Autologous Blood Transfusion During Emergency Trauma Operations

Carlos V. R. Brown, MD; Kelli H. Foulkrod, MSc; Holli T. Sadler, MD; E. Kalem Richards, LP, CCP; Dennis P. Biggan, LP, CCP; Clea Czysz, RN; Tony Manuel, MD

Hypothesis: Intraoperative cell salvage (CS) of shed blood during emergency surgical procedures provides an effective and cost-efficient resuscitation alternative to allogeneic blood transfusion, which is associated with increased morbidity and mortality in trauma patients.

Design: Retrospective matched cohort study.

Setting: Level I trauma center.

Patients: All adult trauma patients who underwent an emergency operation and received CS as part of their intraoperative resuscitation. The CS group was matched to a no-CS group for age, sex, Injury Severity Score, mechanism of injury, and operation performed.

Main Outcome Measures: Amount and cost of allogeneic transfusion of packed red blood cells and plasma.

Results: The 47 patients in the CS group were similar to the 47 in the no-CS group for all matched variables. Patients in the CS group received an average of 819 mL of autologous CS blood. The CS group received fewer intraoperative (2 vs 4 U; \( P = .002 \)) and total (4 vs 8 U; \( P < .001 \)) units of allogeneic packed red blood cells. The CS group also received fewer total units of plasma (3 vs 5 U; \( P = .03 \)). The cost of blood product transfusion (including the total cost of CS) was less in the CS group ($1616 vs $2584 per patient; \( P = .004 \)).

Conclusion: Intraoperative CS provides an effective and cost-efficient resuscitation strategy as an alternative to allogeneic blood transfusion in trauma patients undergoing emergency operative procedures.

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Injury due to trauma is the leading cause of death for children and adults aged 1 to 44 years. Exsanguination plays a significant role in as many as 50% of these deaths, particularly deaths that occur in the operating room or within the first 24 hours after injury. Patients presenting in hemorrhagic shock will require allogeneic blood product transfusion (sometimes massive), most commonly with packed red blood cells (PRBCs) and plasma. Any transfusion with allogeneic blood products is associated with a variety of complications, including transfusion reaction, transmission of infectious diseases, and sensitization to antigens. Massive transfusion has additional implications, such as dilutional coagulopathy, acidosis, and hypothermia. Furthermore, transfusion of allogeneic blood products in trauma patients has been independently associated with increased morbidity and mortality, particularly when transfusing older, stored blood products. In addition to complications associated with allogeneic transfusions, there are systematic and financial issues at play. With a decline in blood donors, higher skilled labor costs, and increases in the cost of testing and processing blood, blood centers have more than doubled the prices of blood products in recent years. Because of the chronic shortage and increasing costs of blood products, many investigators have tried to find alternatives to allogeneic blood transfusion. Alternative transfusion strategies in elective surgery have included autologous (acute) normovolemic hemodilution, autologous preoperative donation, and intraoperative cell salvage (CS) with autotransfusion. Although autologous (acute) normovolemic hemodilution and autologous preoperative donation obviously are not possible in the setting of trauma, intraoperative CS with autotransfusion represents a viable alternative but has received limited attention in trauma patients.

We hypothesized that trauma patients who require urgent operative intervention can be resuscitated with intraoperative autologous blood transfusion and that...
We performed a retrospective matched cohort study at University Medical Center Brackenridge, an American College of Surgeons–verified level I trauma center in Austin, Texas. The medical records of all adult (≥18 years old) trauma patients admitted to our trauma center from January 1, 2006, through December 31, 2007, were reviewed. Patients who underwent an urgent (<6 hours from admission) trauma operation (laparotomy, thoracotomy, or orthopedic) and received intraoperative CS (CS group) were included. A matched cohort population was identified from the remaining trauma admissions who underwent an urgent trauma operation and required transfusion but did not receive CS as part of their resuscitation (no-CS group). The CS group was paired with controls according to the confounding variables of age (±5 years), sex, mechanism of injury (blunt or penetrating), Injury Severity Score (16-25 or ≥25), and operation performed.

Intraoperative CS and return of red blood cells to the patient involves 3 basic steps. As shed blood is collected from the surgical field by vacuum aspiration, it is mixed with heparin sodium and carried to a sterile collection container. When an adequate amount of whole blood has been collected, it is then pumped to a spinning centrifuge bowl where the components are separated and the red blood cells are retained in the bowl. This separation process concentrates the red blood cells to increase the hematocrit of the blood that was salvaged from the surgical field. After concentration, a sterile saline solution is pumped through the spinning centrifuge bowl to displace the remaining components (other than red blood cells) and to suspend the red blood cells. Finally, the concentrated red blood cells suspended in saline are pumped to a transfer pack to be reinfused into the patient.

