

# Minimizing Blood Loss in Burn Surgery

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**Background:** Significant blood loss continues to plague early tangential excision of the burn wound. Although various techniques to reduce intraoperative blood loss have been described, there is an absence of uniformity and consistency in their application. Furthermore, it is unclear whether these techniques compromise intraoperative tissue assessment and wound outcome. The purpose of this study was to evaluate the effects of a comprehensive intraoperative blood conservation strategy on blood loss, transfusion requirements, and wound outcome in burn surgery.

**Methods:** An intraoperative blood

conservation strategy (CONSV) that included donor site and burn wound adrenaline tumescence, donor site and excised wound topical adrenaline, and limb tourniquets was prospectively evaluated and compared with a historical control group (HIST) where only topical adrenaline and thrombin were applied to donor sites and excised wounds.

**Results:** Estimated blood loss was reduced from  $211 \pm 166$  mL per percentage body surface area excised and grafted in the HIST group to  $123 \pm 106$  mL in the CONSV group ( $p = 0.02$ ). Similarly, the intraoperative transfusion requirement in

the HIST group was reduced from  $3.3 \pm 3.1$  units per case to  $0.1 \pm 0.3$  units per case in the CONSV group ( $p < 0.001$ ). There was no compromise in wound outcome in the CONSV group, which had a mean skin graft take rate of  $96 \pm 4.2\%$ .

**Conclusion:** The application of a strict and comprehensive intraoperative blood conservation strategy during burn excision and grafting resulted in a profound reduction in blood loss and transfusion requirements, without compromising wound outcome.

**Keywords:** Burn, Excision, Bleeding, Tumescence.

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Prompt excision and closure of burn wounds has resulted in increased survival,<sup>1–3</sup> lower rates of burn sepsis,<sup>4</sup> as well as shorter hospitalization, reduced costs, and less time away from work or school.<sup>5</sup> Unfortunately, surgical treatment of the burn wound can also produce substantial intraoperative blood loss<sup>6–9</sup> both from excised wounds and from donor sites, which results in increased transfusion requirements.<sup>4–6,10</sup>

A wide variety of techniques intended to reduce intraoperative blood loss have been described. These include the application of topical epinephrine with or without thrombin to excised wounds and/or donor sites;<sup>11–15</sup> the subcutaneous infiltration of vasoconstrictors such as epinephrine,<sup>16–22</sup> phenylephrine,<sup>16</sup> or vasopressin<sup>7</sup> at donor and/or excision sites; the administration of systemic vasopressin;<sup>23</sup> controlled intraoperative hypotension;<sup>24</sup> performing excision with a laser;<sup>25–27</sup> and use of limb tourniquets.<sup>28,29</sup> Whereas many of these methods have successfully diminished intraoperative blood loss, there is a clear lack of uniformity in the approach to reducing blood loss. Some studies have assessed topical epinephrine combined with subcutaneous epinephrine at only specific skin graft donor sites such as the scalp.<sup>17</sup> Others have examined infiltration of epinephrine beneath all burn wounds

and donor sites but have not reported whether tourniquets were used adjunctively.<sup>16</sup> Still others have reported subcutaneous epinephrine infiltration without use of topical epinephrine application.<sup>18</sup> Furthermore, concern has been raised over the ability to reliably assess tissue viability when use of tourniquets or subeschar infiltration of vasoconstrictors<sup>11,17</sup> has altered the bleeding pattern at the site of tangential excision. Surgical experience is obviously an asset, but it is not clear whether most burn surgeons can routinely adopt blood conservation techniques and simultaneously obtain complete wound excision and full skin graft take.

The purpose of this study was to implement a uniform, complete, and consistent approach to intraoperative blood conservation during burn surgery, and to determine how this strategy affects operative blood loss and transfusion requirements. We were also interested in whether an experienced burn surgeon who has previously used only “traditional” techniques could adopt strict blood conservation measures and still obtain adequate wound excision and successful skin graft take. Our hypothesis is that blood loss and transfusion requirements will be reduced by the use of strict intraoperative blood conservation techniques, without an adverse effect on wound management.

## MATERIALS AND METHODS

At our burn center, before April 1, 1999, the only method used by the primary author (R.C.) to control intraoperative bleeding at excision and donor sites was the serial application of coarse gauze, soaked in a warm solution of 1:1,000,000 adrenaline with thrombin (1 mL of 1:1,000 adrenaline with 10,000 units thrombin in 1 liter of injectable normal saline).

