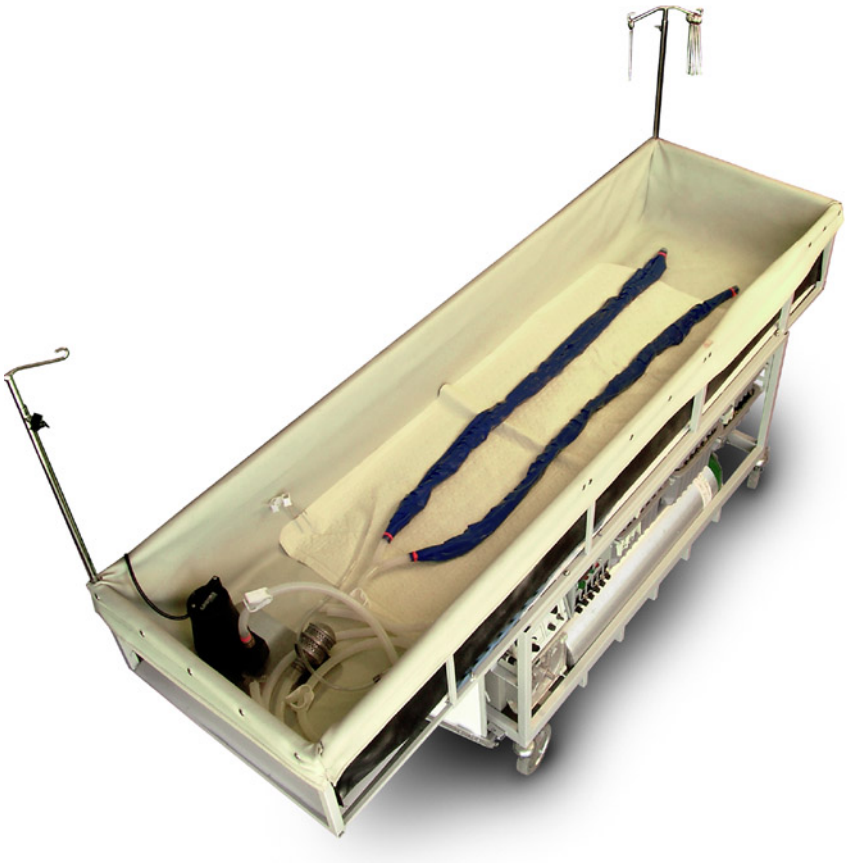

Figure 11-10. Hugh Hixon's MARC viewed from above. The tubes inside it are a SCCD device.

Figure 11-11. Another view of the MARC, showing roller pump, data display, storage drawers, and one of two aluminum oxygen cylinders.

The First Platt Design

When Michael Darwin left Alcor and started Biopreservation Inc. as a service provider for CryoCare Foundation, he expressed interest in a new design of ice bath that would be fully collapsible for air transport. Charles Platt created a scale model of a concept which was approved by Darwin, but Platt lacked a workshop in which to build the final version, and commissioned this from Julian LaVerdiere, a New York artist who had a personal interest in cryonics. LaVerdiere used 1"x1" aluminum tubing and honeycomb-core plastic panels that formed a baseplate in the bottom of the bath. This was the first portable ice bath to have a “designed” look.

Like the Pizer Bath, Platt’s bath was intended to roll at floor level. Unfortunately Darwin failed to supply a detailed specification. Consequently, no provision was made for an IV pole, and Platt was unaware of the weight of

ice that the bath would have to carry. There were doubts about the stability of its zig-zag structure under full load, and during a test one of the honeycomb panels that La Verdiere had chosen cracked, apparently because it was weakened by prolonged exposure to zero-degree temperature. Engineer Mark Connaughton salvaged the design by installing a very strong stainless-steel baseplate, but the bath became too heavy for transport as checked baggage on commercial airlines.

The zigzag folding design is shown in Figure 11-12, while the opened bath is in Figure 11-13, with LaVerdiere beside it.

