Blood Infusion Warmer: Fuzzy Embedded System Design, Latest Developments and Commercial Product Analysis

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1. Abstract

Temperature monitoring is a key consideration in the effective and safe management of a patient. Any mistakes about it can lead to life-threatening conditions for the patient. We all know that blood is stored in a blood bank at low temperatures. Blood and blood products are usually stored in a cool place to prevent bacterial growth and to maintain the integrity and function of the blood. Since the average human body temperature is 37.5 deg. Celsius is therefore very dangerous to directly inject cold blood into patients. To avoid adverse physical effects on a patient's body during a blood transfusion, compared to the actual blood pressure and the patient's body temperature and proper temperature.

Blood warmer is a medical device which is used to warm the blood prior to transfusion. In this paper hot water vapour is used to warm the blood bag which is a convection method of heating that does not cause any damages to the blood components. The main advantage of this system is the automatic working of the heating coil.

This report provides a comprehensive review and analysis of different variations in blood temperature. In addition, recent developments and commercial products have been reviewed. Finally, the report focuses on the development of a blood heater. When the blood reaches the desired temperature, the coil will be automatically turned off and when it drops below the body temperature coil it will be in shape. The LM35 is a very suitable temperature sensor and is the heart of this device. To avoid damage to the blood vessels, care should be taken while warming the blood. So we use a blood heating system using water vapor at low cost and efficiently.

2 Acknowledgement

I would like to use this opportunity to express my heartfelt gratitude to everyone who supported and helped us during the course of this ongoing project. I am thankful for their aspiring guidance, constructive criticisms and friendly advice during the past few weeks. I am immensely grateful to them for sharing their truthful and illuminating views on various issues related to the project.

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Last but not the least, I would like to thank my families and friends who helped us in completion of the project for their moral support in this time of the COVID-19 pandemic. This project would not be possible without his constant guidance and support.

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3. Introduction

Warming of the blood / solution warms the blood or fluid before transfusing it to the patient. It can be used if there is a concern with adding a large amount of very cold water. This may be necessary in cases where patients have experienced severe trauma and need a major transfusion, or when they are weak for medical reasons. Once the patient's body has begun to heal, however, warming the blood will not provide the greatest benefits; it is designed to protect against overheating, not to reverse.

The total blood volume of an adult is about 5 liters, which contains about 8% of body weight. A blood transfusion is a medical procedure designed to replace blood loss through injury, surgery, or disease. The average human body temperature is 37.5 ° C. Blood is usually stored at 4 ° -6 ° C in a cool place to avoid haemolysis and to maintain the fertility and functional integrity of blood components. Patients who receive cold solutions to electrolytes, blood, and blood products are reported to experience life-threatening complications

A colder blood, if transfused into the patient can bring in the following issues :

1. Chronic Hypothermia
2. Surgical Site Infections
3. Myocardial Ischemia
4. Prolongation of Drug effects
5. Bleeding Diathesis
6. Increased morbidity, mortality and hospital expenses

Temperature maintenance is the prime consideration for the effective and safe handling of the patient. Mistakes regarding it can cause life-threatening conditions for the patient. The traditional blood heat of humans is 37.5 deg. Celsius. The blood from the bank is at lower temperature.It is dangerous to directly infuse cool blood during a patient. To avoid hypothermia adverse effects within the patient body while transfusion,real time comparison of blood bag temperature and patient blood heat and accordingly heating is provided to IV line up to equilibrium . Thermistor may be a very suitable temperature sensor with NTC (Negative temperature coefficient) that is the heart of the hotter FOR BLOOD INFUSION and is within the sort of bridge configuration.

When blood is required for major trauma outside of a medical facility, the danger of hypothermia increases when a patient is transfused bags of blood taken directly from chilled storage. Flinders University researchers, knowing that warm blood leads to better transfusion outcomes, have found that an easy , one-piece, disposable heat of transformation fluid warmer provides a secure solution to beat this problem in emergency situations.

The researchers tested portable latent fluid warmers manufactured by Logikal Health Products in New South Wales. Each fluid warmer consisted of a bag with two chambers—one containing liquid nitrate tetrahydrate, and therefore the other containing some solid nitrate tetrahydrate, separated by a frangible plastic strip.

Fluid warmers powered by solidifying nitrate tetrahydrate haven't previously been used clinically, but this test showed that a heat of transformation fluid warmer can safely warm transfused blood during a controlled clinical setting.

The paper—"Warming blood before transfusion using heat of transformation ," by David Roxby, Magdalena Sobieraj-Teague, Jacoba von Wielligh, Romi Sinha, Bryone Kuss, Anne-Louise Smith, and Mark McEwen—has been published in medicine Australasia.
At trauma and medical retrieval sites, mains electricity-powered fluid warmers can't be generally used. Therefore, heat of transformation from fluid warmers that raise the temperature of the red cell units to approximately 35°C provides an alternate practical method of portable temperature-controlled intravenous fluid warming—and this new research proves it's secure and efficient thanks to administering better blood transfusions.

