Autotransfusion of hemothorax blood in trauma patients: is it the same as fresh whole blood?

Marc Salhanick, B.S., Michael Corneille, M.D., Russell Higgins, M.D., John Olson, M.D., Joel Michalek, Ph.D., Chantal Harrison, M.D., Ronald Stewart, M.D., Daniel Dent, M.D.*

Division of Trauma and Emergency Surgery, Department of Surgery University of Texas Health Science Center, 7703 Floyd Curl Drive, Mail Code 7840, San Antonio, TX 78229, USA

Abstract

BACKGROUND: Autotransfusable shed blood has been poorly characterized in trauma and may have similarities to whole blood with additional benefits.

METHODS: This was a prospective descriptive study of adult patients from whom ≥50 mL of blood was drained within the first 4 hours after chest tube placement. Pleural and venous blood samples were analyzed for coagulation, hematology, and electrolytes.

RESULTS: Twenty-two subjects were enrolled in 9 months. The following measured coagulation factors of hemothorax were significantly depleted compared with venous blood: international normalized ratio (>9 in contrast to 1.1, \( P < .001 \)), activated partial thromboplastin time (>180 in contrast to 28.5 seconds, \( P < .001 \)), and fibrinogen (<50 in contrast to 288 mg/dL, \( P < .001 \)). The mean hematocrit (26.4 in contrast to 33.9), \( (P = .003) \), hemoglobin (9.3 in contrast to 11.8 g/dL, \( P = .004 \)), and platelet count (53 in contrast to 174 K/\( \mu \)L, \( P < .001 \)) of hemothorax were significantly lower than venous blood. A hemothorax volume of 726 mL was calculated to be equivalent to 1 U of red blood cells.

CONCLUSIONS: Hemothorax blood contains significantly decreased coagulation factors and has lower hemoglobin when compared with venous blood.

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vage and cell saver technology using anticoagulants\textsuperscript{10–17} and immediate prehospital autotransfusion of shed pleural blood.\textsuperscript{18} Citing a lack of strong outcome data, the Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists clinical practice guidelines do not recommend postoperative direct reinfusion of shed mediastinal blood in cardiac surgery patients.\textsuperscript{19} Little evidence supports the direct transfusion of pleural blood in trauma patients. Recent data from the conflicts in Iraq and Afghanistan suggest a benefit to transfusion of fresh whole blood over components.\textsuperscript{20,21} Finally, this renewed interest comes at a time when allogeneic blood component transfusion has been shown to be associated with an increased risk of acute respiratory distress syndrome, pneumonia, transfusion associated lung injury, exposure to blood-borne pathogens, and other complications.\textsuperscript{6} Because autologous transfusion may lessen these risks and offer a source comparable to whole blood, our purpose was to describe coagulation, hematologic, and electrolyte profiles of blood from an evacuated hemothorax (pleural blood) and to compare these values with a venous blood sample in acutely injured patients.

**Materials and methods**

**Patient selection**

The study was conducted during a 9-month period at the University Hospital, San Antonio, TX (an American College of Surgeons-verified level 1 trauma center). The study was approved by the University of Texas Health Science Center at San Antonio Institutional Review Board as an expedited minimal risk protocol with a waiver of documentation of informed consent. Subjects were included if >50 mL of hemothorax was drained in the first 4 hours after tube thoracostomy (Fig 1). Subjects were excluded if they were <18 years old, pregnant, a prisoner, or had tube thoracostomy at an outside facility. Shed blood was collected from either an autotransfusible collecting unit (Oasis 2050 ATS; Atrium Medical Corporation, Hudson, NH) or a nonautotransfusible collecting unit (Oasis 3,650 ATS, Atrium Medical Corporation).