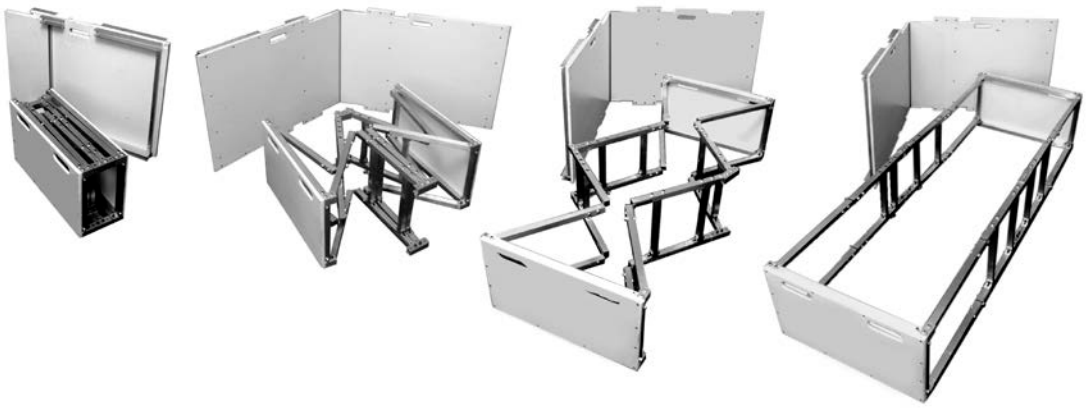

Figure 11-12. The ice bath designed by Charles Platt and built by Julian LaVerdiere for Biopreservation, Inc.

Figure 11-13. New York artist Julian LaVerdiere beside the ice bath that he built.

The Chamberlain PIB

When Fred and Linda Chamberlain acquired a significant role at Alcor in the late 1990s, they introduced yet another ice-bath design, this one intended to be so minimal, multiple copies could be created very cheaply and distributed to

regional groups. It consisted of two thin, X-shaped folding tubular frames which were designed to support the opposite ends of a heavy-duty body removal bag. Instead of an SCCD, two rows of shower heads were clipped along each long edge of the body bag to spray ice-cold water over the patient inside it. This was necessary since the bag was not capable of holding much ice.

The assembled bath fulfilled its objective for being cheap to build and easy to store, but it had very little structural strength. It could be used only by placing it on the floor or a table, although Hugh Hixon suggested that if it was used on a gurney in a hospital, probably no one would notice if the gurney was rolled out of the building while cooling was in progress.

There was concern that the tubular frames could collapse during use, dumping ice water out of the body bag, although we can find no reports of this actually happening. In addition the shower heads were deemed impractical for many cases as they would be spraying recirculated water from inside the bag, which might contain fecal matter or blood. Mist from the spray would be an infection hazard when a patient was infected with hepatitis-C or similarly easily transmissible pathogens. No surviving examples of the Chamberlain ice bath appear to exist.

The Sinclair Design

In England, cryonics activist Alan Sinclair created his own ice bath for use in an ambulance that he purchased personally. Sinclair used pieces of plastic pipe, similar to the design of the Pizer Bath, but he preassembled the pieces into modular sections and color-coded them for quick assembly. The Sinclair bath is probably the best compromise that has been achieved between simplicity, cheapness, and performance. At the time of writing, it has not been used in a cryonics case. Its drawbacks are that it is an exclusively floor-level design, and retains some of the nonmedical, “home made” look of the Pizer Bath.

Figure 11-14 shows the bath in sections that are assembled on the floor of Alan Sinclair’s living room.

Figure 11-14. Alan Sinclair's PIB design at his home in East Sussex, UK.

The Second Platt Design

In 2002 David Shumaker at Suspended Animation, Inc. asked Charles Platt to come up with another ice-bath design. Platt still liked the idea of sides that would unfold rapidly so that the bath could be easily deployed and would not

have any loose pieces that could get lost. He imagined fabricating it from Formica-clad half-inch plywood, for lightness and ease of construction. Two renderings that he prepared are shown in figures 11-15 and 11-16.