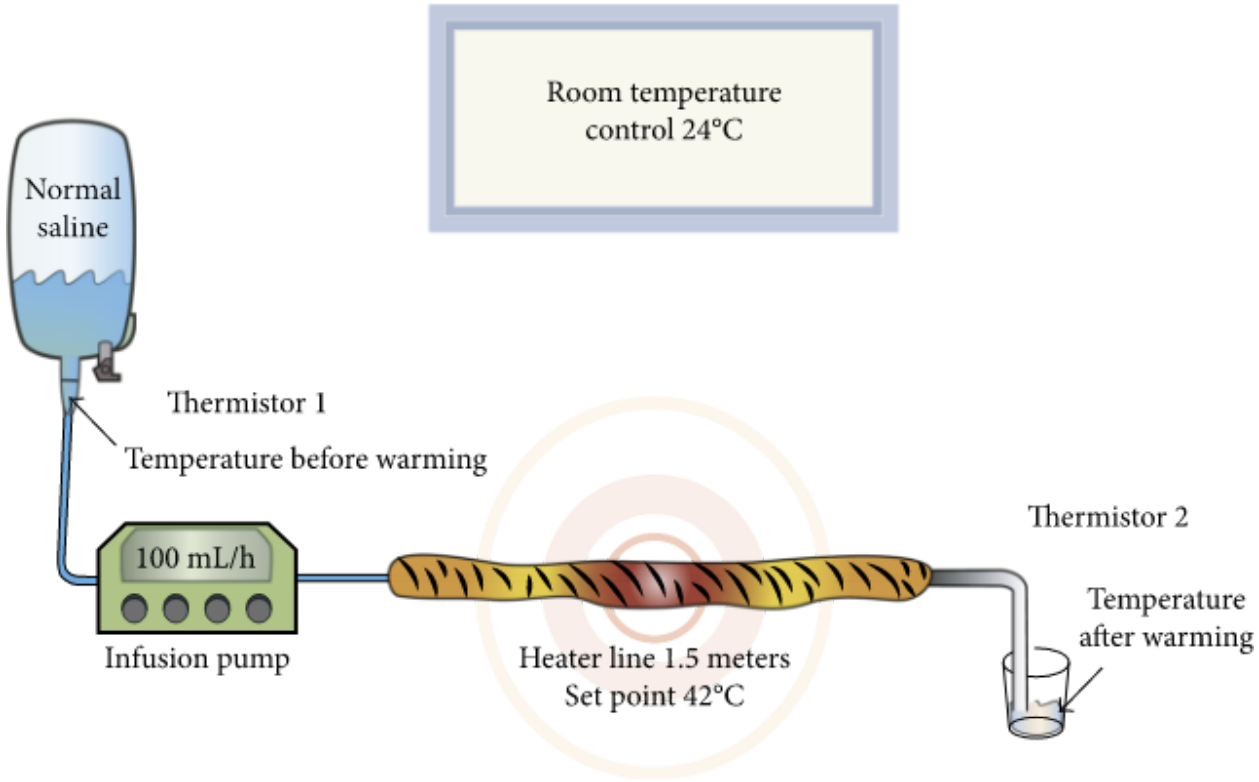
"The great advantage is that heat of transformation can warm fluid to normal blood heat without electricity," says Dr. Roxby. "This study proves that a transportable heat of transformation fluid warmer—which weighs only 2 kg and warms up in but one minute—is safe to use and doesn't overheat."

Currently, intravenous fluid warming for emergency situations in remote locations is being done by a variety of methods which have limitations and even potential dangers. Using warm water to heat fluid bags may take too long to succeed in the specified temperature and carries a risk of bacterial contamination. Electric warmers often need external batteries that take vital time to assemble, and wish to be kept charged. Some chemical reactions can heat fluid above normal blood heat , potentially damaging the blood product. For the trial, physiological signs (oxygen saturation, pulse, temperature, vital sign , respiration) of 25 hematology patients remained stable and no transfusion reactions were observed during warm transfusions.

Latent heat fluid warmers increased the temperature of red cell units to approximately 35°C, and there have been no significant differences in haemolysis markers (plasma hemoglobin, potassium, lactate dehydrogenase, bilirubin) following warmed and unwarmed transfusions, and no contamination of red cell units by nitrate tetrahydrate was detected.

Usually the blood is stored at a temperature from 4°- 6°C so as to take care of its sterility and functional integrity. Administration of cold blood to the patients during rapid transfusion may cause life threatening conditions like hypothermia and even life loss. So it's vital to warm the blood up to blood heat before the administration of blood to the patient. Here we are warming the blood using a convection heating method that never causes any damages to the blood and blood products. This module is meant in such a way that it's so compact and straightforward to work that it is often easily installed in ICU rooms and may be moved anywhere by just removing the facility cord if necessary. This is often a transportable warming device for blood and blood products. These devices have several advantages including reduced contact with blood and blood products, instant preparation of blood for injections, decreased damage to blood and blood products, and precise control of the heating process. Work is ongoing to further refine the planning and to supply a prototype to satisfy the target of warming blood in but 10 minutes. The devices are going to be invaluable in resource-limited settings, where quick blood transfusions are required to save lots of lives.

Accidental or uncontrolled hypothermia may be a common problem among trauma patients [6]. it's been reported that up to 60% of patients admitted to regional trauma centers are hypothermic which suggests patients having a core blood heat of 35°C. additionally , core body temperatures of below 33°C can cause cardiac arrhythmias, and temperatures below 28°C increase the danger for fibrillation . Therefore, efforts to warm the blood before transfusion in hypodermic patients during a timely manner is extremely important Generally, several unconventional methods are used for warming blood before transfusion which could potentially end in red blood corpuscle hemolysis and injuries. General blood warming techniques in practice are use of a normal microwave, immersing the blood bag in predicament , placing blood sac near heaters etc. These methods may result in blood hemolysis thanks to overheating. These transfusion conditions can only be reached with concurrent heating and transfusing, which is merely possible with portable heating devices for blood and blood products that feature a high accuracy and quality.



4. Commercially Available Products

Blood heaters / solutions are online devices that are usually placed on an IV pole between the solution bag or delivery device and the patient line. Ways to give him gravity, pressure, or pump. They are usually classified as an online heat transfer system that they use to heat incoming solutions, such as dry heat; water bath, including the current flow of water; forced spirit; and microwave.

The machine carries a bag of blood, fluids, or solutions and heats it in a safe place for the patient before using it with a suction pump. Nurses and specialists can control the temperature and the degree of delivery. Blood heaters can be used in emergencies, operating theaters, and intensive care units to provide warm blood and fluids to patients who need them, and the hospital can keep most of the floor heating to ensure constant availability.

Therapeutic use of blood is indicated when more than 50% of a patient's fluid volume will be replaced with a transfusion, or when blood will be transfused as soon as possible. Other considerations may be in surgery when more units are needed, and others may be needed later. Reducing the risk of a patient having hypothermia from multiple units of cold blood, can warm the blood. It is important to set the heater in advance, as it requires some time to operate, so if the nurses think it may be necessary, they can start heating it for easy access.

The following section contains a detailed analysis of different commercially available blood warmers, and points out the intriguing feature of each product :-

4.1 Reusable Silicone Ring Nuova Blood Warmers

Nuova 05 and Nuova 05 plus are two commercially available Blood warmer that are clinically proven dry heat rapid warmer. It is a microcontroller controlled with low and high temperature alarms.

Other Key features include :

- New actively heated silicon sleeve to avoid cooling from warmer exit to patient (Nuova/05plus)
- Heating sleeve optional to purchase at any time at a later stage (Nuova/05plus W/O)
- Plastic parts made of fire-retardant compounds to meet future hospital standards
- Temperature setting up to 41°C
- Robust turntable mounting clamp for vertical and horizontal operation (IV pole, Gabler rail, norm bar)
- Multiple independent temperature sensors covering total length of heater
- 13 heating grooves for up to two liquids (e.g. blood/infusion) at the same time.

