Throughout the past century, blood transfusion has been an established medical practice for combating major blood loss due to traumatic injury or surgery. Homologous blood supplies from volunteer donors, long the backbone of transfusion techniques, have lately come under public scrutiny mainly because of the rise in the incidence of infectious agents in the general population. Although safer than ever before, these community sources have thus been commonly regarded as a potential means of cross-infection.

Autologous blood transfusion, or self-donation, has become the procedure of choice when possible and basically is employed by three different techniques: preoperative autologous blood donation, acute normovolemic hemodilution, and perioperative autotransfusion. This last method encompasses both postoperative wound drainage collection and reinfusion and intraoperative autotransfusion (IAT), which will be the focus of this article.

This article discusses the history of blood transfusion, the options available to patients requiring transfusion therapy, the pros and cons of autotransfusion, the perioperative experience of the patient as it relates to autotransfusion, and the process of cell-washing as it pertains to the Baylor Rapid Autologous Transfusion (BRAT) System (COBE Laboratories, Inc., Arvada, Colorado). Other systems on the market include, but are not limited to, the Shiley STAT (manufactured by Dideco, Italy, for Shiley, Inc., Irvine, California) and the Haemonetics Cell Saver 4 (Haemonetics Corp., Braintree, Massachusetts).

As the incidence of infectious disease rises in the general population, the public's apprehension towards homologous blood transfusion will increase and those people requiring surgery will be opting for autotransfusion methods. It is important that all medical personnel come to understand the benefits and technology involved with this procedure, as its expansion into all realms of the hospital experience is distinctly inevitable.

**Historical Background**

It is generally thought that reinusing autologous salvaged blood was first considered in the early 19th century. The usually liberal postpartum bleeding and subsequently reduced bodily state common with pregnant women of that time prompted many physicians to begin initiating and documenting reinfusion techniques.

Dr. William Halsted, in 1883, described the refusion of blood oxygenated in vitro to treat patients with carbon monoxide poisoning. In 1886, the first cell salvage equipment for trauma victims was invented and consisted of a simple dish containing phosphate of soda. Although clinically successful with amputation victims, these early experiences did not attain serious notoriety. By the 1930s, several examples of early IAT devices had come into use in various areas of surgery. These relatively simple mechanisms often employed cheesecloth as a means of filtering out debris.

The modern era of blood banks developed during the 1950s, thus securing an abundant, safe, and accessible supply of homologous blood. Consequently, IAT techniques and their development fell by the wayside. During the Vietnam decade, however, interest was renewed in response to the numerous frontline casualties. In 1966, the first two-chamber suction device was developed for cardiac surgery and eventually led to the forerunner of the present-day canister models. These machines employed a standard.

---

**Figure 1. Typical roller pump assembly. Arrows indicate direction of rotation.**

Gary J. Allen, CST, is employed at Mercy Hospital in Springfield, Massachusetts. He specializes in orthopedic, thoracic, and vascular surgery. This is his second article in *The Surgical Technologist*. 

---
### Table 1. Comparative Values of Salvaged Blood and Blood Stored for 35 Days, Preserved With Citrate-Dextrose-Phosphate-Adenine (CDPA-1)

<table>
<thead>
<tr>
<th>Blood Value*</th>
<th>Salvaged</th>
<th>Stored</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole blood pH</td>
<td>7.16</td>
<td>6.73</td>
<td>Acidosis</td>
</tr>
<tr>
<td>Plasma potassium (mEq/L)</td>
<td>3.30</td>
<td>17.20</td>
<td>Hyperkalemia</td>
</tr>
<tr>
<td>Plasma hemo-globin (mg/dl)</td>
<td>0.50</td>
<td>45.50</td>
<td>Indicates hemolysis and hemo-globin conversion</td>
</tr>
<tr>
<td>RBC hemo-globin (mg/dl)</td>
<td>12.00</td>
<td>12.00</td>
<td>Same oxygen-carrying capacity</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>35%</td>
<td>35%</td>
<td>Unchanged ratio of red blood cells</td>
</tr>
<tr>
<td>White blood cells (x10^3/μl)</td>
<td>7.20</td>
<td>2.40</td>
<td>Decreased chance of febrile reaction</td>
</tr>
<tr>
<td>Whole blood ammonia</td>
<td>82.00</td>
<td>703.00</td>
<td>Hepatic dysfunction</td>
</tr>
</tbody>
</table>

*Milliequivalents per liter = mEq/L; milligrams per decaliter = mg/dl; microliter = μl.