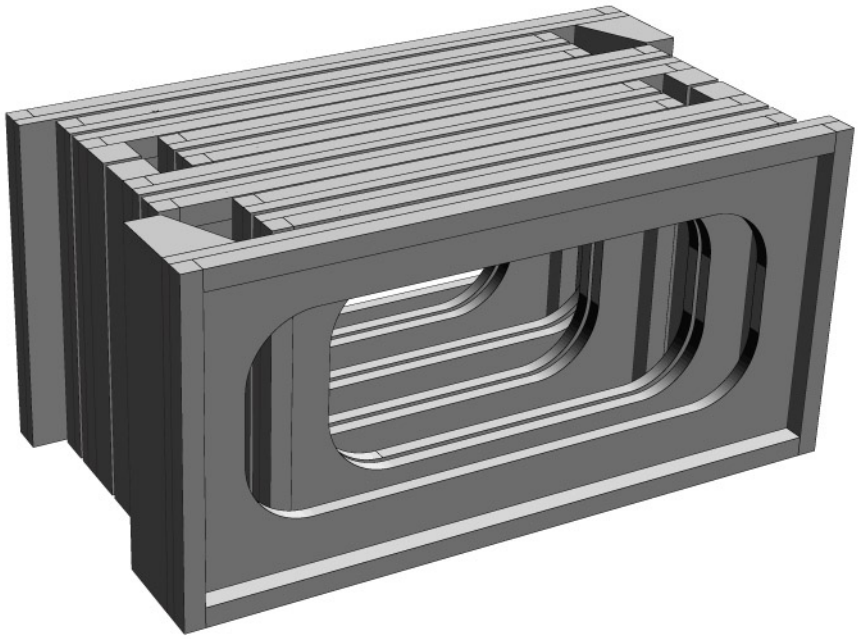

Figure 11-15. A proposed design by Charles Platt would have been fabricated from Formica-clad plywood. It was never built.

Figure 11-16. The design shown in Figure 11-16, partially unfolded.

The Shumaker-Quinn Design

In 2003, while Michael Darwin was doing consulting work for Suspended Animation, Inc. in Florida, he and David Shumaker suggested a major revision of the portable ice bath concept. They wanted a bath that would allow procedures to be carried out at chest height (like the original MALSS) yet would be fully collapsible for air transport.

The finished design was built by Michael Quinn, who worked for Suspended Animation at that time. It used an aluminum baseplate, hinged in the middle and turned down at the edges to provide structural stiffness. Sockets were welded into the baseplate to accept lengths of 3/4" stainless-steel tube. They could be assembled on-site, using pins and screws, to form wheeled legs and a side rail. When all the sections of tube were disassembled, they would just fit inside the baseplate, which folded around them like a clamshell. The liner of the bath was a single, unstitched vinyl rectangle which

was inserted in the frame with its end corners turned inward, like an Origami fold. Strips of velcro on the liner held it in place. An SCCD was included, using a submersible marine pump that could be powered by a 12-volt battery.

This design was a radical step forward in many ways. An example is shown in Figure 1-17 with Darwin's ACDC Thumper installed (see Section 10 for a detailed description of Thumper variants).