**Sample collection**

A convenience sample was drawn directly from the collecting unit through a needleless access port based on research personnel availability. A sterile syringe was used to withdraw 35 mL of pleural blood from the thoracostomy drain, and the sample was submitted to the hospital core laboratory for coagulation, hematology, and electrolyte profiles presented in (Tables 1–3). Venous blood values from emergency center laboratories were extracted from subjects’ charts for time points closest to tube thoracostomy. This venous sample was compared with the pleural blood sample. The Injury Severity Score and the calculated probability of survival using Trauma Score - Injury Severity Score (TRISS) scoring were obtained from the hospital’s trauma database (Digital Inovations).

**Data analysis**

The venous blood values obtained via chart review were compared with hemothorax blood values using the Wilcoxon test, paired $t$ tests, and signed rank $t$ tests. Hematocrits and volumes of the pleural blood were converted to red blood cell (RBC) mass (RBC mass = hematocrit $\times$ volume) and then divided by a red blood cell mass of 200 mL, the approximate RBC mass of 1 U of red blood cells, to estimate RBC equivalent for a given volume of hemothorax. The red cell mass of 1 U of RBCs is approximately 200 mL based on an estimated average volume of 300 mL and an average hematocrit of 66% (300 mL $\times$ .66 = 200 mL). A linear regression was generated to relate RBC equivalents of hemothorax to hemothorax volume. All statistical testing was 2 sided with a significance level of 5% and SAS Version 9.2 for Windows (SAS Institute, Cary, NC) was used throughout.

![Figure 1](image-url)  
*Figure 1* The time to collection.
Results

Patient population

Thirty-two patients were screened over a 9-month period, of whom 22 were included. Of these 22, 77% were men, the overall mean age was 47.16 years, the median TRISS was 0.541 (0.001–0.992), and the median ISS was 28 (10–75). Of the 10 who were excluded, 6 subjects had 50-mL output within 4 hours, 2 were 18 years old, 1 subject’s tube thoracostomy was placed at an outside facility, and 1 was a prisoner.

Hematology and RBC unit equivalents

The mean hematocrit (26.4 ± 9.5 in contrast to 33.9 ± 8.5), (P = .003), hemoglobin, (9.3 ± 3.2 in contrast to 11.8 ± 3.0 g/dL, P = .004), and platelet count (53 ± 41 in contrast to 174 ± 82 K/µL, P < .001) were significantly lower than venous blood, but white cell concentration was not significantly different (P = .47, Table 1). On average, pleural blood sample was equivalent to .7 ± .8 U of RBCs. In all hemothoraces with a volume of <300 mL, the RBC mass was equivalent to <.5 U of RBCs. Using a linear regression technique, the relationship of RBC equivalents of hemothorax to hemothorax volume was established (Fig 2). Based on this equation, 726 mL of hemothorax is equivalent to 1 U of RBCs.

Coagulation

When compared with venous blood, both international normalized ratio (INR) and activated partial thromboplastin time (aPTT) were significantly elevated (P < .001) and fibrinogen was significantly depleted (<50 mg/dL, P < .001). Specifically, no pleural sample had a measurable INR, aPTT, thrombin time, or fibrinogen level. Pleural blood was found to be factor V deficient with moderately reduced factor VIII. Quantitative D-dimer measurements yielded D-dimer >7,360 ng/mL in hemothorax blood with 1 exception measuring 3,584 ng/mL (Table 2).

Chemistries

The measured mean electrolyte concentrations of the pleural blood were found to be in the normal range (Table 3). Although, when compared with venous blood, K⁺ was significantly higher (P = .003) and Cl⁻ (P = .03) and HCO₃⁻ (P <.001) were significantly lower. Aspartate aminotransferase and alanine aminotransferase were significantly higher in hemothorax blood in contrast to venous samples (P < .001 and P <.001, respectively), whereas the mean lactate dehydrogenase of hemothorax blood was elevated to 2,884 ± 1,991 U/L. The total bilirubin was significantly lower in pleural blood than in venous blood (.37 ± .27 in contrast to .46 ± .31 mg/dL, P = .03).