4.2 Beaconn Blood Warmers - BH-600A Blood/Infusion Warmer

This Blood Warmer has 2 styles for using the warmer which makes it durable if one of the functionality fails to work. The 2 methods are as shown below :

It has a Compatible tube for Transfusion set and infusion set or feeding set with diameter 3.5-5mm. The heating board Degree of protection is BF. IpX2 is used as the main engine Protection against ingress of water.
The Control temperature is in the range of 35°C - 42°C and adjustable in 0.1°C steps, while the temperature accuracy is ±0.5°C (heating plate), ±1°C (warming tube).

Other features include :
1. The BH-600A is a warmer for infusions ,feeding or transfusions. The patented heating plate design provides that the length of the tube being heated can be adjusted up to 60cm.
2. The temperature can be set between 35°C and 42°C in steps of 0.1°C and the real -time temperature of the heating media is clearly displayed. The triple protection for high and low temperature are incorporated into the device to assure safe operation.
3. The detachable tube warmer is available as a dependent warming system between the main device and the patient, which is more efficient than a heating plate.
4. The design of the detachable clamp allows rapid and simple fitting to all suitable infusion stands and equipment rails; It also can be hanged on infusion stands or rails.

4.3 Smith's Hotline 1 Blood and Fluid Warmers with double lumen

The HOTLINE Warmer delivers blood and intravenous fluid at normothermic temperatures by surrounding the sterile intravenous line with a layer of warmed recirculating solution. An onboard recirculating solution supply is heated to 41.5°C ± 0.5 and circulated through the outer lumen of the HOTLINE Fluid Warming Set, which surrounds the intravenous line.

The HOTLINE Warmer uses a safe, repetitive solution system, which does not have a "hot spot," to heat the patient's line. The continuous electronic rotation monitors the temperature of the solution. The main temperature control circuit limits the solution to a re-temperature of 42 ° C. The HOTLINE Fluid Warming Set has never been exposed to any harmful or harmful heat while the HOTLINE Warmer is running.

Its distinctive feature adds its ability to bring normothermic fluid to normal flow levels. The unique design of the three lumen tubes removes the patient line and cools down and delivers warm fluid to your patients. Disposal setup is easy and fast, and requires a lower volume than other heating fluids

Its unique feature includes its capability to deliver normothermic fluid at routine flow rates. The unique triple-lumen tubing design eliminates patient line cool down and delivers warm fluids to your patients. Disposable set up is easy and fast, and requires less priming volume than other routine flow fluid warmers

Other features include the following:

- Keeps blood and fluids warm, between 37 - 42°C, delivering warm fluids to the patient at flow rates up to 5000 ml/hr
- Outperforms hotplate technologies in 91% of surgical procedures
- Easy to use: less time to set up and easy to disconnect from the patient
- Once-a-year reservoir maintenance protocol compared to hotplate warmers, which may require maintenance up to 12 times per year, means lower maintenance costs

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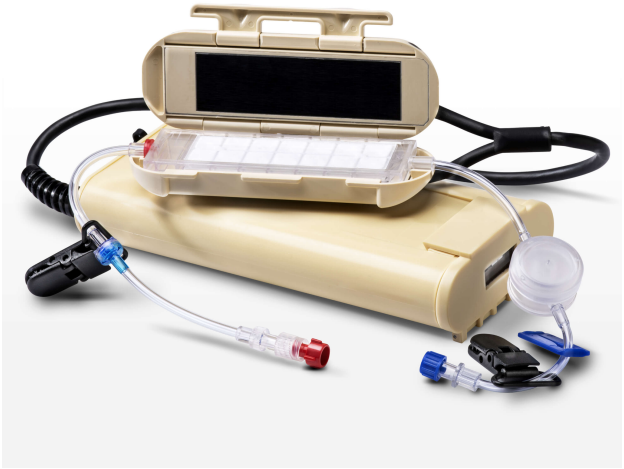
4.4 Aluminium free and portable Buddy Lite Blood Warmer

One of the most intriguing features of this type of warmers is that it is portable and yet Portable blood and fluid warming, in a remarkably compact, lightweight package. Buddy lite is used globally by civilian and military medical personnel to help prevent hypothermia during fluid administration.

Its main features include the following :

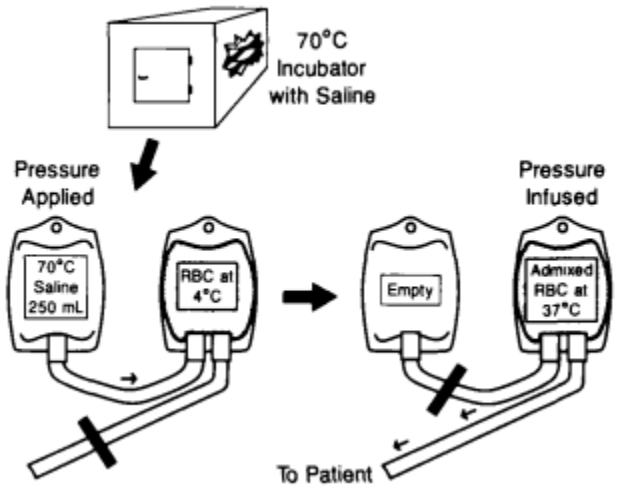
- **Approved for ground and helicopter transport**, buddy lite is used globally in war zones, hospitals, ambulances, air medical helicopters, ski patrols—anywhere warm blood or fluid is needed to help in life-saving efforts. This compact, lightweight, battery-powered IV fluid warmer can warm up to 4.4 liters of fluid on a single charge.* Total weight, including heater, battery, and disposable is less than 1.6 lbs. (0.73 kg). The complete system is small enough to be easily stored in a medical response bag – you can take it just about anywhere.
- **Automatic Air Removal** - Medical personnel can rely on buddy lite’s automatic air removal, featuring a microporous, air-venting membrane within the fluid path designed to prevent air emboli and aid in administration set priming.
- **Close-to-Patient Warming** - Warmed fluid outflow is less than 6 inches between the patient and heater to reduce line-cooldown, ensuring the delivery of normothermic fluid

- **Military tested and approved** - The buddy lite is used extensively by armed services as an effective method for delivering warmed fluid to injured soldiers on the field and during patient transport.
- **Battery or AC powered** - Long battery life helps deliver extended care. A single battery charge can warm up to 4.4 liters of fluid from 20°C to 38° ± 2°C. For continuous use, an optional AC-powered version is available.
- **Automatic Air Removal** - Medical personnel can rely on buddy lite's automatic air removal, featuring a microporous, air-venting membrane within the fluid path designed to prevent air emboli and aid in administration set priming.



