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Patterns of blood product ordering and utilization for surgical pediatric patients scheduled for intraoperative cell salvage

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Red blood cells are a scarce resource whose demand often exceeds its supply. Intraoperative red cell salvage has proven to be a highly effective blood conservation strategy, as it can reduce the need for allogeneic blood transfusion. However, the use of cell saver alone is not sufficient. Without specific blood ordering guidelines, the amount of allogeneic blood product requested and cross-matched is often much greater than the real level of consumption. Efficient blood ordering guidelines have been developed in the past, and have succeeded in providing a more accurate prediction of actual need for intraoperative blood transfusion and minimizing waste. Few studies attempted to examine the blood ordering and utilization pattern with an emphasis on surgical cases that involve the use of intraoperative cell salvage. With the use of intraoperative cell-salvage devices to reduce the amount of blood bank products required during surgery, considerable change in the practice of ordering cross-matched blood should be made. We retrospectively assessed the effectiveness of one Standardized Clinical Assessment and Management Plan (SCAMP) in improving the efficiency of blood utilization and reducing waste. This SCAMP was introduced at our Boston Children’s Hospital in July 2012 as a blood ordering guideline for all pediatric orthopedic patients who are scheduled for intraoperative cell salvage. We retrospectively compared demographic variables,
clinical characteristics, and blood utilization patterns of patients who underwent orthopedic procedure and received cell saver blood during the 17 months prior to the introduction of SCAMP (n = 455) and those who underwent similar procedures during the 15 months after the introduction of SCAMP (n = 487). Results suggested that demographic variables including age, weight, and sex were similar between the pre-SCAMP and post-SCAMP groups. It also demonstrated that after the introduction of SCAMP, the mean percentage utilization of blood (number of units used/number of units ordered x 100%) increased by 24.4% (p < 0.001), while the difference between the number of units ordered and number of units used reduced by 0.5 units (p < 0.001). In conclusion, the introduction of a SCAMP for blood product ordering has led to an increase in the efficiency of blood utilization and a reduction in blood waste. However, further evaluation and modification of the SCAMP need to be made in order to better predict actual level of utilization of blood products.
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<td>America Association of Blood Banks</td>
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<tr>
<td>ARMA</td>
<td>Autoregressive Moving Average</td>
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<tr>
<td>ASA</td>
<td>American Society of Anesthesiology</td>
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<tr>
<td>ATP</td>
<td>Adenosine Triphosphate</td>
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<tr>
<td>BCH</td>
<td>Boston Children’s Hospital</td>
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<tr>
<td>DIC</td>
<td>Disseminated Intravascular Coagulation</td>
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<td>2,3-DPG</td>
<td>2,3-Disphosphoglycerate</td>
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<tr>
<td>FFP</td>
<td>Fresh Froze Plasma</td>
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<tr>
<td>MSBOS</td>
<td>Maximum Surgical Blood Ordering Schedule</td>
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<td>RBC</td>
<td>Red Blood Cell</td>
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<td>SCAMP</td>
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INTRODUCTION

Red Blood Cells and Gas Exchange

Red blood cells (RBCs) in humans play an important role in the transportation of oxygen to various body tissues via the circulatory system. After entering the lung, oxygen first diffuses, in the gas phase, to reach the alveoli-capillary barrier, from an area of higher partial pressure to that of lower partial pressure. Next, diffusion of oxygen takes place in the liquid phase, down its concentration gradient across the alveoli-capillary barrier within the respiratory bronchioles and alveoli, into pulmonary capillaries. These capillaries carry deoxygenated blood from the pulmonary artery, and are extremely thin to minimize the distance of diffusion. Once inside the bloodstream, the majority of the oxygen is chemically combined with hemoglobin in RBCs, while a small amount is physically dissolved in plasma. The binding of oxygen to hemoglobin in RBCs helps unload carbon dioxide in the lung. This is due to the fact that oxygenated hemoglobin is more acidic in comparison with deoxygenated hemoglobin. It readily gives up its hydrogen ions, which combine with bicarbonate ions and shifts the chemical equilibrium towards the direction that favors carbon dioxide production. This way, oxygen is picked up by the blood in the lung, while carbon dioxide is expelled from the blood into the lung, and ultimately exhaled during expiration.

The now oxygenated blood returns to the heart via the pulmonary vein, and is eventually pumped out of the left side of the heart into the systemic circulation to reach various body tissues and organs. The lowered partial pressure of oxygen at the tissue
capillaries reduces the percentage saturation of hemoglobin in RBCs, thereby unloading oxygen into the tissues where they are used for cellular respiration. At the tissue level, deoxygenated hemoglobin in RBCs can pick up hydrogen ions produced from the dissociation of carbonic acid, shifting the reaction of carbon dioxide and water towards the right to facilitate greater uptake of carbon dioxide from the tissue into the RBCs. Additionally, deoxygenated hemoglobin can chemically combine with carbon dioxide to form carbamino-hemoglobin, further increasing the uptake of carbon dioxide from the tissues. Therefore, at the tissue level, oxygen is unloaded from RBCs into the tissue, where carbon dioxide is taken from the tissues into the RBCs, and ultimately carried to the lung.

**Allogeneic Blood Transfusion**

It’s commonly known that RBCs are a valuable yet scarce resource, with demand often exceeding its supply. As a result, it is of vital importance to optimize its use. In the United States, approximately 14 million units of RBCs are transfused each year in order to provide treatment for both acute and chronic anemia (Long et al., 2012). Allogeneic blood transfusion, in which a patient is transfused with blood donated by another individual, has become the standard treatment for potentially detrimental level of intraoperative as well as postoperative hemoglobin caused by the large amount of blood loss during surgery. However, allogeneic blood transfusion is often associated with various risks and complications, and may therefore be undesirable. These risks and complication are often inherent, regardless of one’s efforts to avoid them (Kleinert,
Well-known risks include the transmission of various infections, hemolytic transfusion reactions, transfusion febrile reaction (Dodd, 1992), as well as transfusion-related acute lung injury (Kopko, Marshall, MacKenzie, Holland, & Popovsky, 2002). Transfusion-included immunomodulation, which refers to allogeneic blood transfusion related immunosuppression, is also a reasonable concern. This may result in increased risk of tumor recurrences (Blumberg & Heal, 1994), as well as an increased incidence of postoperative infections (Duffy & Neal, 1996). Among the critically ill, past studies have also indicated that patients who receive allogeneic blood transfusions may be more likely to require prolonged mechanical respiratory support, suffer from multiple-organ dysfunction, and ultimately have an increased rate of mortality (Marik & Corwin, 2008).

