# Early Burn Wound Excision Significantly Reduces Blood Loss

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**The hypothesis that near-total early excision of large burns in children can be performed safely with a reduction in blood loss was tested. Of 1662 acutely burned patients admitted to this institution between 1982 and 1989, 594 underwent near-total excision of cutaneous flame or scald burn injuries in a single procedure. Operations took less than 3 hours and there were no operative deaths. Blood losses in burns of more than 30% total body surface area (TBSA) were significantly less at 0.40 ± 0.06 mL/cm² and 0.49 ± 0.49 mL/cm² excised when surgery was performed within the first 24 hours or after the 16th day after burn, respectively, when compared to 0.75 ± 0.02 mL/cm² for those excised between 2 and 16 days after burn ($p < 0.05$). Blood loss for burns of less than 30% TBSA was of 1.19 ± 0.13 mL/cm². Early excision did not increase mortality rate when compared to later excision times. We suggest that near-total excision of large burns within the first 24 hours reduces blood requirements and morbidity without adversely altering hemodynamic stability or increasing mortality risks.**

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SEVERAL DECADES AGO, the effectiveness of early burn wound excision and subsequent wound closure was described.[1-8] The first proponents of this procedure could not demonstrate a significant improvement in mortality rate in patients with more than 30% total body surface area (TBSA) burns due to infection, massive blood loss, the inability to close excised wounds, and inadequate monitoring capabilities. With the introduction of topical chemotherapeutic agents, survival in patients treated with spontaneous burn wound separation and subsequent grafting improved. This decreased the number of deaths, and in addition to the perceived advantages of less blood loss and a shorter operative time, resulted in a waning of support for early burn wound excision. Burn wound excision was revived with the introduction of tangential excision;[9-13] however excisions were still performed in increments of 15% to 30%, which was thought necessary to reduce associated blood loss, hypothermia, and anesthesia stress. Tangential excision, which allows the removal of denatured tissue while preserving much of the surrounding viable tissue, decreases body contour changes often observed with fascial excision and potentially reduces long-term functional deficits. One of the chief drawbacks of primary tangential excision has been the amount of blood loss associated with its use when compared to fascial or late excision.[9,14-19] It is difficult to quantitate blood loss due to individual variability,[12,18,20,21] surgical technique, total burn size, postburn time of excision, and site and size of the area excised. Recent developments in intraoperative monitoring however, have enabled anesthesiologists to accurately maintain blood volume during surgery. These and other developments have improved mortality rates with early near-total burn wound excision compared to delayed excisional procedures.[22,23] Decreased blood loss related to tangential excision has been suggested during the first few days after burn compared to later excisions.[13,15] Theoretically this may be due to the effects of vasoactive mediators[24-26] and edema formation, which achieve maximal vasoconstriction during the first 24 hours after injury. This study tests the hypothesis that blood loss resulting from near-total burn wound excision in children with large burn wounds is less without increased morbidity and mortality, provided that wound excision is performed within 24 hours after injury.

## Materials and Methods

A total of 1662 acutely burned pediatric patients were admitted to this institution between 1982 and 1989. Five hundred ninety-four patients with cutaneous flame or scald burn injuries required excision and grafting and, of

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these, 318 had burns of more than 30% TBSA. All wounds clearly requiring surgical intervention were excised in one procedure as soon as possible after admission, with special efforts made to excise burns of more than 30% TBSA within 48 hours and smaller burns within 72 hours. All excisions and anesthetics were performed under the direction of the authors, with assistance provided by residents and interns.