It is easy to use, buddy lite's single-button operation allows emergency personnel and first responders to spend more time attending to the critical status of the patient instead of focusing on the device, and that helps in life-saving efforts.

5. Detailed Solution



There is no need of warming blood when direct donor to-patient and immediate indirect transfusions were used. Indirect, delayed transfusions of preserved and anticoagulated blood became the norm, and preservation technology supported refrigeration arose after war II. Blood banking and therefore the storage of blood still demands that the collected blood units be kept refrigerated, for the foremost part within the liquid (unfrozen) state. This enables prolonged storage time that retard the metabolic deterioration of red cells (RBCs) and other components, and prevents the expansion of any accidentally introduced pathogens. Presently, units of RBCs and blood (WB) are stored at 1 to 6°C, a temperature primarily determined by the wants for the preservation of RBC functional integrity. Blood warming before transfusion has been a standard practice since the first 1960s. When cold blood is directly delivered to the patient's body, the blood heat drops to life threatening levels. Rapid and efficient blood‑warming devices are of interest so as to administer large volumes of cold blood safely and rapidly to the patient.

The blood heat may drop to a threatening level (a condition called hypothermia) when many units of cold blood are given during a shorter time. so as to avoid cardiac and general hypothermia in patients needing massive transfusion, the blood should be warmed at bedside [10]. Hypothermia thanks to massive and rapid transfusion in ill and injured patients has associated adverse side effects which are very difficult to be reversed. Hypothermia is the main problem that affects the patients who have major trauma [2]. Crystalloid infusion and unwarmed blood results in coagulopathy and cardiac arrhythmias which leads to life loss. it's always important to warm the Intravenous (IV) fluid before administering the patients.

The bank has no responsibility to warm blood, which it delivers to the ward at a temperature of between +2 °C and +10 °C. on the average , it takes 10 minutes for a unit of blood to succeed in +10 °C at an ambient temperature of between +20 °C and +30 °C [1]. Cold blood are often delivered at a slow rate without ill effects. However, in cases where rapid transfusion is required , e.g. if the patient demands a rapid transfusion of an outsized volume of blood, problems like arrhythmia are often avoided if blood is warmed to +37 °C. Blood should never be warmed during a bowl of predicament , in hot towels or on the

brink of a heating device as this might cause immense haemolysis and significant transfusion reactions. Specially designed blood warmers are obtainable that warm blood safely and this could be a part of the vital equipment of a ward , especially within the medical care unit or operating room . The apparatus should be given a clear temperature monitor and an audible alarm, which should be checked periodically. Blood warmer warms human packed blood from 4°C to 37°C that's to a temperature that's safe for infusion. it's used with rapid transfusion in already hypothermic patients or rare conditions where cold fluid administration is problematic. Conventional way of blood warming is to put the blood bag within the warm water for an approximate period of your time . it's been reported that, in many cases, the temperature of blood exceeds the specified limit or repeatedly not even reach the specified temperature rate. Convection heating method is typically won't to warm the blood because the conduction and radiation heating may damage the blood content that's we increase the temperature of surrounding air inside the box which can then cause to boost the temperature inside the blood bag [4]. The several other methods to warm IV fluids and bloods that are presently available includes immersing coiled IV tubing during a water bath, passing the IV tubing through a conductive surface interfaced with a counter current heated water bath, magnetic induction, microwaving the bag of fluid to be infused, adding heated saline to blood to be infused, passing the IV tubing through a heating block or through a plastic tube warmed with forced air, pre-warming fluids during a convection oven or during a microwave . But these methods consume time and aren't safe. If temperature increases too fast that might damage the red blood cells and plasma content of blood at an equivalent time.

We need to warm the blood within the lowest possible period of time , so we'd like a tool which warms the blood gradually and precisely. Red blood cells and plasma exposed to temperature over 40oC may cause serious transfusion reactions. To achieve all above intentions we'd like a controlled heating plant therefore the blood warmer will increase the blood temperature up to 37oC in quarter-hour . Here the main target is on controlling the temperature parameter

5.1 Specifications of a blood Warming Apparatus

Blood warmers must warm blood effectively, safely and conveniently. The hotter should not damage the blood even when used less carefully than prescribed by the manufacturer. It must be easy to use, must warm rapidly, and preferably be unobtrusive if used within the theatre area. Finally, it should be cheap to purchase and cheap to take care of. To be effective, the apparatus must be ready to provide the patient with blood at a temperature above 32° e at flows up to 150 ml min. At this flow one unit of blood is going to be given in about three minutes; this is often usually the fastest rate at which an infusion is often sustained. Preferably, the hotter shouldn't reduce the speed of infusion then should have minimal resistance. the perfect infusion would be capable of a free flow of 100 ml/min with blood; such a a rapid rate without pumping would go away the anaesthetist's hands free for other tasks.

Generally, the nice and cozy blood will dilate the patient's veins, and this reduction in resistance helps to offset the loss of flow when the hotter is added into the road of the infusion apparatus. This dilatation of the patient's veins is far more important than the reduction in blood viscosity which occurs because the temperature rises. If the nice and cozy blood dilates the patient's veins to twice their former size, the resistance of the veins is reduced to only one-sixteenth of its former value. Warming blood from 40 degrees to 37 degrees, reduces blood viscosity about two and a half times (Burton 1965). Thus, although improved flow are often observed in vitro when blood is warmed, the main a part of the improved flow. The amount of vasodilatation varies from patient to patient, so an in vitro test is preferred for comparison between blood warmers. An approximate value for blood flow are often found if a hotter is tested with iced water and therefore the flow rate divided by three.

The safety of blood warmers for the staff and the patient must be considered. Staff safety is achieved by ensuring that each one electrical apparatus is satisfactorily earthed which any electrically live a part of the apparatus can't be touched or contaminated by blood or water, for example, it shouldn't be possible to put a hand into a radio-frequency warmer while it is switched on, nor to pour water into the motor of a water-bath stirrer, or into the bathtub electronics (Shaw and Monk 1973). Patients must even be shielded from electrical hazard. Standard earthing alone might not be adequate, as only very small currents are often fatal when conducted along a central venous catheter (Monks 1971). Overheating of the infused blood may endanger the patient by haemolysis or by excessive temperature.

The warmers shouldn't allow the operating temperature to exceed 41° C (106·8° F), although this may be excessively cautious (Chalmers and Russell 1973). they ought to have a minimum of one safety device which, when the set temperature is reached, prevents further heating and provides a clear indication of malfunction. It is preferable that apparatus utilized in the theatre shouldn't spark and will be safe when utilized in the presence of probably inflammable anaesthetic agents like cyclopropane.