Because of the risks and complications mentioned above, efforts have been made to reduce the amount of allogeneic blood transfusion. The scarcity and cost of RBCs are also part of the consideration. Blood products can only come from donors, as it clearly cannot be manufactured. According to the estimated figured provided by the American Red Cross, of the 38% of the U.S. population who are eligible to donate blood, less than 10% actually do so each year (“Blood Facts and Statistics,” n.d.). Meanwhile, the demand continues to grow each year, as the general population continues to age and age-related diseases becomes more prevalent (Bagot, Bove, Masser, & White, 2013). In terms of cost, the shrinking donor availability, as well as the application of laboratory tests and post-donation processing to minimize the risk of transfusion, continue to drive up the cost of allogeneic blood products. The cost for a single unit of packed red blood cells have
been reported to be anywhere between $270 and $780, depending on the costs for storage, as well as precautionary tests and processing to ensure minimal transfusion risk (Shander, Hofmann, Gombotz, Theusinger, & Spahn, 2007).

**Intraoperative Cell Salvage: Overview**

In light of the scarcity and cost of RBCs, as well as the associated risks and complications, the use of intraoperative cell salvage becomes an extremely attractive and effective blood conservation strategy. It is used for many surgical procedures where medium to high volume blood loss occurs, given that the blood is not contaminated with undesirable substances. The standard setup of a cell salvage unit is shown in Figure 1 (Ashworth & Klein, 2010). In general, cell salvage is the process in which blood lost during the surgery is collected from the operative field, washed, concentrated, filtered, and ultimately re-administered to the patient. More specifically, blood is first suctioned from the operative field during surgery. A large bored suction tip (minimum 4mm) should be used, and one should attempt to avoid surface skimming, which is the aspiration of blood mixed with large amount of room air. This is because air entrainment may lead to formation of bubbles that can result in cellular destruction (Liumbruno, Liumbruno, & Rafanelli, 2011). Together, these measures can help minimize damage to RBCs and increase yield and quality of collected blood. Additionally, when a blood moves in contact with a solid surface, shear forces occur and may cause damage to RBCs. Therefore, in order to prevent shear-induced hemolysis, it is recommended that the vacuum pressure be set as low as practical. Typically a value anywhere between
100mmHg and 150 mmHg is used. At times, the suction vacuum pressure can be increased temporarily, especially when there is a large amount of blood loss, and then returned to lower values later on. One study in the past demonstrated that when necessary, the vacuum pressure can be increased to as high as 300 mmHg without causing excessive hemolysis (Gregoretti, 1996).

It is important to use a double lumen suction tubing: one lumen holds the suctioned blood, while the other allows the addition of anticoagulant to salvaged blood in order to prevent clot formation (Ashworth & Klein, 2010). Blood clots are undesirable because they will not only render the recovered blood useless, but also potentially obstruct blood flow through the entire cell saver system. Either heparin or citrate can be used as anticoagulant in the process of cell salvaging. There have been controversies as to which one is the best (Oller et al., 1976), although heparin is often preferred due to its ready availability and low cost. Attention should be paid in particular to the amount of anticoagulant added to the salvaged blood. Typically it is recommended that the ratio of the volume of anticoagulant solution to salvaged blood be 1:5 if heparin is used, and 1:7 if citrate is used instead (Kuppurao & Wee, 2010). With this being said, over administration of heparin is usually of no serious consequence during the process of cell salvaging, due to the fact that all but a trace amount of heparin will be removed during the process of washing (Waters, 2013).
The anticoagulated blood is next collected in a large reservoir, and filtered in order to remove large clots or debris. The remaining volume is pumped into the processor, which is essentially a centrifuge bowl. The structure of the bowl is depicted in Figure 2 (Waters, 2013). Shed blood enters the bowl through a central straw, which runs through a spacer that occupies the middle of the bowl, and exits at the bottom. Because RBCs are denser and heavier than other components of the blood, the force supplied by the centrifuge will push them towards the outer walls of the bowl once they passed the central straw. In comparison, the other less dense components such as plasma tend to sediment closer towards the center of the bowl, and thereby passing though the central straw easily and exit at the bottom into a waste bag. It is important to beware that the
pumping force may exceed the centrifugal force when the pumping speed is set to high values, resulting in poor separation of RBCs from other blood components and spillage of RBCs into waste product. Therefore, extra attention must be paid to ensure that RBCs are not being lost in the event of massive blood loss when a higher than usual pumping speed is chosen. The pumping of shed blood into the bowl stops when packed RBCs nearly fill the bowl.
Figure 2. Structure of a processing bowl in cell savers. Shed, anticoagulated blood enters the bowl via the inlet, pass through the central straw that runs through the middle of the bowl, and exit at the bottom. The grey centerpiece through which the central straw runs simply acts as a spacer and does not contain any blood. Rather, blood runs outside the spacer. At the bottom of the central straw, centrifugal force pushes the heavier RBCs towards the surface of the bowl. In contrast, lighter components of blood such as plasma sediments closer towards the middle and leave the bowl as waste. The red arrows demonstrate direction of the blood flow, and the yellow arrows shows the mechanical forces that are applied to the fluid as it enters the bowl. (Figure taken from Waters, 2013)

The concentration of RBCs using centrifugal force can remove approximately 70-90% of the contaminants in shed blood. However, some contaminants remain in the blood and need to be further removed by the process of washing. This is done by pumping a wash solution into the bowl. Typically, normal saline (0.9% saline solution) is used as the wash solution of choice. However, one past study concluded that Isolyte S, a
physiologic multi-electrolyte solution, is the better choice to wash cell saver salvaged blood, on the basis that the use of Isolyte S resulted in fewer electrolyte or acid and base derangements (Halpern, Alicea, Seabrook, Spungen, & Greenstein, 1997). The process of washing takes approximately 5 – 10 minutes to complete, and usually produces a blood suspension with a hematocrit of 50-80% (Gregory & Andropoulos, 2012). After washing is completed, all waste products collected, including white blood cells, plasma, platelets, clotting factors, anticoagulant, and free plasma hemoglobin are discarded as clinical waste. The washed blood is next collected into a reinfusion bag. Many factors can influence the quality of collected blood. These include the quality of shed blood, the type of surgical procedure, the amount of wash solution used, as well as the degree of concentration achieved during separation (Kuppurao & Wee, 2010).