All patients received Ketamine anesthesia and oxygen supplementation *via* mask or, infrequently, endotracheal tube at 37 C and 100% relative humidity to maintain normal $PaO_2$ levels during the excisional procedure. No time constraints were placed on the length of operation. The entire burn wound, with the exception of the face and perineum, was excised tangentially with fascial excision used only when fat or muscle was burned. Rectal temperatures were continuously monitored during the surgical procedure with environmental temperatures adjusted to maintain a core temperature of more than 36 C and less than 38 C. Intravenous fluids, including blood, were administered at temperatures of 38 C using a high-volume fluid warmer (Model H-500, Level I Technologies Inc., Plymouth, MA). A surgical knife (Storz, St Louis, MO) was used to excise all full-thickness wounds at a depth of 0.01 to 0.1 inches and a surgical blade (Weck, Research Triangle Park, NC) used for excision of the small surfaces of the hand or foot. Contiguous deep partial-thickness wounds were tangentially excised using serial passes of an electric dermatome (Padgett, Kansas City, MO) set at a depth of 0.005 to 0.01 inches until punctate bleeding was achieved. Donor sites were harvested at 0.005 inches during the excisional procedure. Bleeding was controlled with topical thrombin combined with pressure and electrocautery (Aspen Labs, Utica, NY) or ligation of identified large vessels. After hemostasis, large excised wounds were covered with 0.005 to 0.01 inches thick autograft meshed 4:1 (Bioplasty Ampligraffe, Genetic Laboratories Inc., St Paul, MN) or meshed 2:1 for small burns, as available donor sites permitted. The 4:1 meshed autograft was overlaid with 2:1 meshed ABO-matched fresh or frozen cadaveric allograft. Meshed homografts (2:1) were used to cover all excised sites when autologous donor skin was unavailable. Donor sites were covered with Scarlet Red impregnated fine mesh gauze (Cheeseborough-Pond, Greenwich, CN) and grafted areas were covered with triple antibiotic (Polysporin® Burroughs Wellcome Research, Triangle Park, NC)/nystatin (1:1) impregnated fine mesh gauze,[27] bulky dressings, orthoplast splints (when appropriate), and elastic wraps. Postoperative hematology, serum chemistry, and blood gas values were determined within 1 hour of patient arrival at the post-anesthesia care unit and chest radiographs were obtained and assessed for the development of intraoperative pulmonary edema.

Inadequacy of intraoperative resuscitation was determined by the following criteria: (1) blood pressure deviations of more than 40% of baseline, (2) cardiac dysrhythmias, (3) inability to maintain a patent airway, (4) $PaO_2$ less than 50 torr, (5) $PaCO_2 > 60$ torr, (6) hemoglobin of less than 8 or more than 12 g% or hematocrit of less than 24 or more than 48%, (7) urine output less than 0.75 mL/kg/hr, (8) pulmonary edema on postoperative chest radiograph, and (9) any neurologic deficit. The presence of any of the above criteria indicated inadequate resuscitation. Operative blood loss was calculated by the formula[20]:

$$\text{Blood Loss (mL)} = \frac{(\text{Preop RBCV}) + (\text{TX RBCV})] - (\text{Postop RBCV})]}{\text{PostOp Hct} \times 0.01}$$

Where:

$$\text{PreOp RBCV (mL)} = \text{Body wt (kg)} \times 80\ (\text{mL/kg}) \times [\text{PreOp Hct (\%)} \times 0.01]$$

$$\text{PostOp RBCV (mL)} = \text{Body wt (kg)} \times 80\ (\text{mL/kg}) \times [\text{PostOp Hct (\%)} \times 0.01]$$

$$\text{TX RBCV (mL)} = \text{Total mL whole blood administered during surgery} \times 0.3$$

(assuming a Hct of 30% for all whole blood units)

Preoperative red blood cell volume (PreOp RBCV) was calculated using the body weight obtained within 24 hours and the hematocrit obtained within 12 hours before the surgical procedure. Direct postoperative weights were not measured due to the inadvisability of patient movement after graft placement. Postoperative red blood cell volume (PostOp RBCV) was therefore calculated from the preoperative body weight corrected for the weight of the excised tissue and the hematocrit obtained within 1 hour of completion of the surgical procedure. To validate this procedure, intraoperative blood loss was measured gravimetrically on a series of five patients. Tare weights of all drapes, sponges, gauze, gowns, gloves, and related paraphernalia were obtained before use and subtracted from gross weights after use. Care was taken to weigh all items immediately after removal from the sterile operating field to decrease the evaporative loss. No additional topical liquids (*e.g.*, sterile water or saline) were used during the procedure, thus the difference between pre- and postoperative weights of the various items was assumed to be the amount of blood loss. The specific gravity of whole blood varies from 1.050 to 1.064, depending on the total number of cellular elements present. Our calculations

TABLE 1. *Patients with More Than 30% TBSA Burn Who Failed Intraoperative Resuscitation Criteria*

| Criteria for Exclusion | | Hemoglobin (Hgb) Hematocrit (Hct) | Blood Pressure | Urine Output | Respiratory Criteria | Pulmonary Edema |
|---|---|---|---|---|---|---|
| Group (PBD) | % (N) | Hgb <8 or >12 g % Hct <24 or >48% | > ± 40% of Preoperative Baseline | <0.75 mL/kg/hr | Nonpatient Airway $PaO_2 < 50$ torr $PaCO_2 > 60$ torr | X-ray: Positive or Negative |
| 0–1 | 0 (0) | — | — | — | — | — |
| 1–2 | 15 (9) | 55 (5) | 22 (2) | 22 (2) | — | — |
| 2–16 | 14 (28) | 36 (10) | 25 (7) | 18 (5) | 7 (2) | 14 (4) |
| >16 | 37 (15) | 47 (7) | 20 (3) | 20 (3) | 7 (1) | 7 (1) |
| Total Percentage Failed | 16 (52) | 42 (22) | 23 (12) | 19 (10) | 6 (3) | 10 (5) |