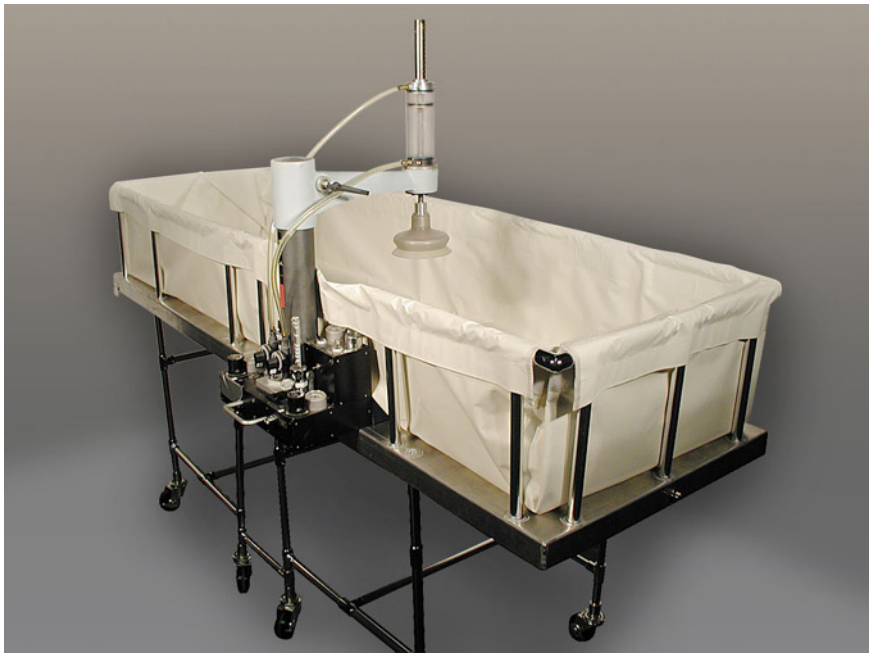

Figure 1-17. The PIB created by David Shumaker and Michael Quinn for Suspended Animation.

The major defect of the design was its assembly time. Quinn claimed he could put all the sections of tubing together within half an hour, but when Ben Best at the Cryonics Institute took delivery of a bath and tried to assemble it, he said he gave up after two hours. In theory, many of the parts were interchangeable; in practice, small errors in the placement of holes drilled through the tubes forced a series of trial-and-error assembly attempts, and a rubber mallet was essential. The pins to secure the tubes were easily lost, and the complete package exceeded size and weight limits on some airlines. While the bath was conceptually important, it was not practical.

David Shumaker subsequently commissioned a completely new Thumper design from Michigan Instruments. This straddled the ice bath by using clamps on the side rails, and together with the depth and width of the ice bath itself, would accommodate very large patients. A privacy cover was included, completely concealing the patient while allowing continuing Thumper use through a zippered slit in the center, as shown in Figure 1-18.

Figure 1-18. The final version of the Shumaker-Quinn ice bath included a redesigned Thumper chest-compression device, and a removable zippered privacy cover secured with Velcro.

The Third Platt Design

After Charles Platt joined at Suspended Animation, he tried to retain the most popular aspects of Shumaker's design while simplifying the assembly process. Platt still believed it should be possible to have a design that would unfold as one piece. At this point he had the luxury of working with Piotr Ruk, a master welder.

Platt maintained the same bath size as the Shumaker-Quinn design, so that the redesigned Thumpers could still fit across the rails. He borrowed from Hugh Hixon's MARC the idea of end sections that could be retracted if the cart had to fit inside a small elevator or traverse tight turns in a hallway. The baseplate of the bath was made from expanded stainless steel mesh, welded to the stainless-steel frame.

Figure 1-19 shows then-employee Kelly Kingston demonstrating how the completed ice bath could be unfolded within a few minutes. Six steel pegs were required to maintain it in its unfolded mode, but they were retained on two-inch lengths of stainless steel braided wire, welded to the frame. Thus, there were no separate metal pieces other than the wheels and an IV pole, all of which would fit inside the bath when it was folded and stowed in a nylon bag. The design was heavy, being entirely made from stainless steel, but it was within airline weight limits, and Platt successfully took it on an airline from Florida to Arizona and back.

Figure 11-19. The collapsible ice bath designed by Charles Platt for Suspended Animation. After assembly, each end section could be tilted upward to fit into small elevators or navigate tight turns in hallways.

The bath was criticized primarily for its weight and cost of fabrication. For a second copy of the bath, Platt substituted thinner, 18 gauge square tubes instead of the 16 gauge that had been used previously, and he simplified the folding end sections. Three copies were made altogether.

Because Shumaker's idea of an ice bath that could be raised to chest height with detachable legs still seemed desirable, Platt created a set of legs that could be plugged into his ice bath design. These are shown in Figure 11-20. Like the ice bath, they were all in one folding assembly, with no loose

parts. The legs plugged into the same sockets in the underside of the bath that were used to retain the wheels. The wheels were then transferred to the bottom ends of the legs.

Figure 11-20. A foldable set of legs for the ice bath shown in Figure 11-19.