The proportions of risk versus benefit of IAT is determined on an individual basis by the anesthesiologist, the surgeon, and the IAT specialist collectively. Three points considered are the needs to supplement the patient's blood volume, to enhance oxygen-carrying ability, and to promote hemostatic function, both intraoperatively and postoperatively. Although blood volume may be increased with the use of noncell fluids (Ringer's lactate, dextran), the latter two concerns can only be met through blood transfusion techniques. Therefore, in most cases where anticipated blood loss is two or more units, transfusion is generally planned for.

The use of IAT is readily practiced during cardiac and vascular procedures, total joint replacements, and spinal surgery. It is also employed during transplantation procedures, splenectomies, and traumatic incidences. In all cases, the recovery and reinfusion techniques are about the same; however, the diverse filtering capabilities of today's IAT models allow the machine to be adapted to each situation accordingly.

**Use of Perioperative Autotransfusion**

Indications for the use of perioperative autotransfusion include procedures that generate high blood loss and the availability of compatible stored blood products. Contraindications include the presence of either infection or tumors in the surgical area, as both may be spread systemically through infusion techniques.

In the 1970s, modifications added greater protection from air emboli and soon this concern became rather uncommon. Today, IAT machines set up easily, gather blood effectively from the operative field, offer various filters for selective blood processing, and adapt to a wide range of medical applications.

Two basic reinfusion devices are currently available. The first is a simple canister with a disposable filter. This device may be used solely as a collection and reinfusion reservoir that returns filtered blood back to the patient. This blood may also be pumped to the second type of device known as a cell washer for further filtration prior to delivery to the patient. This machine goes one step beyond simple debris removal by selectively concentrating specific blood products in solution before reinfusion.

**Autologous Transfusions**

There are three methods of obtaining and reinfusing autologous blood. all of which eliminate the risk of cross-infection due to homologous transfusion and help alleviate the strain on community blood banks.

**Preoperative Autologous Blood Donation.** This technique is highly effective and safe and is common with patients about to undergo major elective surgery. Begun 4 to 6 weeks prior to an operation, this process's main advantage is that the patient's own blood can be reinfused as needed perioperatively. The blood may be redeposited in the form of whole blood, red blood cells (RBCs), plasma, or platelets and will be of the same quality as stored blood products (Table 1).

Disadvantages include a possible delay of surgery in order to accommodate the proper accumulation of autologous blood supply and possibly reduced patient status prior to surgery. This technique is also contraindicated in cases of bacteremia and osteomyelitis and will not be considered 72 hours prior to any surgery.

**Acute Normovolemic Hemodilution.** This method requires that a vascular access catheter be introduced prior to surgery. After anesthetic induction, the anesthesiologist removes a specific volume, usually 1 to 3 units or 500 to 1,500 ml of the patient's blood while noncell fluids are infused simultaneously. In this way, total blood volume is maintained, but the circulating blood is now less viscous or watered down. This process may decrease heart workload and increase capillary circulation during the operation.

Following surgery, the patient's blood is infused immediately, providing fresh whole blood containing platelets and clotting factors. An advantage to this method is that while autologous donation is utilized, the blood is not subjected to the effects of long-term storage.

**Perioperative Autotransfusion.** This is the collection and reinfusion of the patient's blood both intraoperatively and postoperatively. These methods incorporate both the salvage and reinfusion of postoperative wound drainage through a simple filtering device and the more sophisticated IAT process.
To prevent the formation of air embolism, all IAT machines are designed to detect air in the reinfusion line, commonly utilizing ultrasonic technology to do so. All models also must be effective in the removal of the anticoagulant heparin from the salvaged blood (heparin’s role in the salvage process will be covered later in the article).

The rate of efficiency of this task can fluctuate between 65% to 99%, depending on the unit involved. The removal of heparin prior to reinfusion is essential for the promotion of clotting postoperatively.

The speed with which the washing process occurs is consistently under 2 minutes, and a distinct relationship does exist between speed and efficiency. Some models will complete the process very quickly, yet deliver a product of comparatively less quality. This problem is sure to be overcome as it is a primary focus of current manufacturers.