Data presented as % with number in each group in ( ).

were made using 1 g equal to 1 mL of blood. To compare the gravimetric analysis to values calculated from the blood loss formula, postoperative body weights were determined by correcting for the weight of excised tissue and intraoperative fluid balance.

The average blood loss per surface area excised (mL/$cm^2$) was compared at various postburn periods of excision. Comparisons were made using analysis of variance (ANOVA) and Duncan's Multiple Comparison Procedures. A variable selection procedure was used with the regression of blood loss on potential predictors (*i.e.*, age, sex, burn size, causative agent) to develop a predictive blood loss formula at various postburn periods. All data presented are means ± SEM, with significant differences accepted at $p < 0.05$.

## Results

Sixteen per cent (n = 52) of the patients who underwent near-total excision of more than 30% TBSA burns failed to meet intraoperative resuscitation criteria. All patients excised within the first 24 hours of injury were adequately resuscitated; however 15% of those excised between days 1 and 2, 14% of those operated on between postburn days 2 to 16, and 37% of those operated on 16 days after burn were inadequately resuscitated intraoperatively. Reasons for not meeting the criteria were high or low postoperative hematocrits (42%), transient blood pressure changes (23%), or low intraoperative urine output (19%) (Table 1). No significant differences could be shown in the other monitored intraoperative parameters between those identified as not meeting intraoperative resuscitation criteria and the group who did (Table 2). Intraoperative asanguinous fluid and whole blood administration maintained stable intraoperative urine output, central venous pressures (CVP), mean arterial pressures (MAP), core temperatures, and postoperative hematocrits. Transient increases in creatinine occurred in one patient. More serious complications, such as postoperative pulmonary edema and intraoperative airway obstruction, occurred in only eight patients. There were no operative deaths in patients with burns of more than 30% TBSA. In all patients with more than 30% TBSA burns, asanguinous fluid administered was 42.4 ± 3.5 mL/kg with a urine output of 2.8 ± 0.5 mL/kg/hr, CVP was 6 ± 1 mmHg, core temperature was 37.1 ± 0.2 C, MAP was 85 ± 2 mmHg, and postoperative Hct was 38% ± 3%. Mean operative time was 2.4 ± 0.1 hours. No significant relationship could be shown between length of the procedure and blood loss.

Blood loss calculated for patients who did not meet the intraoperative resuscitation criteria were compared to those who did by regression analysis and were found to be no different at $p < 0.05$. Patients were divided into groups by postburn day (PBD) of excision: PBD 0 to 1, 1 to 2, 2 to 16, and more than 16. All excised patients with less than a 30% TBSA burn showed a blood loss that

TABLE 2. *Intraoperative Monitored Data* for all Subjects with More Than 30% TBSA*

| Group (PBD) | Asanguinous Fluid (mL/kg) | UOP (mL/kg/hr) | CVP (mmHg) | Core Temp (C) | MAP (mmHg) | OR Time (hrs) | PreOp Hct (%) | PostOp Hct (%) | Amount Excised (g) |
|---|---|---|---|---|---|---|---|---|---|
| 0–1 | 34.5 ± 5.3 | 2.9 ± 0.3 | 6.1 ± 0.4 | 37.2 ± 0.1 | 85 ± 2 | 2.4 ± 0.1 | 42 ± 3 | 41 ± 3 | 688 ± 191 |
| 1–2 | 49.2 ± 4.8 | 3.6 ± 0.4 | 6.0 ± 0.3 | 37.1 ± 0.1 | 82 ± 2 | 2.5 ± 0.1 | 40 ± 1 | 33 ± 1 | 981 ± 258 |
| 2–16 | 40.7 ± 2.6 | 2.5 ± 0.3 | 5.7 ± 0.6 | 36.9 ± 0.2 | 88 ± 2 | 2.8 ± 0.2 | 35 ± 1 | 33 ± 1 | 913 ± 88 |
| >16 | 43.2 ± 9.6 | 3.8 ± 0.6 | 4.3 ± 0.4 | 37.2 ± 0.1 | 88 ± 2 | 2.3 ± 0.3 | 33 ± 1 | 35 ± 1 | 280 ± 125 |

UOP, Urine Output; CVP, Central Venous Pressure; MAP, Mean Arterial Pressure; OR, operating room; Hct, hematocrit.