The salvages RBCs can be given back to the patient either immediately or within 4 hours after process if stored in room temperature. Currently, the maximal accepted storage time of salvaged RBCs is 6 hours (Allam, Cox, & Yentis, 2008). However, it is worthy to note that in a prospective study carried out in 1995 of 101 pediatric patients who underwent cardiopulmonary bypass, it was demonstrated that salvaged blood can be stored at room temperature for up to 18 hours with minimal chemical deterioration and limited microbiologic contamination (Hishon, Ryan, Lithgow, & Butt, 1995). During reinfusion of salvaged blood, if citrate is used as the anticoagulant, citrate toxicity may become a reasonable concern. Normally, liver metabolism is rapid and this makes citrate toxicity very unlikely to occur. But in patients with compromised liver function, it is
important to give small doses of calcium in order to provide immediate and nontoxic reversal (Waters, 2013).

**Intraoperative Cell Salvage: Benefits**

The use of perioperative cell salvage possesses many benefits. With the ability to deliver between 50%–85% hematocrit and to remove nearly all traces of free hemoglobin and potassium, intraoperative cell salvage is often the standard of care in many elective surgical procedures. It can help reduce or avoid allogeneic transfusions altogether, thereby minimizing the associated risks and complications. According to a meta-analysis carried out in 2006 of studies that examined the use of cell salvage to minimize allogeneic blood transfusion published prior to 2003, it was discovered that intraoperative cell salvage could reduce the exposure to allogeneic blood transfusion in adult patients by up to 40%. This translates to an average saving of 0.67 units of allogeneic blood per patient without causing any adverse impact on clinical outcomes (Carless et al., 2006). Similarly, in pediatric surgeries, intraoperative cell salvage has also shown to reduce the need for allogeneic blood transfusion in procedures such as craniofacial surgery (Krajewski et al., 2008), elective cardiac surgery (Golab, Scohy, de Jong, Takkenberg, & Bogers, 2008), and spinal fusion surgery (Bowen, Gardner, Scaduto, Eagan, & Beckstead, 2010). Additionally, perioperative cell salvage can effectively limit blood loss during surgery without carrying any side-effects that may be associated with the use of hemostatic agents such as lysine analogous, coagulation factor concentrates, or antifibrinolytic agents (Kuppurao & Wee, 2010). Furthermore, it reduces the risk of
human error that may lead to the wrong unit of blood being given during a transfusion.
The fact that intraoperative cell salvage requires no preoperative preparation on the part
of the patient also makes it ideal for unexpected massive hemorrhage during surgery.
Finally, from an economical standpoint, the use of intraoperative cell salvage has shown
to be both cost-saving and cost-effective, especially when used in combination with
allogeneic blood transfusion (Samnaliev et al., 2013).

Compared with allogeneic blood, salvaged blood has shown increased mean
erythrocyte viability as high as 88%. This is well above the minimum erythrocyte
viability of 70% in cross-matched allogeneic blood or pre-donated autologous blood – a
standard of the American Association of Blood Banks (Colwell, Beutler, West,
Hardwick, & Morris, 2002). Past studies have also demonstrated normal or increased
adenosine triphosphate (ATP) and 2,3-disphosphoglycerate (2,3-DPG) content in
salvaged blood (Muñoz Gómez et al., 1999). Salvaged RBCs can better maintain their
biconcave disc shape than allogeneic blood that has been stored for long periods of time.
A 1999 study examining the changes in RBC aggregability and shape during long periods
of storage showed that after 2 weeks of storage, the structural changes in RBCs took
place and led to a continuous increase in their agreeability. More specifically, structure of
RBCs changed from the normal biconcave disc to echinocytes, and this may impair the
ability of RBCs to cross capillary beds (Hovav, Yedgar, Manny, & Barshtein, 1999).
Therefore, given the above reasons, salvaged blood possesses better oxygen-carrying
capacity and can delivery oxygen to body tissues more efficiently in comparison with
allogeneic blood. Additionally, the use of salvaged blood instead of allogeneic blood
often resulted in an increased rate of survival after some surgical procedures, as well as reduced incidence of post-operative infections. According to Takemura et al., substituting allogeneic blood with autologous salvaged blood for patients undergoing radical oesophagectomy for cancer favorably affected the survival of patients (Takemura et al., 2005). Another randomized controlled trial of 70 patients who underwent unilateral total knee replacement demonstrated that when autologous salvaged blood is used rather than allogeneic blood, the incidence of post-operative infections is significantly less and the mean length of hospital stay is also reduced (Newman, Bowers, & Murphy, 1997). Gharehbaghian et al. proposed that the reduced incidence of post-operative infections associated with the use of autologous salvaged blood may be due to its effect on natural killer cell precursor frequency as well as levels of interferon gamma. Normally, immunosuppression, as a result of invasive surgery and blood loss, cause a decrease in natural killer cell precursor frequency and level of interferon gamma. Gharehbaghian et al. discovered that autologous salvaged blood could reverse this effect. Therefore this suggests that autologous salvaged blood contain immunostimulants (Gharehbaghian et al., 2004).
Intraoperative Cell Salvage: Disadvantages and Complications

Despite its relative safety and numerous advantages, the use of intraoperative cell salvage as a blood conservation strategy is not completely without complications. Air embolism is one of the major complications that may result from intraoperative cell salvage (Ashworth & Klein, 2010). When blood is initially suctioned from the operative field and pumped into the processing bowl of a cell saver, air in the system is forced into the waste bag. Once processing is completed and the blood is pumped into the primary reinfusion bag, some of the air in the waste bag may follow the movement of blood. Over time, this leads to the build up of air in the primary reinfusion bag, putting the patient at risk of air embolism if this blood is re-administered directly. Thus, it is vital that salvaged blood should never be given back to the patient directly from the primary reinfusion bag. Instead, it should always be transferred to a secondary bag before reinfusion (Waters, 2013). This way, as blood moves out of the primary bag into the secondary one, air is “burped” out of the secondary bag back into the primary one. Therefore, air embolism, although dangerous, is completely preventable. Figure 3 depicted the set up of primary and secondary reinfusion bags (Waters, 2013).
Figure 3. Processing steps of cell salvage. As processed, salvaged blood is pumped into the primary reinfusion bag, air from the waste bag may follow. Over time, build up of air may become significant in primary reinfusion bag. Therefore, one should never give blood in primary reinfusion bag back to the patient directly. In order to avoid air embolism, processed, salvaged blood should be transferred to a secondary bag before reinfusion. The arrows indicate the direction of blood flow. (Figure taken from Waters, 2013).