The same dimensions of this ice bath were used to make two additional noncollapsible copies with nonfolding legs to go into the vehicles being converted by Suspended Animation. This design is shown in Figure 11-21, and in Figure 11-22 with its ends turned upward to reduce the length for use in tight spaces.

Figure 11-21. A noncollapsible variant of the Suspended Animation ice bath.

Figure 11-22. Ends of the noncollapsible ice bath in Figure 11-22 could be turned upward to reduce the length when necessary.

One of the folding baths and one of the nonfolding baths have each been used in cryonics cases. A lowered version of the nonfolding bath is currently in Alcor's transport vehicle.

The Cryonics Institute Variant

A variant of the final Platt ice bath was built for the Cryonics Institute at the request of their mortician, who wanted legs that would flip up so that he could slide it into his Chevy Suburban. This ice bath would never be deployed by air, as the Cryonics Institute did not run its own standbys. Therefore, the legs could be permanently attached, and the bath itself did not have to be collapsible. It is shown in Figure 11-23, and the design of the legs is illustrated in Figure 11-24.

The design was similar to that of a gurney of the type used by paramedics, but was heavier and stronger, being fabricated from stainless steel to carry a patient with large quantities of ice and water.

Figure 11-23. This variant of the Suspended Animation ice bath was built for the Cryonics Institute.

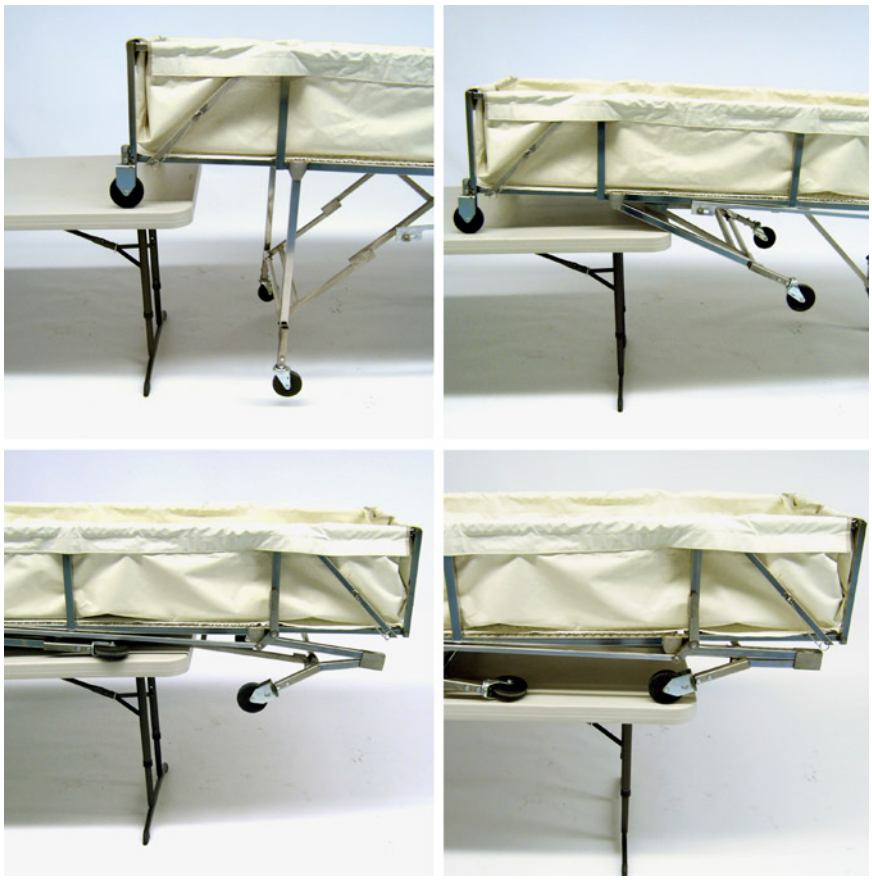

Figure 11-24. The variant for the Cryonics Institute featured legs that could be retracted by pulling a lever, so that the bath would slide into a vehicle with limited head room, such as a Chevy Suburban. The bath was not air-transportable.