* Data presented as means ± SEM.

did not vary with postburn day of excision, but few of these were operated on during the first 24 hours (n = 2) or after the 16th day after injury (n = 3) (Table 3). Blood loss in patients excised within the first 24 hours was compared to that in patients excised 24 or more hours after injury (Fig. 1). Blood loss for those patients excised during the first 24 hours after injury was significantly less for all burn sizes than that of the regression equation for those excised after the first day ($p < 0.001$), with the standard error of the estimated slope being 0.022 and 0.013 mL, respectively. Blood loss in patients with burns larger than 30% TBSA was $0.41 \pm 0.06$ mL/cm$^2$ when excised within the first 24 hours after injury, while blood loss in similarly burned patients excised between 2 and 16 days was significantly higher at $0.75 \pm 0.04$ mL/cm$^2$. In patients with more than 30% TBSA burns admitted more than 16 days after burn with partially separated or granulating wounds or those with wounds of questionable depth on admission, blood loss was $0.49 \pm 0.07$ mL/cm$^2$. This was not different from the early excision group of patients but was significantly less at $p < 0.01$ than those excised between PBD 2 to 16 (Fig. 2).

Table 4 depicts age, burn size, and incidence of inhalation injury in subjects with more than 30% TBSA burns and excised at various times after injury. Burns excised more than 16 days after burn had significantly less area of third degree burn than those excised earlier. Total blood loss, area excised, sex distribution, and length of hospital stay (LOS) were compared for patients excised within each study period. No significant increase in mortality in burns of more than 30% TBSA when excised within the first 24 hours after burn could be shown compared to the other time periods. Multiple regression analysis failed to show any significant influence of age, sex, cause of burn (flame *versus* scald), or TBSA burn in burns larger than 30% TBSA on blood loss. Characteristics, mortality, hematocrit, and blood loss for patients with less than 30% TBSA burns are depicted in Table 4. Blood loss in these patients was $1.2 \pm 0.1$ mL/cm$^2$.

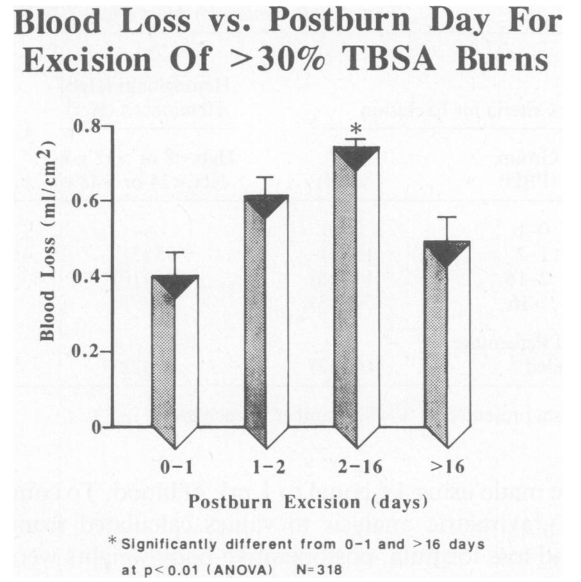


FIG. 2. Bar graph depicting changes is blood loss (mL/cm$^2$ excised) at 0 to 1, 1 to 2, 2 to 16, and more than 16 days after burn for 318 excised patients with more than 30% TBSA. *Significantly higher from 0 to 1 days and more than 16 days at $p < 0.01$ (ANOVA).