Coagulopathy, the impaired ability of blood to clot, is another major issue that may be associated with the use of intraoperative cell salvage. Salvaged blood essentially contains only RBCs suspended in normal saline, since platelets and any coagulation factors are removed during the washing process (Ashworth & Klein, 2010). This becomes problematic when large volume of salvaged blood is re-infused as a result of massive hemorrhage during surgery, as the coagulation factors and platelets in the body are being diluted in essence. It has been suggested that a coagulopathy should be expected after
more than 2 liters of blood loss, and that under these conditions, appropriate allogeneic blood components, such as platelets, fresh-frozen plasma, and cryoprecipitate, should be given to ensure sufficient coagulation. It has been recommended that the anesthesiologist should also repeat full blood count, prothrombin time, activated partial thromboplastin time, and fibrinogen levels after the reinfusion of each liter of salvaged blood, in order to detect coagulopathy and to provide appropriate treatment in time (Waters, 2013).

Additionally, disseminated intravascular coagulopathy and/or increased vascular permeability have been observed on occasion in patients following the infusion of washed salvaged blood (Bull & Bull, 1990). Increased vascular permeability may further lead to respiratory distress syndrome or extreme generalized edema (Heath & McFadzean, 1995). This has been labeled the “the salvaged blood syndrome”, and is thought to be related to the dilution of salvaged blood from large quantities of saline solution, which creates deposits of platelets and leukocytes when used with the fixed volume bowl system. It has been hypothesized by some that the mechanical deposition on the centrifuge bowl wall during the cell saving process causes activation of platelets and the release of leukoattractant substances, ultimately leading to increased vascular permeability and disseminated intravascular coagulation (DIC) (Bull & Bull, 1990). However, others have proposed that DIC and increased vascular permeability in patients who received salvaged blood is the result of a complex interaction of shock, hypothermia, reperfusion injury and multiple transfusions, rather than the autotransfusor itself (Tawes & Duvall, 1996). Therefore, it remains unclear whether the salvaged blood syndrome is a myth or reality.
Other disadvantages of the use of intraoperative cell salvage include contamination risks as well as hemolysis. Incomplete removal of contaminants from the salvaged blood may cause unwanted complications. For example, blood salvaged during the removal of pheochromocytomas has been shown to cause hypertension in patients after reinfusion (Smith, Mihm, & Mefford, 1983), because the extensive washing did not result in the complete removal of epinephrine and norepinephrine. Similarly, during ear, nose, and throat surgery, a nasal spray, oxymetazoline, is sometimes used. This substance may remain in salvaged blood in high concentrations even after washing, and is likely to cause hypertension and tachycardia upon re-administration (Waters, 2013). Hemolysis of RBCs may be caused by sheer stress or skimming during suction. This can be avoided by diluting blood with normal saline and using low vacuum pressure while suctioning (Waters, Williams, Yazer, & Kameneva, 2007).

Overall, regardless of its associated complications, salvaged autologous blood is still relatively safe for the patient to receive. The Cleveland Clinic carried out a 5 year retrospective review that examined the adverse events associated with allogeneic blood transfusion and salvaged blood transfusion. It was discovered that incidence of adverse reactions with auto-transfusion was only 0.027%, in comparison with that of 0.14% with allogeneic blood transfusion. Additionally, the total reported adverse reactions associated with salvaged blood transfusion composed only 2.1% of all transfusion reactions investigated in the hospital during the 5-year period (Domen, 1998).
Intraoperative Cell Salvage: General Indications and Contraindications

Past recommendations from the America Association of Blood Banks (AABB) suggest that cell salvage is indicated when one or more of the following conditions is met: the patient’s anticipated blood loss is greater than 20% of his or her estimated blood volume; crossmatch-compatible blood is unavailable or unobtainable; the patient is unwilling to receive allogeneic blood transfusion, but will give consent to receive salvaged blood from surgery; more than 10% of patients undergoing the procedure require transfusion; the mean transfusion for the procedure should exceed 1 unit (American Association of Blood Banks Autologous Transfusion Committee, 1997).

It is worthy to note that the above recommendations were developed from comparing the cost of allogeneic blood to that of blood salvage. Since the development of these recommendations, the cost of allogeneic blood transfusion has increased, thereby changing the economic relationship from which the above recommendations were derived. Additionally, the expenses associated with cell salvage are much better understood now than before. Therefore, the above recommendations need not to be strictly followed. In fact, intraoperative cell salvage should still be considered even though only a small amount of anticipated blood loss is expected (Esper & Waters, 2011).

The use of intraoperative cell salvage might be indicated in numerous types of invasive surgical procedures according to Table 1 (Waters, 2013), especially those that are likely to result in large amount of blood loss, such as cardiac and orthopedic procedures. Overall, the decision to implement the use of cell salvage should always be
appropriately communicated between the case-specific surgeon and the anesthesiologist (Waters, 2013). It is also important to note that since the patients starting hematocrit, sex, age, and body weight can all influence the risk of receiving blood products (Scott, Seifert, Glass, & Grimson, 2003), the decision to provide cell salvage should be individualized in many cases.

**Table 1: General indications for intraoperative cell salvage** (Table taken from Waters, 2013)

<table>
<thead>
<tr>
<th>Surgical Category</th>
<th>Type of Surgical Procedure</th>
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<td>Hepatic resection</td>
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<td>Porta-caval shunt</td>
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<td>Nephrectomy</td>
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<td>Kidney transplant</td>
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<td>Revascularization for femoral injuries</td>
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<td>Cardiac transplant</td>
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<td>Open reduction/fixation of long bone fractures</td>
</tr>
<tr>
<td></td>
<td>Spinal fusion—bone graft or instrumentation</td>
</tr>
<tr>
<td></td>
<td>Laminectomy</td>
</tr>
<tr>
<td></td>
<td>Extremity implantation</td>
</tr>
<tr>
<td>OB/GYN</td>
<td>Hysterectomy</td>
</tr>
</tbody>
</table>

OB/GYN, obstetrics/gynecology.
In terms of general contraindications, Table 2 (Esper & Waters, 2011) provides an extensive list. However, one must beware that most contraindications are considered relative rather than definitive. That is to say that there exist little experimental data to support the adverse effect that may be caused by the contraindications suggested. Thus, when a decision is made to not use blood salvage, it needs to be considered in light of the known risks associated with the alternative therapy, which is allogeneic blood (Waters, 2013).
Table 2: General contraindications for intraoperative cell salvage (Table taken from Esper & Waters, 2011).