Controls which require electro-magnetic switches, such as a water level safety cut-out, are often designed as magnetically switched reed relays if they're for modest current. The reed relay may be a set of contacts sealed into a glass tube. When the relay opens, any sparking is isolated and can't ignite an explosive anaesthetic mixture. Cost is a crucial consideration for any hospital, but the initial cost isn't the sole consideration. The value of maintenance can be very significant, particularly for equipment which must be cleaned and sterilized repeatedly.

5.2 Traditional Warmers

The following are the traditional methods of warming the blood :-

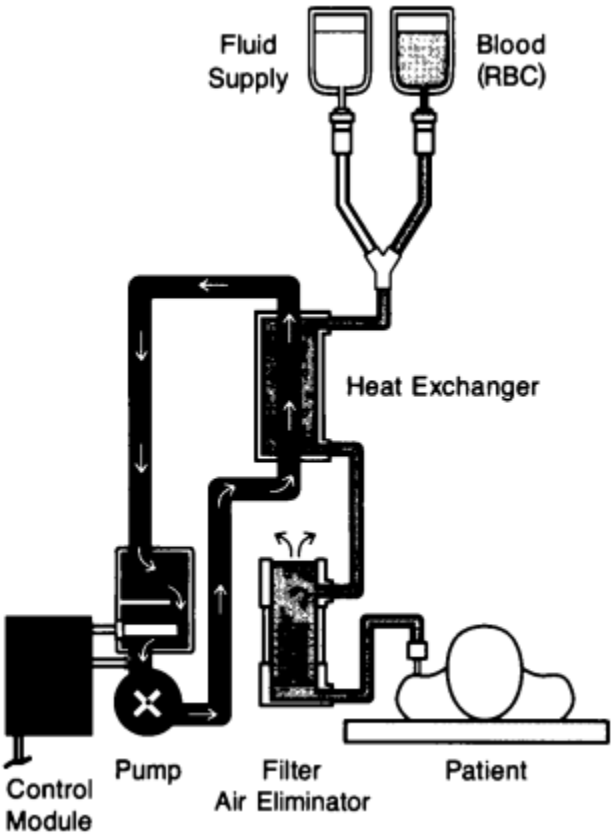
1. **Non-Disposable Blood warmers -** Because metal conducts heat well, nondisposable blood warmers are usually made of stainless steel. They are highly efficient and can warm blood from 4°C to 38° C at flows of over 3 'min. It is this efficiency which makes these the devices of choice for cardiopulmonary bypass circuits. Heat is supplied by circulating water at 40° C through the outer and inner chambers. The blood flows through the middle chamber. One such device is shown in Figure 2. As well as having good warming efficiency, these warmers have very low resistance to flow. It must be remembered that although the heated bath for the circulating water may be in the next room, it is still an electrical device and the water, the stainless steel warmer and the blood provide a direct electrical connection to the patient's heart. A small leak of current from an electrical fault could cause sudden ventricular fibrillation. The Honeywell warmer is now manufactured by Medisco Equipment Limited under licence.

2. **Heated Humidifiers -** A heated humidifier uses heat to warm water in the humidifier chamber to produce moisture which is carried by the air you breathe. The heat level is adjustable to receive more or less moisture. Patients who use heated humidifiers have a much higher rate of therapy effectiveness with CPAP treatment.

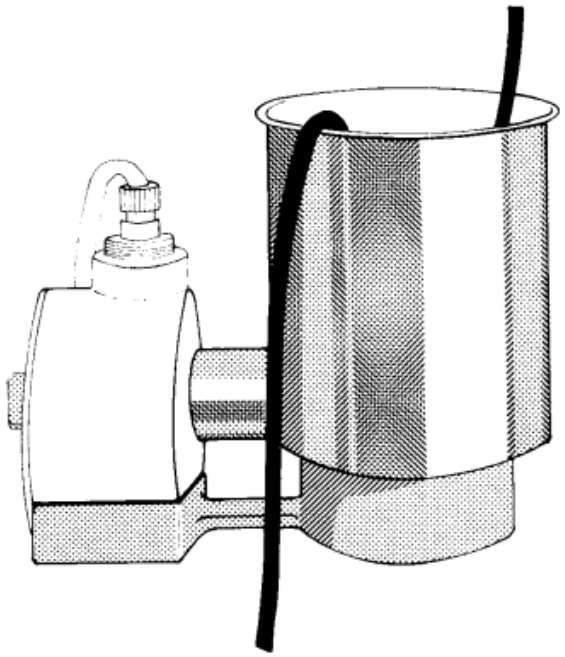
3. **Heated Moisture Exchangers -** Heat and Moisture Exchangers (HME) are devices used in mechanically ventilated patients intended to help prevent complications due to "drying of the respiratory mucosa, such as mucus plugging and endotracheal tube (ETT) occlusion."[1] HMEs are one type of commercial humidification system, which also include non-heated-wire humidifiers and heated-wire humidifiers. HMEs have been in clinical use for over 30 years. Heat and moisture exchangers (HMEs) are intended to conserve a portion of the patient's exhaled heat and moisture, and condition inspired gas by warming and humidifying it.

4. **Countercurrent warmers -** A relatively new and unique type of water bath warmer is the countercurrent heat exchanger. Designed primarily to warm blood rapidly for transfusion to

patients in hemorrhagic shock, the systems use a countercurrent flow of heated water around or interdigitated with the IV blood tubing circuit (Fig. 3).15J2s131 With the newest models, up to 750 mL per minute can be delivered with blood warmed from about 10 to 35°C. The primary limitation of these systems is the flow capacity of the IV catheter: because the IV catheter is the flow-limiting part of the transfusion system, the use of either a 12-gauge or a No. 8 French catheter is necessary to achieve the maximal flow rates that the fastest units are capable of delivering. Countercurrent warmers are more expensive than other in-line warmers, set-up times are longer, and more time is needed for training.



5. **Conductive Warming -** The warming baths differ widely in detail but some common features. One is that heating is achieved by a thermostatically controlled electric element. With electrical heating it is important that the apparatus is well earthed. The water in the bath must also be earthed. Although plastic coils electrically insulate the infused fluid from the water bath, anv fault or fracture in the coil would allow an electric current to flow from the bath down the infusion line. Poor earthing would also mean a hazard to staff.