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Patients treated in this fashion formed the control group, referred to as the "historical" (HIST) group. All patients who required excision and grafting of their burns and who had adequate data in their medical records were selected for retrospective analysis from 125 patients consecutively admitted to our adult regional burn center from February 1, 1993, to March 31, 1994. From 1994 to 1999, the author (R.C.) continued to use this method, but at a different institution, before returning to this burn center. Hence, to keep the control group as consistent as possible, data from the 1993 to 1994 era was used.

The treatment group, managed with blood conservation techniques (CONSV), consisted of all patients who required surgery for their burns, prospectively studied from 58 patients consecutively admitted to our burn center, between April 1, 1999, and June 30, 1999. The methods of intraoperative blood conservation used in this group were as follows:

Donor sites were infiltrated subcutaneously with a 1:500,000 adrenaline solution (2 mL of 1:1,000 adrenaline in 1 liter of warm injectable normal saline), using 60-mL syringes attached to 18-gauge spinal needles. Infusion was by hand pressure. The tissues were infiltrated until they were firm (i.e., tumescent).<sup>19,22</sup> After grafts were harvested by power dermatome, the sites were repeatedly dressed with Telfa pads (Kendall Inc., Peterborough, Canada) soaked in warm 1:33,333 adrenaline solution (30 mL of 1:1,000 adrenaline in 1 liter of injectable normal saline).

Burn wounds in areas where tourniquets could not be applied received subeschar infiltration with the 1:500,000 adrenaline solution to the point of tumescence. After tangential excision with the Humby knife, the wounds were dressed with serial applications of Telfa pads soaked in the topical 1:33,333 solution.

Burn wounds on limbs were tangentially excised under tourniquet control. The limb was first elevated and suspended, and then the tourniquet was inflated to 100 mm Hg above systolic blood pressure. When the excision was complete, the limb was wrapped with Telfa soaked in the topical 1:33,333 adrenaline solution, secured with a circumferential firm wrapping of Kerlex (Allegiance Healthcare Corp., McGaw Park, IL), also soaked in the topical adrenaline solution, for a full 10 minutes before deflation of the tourniquet. At deflation, the dressing was removed, major bleeders were cauterized, and the limb was rewrapped for another 5 minutes with the adrenaline-soaked Telfa pads and Kerlex. Final hemostasis was then achieved with serial applications of adrenaline-soaked Telfa pads and with cautery. Grafts were applied only when hemostasis was complete. Grafts were never applied before tourniquet deflation out of concern for subgraft hematoma formation.

The same surgeon (R.C.) performed all operations in both groups. All excisions were tangential and no fascial excisions were included in this study. In both the HIST and CONSV groups, sheet grafts were applied to the hands, distal

forearms, and face, while 1.5:1 meshed grafts were used for all other areas. In both groups, grafts were applied immediately after excision but only after complete hemostasis had been obtained. In the CONSV group, the anesthesiologists and intensivists in our burn unit were unaware that data regarding blood loss and transfusion requirements were being collected.

The data collected from both groups included age, burn size (total body surface area burn [TBSA]), preoperative hemoglobin levels (HGBpre), percentage body surface area (BSA) excised (%EX), percentage BSA harvested (%HV), intraoperative units of blood transfused (Uintra), total intraoperative and 24-hour postoperative units of blood transfused (U24), postoperative hemoglobin level at 24 hours postoperatively (HGBpost), and the duration of surgery. The anesthetic record was reviewed in each case for signs of adrenaline toxicity such as tachyarrhythmias, and hypertension.

Blood loss can be calculated using the formula described by Budney,<sup>6</sup> and Judkins:<sup>30</sup>  $CBL = EBV \times [(HGBpre - HGBpost)/HGBpre] + Tx$ , where CBL is calculated blood loss, EBV is estimated blood volume (70 mL/kg of body weight), HGBpre is preoperative hemoglobin, HGBpost is hemoglobin at 24 hours postoperatively, and Tx is total intraoperative and 24-hour transfusion volume received (in milliliters). However, this formula implies that the decrease in hemoglobin is equivalent to the fraction of the total blood volume lost. In other words, this formula applies only if all shed blood has the initial hemoglobin concentration. Since patients can receive considerable amounts of crystalloid intraoperatively, the shed blood becomes progressively more dilute as the operation proceeds. Thus, the above formula would overestimate the blood loss.<sup>31</sup> Therefore, we used a modification of this formula that was described and validated by Gross<sup>31</sup> as follows:  $CBL = EBV \times [(HGBpre - HGBpost)/HGBav] + Tx$ , where HGBav is the mean of the HGBpre and HGBpost. We chose 70 mL/kg for the calculation of EBV, since women and men may have EBVs ranging from 55 to 70 mL/kg and 60 to 75 mL/kg, respectively, depending on their body habitus.<sup>31,32</sup>

In the CONSV group, the percentage graft take was determined on the basis of the consensus of the personnel that took down the graft dressings (experienced burn nurse and a surgical resident or burn fellow), usually on postoperative day 5, as recorded in the medical record. The surgeon (R.C.) was not involved in the estimation of graft take. However, because percentage graft take was not routinely recorded in the HIST group database, a mean rate of graft take could not be obtained for this group.