Variables collected included age, sex, mechanism of injury (blunt vs penetrating), Injury Severity Score, and, at admission, the heart rate (in beats per minute), systolic blood pressure (in millimeters of mercury), and Glasgow Coma Scale score. The primary outcomes were amount of intraoperative and total transfusion with allogeneic PRBCs and fresh frozen plasma. Secondary outcomes included measured intraoperative blood loss and the total cost of transfusions (CS + allogeneic). At our institution, CS costs $375 (including technician time), and blood component therapy costs per unit are as follows: PRBCs, $216; plasma, $63; platelets, $562; and cryoprecipitate, $745. Additional secondary outcomes included lengths of stay in the intensive care unit and hospital and mortality. The CS and no-CS groups were compared by univariate analysis using the χ² and paired, 2-tailed t tests and nonparametric tests when appropriate. Values are reported as mean (SD) or raw percentages; statistical significance was set at $P<.05$. The local institutional review board approved this study.

### RESULTS

During the 2-year study, 76 patients were identified who underwent an emergency trauma operation and received intraoperative CS as part of their resuscitation. Of these, 47 patients (62%) were individually matched to 47 patients who underwent an emergency trauma operation but did not receive intraoperative CS. The remaining 29 patients who received CS were excluded because they could not be matched on the specified criteria. The matched and unmatched CS populations were similar for all variables analyzed, except that the patients in the matched CS group received more total plasma than did those in the unmatched group (3 vs 1 U; $P=.02$). When the 47 patients in the CS group were compared with the 47 matched controls in the no-CS group, the 2 groups were similar regarding age (39 [18] vs 40 [18]; $P=.72$), male sex (33 male patients [70%] in each group; $P>.99$), mechanism of injury (42 patients [89%] in each group experienced blunt trauma; $P>.99$), Injury Severity Score (30 vs 31; $P=.76$), type of operation performed, and Glasgow Coma Scale (12 vs 12; $P=.98$), heart rate (109 vs 109 beats/min; $P=.93$), and systolic blood pressure (115 vs 111 mm Hg; $P=.54$) on admission. Operations performed in each group included laparotomy (n = 39), thoracotomy (n = 2), and orthopedic (n = 9) procedures, with 3 patients in each group receiving more than 1 procedure.

The CS group had an average measured intraoperative blood loss of 1795 (1197) mL and an average intraoperative autologous blood return of 819 (583) mL. The no-CS group had an estimated intraoperative blood loss of 978 (890) mL ($P<.001$ when compared with measured blood loss in the CS group) and received no autologous return of blood. The Table gives blood product usage between the 2 groups. The cost of blood product transfusion (including the total cost of CS) was less in the CS group ($1616 vs $2584 per patient; $P=.004$). The CS group and no-CS group had similar lengths of stay in the intensive care unit (8 vs 8 days; $P=.54$) and hospital (18 vs 20 days; $P=.75$), and there was no difference in mortality (6 patients [13%] vs 10 [21%]; $P=.56$).

### COMMENT

We performed a matched cohort analysis of trauma patients undergoing urgent operative intervention and requiring transfusion. The experimental group received CS...
with autologous blood transfusion in addition to allogeneic transfusion, whereas the control group received only allogeneic transfusion. Matching the 2 populations for age, sex, mechanism of injury, Injury Severity Score, and operation performed, we found that the CS group received fewer units of allogeneic PRBCs and plasma and also had fewer costs related to transfusion therapy. The present study supports the use of CS and autotransfusion during urgent trauma operations and corroborates previous literature regarding the use of autologous transfusion in an emergency setting.

The first described use of autotransfusion in the urgent setting was in 1886, when Duncan9 reported autologous transfusion during an amputation. Autotransfusion during abdominal trauma was subsequently described in 1927 by Van Schaik.10 One of the early large series was published during World War II, when Griswold and Ortner11 described the use of autotransfusion for patients with thoracic and abdominal trauma. Since these early studies, several authors have published reports of intraoperative CS and autologous blood transfusion in trauma.8,12-17 To our knowledge, the only randomized controlled trial of intraoperative CS and autotransfusion to date was published in 2006 by Bowley et al.18 in South Africa. They reported 44 patients who sustained penetrating thoracoabdominal trauma, displayed hypotension, and required laparotomy. There were 21 patients in the CS group and 23 in the control group, and patients in the CS group received significantly fewer units of PRBCs during the first 24 hours (6 vs 11 U; P = .008).