6. **Forced Air Warming** - The Fenwal blood warmer is the only commercially available unit which warms during infusion, but is not a water bath warmer. It is rectangular (Figure 3) with a door which is opened to insert the blood warming bag (Fenwal 4C2416). The unit is available in 110 and 240 volts and the heating elements are rated at 750 watts. The bag is heated by warming elements on both sides. However, the door is not separately earthed and could cause a serious shock if it becomes live while open. When closed, the door is effectively earthed into the case by locking catches. The unit weighs 8·7 kg and takes about two minutes to reach its operating temperature. The warmer will stand on a table or can be mounted on a drip stand approximately t in to It in diameter. The heating circuit is controlled by two sets of thermostats in the door; one set maintains the heating pad between 37° and 38° C, the second set are safety thermostats which operate at above 410 C. The safety thermostats turn off the heaters and trigger the alarm, which is a loud steady tone. The unit has an amber light to indicate when the power is on.

5.3 New Technologies and Innovation

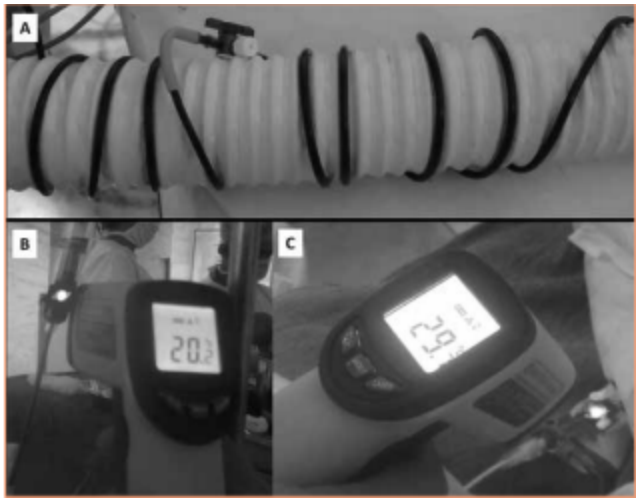
Low-cost, high-impact techniques are the way to overcome resource deficits in developing countries. We describe a novel yet simple technique to prevent intraoperative hypothermia as an alternative to costlier fluid-blood warming units. The following latest innovations are a brief of the future scope in the technology:-

1. **Quantum Blood Warmers** - The Quantum Blood and Fluid Warming System is a Game-Changing innovation that has succeeded in closing a critical capability gap previously left exposed by other commercial off-the-shelf fluid warmers currently fielded. Size, weight, performance, and ease of use are no longer collective barriers to the delivery of whole blood in far forward and near point of injury (POI) prehospital casualty management.
   The Quantum exceeds all healthcare and logistical requirements for the delivery of warmed blood or fluids across the defined spectrum of care. The system consists of unique thermal administration sets that incorporate sensing elements with an integrated heating system that does not disrupt the fluid path. With advanced intelligence throughout the system, the lightweight Controller modulates and moderates the energy flow to the integrated heating elements to ensure consistent normothermic fluid delivery to the casualty. The 44V battery is the smallest in category, able to rapidly adjust power distribution based on the temperature and flow rate of the input fluid. This creates a highly efficient system capable of previously unrealized performance optimizations. The Quantum system has an operational weight of just 22 total ounces yet can deliver two units of 39°F Whole Blood (WB) at 100mL/min with an output temperature of 100.4°F (38°+/- 2°C) with only a 24 second warm-up period. The Quantum Blood and Fluid Warming System provides the Tactical Health Care Professional with significant technological overmatch in the fight to eliminate preventable combat death.

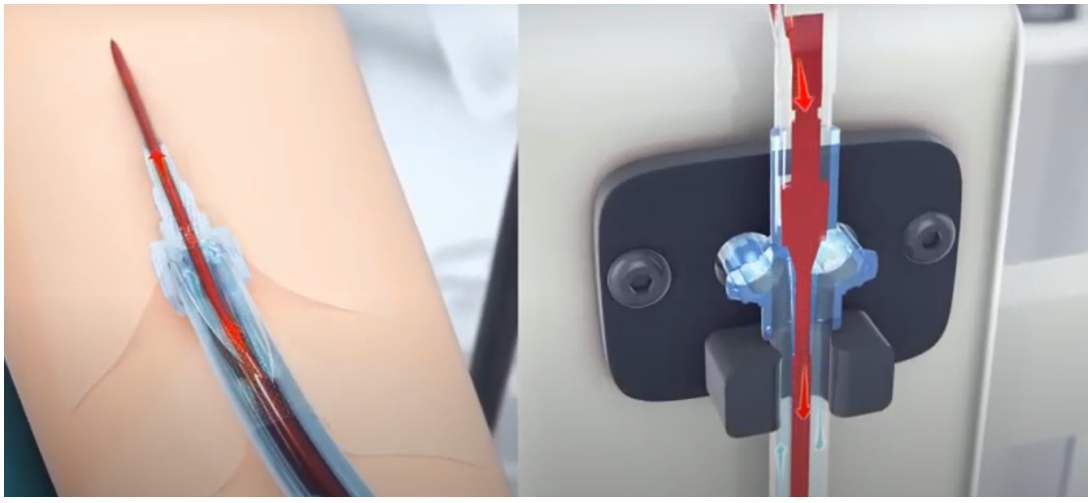
2. **Thermoelectric Blood Warmer** - Briefly described, the invention provides a blood warming device that warms blood passing through a cartridge held in intimate thermal contact with a blood warmer supplying heat from a minimum of one thermoelectric apparatus . Blood is supplied to a self-purging liquid cartridge through a liquid inlet and outlet attached to infusion tubes. because the blood fills the cartridge, any air bubbles at the air/liquid boundary are purged from the liquid because the cross-sectional area of enclosed volume is meant to decrease to a minimum at the very best point within the cartridge. The cartridge encloses a good , thin volume of short path length which contains the blood while heat is transferred thereto . a minimum of one high area wall defining the cartridge is thin, has good heat transfer properties and Low Mass , and is maintained in intimate thermal contact with a minimum of one thermoelectric apparatus in order that heat is rapidly transferred or absorbed from the blood. The blood warmer contains a minimum of one thermoelectric apparatus which pumps heat to the blood at a rate proportional to the speed the cartridge transfers heat to the blood. Because the chilled blood warms within the cartridge, heat transfer from the cartridge wall to the blood slows due to the smaller temperature difference therebetween which causes the thermoelectric apparatus to slow the speed of warmth pumping. As blood within the cartridge approaches the specified temperature, the decreased rate of warmth pumping helps prevent the blood from overshooting the specified temperature. The blood temperature near the liquid outlet is continuously monitored by a temperature sensor disposed of near the outlet. When the blood reaches the specified temperature, the sensor controls operation of the warmth pump. As a results of current interruption, the recent and cold sides of the thermoelectric apparatus almost instantaneously reach equilibrium at a temperature below the specified blood temperature causing the thermoelectric apparatus to quickly absorb a little amount of warmth from the cartridge which successively absorbs a like amount from the blood. Thus, the invention will pull back slightly from the specified temperature and thermal overshoot is avoided. After warming, the blood exits the cartridge at the fluid outlet and enters a tube connected to a venipuncture needle for insertion into the patient. electrical power could also be supplied to work the blood warmer as either A.C. or D.C. power source. within the most preferred embodiment, a disposable cartridge is provided which encloses a volume that decreases to a minimum at the outlet. The disposable cartridge is meant to slip into a slot on the blood warmer and displace a minimum of one forward biased temperature sensor and a minimum of one forward biased thermometric apparatus .