The data are presented as the mean  $\pm$  SD. A two-tailed Student's *t* test was used to determine statistical significance between the groups, with significance ascribed to  $p < 0.05$ . The collection of data for this study has been approved by an ethics review board.

**Table 1** Comparison of Historical (HIST) Group and Conservation (CONSERV) Group Patients and Procedures<sup>a</sup>

	HIST	CONSERV	p Value
Patients	16	19	
Age (y)	49 ± 18	45 ± 19	NS
%TBSA	19 ± 14	21 ± 15	NS
Procedures	30	29	
HGBpre (g/L)	109 ± 15	111 ± 25	NS (p = 0.75)
%EX	9 ± 5.5	11 ± 7.7	NS (p = 0.15)
%HV	7 ± 5.1	9 ± 6.8	NS (p = 0.19)

<sup>a</sup> Values are the mean ± SD.

## RESULTS

The HIST group consisted of 30 procedures in 16 patients, and the CONSV group consisted of 29 procedures in 19 patients. The groups were well matched with respect to age, %TBSA, HGBpre, %EX, and %HV (Table 1). Of note, the single largest excision in the CONSV group was 30% BSA, and there were an additional four cases in which ≥20% BSA was excised and grafted in one operative setting. This contrasts sharply with the HIST group, where the largest single excision was 18% BSA.

The CONSV group required significantly fewer intraoperative transfusions ( $p < 0.001$ ) and fewer total transfusions from the start of surgery to 24 hours postoperatively ( $p < 0.001$ ) (Table 2). The total units of blood required from the initiation of surgery to 24 hours postoperatively per percentage wound excised was  $0.42 \pm 0.4$  units in the HIST group, and  $0.15 \pm 0.5$  units in the CONSV group ( $p = 0.022$ ) (see Table 2).

In the CONSV group, 21 procedures (72%) were carried out without the need for either an intraoperative transfusion or a transfusion within 24 hours postoperatively. The range of %EX and %HV within this set of procedures was 2% to 27% and 2% to 23%, respectively. Also, in the CONSV group there were five cases where ≥20% BSA was excised and grafted in one operation, without the need of an intraoperative transfusion, and a mean U24 of only 0.4 units (range, 0–2 units). In comparison, in the HIST group, only five cases (17%) were performed without a blood transfusion.

**Table 2** Comparison of Historical (HIST) Group and Conservation (CONSERV) Group Transfusion Requirements

	HIST	CONSERV	p Value
Uintra	3.3 ± 3.1	0.1 ± 0.3	<0.001
U24	4 ± 3.7	0.6 ± 1	<0.001
U24/%EX	0.42 ± 0.4	0.15 ± 0.46	0.022

<sup>a</sup> Values are the mean ± SD.

**Table 3** Comparison of Historical (HIST) Group and Conservation (CONSERV) Group Calculated Blood Losses and Operative Duration

	HIST	CONSERV	p Value
CBL (mL)	1531 ± 1048	864 ± 637	0.011
CBL/%EX (mL)	211 ± 166	123 ± 106	0.02
DN (min)	108 ± 62	229 ± 72	<0.001

DN, duration of surgery.

<sup>a</sup> Values are the mean ± SD.

Although patients in both groups started out with similar HGBpre concentrations, the patients in the HIST group had significantly greater calculated blood loss ( $p = 0.011$ ), and greater calculated blood loss per percent excised, compared with patients in the CONSV group. However, the duration of surgery was significantly longer in the CONSV group ( $p < 0.001$ ) (Table 3).

In the CONSV group, there were three cases where intraoperative tachycardia and/or hypertension occurred simultaneously with the infiltration of the adrenaline solution: a previously healthy 18-year-old woman developed a sinus tachycardia of 150 beats/min during subeschar infiltration of a 3% BSA facial burn. In the second case, an 86-year-old man with a past history of hypertension developed transient sinus tachycardia of 120 beats/min along with elevation of the systolic blood pressure to 185 mm Hg during subeschar infiltration of an 11% BSA burn on the trunk. In the final case, an otherwise healthy 39-year-old man developed a sinus tachycardia of 135 beats/min during infiltration of leg donor sites totaling 15% BSA. In all cases, the tachycardia and hypertension lasted less than 5 minutes, and did not require treatment.