Comments

Although reduced compared with venous blood, the pleural blood does provide a sufficient concentration of red blood cells for autotransfusion use; however, the pleural blood is extremely deficient in coagulation factors and contains the products of fibrinogen degradation. Hemothorax blood may be useful for acute resuscitation but would require significant concomitant factor replacement. Direct transfusion of the pleural specimen would, at least poten-

Table 2  Coagulation profile

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pleural blood (median)</th>
<th>Venous blood (median)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>INR</td>
<td>&gt;9</td>
<td>1.1</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>aPTT (s)</td>
<td>&gt;180</td>
<td>28.5</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Fibrinogen (mg/dL)</td>
<td>&lt;50</td>
<td>288</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>D-dimer (ng/mL)</td>
<td>&gt;7,360†</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Factor V (%) of normal</td>
<td>&lt;5†</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Factor VIII (%) of normal</td>
<td>64.7 (42.1)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Thrombin time</td>
<td>&gt;120</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

SD = standard deviation.
*Wilcoxon Test.
†Twenty-one of 22 subjects had immeasurably high D-dimer, and the only subject with measurable D-dimer had a concentration of 3,584 ng/mL.
The fact that the enzymes were elevated indicates hemolysis. We expect the potassium to be high, but it was normal. We speculate that this potassium equilibrates through extracellular cations and that the amount of hemolysis is not great enough to elevate venous potassium. This raises concern over the effects of autotransfusion of shed blood because of the risk of transfusing coagulation breakdown products and disrupting the balance of pro and anti-coagulation factors.

The hematologic and coagulation findings in our study were consistent with those previously reported in the literature. This agreement on shed blood being defibrinated, thrombocytopenic, and anemic points to a general mechanism in which fibrin is formed and either lysed in the process of drainage or lysed in vivo before drainage. This raises concern over the effects of autotransfusion of shed blood because of the risk of transfusing coagulation breakdown products.

The fact that the enzymes were elevated indicates hemolysis. We expect the potassium to be high, but it was normal. We speculate that this potassium equilibrates through extracellular cations and that the amount of hemolysis is not great enough to elevate venous potassium. There was no appreciable clot in the collection unit, indicating consumption in the chest. This is supported by the INR >9 and PTT >120 seconds. Evidence of hemolysis raises an important safety concern with respect to plasma-free hemoglobin. This has been a continuing concern surrounding autotransfusion of shed blood in general and requires further investigation.

Hemothorax blood cannot substitute for whole blood, cryoprecipitate, or fresh frozen plasma. Based on the coagulation profile seen in Table 1, there is, in some cases, residual factor VIII; however, the aPTT and INR show that other remaining coagulation factors are either markedly reduced or inhibited in their current form. Although platelets are present in the hemothorax blood, their numbers are not sufficient for restoration of the platelet count, and the function of these platelets is not known. In no way can hemothorax be considered a resource for coagulation factors sufficient to resuscitate the patient.

Recent evidence has shown that use of RBC units is directly related to increased 30-day mortality, acute respiratory distress syndrome, nosocomial infection rates, and hospital length of stay. Recommendations of the Eastern Association for the Surgery of Trauma and Society of Critical Care Medicine both suggest autotransfusion as an alternative to avoid allogeneic RBC use. Our data indicate that a 726 mL of hemothorax would provide the equivalent of 1 U of RBC, underscoring the large volume of hemothorax blood needed to provide only a single unit of RBC. A possible limitation of our study may be the age of the hemothorax blood. Hemothorax blood that is only 1 hour old may have a higher hematocrit than 4-hour-old hemothorax blood. Additional studies are needed to determine the effect of time in the collection chamber on the autotransfusable product. We have no data to assess the quality of RBCs obtained through autotransfusion or how they compare with banked RBC units.

Banked RBCs are known to have a “storage lesion” including reduction in 2,3 diphosphoglycerate that impairs oxygen delivery when compared with native red blood cells. Because hemothorax blood is not banked, it may not have the same storage lesion. Recent work has shown the decreased ability of aged RBCs to increase oxygen saturation compared with younger cells, supporting this idea. However, it is not known at this time whether autotransfusion of hemothorax blood would provide better oxygen delivery.