3. **Using intravenous tubing coiled around the hose of a convective body warmer** - The method uses an easily accessible unit for heating the air and is forced to heat the blood against the liquid before ingestion within the surgical period. Intravenous tubing (IV) (including extension tubing about 150 cm) was attached around the heating pipe conveying forced air to the warm coat, before connecting to cannula IV in the patient. Inactive digital infrared thermometer used to verify temperature in the near and far ends of the supply tube.

   Statistical analysis, using the Wilcoxon-signed position test for output input temperatures and the Mann-Whitney (U) test by comparing the temperature differences (TO - Ti = Tdiff) between different flow rates and different pipe temperatures and Spearman integration tests were performed on to establish a relationship between Ti and TO. Results are available shown as means of standard deviation, and P value below .05 is considered important.



4. **Using Feeding Tube -**

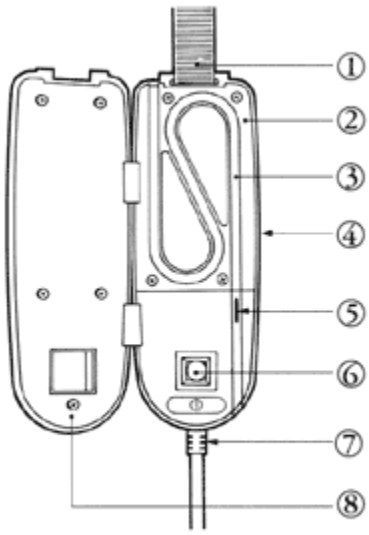


The feeding tube is a dedicated lumen tube that contains thermal memory. The gravity flow mechanism based blood infusor is covered by this feeding tube and it is constantly re-filled with warm fluids. The blood and the fluid never come in each other's contact yet the fluid keeps the blood warm and at a steady temperature.
A typical example is shown in the figure above, wherein we have a 2 layered feeding tube. This tube is reusable as the fluid never gets contaminated with the blood. Hence, it is economical and a simple but effective solution.

6. Design of an Embedded Blood Infusion Warmer

The machine can be held by hand or fixed on an IV panel near the patient's bed. Warm blood has the advantages of non-contamination, easy deception, portability, a clear digital temperature indicator, with immediate effect.

Here is a model with the same function and use of electrical circuits at the beginner level to better understand the above-mentioned concept of blood heating. With the latest electronic circuit containing a built-in PID microcontroller, as well as an audible alarm system, blood temperature can be made more powerful but more expensive. There is no doubt that the real device is completely different in terms of clarity, precision, flexibility and appearance.We take water or dextrose instead of blood. However, this project is sufficient to provide a practical imitation of the real warmth of the blood transfusion period.



① **Adjustable suspension belt**
: To hang the device on an IV stand or other support and adjust height from the floor.

② **Heating plate**
: For heating infusion fluid in the tubing.

③ **Tube channel**
: Place the tubing inside the "s" shaped channel.

④ **Main body**

⑤ **Temperature sensor**
: Sensing temperature of the effluent at the exit point of the device.

⑥ **Power switch**
: Press this button to turn on/off the main power.
When the power is turned on,
the green LED will illuminate
The switch cover protects against the accidental introduction of fluids into device from splashing or other source.

⑦ **Electrical cord**

⑧ **Cover**

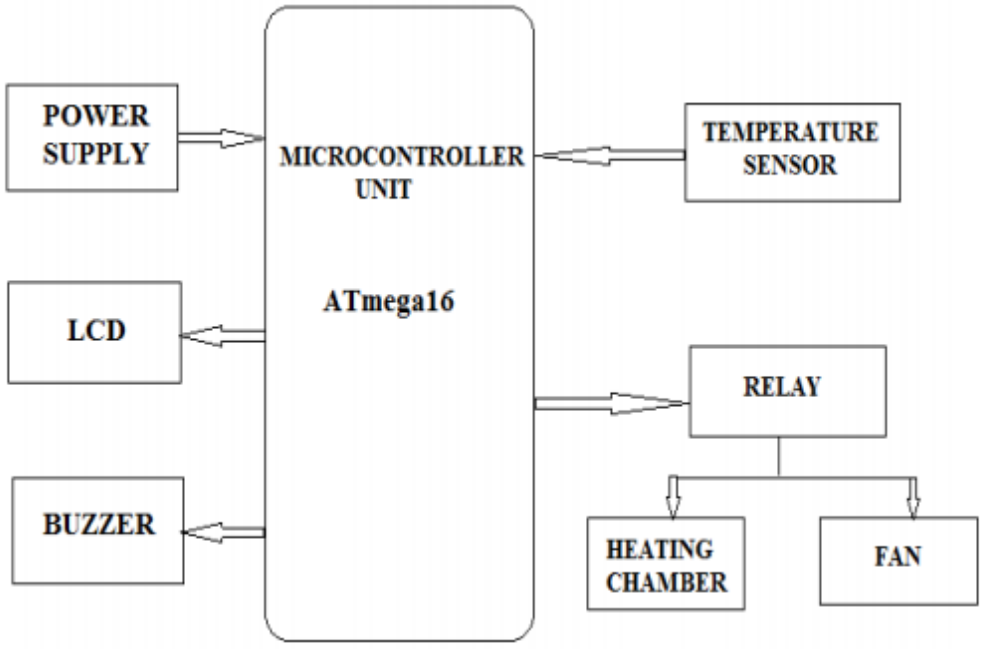
Working Principle:

The main concept behind this project is use of temperature difference signal for proportional heating of the cold blood. This difference is of two temperatures: one among the patient's body and other Of blood bag. As, sensing range of the thermistor is in microvolts, directly the error signals are often given as input to the heating circuit because it'll provide insufficient heat production.So,it is required to be properly amplified.