Despite such compelling evidence supporting the use of intraoperative CS and reinfusion of autologous blood for trauma patients, the technique has not been widely accepted for trauma patients undergoing urgent operations. Several concerns regarding the urgent use of autologous blood in trauma patients have been raised, including logistic issues for implementing an autotransfusion protocol, infectious complications due to transmission of contaminated blood, exacerbation of coagulopathy, and cost-effectiveness. Although the use of autologous transfusion in the elective setting allows preoperative planning and preparation, its application in trauma does not have the luxury of time, which may limit its use in many trauma centers. Our trauma center has a perfusionist on call 24 hours a day, 7 days a week, 52 weeks a year. At the discretion of the trauma surgeon and at the time a decision to go to the operating room has been made, the perfusionist is called in to support and coordinate intraoperative CS and autologous transfusion. While the perfusionist is on the way to the hospital, the operating room team sets up and primes the CS system so that the system is functioning at the beginning of the operation. Once the perfusionist arrives, the intraoperative CS and reinfusion proceeds as described previously. Trauma programs not currently using autologous transfusion should set up a multidisciplinary protocol to allow efficient activation and implementation of intraoperative CS and autologous transfusion during urgent operations for trauma patients.

Concerns for infectious complications following the collection and reinfusion of contaminated blood may dissuade surgeons from implementing an autologous transfusion program, especially during laparotomy for trauma, in which enteric violation is common. Although our study did not specifically address this issue, many authors have challenged the dogma that contaminated blood cannot be autotransfused in the trauma setting. Even one of the earliest reports of CS and autotransfusion mentioned the reinfusion of contaminated blood. Griswold and Ortner11 concluded that giving grossly contaminated blood was better than giving no blood at all. While few would argue with that statement, the question arises of what to do with contaminated blood salvaged intraoperatively when autologous transfusion is available. Although early reports of autotransfusion of unprocessed, contaminated blood were associated with high mortality rates,3 more recent studies have found that the bacterial load can be nearly eliminated with current cell-washing techniques.8,19

Most of the series published to date have included patients autotransfused with contaminated blood and have not identified increases in infectious complications for those patients.8,13-15 The recent randomized controlled trial of intraoperative CS and autotransfusion for patients with abdominal trauma by Bowley et al.18 had a high rate of reinfusion with contaminated blood. Overall, 85% of patients in the CS group had enteric contamination and 38% had a colonic injury; all were autotransfused. Of the CS blood samples sent for culture, more than 90% of the cultures were positive, but there was no correlation between the initial microbiologic characteristics of the reinfused blood and subsequent infectious complications. In addition, there was no increase in septic morbidity or mortality in patients who received autotransfusion with contaminated blood. Based on the existing literature, it appears that contaminated blood from intraoperative CS and cell washing can be reinfused without increasing the risk of infectious complications.

Another obstacle to using CS and autologous transfusion is the concern for exacerbating coagulopathy in an actively bleeding patient. The results of our study suggest the opposite because patients in the CS group received fewer units of plasma than did patients receiving only allogeneic transfusion (3 vs 5 U; P = .03). Similarly, Bowley et al18 found no difference in rates of coagulopathy when they compared autologous with allogeneic transfusion. Most of the data implicating autologous transfusion as a causative factor for coagulopathy arise from animal studies and after reinfusion of unprocessed CS blood; however, on review of the current literature, it does not appear that reinfusing collected and washed red blood cells should lead directly to coagulopathy. Nevertheless, as with any massive transfusion, that of large amounts of autologous blood may lead to a dilutional coagulopathy. In fact, Horst et al15 found that coagulopathy occurred in patients receiving more than 15 U of autologous blood. Furthermore, patients who received blood contaminated by enteric contents were more likely to develop coagulopathy.

An additional limitation to the widespread use of CS and autologous transfusion is the associated cost. In our matched population, the CS group required fewer total transfusion costs ($1616 vs $2584 per patient; P = .004) when the cost of the CS process was included. Hard conclusions regarding cost-effectiveness may be difficult to
ascertain in our study because we did not include patients for whom CS was performed but not infused. The most common reasons for performing CS and not reinfusing are inadequate collection of blood, concerns over reinfusing contaminated blood, and mortality prior to infusion of collected blood. Cost-effectiveness is closely associated with the amount of autologous blood that can be autotransfused and the percentage of autologous blood in the total transfusion. Our CS population received 58% of intraoperative transfusion and 41% of total transfusion from their autologous source. The autologous percentage of intraoperative transfusion ranges in the literature from 11% to 45%. Smith et al reported the highest rate of autologous transfusion (45%) and found a definite cost savings when using CS as opposed to allogeneic transfusion. Another way to look at the same question would be to determine how many units of autologous transfusion would be required to offset the cost of a similar allogeneic transfusion. In our population with a CS cost of $375 per unit and a PRBC cost of $216 per unit, we would have to collect and reinfuse 2 U of autologous blood to offset the cost of 2 U of allogeneic blood and make the CS process cost-effective. To maximize the cost-effectiveness of intraoperative CS and autologous reinfusion, preoperative patient criteria need to be developed that identify patients who will require at least 2 U of autologous transfusion and who can maximize the percentage of intraoperative autologous blood used.