Based on the findings in this article, we cannot conclude whether or not shed pleural blood from traumatic hemothorax should be used, when it should be used, or which patients are appropriate candidates for use because our study was not designed to answer any of these questions. Our purpose was to characterize shed pleural blood. We can speculate based on this article and all the other available data that autotransfusion in the acute hospital setting would be indicated only if banked blood were not available or if the volume of shed blood to be transfused was large (ie, >1,000 mL). After 4 hours, shed pleural blood is more similar to packed RBCs than fresh whole blood, and transfusion of other blood components should be performed as well if indicated. Further study into how the hematologic and inflammatory mediators change with time will help direct clinicians on optimal timing of using shed pleural blood, but a randomized controlled trial would be needed to make conclusions on whether or not it should be done at all.

### Table 3 Electrolyte profile

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pleural blood (SD)</th>
<th>Venous blood (SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na (mmol/L)</td>
<td>141.2 (7.4)</td>
<td>141.8 (4.7)</td>
<td>.76*</td>
</tr>
<tr>
<td>K (mmol/L)</td>
<td>4.9 (1.2)</td>
<td>3.95 (.7)</td>
<td>.003*</td>
</tr>
<tr>
<td>Cl (mmol/L)</td>
<td>105.7 (7.0)</td>
<td>108.1 (5.8)</td>
<td>.03*</td>
</tr>
<tr>
<td>CO3 (mmol/L)</td>
<td>19.5 (4.0)</td>
<td>22.1 (4.0)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>13.9 (6.5)</td>
<td>14.14 (6.3)</td>
<td>.09*</td>
</tr>
<tr>
<td>Ca (mg/dL)</td>
<td>9 (2.8)</td>
<td>8 (1.6)</td>
<td>.99*</td>
</tr>
<tr>
<td>AST (U/L)</td>
<td>890.2 (820.7)</td>
<td>170.4 (150.6)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>ALT (U/L)</td>
<td>421.7 (774.6)</td>
<td>145.1 (156.5)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Total bilirubin (mg/dL)</td>
<td>.37 (.27)</td>
<td>.46 (.31)</td>
<td>.03*</td>
</tr>
<tr>
<td>LDH (U/L)</td>
<td>2884.3 (1991.2)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Signed rank test.

SD = standard deviation.
There is no head to head in trauma surgery data for component therapy to shed pleural blood. There are data from elective cardiothoracic surgery. These data are summarized by the Society for Thoracic Surgery and Society for Cardiovascular Anesthesiology’s (2007) practice guidelines and conclude that “Because of the risks associated with this technique and the lack of clear cut benefit, direct reinfusion of shed blood cannot be recommended for routine blood conservation . . .”6

Hemothorax blood is not the same as fresh whole blood. It is depleted in coagulation factor V and fibrinogen and has a high concentration of fibrin degradation products. When hemothorax blood is used in trauma resuscitation, monitoring of the patient’s coagulation with appropriate infusion of fresh frozen plasma, platelets, and cryoprecipitate as indicated would be necessary. Our data, similar to other studies of direct transfusion of pleural blood, raise safety concerns. Further data are required to fully assess the safety of this practice.