Cost-Effectiveness of IAT

The initial cost of an IAT device can range from $15,000 to $20,000 for manual models and to $40,000 for fully automated versions. Although quite sophisticated, the computerized machines still will require the undivided attention of a trained operator, often times a specialized surgical technologist. The employee cost also adds to the functional expenditures of the device.

Disposable items used on a per-case basis can run more than $200.00. Disposable items generally include the storage reservoir and filter, the centrifuge bowl, suction and anticoagulant tubing, and saline for use in the washing process. In comparison to the use of cross-matched units from blood banks, the IAT technique seems to become cost-effective when two or more units of blood can be salvaged from the operative field and reinfused.

With moderate use, an IAT device can return 1,000 units of blood per year. As stored blood currently costs about $7.00 per unit, the annual savings could pay for the machine in a relatively short period of time.

The start-up cost for IAT procedures is not a minor consideration for many institutions. Hospitals that do own devices obviously will have little difficulty setting up the needed equipment in a timely manner, even for an emergency surgery. Fortunately for the other facilities, IAT services are available through local blood services such as those provided by the regional American Red Cross (ARC).

IAT Procedure

If an outside IAT service is being used for a planned operation, the personnel and their IAT device will arrive about one-half hour prior to the scheduled start. This is ample time for the IAT operator to set up the necessary equipment and become familiar with the case. In some instances, the surgery may be delayed slightly to allow an IAT machine in transit to arrive. On-call surgeries require a 1-hour grace period for travel and setup, and so the IAT service may not be fully utilized for this reason. Once the operator and the device is in the operating room, however, each procedure incorporates the IAT process in basically the same way.

The IAT machine is set up in conjunction with anesthesia. A disposable unit is run from the operative field to the BRAT system (Figure 2). This includes the hand suction wand to salvage the blood, anticoagulant tubing that delivers heparin to the wand tip to mix with the blood as it is gathered, and suction tubing that brings the blood to a sterile collection reservoir. The amount of heparin used varies with the quality of the salvaged blood, and the vacuum pressure is generally kept below 100 mm Hg. The scrub person secures the tubing to the field as is normally done with suction tubing. It should be situated so that it is easily accessible by all members of the sterile surgical team, and it should be free of kinks and never clamped as this will inhibit the proper flow of anticoagulant to the recovery tip.

The collection reservoir serves as both a preliminary filtering mechanism for the removal of gross debris (bone,

---

**Figure 2.** Steps of the IAT process: 1, Collection and anticoagulation; 2, Washing and packing RBCs; and 3, Reinfusion. Arrows indicate direction of flow.
fat, etc) and a holding unit until the quantity of blood necessary for processing has been salvaged. The filter used in the reservoir is in the 120- to 150-μm range. A finer filter may increase the incidence of hemolysis. The amount of blood collected prior to the start of a washing cycle is dependent upon the rate of operative blood loss and the quality of the salvaged blood.

The cell-washing process begins as the collected blood is drawn by the roller pump to the Baylor centrifuge bowl. From this point, the flow of fluids to and from the centrifuge is controlled by three valves. As the bowl fills, it begins to spin and by centrifugal force pushes the heavier RBCs against the inner wall, causing the supernatant, or less dense blood components (plasma, white blood cells, and platelets), to flow out of the bowl into a waste bag. The Baylor centrifuge bowl rotates at a speed less than 4,400 revolutions per minute, which reduces the amount of processing hemolysis (cell destruction), and the bowl's comparatively larger size accounts for its ability to produce up to 250 ml of packed RBCs (equal to one unit of whole blood) per cycle. This also attributes to the high per unit hematocrit (55% to 65%) the BRAT system delivers back to the patient.

Once RBC concentration is completed, an isotonic solution is pumped into the spinning centrifuge bowl. The American Association of Blood Banks recommends that only sterile 0.9% intravenous saline solution should be used with heparin anticoagulant. As the wash solution flows into the bowl, centrifugal force keeps the RBCs packed along the inner wall, and the remaining supernatant and heparin are removed. This generally requires 300 to 750 ml of saline infusion that continues until crystal clear effluent runs into the waste bag. The end product of the cell-washing process is a bowl of packed RBCs suspended in saline.