It is not the particular design but at the start phase with almost simulation of basic function of the hotter . So,the component specifications may differ from the particular one. The blood stored at lower temperature to lower the rate and bacterial growth.Now,if it's directly infused within the patient body,it

results in a life-threatening situation thanks to adverse reaction of normal blood and transfused blood named as “Hypothermia”. The result's shearing of blood cells,slow metabolism thanks to hypodynamia, ague, spasm of vessel ,arthritis ache,stomach ache,platelet dysfunction, increase in blood viscosity,disturbed CVS function.

To avoid it,BLOOD INFUSION WARMER is employed .This device heats the blood of the blood bag till it equals to the blood heat by detecting the temperature difference between both. Thus it's a really needy instrument in operational theaters, I.C.U.s or in other environments which require transfusion therapy to stop mishaps associated with coldness transfusion .



Methodology :

The proposed system consists of an ATmega 16 microcontroller designed in such a way that the system operates efficiently, the LM35 temperature sensor continuously heats the blood bag, transmits the IC ULN 2803 transmission driver, a warning bus, a copper coil and a fan for cooling. An effective blood heating system is proposed using an arduino microcontroller.

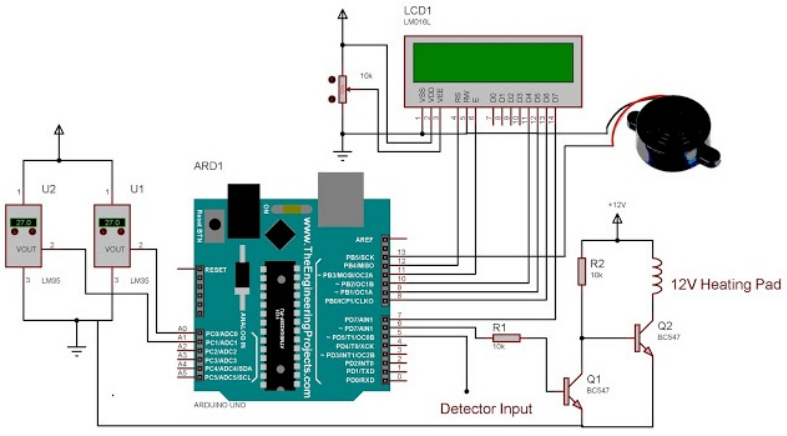
Blood should be heated to 37◦C before transfusion. To work with blood heating, we take 230 Volt AC (Alternating Current). To convert this into pure, filtered and durable DC (Direct Direct), we use step down transformers, rectifier, filter and controller respectively. A power switch is used to unlock the device whenever needed. The copper heat coil is immersed in water inside a water bath for boiling water. When water begins to boil at a certain temperature, hot water vapor is released. A bag of blood hangs over the water so that water vapor can easily warm the blood to the desired temperature. To detect the temperature of water vapor, we use the LM35 temperature sensor. The heat sensor is supplied with the ATmega16

microcontroller which is used to control and process the function of warm blood. It is designed in such a way that our system works well.

Exit the microcontroller to the IC ULN 2803 drive. Basically there are two stages of transmission. When turned on by the normal (NO) fan it turns on the heat dissipation and when the relay is turned off (NC) the 12Watt heat coil stops heating. When the temperature exceeds 37 ° C, the heat coil will be turned off automatically and the fan will start circulating for cooling purposes. When the temperature drops below 36 ° C, the heat coil will be turned on. The Microcontroller is also connected to the LCD display and buzzer. Output can be displayed on the LCD screen.

Tools Required:

Power supply
Temperature sensor with bridge for blood bag temperature.
Temperature sensor with bridge for patient body temperature.
Instrumentation amplifier for channel-1.
Instrumentation amplifier for channel -2
Differential amplifier for obtaining temperature difference.
Voltage to Current converter
Power amplifier
Heating element.
ADC-Analog-TO Digital converter
Micro controller. Audible alarm circuit.



Blood Infusion Warmer Circuit

7. Conclusions

Active blood warming may be a recent practice and arises out of conflicting needs. On the one hand, the security and preservation of blood require refrigerated storage and delivery up to the instant of transfusion. On the opposite hand, modem methods of very rapid transfusion in resuscitation would cause clinically dangerous hypothermia if unmodified, ice-cold blood were to be so transfused. These needs must be reconciled within the interest of adequate patient care-hence the necessity for blood warming. Nevertheless, blood warming creates risks of its own and will not be used without justifying clinical indications. Within limits that reach somewhat above normal blood heat , the appliance of warmth does no harm to stored RBC, an incontrovertible fact that isn't reflected in current standards for blood warmers. Bearing in mind the human tendency to “stretch” standards and therefore the fallibility of mechanical devices, caution is usually wise. But perhaps the time has come for reconsideration of this upper limit of 38°C. many sorts of blood warmers are available within the US, but none at this point is predicated on electromagnetic activity. the foremost common systems now in use are inline warmers, most of which aren't adequate for the sort of rapid-transfusion systems currently available. Countercurrent in-line blood warmers and therefore the method of rapid warm saline admixture can both be used successfully for rapid, massive transfusions. Blood warming is seldom necessary or desirable for elective transfusions at conventional rates, even for patients with cold auto agglutinins.

Further, a fuzzy embedded system can provide a robust control to the blood warming activity. A review of traditional and latest techniques show that the new technology focuses more on controllability of the temperature rather than heating methods. Also, precision yet portability is the latest trend in the current research practices.

Besseling et al. J3 and Russell13 (in his blood review warmers) explain the details of acceptance blood heater. Strong specifications continue to be used, with appropriate changes, to explore new programs. Any such system should be warm blood (both WB and RBC units) effectively, safely and quickly. This including warming in the same way without damage to RBCs as well fast enough to receive the expected rate flow rate. Proper monitoring and alarms are essential. Electrical protection should protect the patient once and for all staff. Optional means compact size, easy to use, a little technical training, and the power of regular employees to use the system. Current standards4 define what online blood temperature is fitted with a visible thermometer and, accordingly, a sound alert system. Blood should not be heated above 38 ° C.4 This level seems unnecessarily limited, because, as already mentioned, the short exposure of RBCs to temperatures below 46 ° C does not cause the visible cell damage.5'8 * 59.64.
Another desirable feature in warm systems is the whole container is a way to mark the container in such a way as to make it clear that it is a unit it's warmed up. Therefore, in the case where that unit is unused and returned to the blood bank, will not improperly placed on the shelf for retrieval, in order to be given to another patient. In addition to the above methods, cost is an important factor in the purchase of equipment. When a variety of practical options are available, the cost guides the decision-making process.

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