<table>
<thead>
<tr>
<th>Pharmacological agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clotting agents (Avitene, Surgicel, Gelfoam, etc.)</td>
</tr>
<tr>
<td>Irrigating solutions (betadine, antibiotics meant for topical use)</td>
</tr>
<tr>
<td>Methylmethacrylate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine</td>
</tr>
<tr>
<td>Bone chips</td>
</tr>
<tr>
<td>Fat</td>
</tr>
<tr>
<td>Bowel contents</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Amniotic fluid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Malignancy</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Haematological disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sickle cell disease</td>
</tr>
<tr>
<td>Thalassaemia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide (electrocautery smoke)</td>
</tr>
<tr>
<td>Catecholamines (pheochromocytoma)</td>
</tr>
<tr>
<td>Oxymetazoline (Afrin)</td>
</tr>
<tr>
<td>Papaverine</td>
</tr>
</tbody>
</table>
Blood Ordering Practice for Elective Surgeries

When a patient is booked for a surgical procedure, it is often the surgeon’s office that is booking the procedure and ordering the blood products. A type and screen is typically ordered if transfusion is possible. This test verifies the blood type of the patient and screens the patient for any alloantibodies that might be present but does not set aside any blood units for the patients. Other times, a type and cross is ordered when transfusion seems highly likely or imminent. In this case, compatible RBCs are secured exclusively for a patient so they’ll be readily available when needed.

The amount of blood ordered is usually based on routine practice or previous experiences of clinicians. Fear of not having sufficient blood available during surgery is common and leads to requests for larger amounts of blood products than necessary. As a result, without appropriate blood ordering guidelines, blood product waste easily becomes an issue (Khoshrang, Madani, Roshan, & Ramezanadeh, 2013). Even when intraoperative blood salvage is used to reduce the amount of blood bank products required, unnecessary ordering of blood products is still a regular occurrence. Excessive ordering of blood products for a particular procedure is wasteful in many ways. Blood that can be used for other patients is set aside and reserved, thereby limiting the available inventory for other patients. If any particular bag of blood is set up for multiple patients before use, the time between irradiation and use will be increased, thus leading to a significant degradation in the quality of the RBCs. Furthermore, cells that are set up and then not used may expire, which will mean they will need to be disposed of as hazardous waste, adding to the operating expenses of the blood bank without any direct patient
benefit. Therefore, excessive ordering of blood can lead to outdating of blood, overburdening of blood bank personnel, depletion of blood bank resources, as well as wastage of time (Subramanian et al., 2010).

In the past, efforts have been introduced to reduce unnecessary ordering of blood products. The maximum surgical blood ordering schedule (MSBOS) is one of the many examples. MSBOS aims to reduce the amount of blood crossmatched preoperatively for patients undergoing elective surgery (B. A. Friedman, Oberman, Chadwick, & Kingdon, 1976). It is a list that comprises the maximum number of units of blood that should be crossmatched preoperatively for each commonly performed elective surgical procedure, and is established based on retrospective review of actual blood utilization pattern associated with each type surgical procedure at individual hospitals (Green, 1991). Past studies have shown that successful establishment and implementation of MSBOS can effectively lower crossmatch to transfusion ratio and reduce crossmatch charges (Lowery & Clark, 1989).

Although MSBOS has led to improvement in blood utilization, there are still certain drawbacks. The most significant one is the lack of accountability for individual differences, since the transfusion requirements between different patients undergoing the same surgery may not always be the same (Murphy et al., 1995). In comparison, surgical blood order equation (SBOE) provide a way to calculate the number of units of blood that should be ordered while giving consideration to specific patient variables, such as pre- and postoperative hemoglobin (Hb) levels (Subramanian et al., 2010). SBOE was shown to be a highly accurate and cost-saving tool in predicting blood use in many types of

**Standardized Clinical Assessment and Management Plan (SCAMP)**

SCAMPs are a novel quality improvement initiative that aim to standardize the assessment and management of a heterogeneous patient population who carry a predefined diagnosis (K. G. Friedman et al., 2010). The first SCAMP was conceived, designed, and implemented by physician and nursing leaders of the Cardiovascular Program at Boston Children’s Hospital (BCH) in 2009 (Rathod et al., 2010). Since then, more than 12,000 patients have been enrolled in forty-nine SCAMPs in nine states and Washington, D.C. (Farias et al., 2013). SCAMPs are essentially a practice tool for reducing practice variability while permitting flexibility, allowing providers to best exercise their clinical judgment and adapt treatment to individual patients (K. G. Friedman et al., 2010). Typically, a SCAMP is developed through retrospective analysis of current practice or review of medical literatures and relevant professional society standards, usually carried out by a multidisciplinary team of physicians and other healthcare providers, in order to establish a foundation for sound clinical practice (Fortescue, Lock, Galvin, & McElhinney, 2010). Once a SCAMP is developed initially, it
typically takes three to six months before it can be fully implemented. Analysis and modification of the SCAMP are continually conducted and made in order to rapidly optimize clinical decision-making and care delivery (Farias et al., 2013).

In July 2012, a SCAMP relating to blood ordering practice was introduced at BCH in order to standardize blood ordering for orthopedic surgical procedures and reduce unnecessary utilization of blood products. This SCAMP involves an algorithm that is used as a reference when ordering blood products for orthopedic surgical patients scheduled for intraoperative cell salvage. Prior to the introduction of this SCAMP, blood ordering at BCH was largely based on personal preference and routine practice. Guidelines for blood ordering did exist, but were followed loosely at best. According to this SCAMP, if autologous blood was available and patients’ baseline hematocrit is greater than 35%, it is not necessary to order any additional blood products. If autologous blood was available and the baseline hematocrit was less than 35%, it is recommended that 1 unit of RBC should be ordered. In comparison, for those patients who do not have autologous blood readily available, it is suggested that 1 unit of RBC should be ordered for those with a baseline hematocrit greater than 35%, and 2 units of RBC should be ordered for those whose baseline hematocrit is less than 35%. Figure 4 demonstrates the SCAMP’s decision support tree for blood ordering (“SCAMPs Program: Blood Ordering/Cell Saver SDF 1,” 2012).
Specific Aims

Without specific blood ordering guidelines or algorithm, the amount of blood product requested and cross-match is often much greater than the actual level of consumption. In a study published in 2013, Fernández et al. performed a retrospective chart review of intraoperative RBC transfusion for pediatric patients undergoing non-cardiac surgery at a single institution. This analysis identified several procedures for which preoperative testing is performed and blood products are ordered, but which rarely, if ever, necessitate patient transfusion (Fernández, Cronin, Greenberg, & Heitmiller,
Another study published in 2012 indicated that requests for blood often exceed its real use: of a total of 435 patients who underwent elective urological surgery at a single institution, cross-matching was performed for 97.5% of patients but only 8.5% required a blood transfusion in the operating room (Khoshrang et al., 2013).

Efficient blood ordering guidelines have been developed in the past to provide a more accurate prediction of transfusion needs and to minimize waste. However, few studies in the past attempted to examine the blood ordering and utilization pattern with an emphasis on surgical cases that involve the use of intraoperative cell salvage. With the use of intraoperative cell-salvage devices, considerable change in the practice of ordering cross-matched blood should be made. The development of more efficient blood ordering guidelines, in conjunction with intraoperative cell-salvage, could promote maximum blood conservation and financial savings.