This fluid is now pumped into a reinfusion bag, flowing past an air detector, in this case an ultrasonic device. If the sensor detects an absence of fluid in the line it automatically shuts down the pump. The BRAT’s operator is trained to correct this problem and re-establish the continuity of the reinfusion process.

Once the reinfusion bag is full, the packed cell may be administered to the patient through an IV, employing either gravity or pressure at the direction of the anesthesiologist. This method of reinfusion routinely uses microfilters to prevent air from entering the IV. Direct reinfusion is also possible with the BRAT system but requires constant monitoring of the air detector to guarantee against formation of air emboli. Reinfusion will continue, as will the collection/washing processes, as necessary, and many times will be continued in the postoperative recovery area.

It is important to note that many precautions are considered prior to this procedure, and that only diligent care and attention by a trained operator will assure a quality product, efficiently produced, and safely delivered.

### Postoperative Process

Postoperatively, any units of packed cells remaining from the intraoperative washing process are reinfused as needed. Wound drainage systems, when applicable, are also used. These units incorporate a collection container with a selective filter and when full may be inverted to serve as a reinfusion bag. These devices have proven effective and moderately beneficial and are essentially replicas of early autotransfusion devices. This collected wound drainage may also be pumped to a cell-washer, such as the BRAT, for processing and delivery, depending on the amount salvaged.

### IAT Disadvantages

The disadvantages of IAT are few but notable. The only limiting factors for its use are the time required to set up the equipment and the discouragement of its application in areas involving bacterial infection (ie, open bowels, perforitis, and abcesses) and malignant tumors, as these cannot be removed from salvaged blood. Other inhibiting factors that may occur during blood collection, such as the use of hemostatic agents and bacteriocidal wound irrigating solutions on the operative field, are considered to be easily avoided. IAT is also contraindicated in the presence of amniotic fluid due to its tendency towards embolus formation.

Although it is advantageous to salvage blood perioperatively, some cell damage (hemolysis) can occur during the procedure. The dynamics of suctioning, contact with tubing, the roller pump, and the washing process itself can cause cell injury. Platelet activation or destruction during this procedure may also further inhibit proper hemostatic function. Finally, though rare in occurrence, air embolism remains a problem with IAT, but new developments in this area are very promising.

### IAT Advantages

An immediate and safe supply of autologous blood and a subsequent reduction in the demand of homologous blood, commonly stretched thin in most major cities, are the major advantages of IAT. Inherent in this technique is the elimination of cross-infectious agents, such as hepatitis virus, syphilis, malaria, and human immunodeficiency virus, all of which are possibly contractable through homologous blood transfusion (Table 2). Problems associated with the storing of blood products also are avoided. These include increased potassium and ammonia concentrations in plasma and reduced tissue oxygenation capacity in RBCs. In this respect, RBCs harvested from the operative field are actually superior in quality to those found in stored blood. Platelets are also detrimentally affected during the refrigeration process of storage.

Another consideration for the use of IAT is the patient's
religious beliefs. Some patients object to the infusion of stored blood; however, IAT may offer an acceptable and important life-sustaining alternative without infringing upon a patient's personal spiritual tenets. Finally, with IAT, clerical errors involving homologous ABO blood-type mismatches, which can result in allergic reactions and fatalities, are eliminated.

Conclusion
There is no doubt that the medical profession has long sought an effective method of blood transfusion. During this quest, the years of dedication and development have yielded the IAT device. The efficient manner of the IAT models currently on the market provide both a safe and secure supply of blood and an immediate transfusion capability of high quality blood products.

As these machines are further developed, quieter, smaller, and more versatile models are expected. Concerted research efforts in the areas of hemostatic maintenance and host immune reactions will enhance and enable the refinement of the IAT's cell-washing system. Also, as patient awareness of the IAT process heightens and IAT demand increases, the cost-effectiveness of the procedure may eventually equal its rewards.

Of the many technological developments gaining recognition and interest today, IAT devices continue to hold the most promise for increased overall patient benefit, and too, as another branch of diversification available to the surgical technologist.

Acknowledgements
The author thanks Marlene Sanders, RN, of the American Red Cross and Terry Courtney of COBE Company for their cooperation and guidance in the preparation of this article.

Bibliography