The mean graft take in the CONSV group was  $96 \pm 4.2\%$ . One wound healing complication occurred. A 34-year-old woman with 25% BSA flame burns required reexcision and regrafting of wounds on the trunk and right arm. The initial take in these areas was rated at 90%, but subsequently there was progressive loss of the grafts, and wound swabs grew *Staphylococcus aureus* and *Escherichia coli*.

## DISCUSSION

Significant blood loss has plagued the early excisional approach to the burn wound. Ironically, in Janzekovic's<sup>33</sup> early description of tangential excision, the simple and highly reliable method of assessing tissue viability on the basis of the bleeding pattern of an excised wound is also the technique's chief disadvantage. Nonetheless, the tangential method continues to be widely utilized, but it is clearly bloodier than the functionally and cosmetically inferior method of fascial excision. Estimates of blood loss in adults during burn surgery range from 196<sup>8</sup> to 269 mL<sup>6</sup> for each percent of the body surface area excised and grafted. To put

this into perspective, on the basis of these estimates, as much as 36% to 49% of the blood volume of a 70-kg man could be lost during the excision and grafting of one upper extremity.

The use of methods to diminish intraoperative blood loss during burn excision and grafting is not new. Essentially, there are three classes of blood conservation techniques: the use of topical solutions containing thrombin and/or vasoconstrictors on donor sites and excised wounds;<sup>11-13,15</sup> subeschar and/or subdonor site infiltration of vasoconstrictors;<sup>16-18,20,21</sup> and the use of limb tourniquets.<sup>28,29</sup> Whereas some of these individual techniques are successful in reducing blood loss, there has been a lack of uniformity in their assessment and application. It is not clear whether further reductions in blood loss could be obtained by combining the methods rather than using them in part or in isolation. Additionally, some of the studies<sup>16,22</sup> report only the effects on transfusion requirements, without any estimation of blood loss. Since the decision to transfuse a patient is often made on less than objective grounds, this adds uncertainty as to the true effectiveness of the blood conservation method under study.

In one of the earliest reports on the tumescent technique, Kahalley et al.<sup>16</sup> demonstrated that infiltrating donor sites and burn wounds with a saline-vasopressor solution could reduce intraoperative transfusion. This study compared intraoperative transfusion requirements with a historical control, but unfortunately did not report on the immediate postoperative transfusion rates. Aside from the subjective bias introduced by examination of transfusion rates (both in the study group and in the historical control), there was no conclusive proof that blood loss was actually reduced with the tumescent method. Barret et al.<sup>17</sup> have reported that topical treatment of donor sites and excised wounds with epinephrine and thrombin along with subcutaneous epinephrine infiltration of scalp donor sites did not reduce blood loss compared with use of topical thrombin on donor sites and excised wounds alone, in pediatric burn patients. This study raises two questions. First, why were only the scalp donor sites infiltrated? Second, if all donor sites and burn wounds had been infiltrated, would there have been an appreciable reduction in blood loss? In a recent study, Sheridan and Szyfelbein<sup>20</sup> have shown that epinephrine clysis of burn wounds and donor sites significantly reduced intraoperative and perioperative blood loss in burned children. Limb burns and use of tourniquets were specifically excluded to clarify the effect of epinephrine clysis alone. However, this creates a somewhat artificial study population, which does not represent the wide spectrum of wound sizes and locations seen in clinical practice. It would be useful to know, for example, if it is possible to obtain a significant reduction in blood loss in the common scenario where burns on a limb and on the trunk are to be excised and grafted in one operation.

This study was undertaken to answer some of the questions raised by these previous studies. Our primary purpose was to examine the effects of a comprehensive blood conservation strategy on blood loss and transfusion requirements.

Hence, the tumescent technique with adrenaline was used on all nonlimb wounds and on all donor sites, tourniquets were used for all limb excisions, and all excision and donor wounds were treated with topical adrenaline. These techniques were used in every case in the CONSV group, regardless of size or location of the wounds, thus creating a consistent and reproducible strategy that is clinically applicable.