The aim of this study is to examine the blood ordering and utilization pattern for orthopedic surgical cases at BCH, with an emphasis on patients who are scheduled for intraoperative cell salvage. We sought to compare the blood ordering and utilization pattern before and after the introduction of SCAMP, in July 2012, in order to assess its effectiveness in reducing excessive blood product ordering. This is in an effort to minimize blood product waste and unnecessary utilization of blood bank services while maximizing patient benefit. We hope the results of this study may be used to assess the progress of quality improvement of the blood product management process at BCH. This ultimate will allow us to revise current guidelines and develop new patient-specific, procedure-specific guidelines for preoperative blood product ordering and intraoperative
cell salvage scheduling. Additionally, the data from this study may reveal trends and areas where blood utilization practices can be improved.
METHODS

This is a retrospective study and chart review on all pediatric patients who were scheduled for orthopedic surgical procedures that have had blood products ordered and scheduled for intraoperative cell salvage at BCH from January 2011 to December 2013. Since SCAMP was introduced in July 2012, the blood ordering and utilization pattern before and after the introduction of SCAMP was compared, in order to assess SCAMP’s effectiveness in reducing excessive blood product ordering and increasing efficiency of blood utilization. Patients were grouped into one of two cohorts: those who had surgery scheduled during the 17 months before SCAMP was introduced, and those who had surgery during the 18 months after the introduction of SCAMP.

Retrospective analysis of two cohorts was performed through reviewing electronic medical records at BCH for relevant clinical and demographic information. These include intraoperative records, anesthesia records, operative notes, progress notes, laboratory results, as well as blood bank records. The following variables were collected: age, gender, weight, American Society of Anesthesiology (ASA) physical status, operative procedure, name of attending surgeon and anesthesiologist, estimated blood loss, availability and usage of autologous blood, units of allogeneic blood that were ordered, sent, transfused, and returned, volume of salvaged blood re-infused, hemostatic agent usage, the use of blood products including fresh frozen plasma (FFP), cryoprecipitate, as well as whole blood, pre and post-operative hemoglobin levels, and intraoperative use of crystalloid and colloid.
The difference between blood units ordered and used, and the ratio of blood units transfused to units of blood ordered was calculated. These values were compared between two cohorts over time in order to assess whether there was a change in the effectiveness of blood ordering and utilization since the implementation of SCAMP. More specifically, efficiency of blood product utilization was evaluated using the difference between units of blood that are ordered and transfused. For each month, the difference (units ordered – units transfused) and the percentage utilization (units transfused ÷ units ordered) × 100% were calculated and recorded. Higher percentage utilization and a smaller difference between units ordered and units transfused was expected to be observed after the implementation of SCAMP, and would indicate better efficiency of blood utilization and measurable improvement. Similar calculations were done using the number of units of blood that is sent from the blood bank to the operative room instead of the number ordered. This is due to the fact that the number of units of blood ultimately sent to the operating room does not always equal the number of units initially ordered.

To evaluate the implementation of SCAMP over time, we also compared the number of blood units that should be ordered according to the SCAMP algorithm with what was actually ordered. A small difference between these two values would indicate good compliance with SCAMP protocol, while a larger difference would indicate that the SCAMP algorithm was poorly followed. In addition, we compared the difference between the number of blood units that should be ordered according to the SCAMP and the number of blood units that were actually transfused. This was done to assess whether
SCAMP provided an accurate prediction of the actual utilization of blood products during various elective surgical procedures included in this study.

**Statistical Analysis**

Before the study, the projected sample size was estimated to be 900 procedures - 500 for the 17 months pre-SCAMP and 400 post-SCAMP. It was assumed that this projected sample size would provide 80% statistical power to capture moderate effect sizes of 0.50 with respect to: 1) mean difference of 1 units of blood between what is ordered and transfused, assuming a standard deviation of 2 units and 2) a mean difference of 15% assuming a standard deviation of 30% in the percentage utilization ratio using paired t-tests. Patient characteristics were compared across cohorts using student’s paired t-test for continuous variables and Chi-square test for categorical variables. In addition, a longitudinal data analysis was applied using a time series autoregressive moving average (ARMA) model to evaluate whether the implementation of SCAMP has led to significant improvements in blood product utilization over time (Brockwell and Davis, 2002). Statistical analysis was performed using IBM SPSS Statistics (version 21.0, IBM, Armonk, NY) and Microsoft Excel 2012. Two-tailed values of $P < 0.05$ was considered statistically significant.
RESULTS

From 1/1/2011 to 12/31/2013, 942 pediatric orthopedic surgical procedures were performed at BCH during which intraoperative cell salvaged was used. Data from July 2012 to August 2012 could not be located, and therefore were not included in this study. Demographic data for all patients included are indicated in Table 3. Of the 942 patients, 455 underwent operations before SCAMP was introduced, while 487 operations took place after the introduction of SCAMP. P values suggest that patient demographic across the two cohorts did not show any statistically significant differences.

Table 3. Demographic Data.

<table>
<thead>
<tr>
<th></th>
<th>PRE-SCAMP</th>
<th>POST-SCAMP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>455</td>
<td>487</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53.4 ± 22.1</td>
<td>51.7 ± 22.3</td>
<td>0.245</td>
</tr>
<tr>
<td>Age (Years)</td>
<td>14.7 ± 4.6</td>
<td>14.3 ± 5.2</td>
<td>0.228</td>
</tr>
<tr>
<td>Male Gender (n, % of total)</td>
<td>162 (35.8%)</td>
<td>291 (37.4%)</td>
<td>0.609</td>
</tr>
</tbody>
</table>

In terms of clinical conditions of patients that are included in this study, the characteristics of patient populations in the two different cohorts were fairly similar with respect to ASA status, pre-operative hematocrit, as well as the amount of colloids given during surgery. Other variables listed, such as procedure type, estimated blood loss, pre-donated autologous blood availability, volume of salvaged blood that was transfused, volume of crystalloid used, and TXA usage, were significantly different between the two
cohort. Table 4 demonstrates the differences in patient characteristics between the pre-SCAMP and post-SCAMP groups.

Table 4. Patient Characteristics: Clinical Condition.