10. The Van Sickle Design

Alcor expressed interest in Platt's folding ice bath, but decided it was too expensive. While Steven van Sickle and Tanya Jones were developing new equipment for Alcor in 2007, they created an ice bath of their own, shown in Figure 11-25. This consisted of a slightly modified aluminum stretcher of the type used by rescue teams in mountainous areas.

Figure 11-25. The ice bath designed by Steven van Sickle for Alcor.

The advantages of this design were that it was light, cheap, and compact. The sections could be disassembled and stowed in a back pack, as shown in Figure 11-26. Unfortunately, the design also had one major disadvantage: it wasn't big enough. The bath could not accommodate tall or obese patients, and didn't have enough room for necessary volumes of ice and water. While it could be used with a side-mounted Thumper, its rounded bottom made it unsuitable for a LUCAS chest-compression device.

The design was used in one cryonics case, during which it sustained some minor damage. We are not aware of any cases where it has been used subsequently.

Figure 11-26. The van Sickle ice bath was very compact.

The Graber Ice Bath

Steve Graber, at Alcor, developed a less compact but more robust ice bath to replace the van Sickle version. This is made from sections of painted steel that plug together. Graber is shown assembling the bath in figures 11-27, 11-28, and 11-29. This is the default ice bath used by Alcor at the time of writing. Its primary limitation is the number of separate parts. It is also smaller than the Shumaker-Quinn ice bath.

Figure 11-27. Steve Graber at Alcor begins to unpack the ice bath that he designed.

Figure 11-28. Step two in unpacking the Graber ice bath.

Figure 11-29. The frame of Graber's ice bath, attached to its baseplate.

Desirable Features for Portable Ice Baths

The hypothetical ideal ice bath may still not exist, and may never exist, as its desirable features conflict with each other. They are summarized below.

Strong
When loaded with a patient weighing up to 250 lbs, with 100 lbs of ice, 5 gallons of water, a chest-compression device, and ancillary items, an ice bath must still be strong enough to be lifted either by its base or by its side rail, from opposite ends and with no support in the middle. We cannot expect team members to follow special, restrictive instructions for handling the bath.

Transportable
A portable ice bath should fold or disassemble to a size compatible with airline regulations for checked baggage. It must be sufficiently robust to withstand airline baggage handling.

Easy to Assemble, With No Loose Pieces
An untrained person should be able to put it together. There should be no possibility of a person under stress losing pieces that are necessary.

Not Too Heavy
One person of average strength should be able to lift the folded bath, or its separated subsections (if any).

Affordable
Materials and fabrication time should be reasonable. No exotic materials should be necessary.

Easy to Build
No special skills needed.

Compatible With CPS Devices.
This requirement is less taxing than it used to be, as LUCAS devices have become widely used and fit in almost any ice bath except for the discontinued van Sickle design.

Able to Acommodate Large Patients
While we recognize that any piece of medical equipment must have design limits that exclude some patients, we feel that 6 feet 6 inches is a reasonable requirement. For obese patients, the bath should be 2 feet wide. To enable submersion of most of the skin area, the bath should be more than 1 foot deep.

Retractable End Sections
An ice bath of the size described above may not fit into small elevators or go around tight corners in hallways. Hugh Hixon's decision to use a retractable end section was prescient. This feature is not often needed, but can make the difference between an ice bath being usable and unusable in some cases.

Convertible for Use With or Without Legs
The bath should slide into a van or SUV but should also be usable at (or near) gurney height for surgical procedures. If removable wheels are used, they should be easy to plug in and unplug, but should never fall out accidentally.

Usable With an IV Pole
An IV pole should be easily attached to the ice bath, and height-adjustable to fit into vehicles.

Usable With Medications
Ideally, a tray should fit across the side rails so that meds can be laid out prior to being administered.

Safe in Transport Vehicles
When installed in a vehicle, the bath should be easily clamped and unclamped. When clamped in position, it must be secure against longitudinal, lateral, and vertical forces. The heavy load in an ice bath can cause it to injure personnel if it rolls around.

Professional in Appearance
The look of cryonics equipment may not be relevant to its function, but may play an important part in establishing credibility during standby/stabilization procedures. Credibility, in turn, can encourage cooperation from medical professionals.