Our data show that there was a profound reduction in both the intraoperative transfusion requirements as well as the total transfusion requirement in the intraoperative and 24-hour postoperative period. The intraoperative transfusion requirements probably better reflect blood loss than the total 24-hour transfusion requirements. Anesthesiologists familiar with burn surgery can accurately estimate intraoperative blood loss<sup>6</sup> and will transfuse the patient appropriately. However, since postoperative transfusion is often dictated by the clinical scenario or by arbitrary hemoglobin levels, the total transfusion requirement is a less reliable reflection of blood loss. Nevertheless, the very low total transfusion requirement in the CONSV group ( $0.6 \pm 1$  unit), suggests that there was a real reduction in intraoperative blood loss, with no need to "catch up" with transfusions in the 24 hours after surgery.

We must emphasize that the transfusion rate is not an accurate measurement of blood loss, especially since we used a historical control group where transfusion practices may have been different.<sup>10</sup> Furthermore, we believe that some of the studies on blood conservation techniques<sup>16,18,22</sup> are weakened by the absence of showing estimated blood losses. Therefore, we also calculated blood loss using a previously documented formula<sup>6,30</sup> that was modified<sup>31</sup> to account for the hemodilution that occurs when patients receive crystalloid fluid intraoperatively. The blood loss in the HIST group, expressed per percentage of wound excised and grafted ( $211 \pm 166$  mL), is similar to other estimates of blood loss in the literature.<sup>6,8</sup> Our blood conservation protocol cut this blood loss nearly in half, and this would account for the substantial reduction in transfusions that we observed. The most impressive finding was that several large excision and grafting procedures ( $\geq 20\%$  BSA) could be performed in one operation, with minimal or no blood transfusion.

It should be recognized that there was a lengthy interval between the observations of the HIST group (1993-1994), and those of the CONSV group (1999). Although factors such as increasing experience of the surgeon and variations in anesthesia techniques may have affected the results, there was nonetheless a substantial difference in blood loss between the groups.

There were few if any acute complications associated with the subcutaneous infiltration of adrenaline solution. Although three patients developed tachycardia and/or hypertension during infiltration, these events were transient and none required treatment. Similarly, two other studies<sup>17,20</sup> have found that there were no adverse effects associated with subcutaneous adrenaline infiltration. The only obvious drawback to our approach is that the duration of surgery is pro-

longed. Extra time was required to infiltrate tissues by hand, and to allow hemostasis before tourniquet deflation. Tissue infiltration would be faster if a roller pump<sup>16</sup> or Hunstad liposuction injector<sup>22</sup> were used, but the author's preference was to inject by hand to have better control of the infiltration.

One of the main criticisms of techniques that reduce bleeding at the excision site is that the assessment of tissue viability is compromised. Concern about inadequate excision<sup>17</sup> as well as excessive excision<sup>11</sup> has been raised. Therefore, the second purpose of this study was to determine whether this comprehensive blood conservation protocol could be adopted by a surgeon who has used only "traditional" techniques previously, without compromising the adequacy of the excision, or the wound outcome.

The assessment of tissue viability proved to be less difficult than anticipated, as long as the following principles were observed: the dermis must be pearly white, with no hemorrhagic staining; minor vessels on the wound surface must be patent; the fat must be pale yellow, firm, and moist (dry, or golden brown fat is unhealthy); and the excised wound rapidly becomes hyperemic, even under tourniquet control. In particular, shortly after what appears to be adequate excision, the white dermis and pale yellow fat appear to develop hemorrhagic staining. Although this usually represents reperfusion, it can easily be confused with the staining that characterizes thermally injured tissue. Thus, there may be a tendency to unnecessarily reexcise the area. Hence, the level of excision is most easily determined with the initial passes of the debriding blade, and should not be altered thereafter unless there is convincing evidence of inadequate excision (e.g., tissue fails to reperfuse, remains dry, or contains thrombosed vessels on the wound surface).

Although a mean graft take rate of  $96 \pm 4.2\%$  was obtained in the CONSV group, a definitive comparison of graft take rates between the groups cannot be made. Graft take in the HIST group was not recorded, there were variable observers of graft take in the CONSV group, and graft take in the CONSV group was assessed relatively early (day 5). However, our firm impression was that graft take was not impaired by the conservation method. There were no donor site complications in the CONSV group.

In summary, we can conclude that a comprehensive blood conservation technique, which included tumescence with adrenaline solution, topical adrenaline solution, and use of tourniquets, had a major impact on intraoperative blood loss in our patients. Not only were calculated blood losses and transfusion requirements reduced, but also the technique allowed us to perform several extensive excisions and grafts with minimal or no blood transfusion. The technique appears to be safe, and was easily adopted by a surgeon who had previously used only "traditional" methods, without any adverse effects on wound outcome. We are confident in recommending this type of an approach for burn surgery.

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