<table>
<thead>
<tr>
<th></th>
<th>PRE-SCAMP</th>
<th>POST-SCAMP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA Status (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18.5</td>
<td>15.6</td>
<td>0.672</td>
</tr>
<tr>
<td>2</td>
<td>50.3</td>
<td>51.2</td>
<td>0.672</td>
</tr>
<tr>
<td>3</td>
<td>29.5</td>
<td>31.3</td>
<td>0.672</td>
</tr>
<tr>
<td>4</td>
<td>1.8</td>
<td>1.6</td>
<td>0.672</td>
</tr>
<tr>
<td>Procedure Type (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spine</td>
<td>58.9</td>
<td>63.0</td>
<td>0.006</td>
</tr>
<tr>
<td>Hip</td>
<td>29.0</td>
<td>27.9</td>
<td>0.006</td>
</tr>
<tr>
<td>Femur</td>
<td>9.5</td>
<td>4.3</td>
<td>0.006</td>
</tr>
<tr>
<td>Hip &amp; Femur</td>
<td>2.2</td>
<td>4.7</td>
<td>0.006</td>
</tr>
<tr>
<td>Spine &amp; Hip</td>
<td>0.2</td>
<td>0 (0.0%)</td>
<td>0.006</td>
</tr>
<tr>
<td>Spine &amp; Femur</td>
<td>0.2</td>
<td>0 (0.0%)</td>
<td>0.006</td>
</tr>
<tr>
<td>EBL (ml)</td>
<td>841.6 ± 648.5</td>
<td>687.9 ± 688.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EBL (ml/kg)</td>
<td>18.1 ± 17.4</td>
<td>14.2 ± 15.8</td>
<td>0.002</td>
</tr>
<tr>
<td>EBL (% of EBV)</td>
<td>25.9 ± 24.8</td>
<td>20.2 ± 22.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Autologous Blood Availability (%)</td>
<td>18</td>
<td>12.90</td>
<td>0.031</td>
</tr>
<tr>
<td>Cell Saver Auto-reinfusion (ml)</td>
<td>224.7 ± 221.9</td>
<td>174.3 ± 184.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cell Saver Auto-reinfusion (ml/kg)</td>
<td>4.4 ± 5.2</td>
<td>3.4 ± 3.7</td>
<td>0.001</td>
</tr>
<tr>
<td>Pre-op Hematocrit</td>
<td>39.2 ± 3.9</td>
<td>39.1 ± 3.6</td>
<td>0.558</td>
</tr>
<tr>
<td>TXA use (%)</td>
<td>29.4</td>
<td>37.0</td>
<td>0.013</td>
</tr>
<tr>
<td>Crystalloid Use (ml)</td>
<td>2880.6 ± 1359.9</td>
<td>2485.8 ± 1187.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Colloid Use (ml)</td>
<td>321.1 ± 458.3</td>
<td>296.7 ± 416.6</td>
<td>0.387</td>
</tr>
</tbody>
</table>

According to Table 5, our data indicated that since the introduction of SCAMP in July 2012, there has been a mean difference of 0.5 units of blood between what was ordered and transfused, from a value of 1.4 before the introduction of SCAMP to that of
0.9 afterwards. Additionally, the mean percentage utilization of blood products increased from 29.2% to 53.6% since the introduction of SCAMP, demonstrating an increase of 24.4%. Similar calculations that were done using the number of blood units that were sent to the operating room instead of ordered also indicated an improvement in blood utilization, with a mean reduction of a difference of 0.5 units of blood between what was sent and what was transfused, with a mean percentage utilization increase of 25.3%. The extremely small P values indicated these reductions in the difference between units of blood that were ordered/sent and transfused, as well as the increases in percentage utilization, are highly statistically significant. In addition, the percentage utilization of blood products and the difference between units of blood that were ordered or sent and transfused were also evaluated on a monthly basis. These trends are demonstrated in Figure 5–9.

Table 5: Blood Utilization Pattern

<table>
<thead>
<tr>
<th></th>
<th>PRE-SCAMP</th>
<th>POST-SCAMP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ordered – Used</td>
<td>1.4 ± 0.9</td>
<td>0.9 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>Sent – Used</td>
<td>1.1 ± 0.9</td>
<td>0.6 ± 0.8</td>
</tr>
<tr>
<td>Used/Ordered x 100%</td>
<td>29.2 ± 45.8</td>
<td>53.6 ± 57.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sent/Ordered x 100%</td>
<td>40.6 ± 45.1</td>
<td>65.9 ± 45</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Figure 5. Comparison of Ordered and Used Blood Products. Differences between blood units that were ordered and used before and after the introduction of SCAMP in July 2012 were calculated.
Figure 6. Comparison of Sent and Used Blood Products. Differences between blood units that were sent to the operative room and used before and after the introduction of SCAMP in July 2012 were calculated.
Figure 7. Percentage Utilization of Blood Products Over Time. Before and after the introduction of SCAMP in July 2012, percentage utilization of blood products were calculated using number of units of blood ordered as the denominator.
Figure 8. Percentage Utilization of Blood Products Over Time. Before and after the introduction of SCAMP in July 2012, percentage utilization of blood products were calculated using number of units of blood sent as the denominator.
Figure 9: Comparison of Percentage Utilization Over Time. Percentage utilization values calculated using units of blood products ordered and sent respectively as the denominator were compared on a monthly basis over time.
**Figure 10. SCAMP Implementation.** The difference between number of blood units recommended and number of blood units ordered demonstrates the difference between SCAMP recommended usage and actual usage of blood products.
To evaluate the implementation of this SCAMP, the difference between the number of units of blood that should be ordered according to SCAMP calculation and number of units of blood that were actually ordered were calculated. This value was not statistically significant between the pre and post SCAMP group (p > 0.05). Table 6 shows an average of 0.85 unit of difference after the introduction of SCAMP. This value was also evaluated over time on a monthly basis. The resulting trend is shown in Figure 10.

Table 6. SCAMP Implementation and Accuracy.

<table>
<thead>
<tr>
<th></th>
<th>PRE-SCAMP</th>
<th>POST-SCAMP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommended – Ordered</td>
<td>0.86 ± 0.87</td>
<td>0.85 ± 0.73</td>
</tr>
<tr>
<td></td>
<td>Recommended – Used</td>
<td>0.89 ± 0.75</td>
<td>0.99 ± 0.61</td>
</tr>
</tbody>
</table>

Additionally, to assess the accuracy of SCAMP in predicting actual blood product usage, we calculated the difference between the SCAMP recommended usage and actual usage of blood products, and compared this value between the pre-SCAMP and post-SCAMP group. Table 6 shows the results.
DISCUSSION

This retrospective analysis identified that in general, the introduction of SCAMP at BCH in July 2012 led to a statistically significant improvement in the efficiency of blood product utilization. Percentage utilization was markedly improved, and the number of units of blood that were ordered better matched actual consumption after the introduction of SCAMP. Since the number of units of blood ordered does not always equal the number of units that of sent to the operating room, we felt that the difference between the number of units of blood sent to the operating room and those used would better reflect the actual utilization and wastage of blood products. Consequently, $|\text{units sent} - \text{units used}|$ and percentage utilization calculated this way also demonstrated significant improvement in the efficiency of blood production utilization. Analysis of blood utilization patterns on a monthly basis also indicated a similar result. After introduction of SCAMP, data showed that blood utilization was improved overall. However, when analyzed on a monthly basis, our data did not reveal an upward trend in percentage utilization or a downward trend in blood wastage after the introduction of SCAMP.