In conclusion, the present matched cohort study adds to the existing literature regarding the beneficial effects of intraoperative CS and autologous transfusion in trauma patients undergoing an emergency surgical intervention. Cell salvage is associated with fewer transfusions of PRBCs and plasma while providing a savings in total transfusion costs. Additional studies are needed to definitively confirm the safety of transfusing contaminated blood, to preoperatively identify patients who would most benefit from autologous transfusion, and to optimize cost-effectiveness. In the meantime, centers with access to a CS program should routinely use autologous transfusion as part of their intraoperative resuscitation. More important, centers not currently using intraoperative CS and autotransfusion should identify and overcome barriers to implementing this life-saving technique.

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Correspondence: Carlos V. R. Brown, MD, Trauma Services, University Medical Center Brackenridge, 601 E 15th St, Austin, TX 78701 (CVRBrown@seton.org).
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Additional Contributions: The Capital Area Perfusionists (Austin) office manager, Jennifer Garcia, BS, MT(ASCP), and the University Medical Center Brackenridge blood bank supervisor, Janet Hill MLS(ASCP), SBB, assisted with data acquisition.

REFERENCES

DISCUSSION

James Tyburski, MD, Detroit, Michigan: Dr Brown and his colleagues present a series of 47 trauma patients who received cell-saver blood during a variety of surgical interventions and who were matched against 47 patients with similar injuries who didn’t receive cell-saver blood. In the past, concerns of septic complications and coagulopathy have been raised in the use of cell-saver blood, particularly with enteric contamination. The authors report no increase in coagulopathy, no difference in mortality, intensive care unit stay, or hospital length of stay. One
of the major conclusions is stated that it is a cost-effective alternative to a blood bank. I have a few questions for the authors.

You identify 76 patients who received cell-saver blood by protocol, but you only matched 47 of them to control patients. What was unique to the other 29 patients that did not allow them to be matched and included in the analysis?

This is a patient population with 89% blunt trauma. How many of these patients had enteric spill? As this has been a major historical concern for the use of cell-saver blood, how was this addressed and was there any difference in the 11% that were penetrating trauma? Was there any enteric contamination in any of these patients?

Third, do you have any data on septic complications, positive blood cultures, use of antibiotics, or additionally on coagulopathy? Were there any coagulation studies or platelet counts included in your data?

Lastly, how did you consider the cost of calling in the perfusionist for the cell-saver setup? Were the individuals compensated for being brought in? If they worked all that night, did they get the next day off? These would be crucial factors in your cost analysis to determine whether the autotransfusion was cost-effective. The premise of using autologous blood is a valid one and should be considered and should be used in many trauma centers.

**Dr Brown:** In response to your comment on septic complications and coagulopathy, there have been several studies published on these. Most included enteric-contaminated blood and, in general, could not find a difference in septic complications with or without contaminated blood, including the most recent study, a randomized trial from South Africa with the same results. However, our group did not transfuse any contaminated blood, even though there is no protocol to that effect. We don’t transfuse blood that is grossly contaminated. Could the blood be infected? Absolutely and, if cultured, would yield positive blood results in a large majority of patients. However, the bacteria grown at the time of the culture are not the same pathogenic bacteria that cause the complications. Regarding coagulopathy, similar to transfusing allogeneic PRBCs, giving multiple units of PRBCs will lead to coagulopathy. Similarly, multiple units of PRBCs from autotransfusion will also lead to coagulopathy. These questions deserve further investigation in the era of 1:1:1 transfusion, starting with the first unit of autotransfused red blood cells with the same ratio of plasma and platelets.

The difficulties matching patients is difficult to explain. We did a hand match from the registry, but we just could not fit them all. This is despite what we thought were pretty easy matching criteria when we set it up. We just could not match all patients with the combination of age, sex, mechanism, and operation.

Once again, none of these patients had enteric spill who were autotransfused, including either blunt or penetrating trauma. Our series is pretty representative of our population, including about 15% penetrating trauma.

We did not initially record complications for this paper. However, our research team will be retrieving septic complications and coagulation parameters.

Regarding the cost of the perfusionist, we reviewed our hospital costs specifically, and the perfusion company that runs our cardiac program charges us a flat rate of $375 to have that perfusionist come in and run the perfusion for 4 hours. If we exceed the initial 4 hours, an additional 4-hour block would cost another $375.

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