References


Discussion

Dr Waseem Al-Khatib (Stanford, CA): I congratulate the authors on attempting to better elucidate the composition of pleural blood and autotransfusion. This is kind of born of the cardiac and vascular world where the use of cell saver has actually helped in decreasing the amount of exogenous blood given to patients, especially in the high-risk patients; however, many newer studies from 2009 to the end of this year have shown that in low-risk patients in that population there is questionable benefit with regard to giving autotransfusion. However, the data with regard to giving pleural blood is not as strong; there has not been as many studies, and although the authors have devised a clever method to use red blood cell equivalents to determine the amount of red blood cells to turn the amount of blood equivalent to packed red blood cells given, I am pretty skeptical about the value of 726 mL to equal the unit of red blood cells. So, without going into much mathematical detail, it is really extremely rare to define a linear equivalent or linear regression with regards to the degradation of red blood cells over time and use that as kind of a crutch to determine 726 mL should be given. So, based on that, I have 3 sets of questions to really ask the authors. First, it is clear that pleural blood was sampled at >50 mL of fluid appearing through thoracostomy tubes after 4 hours. However, did the authors sample blood before the 4-hour mark, such as the 1-hour, 2-hour, or 3-hour mark? You believe that pleural blood hemolytic and coagulopathic properties would be different if they were sampled earlier. Therefore, would autotransfusion early in the course of hemothorax give the patients a higher red blood cell equivalent, thus increasing the impact of pleural blood autotransfusion in changing that value of 726 mL? Second, what is the impact of giving blood devout of coagulation factors with fibrinogen degra-
Would this worsen the patient’s coagulopathy and possibly worsen the patient’s outcome or survival? Would not giving fresh frozen plasma or cryoprecipitate to compensate for the possible impact of worsening coagulopathy defeat the purpose of decreasing the amount of blood that you are going to the patient? For my own education, why did you exclude prisoners?

Mr Marc Salhanick (San Antonio, TX): Thank you Dr. Al-Khatib for your questions. We will start off with the first one; did we sample it earlier than 4 hours? No, we chose to sample it at 4 hours because the American Association of Blood Banks stated in their recommendations for shed blood transfusion that it should not be done after 4 hours. We wanted to figure out worst-case scenario (ie, what this looks like at 4 hours). We did have 1 patient; this was not part of our protocol, but just in the course of treatment they got autotransfused and fibrinogen was sent off on him and there was actually measurable fibrinogen within the first hour or so. So, we have some preliminary data that say that this probably changes a lot over time with respect to coagulation factors. Our future work will look at what is that change in time and what does it look like at about an hour after it comes out. With regard to the effect on transfusing this and the trauma patient, that is a limitation of our study. It is observational. One patient who was transfused did not have any adverse transfusion actions, but we would need to build a randomized trial to figure out any kind of outcome or generate any kind of outcome data, which we just do not have. As far as why prisoners were excluded, that was just part of getting institutional review board approval. We excluded all pediatric, pregnant, and prisoners. My Collaborative Institutional Training Initiative training taught me the ethical dilemmas of including these populations in research. Specifically, prisoners were excluded because of the dilemma of obtaining informed consent without implied pressure. I am actually a medical student.

Dr Dan Margulies (Los Angeles, CA): You showed that the blood reaccumulated from the chest is not the same as fresh whole blood, but I was wondering whether your actual recommendation is to not give it back to the patient? It does have the packed cells, it is warm, and has some of the same factors, even if not exactly the same factors, so are we doing a harm to the patients by giving this, or should we continue as most of us do to autotransfuse patients with the idea that we are giving them less of other patients’ blood later?

Mr Marc Salhanick (San Antonio, TX): Again, that is a great question, and we just do not have the data to conclude whether or not you should give it back. What we encourage you to think of is if you are giving this back, somewhere between 700 mL and 750 mL is pretty much equivalent to a unit of packed cells so think of it as you are giving back packed cells and because there has been demonstrated storage lesion in packed cells, this is not stored so it essentially could avoid that, but we do not have any data to back that up.

Dr Walt Biffl (Denver, CO): Do you have any sense of whether these findings correlate with a clot in the chest?

Mr Marc Salhanick (San Antonio, TX): We developed two theories: either it clots and then lyses in the chest, we take out what is lysed, or we lyse it as we drain it and based on what was seen in that patient, that preliminary data that says there is fibrinogen an hour; probably we are taking out as it clots so there is still some fibrinogen left, but as far as our data here, it is 4 hours out, so we cannot really because we are not using any kind of anticoagulant so we are not stopping the process. It is hard to know for certain.