Efficient blood ordering guidelines have been developed in the past and led to a more accurate prediction of the need for intraoperative blood transfusion and improved blood utilization in many cases. In a study published in 2003, a patient-specific blood ordering system, which included patient and surgeon variables in transfusion prediction, was developed and was proven to be more accurate than the commonly used MSBOS.
(Palmer, Wahr, O’Reilly, & Greenfield, 2003). Additionally, Frank et al. at the John Hopkins Medical Institution used blood utilization data extracted from an anesthesia information management system to create an institution-specific blood ordering algorithm. This algorithm helped eliminate unnecessary blood orders and led to a calculated potential reduction in their hospital charge of $211,448 per year (Frank et al., 2013).

Interestingly, when examining the actual implementation of SCAMP since its introduction, data revealed that SCAMP did not become better implemented over time. The mean difference between the units recommended and units ordered did not decrease over time. Data also suggested that in terms of the difference between units recommended and units ordered, there is no statistical difference between the pre-SCAMP and post-SCAMP group. This may be explained by the fact that although the absolute difference between the number of units recommended and units ordered were similar between the pre-SCAMP and post-SCAMP, the pre-SCAMP group mostly represented “over-ordering” scenarios, whereas the post-SCAMP group represented “under-ordering” scenarios. Prior to the introduction of SCAMP, the amount of blood ordered usually exceeded SCAMP recommendation, since over ordering was common practice. In comparison, after the introduction of SCAMP, less blood products were ordered in general, and in many cases, the amount of blood ordered was less than what was recommended by SCAMP but was still sufficient. As a result, both “over-ordering” and “under-ordering” lead to the similar absolute difference between the number of units recommended and units ordered.
Additionally, upon examining SCAMP’s decision support tree for blood ordering, one would notice that in order to have 0 units of blood ordered, a patient must have autologous blood available and have a pre-operative hematocrit value that is greater than 35. Among the study population, less than 20% of the patients have pre-donated autologous blood readily available. This means that if SCAMP was to be followed strictly, the majority of the patients would need to have at least 1 units of RBC ordered. With the use of intraoperative cell salvage especially, many patients did not require any blood transfusion at all. Data from this study also indicated a mean difference of 0.99 units of blood between the number of units recommended by SCAMP and the number of units transfused, with a standard deviation of 0.61, after the implementation of SCAMP. Without other studies to compare to as references, it is difficult to conclude whether this difference indicated poor or satisfactory prediction of actual utilization of blood products.

Furthermore, the existing SCAMP algorithm did not take into consideration the number of units of pre-donated autologous blood that are available. Its decision support tree separates patients into categories based on the availability of autologous blood without further differentiation. In other words, a patient who has multiple units of autologous blood available should obviously have less blood ordered than someone who only has 1 unit. Therefore, further study should be carried out in order to provide better knowledge of the actual level of utilization of blood products, as well as other parameters that may affect blood product ordering and utilization. In terms of data analysis, future studies should also investigate both incidences of over-ordering as well as under-ordering of blood products, in order to gain a more complete understanding of actual utilization.
pattern. Appropriate modifications of the current SCAMP protocol should be made base on these knowledge, so that blood products orders can more accurately reflect actual transfusion needs.

Because this is a retrospective study, some of the electronic medical record were entered incorrectly and therefore omitted. Data from the first two months after the implementation of SCAMP were also missing. Additionally, we examined a 34-month period only. A longer study period with a larger study population may reveal numbers and trends that may be different from the results of this study. Finally, it was difficult to determine the person responsible for ordering the blood products. Knowledge of the ordering provider may provide valuable insights into blood ordering practice, since the level of past experience of the provider may influence the amount of blood ordered.

In conclusion, the introduction of SCAMP in July 2012 at BCH did improve blood product utilization and reduce unnecessary blood product ordering. However, further studies should be conducted to provide knowledge that can be used to modify the existing SCAMP to better predict actual transfusion needs.
REFERENCES


VITA

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qchen23@bu.edu \ 937-207-4834 \ Year of Birth 1989

EDUCATION

Boston University School of Medicine
Master of Science: Medical Science GPA: 3.91
Aug 2012 – Present

Cedarville University
Bachelor of Arts: Chemistry, GPA: 3.78
2008 - May 2012

MEDICALLY RELEVANT EXPERIENCES

Greene Memorial Hospital
Emergency Room Volunteer
Aug 2008 – May 2009
• Provided necessary assistance to patients, their family, as well as ER staff

Cedarville Township Volunteer Fire Department
EMT-Basic
Aug 2010 – Aug 2011
• Provided basic life support and transport patients to nearby medical facilities
• Attended regular trainings and meetings

Dominican Republic Medical Mission Trip
Medical Team Member
March 2011
• Performed triage work at various clinics
• Assisted physicians with physical examinations and diagnosis

Acclaim Hospice
Patient Volunteer
Oct 2011 – May 2012
• Visited Patients on a weekly basis to provide companionship as needed

Cleveland Clinic Department Cardiovascular Surgery
Shadowing Experience
Jun 2011 – Aug 2011
• Observed various types of cardiovascular surgeries as well as non-surgical events
RESEARCH EXPERIENCES

Cleveland Clinic Lerner Research Institute
Research Student
Jun 2011 – Aug 2011
• Participated in the design, prototyping, and testing of an innovative strapless respiratory mask.

IU Health Methodist Hospital
Research Assistant
Indianapolis, IN
May 2012 – Aug 2012
• Assisted with retrospective clinical study that compared two different antibiotic prophylaxis regimens among Ventricular Assist Device (VAD) recipients

OTHER EXPERIENCES

Union of Cedarville International Student
President (2011,2012) / Vice President (2010)
Cedarville, OH
Aug 2009 – May 2012
• Planned and organized weekly and monthly activities for international students
• Worked with school administration to secure scholarships and develop special orientation programs for international students

Cedarville University Academic Enrichment Center
Academic Peer Coach
Cedarville, OH
Jan 2012 – May 2012
• Attended class with students
• Prepared and presented weekly study sessions as well as “walk in” tutoring sessions