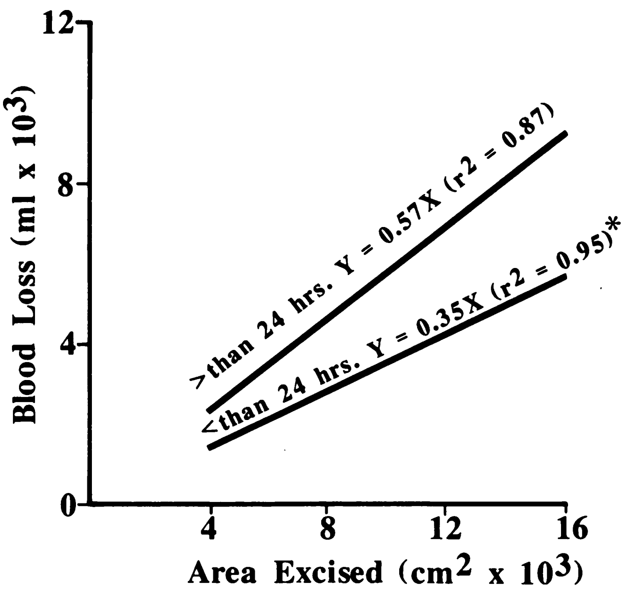


FIG. 1. Regression slopes and equations for patients with $\geq$30% TBSA burn excised within 24 hours of injury (n = 15) and those excised after 24 hours (n = 299). *Significantly lower slope at $p < 0.001$.

Blood loss associated with burn wound excision can be described by:

TABLE 3. *Characteristics of Patients with Less Than 30% TBSA Burn*

| Characteristic | |
|---|---|
| N | 276 |
| Age (yrs) | $6.0 \pm 0.3$ |
| TBSA burn (%) | $14 \pm 2$ |
| TBSA 3rd (%) | $5 \pm 1$ |
| BSA (m$^2$) | $0.83 \pm 0.02$ |
| Weight (kg) | $24 \pm 2$ |
| LOS (days) | $21 \pm 1$ |
| Inh Inj (%) | 11 |
| Male (%) | 67 |
| Mortality (%) | 0.5 |
| PBD Excision | $8 \pm 0.4$ |
| PreOp Hct (%) | $36 \pm 0.4$ |
| PostOp Hct (%) | $35 \pm 0.4$ |
| M$^2$ Excised | $0.10 \pm 0.01$ |
| Blood loss/cm$^2$ | $1.2 \pm 0.1$ |

Data presented as mean ± SEM.
LOS, length of hospital stay.
PBD, postburn day; Hct, hematocrit; Inh Inj, inhalation injury.

TABLE 4. *Characteristics of Patients with More Than 30% TBSA Burns Grouped by Postburn Day of Excision*

| | Postburn Days of Excision | | |
|---|---|---|---|
| Characteristic | 0–1 | 2–16 | >16 |
| N | 15 | 262 | 41 |
| Age (yrs) | 7 ± 2 | 7 ± 1 | 8 ± 1 |
| TBSA burn (%) | 64 ± 6 | 58 ± 3 | 44 ± 2 |
| TBSA 3rd (%) | 54 ± 3 | 39 ± 5 | 28 ± 3* |
| BSA ($m^2$) | 0.96 ± 0.15 | 0.97 ± 0.06 | 0.93 ± 0.06 |
| Weight (Kg) | 30 ± 7 | 31 ± 3 | 27 ± 3 |
| LOS (days) | 42 ± 6 | 44 ± 4 | 54 ± 4 |
| Inh Inj (%) | 0 | 25 | 20 |
| Male (%) | 61 | 54 | 54 |
| Mortality (%) | 7 | 5 | 2 |
| PBD excision | 0 | 4 ± 1 | 29 ± 2 |
| $M^2$ Excised | 0.51 ± 0.10 | 0.42 ± 0.04 | 0.24 ± 0.03† |
| Blood loss/$cm^2$ | 0.41 ± 0.06 | 0.72 ± 0.03 | 0.49 ± 0.07 |

* Significantly different compared to 0–1 days at $p < 0.05$ (ANOVA).
† Significantly different compared to other groups at $p < 0.05$ (ANOVA) Data presented as Mean ± SEM.
LOS, length of hospital stay.
Inh Inj, inhalation injury.

(1) Average amount of blood loss for more than 30% TBSA burns when excised in the first 24 hours = 0.35 × area of excision ($cm^2$), $r^2 = 0.95$
(2) Average amount of blood loss for more than 30% TBSA burns when excised between 2 and 16 days after injury = 0.60 × area of excision ($cm^2$), $r^2 = 0.86$
(3) Average amount of blood loss for less than 30% TBSA burns when excised from admission to discharge = 0.68 × area of excision ($cm^2$), $r^2 = 0.81$

To ensure that the results obtained were valid, regression analyses and blood loss calculations were performed on a group of patients (n = 292) with hematocrits of ≥30% and ≤50% and a second group with pre- and postoperative hematocrits within ±5% (n = 179) (Table 5). No significant differences could be determined between these two groups of patients and the initial group (n = 318) of patients presented.

## Discussion

Blood loss in large burn injuries (more than 30% TBSA) was significantly decreased when surgical excision was performed within the first 24 hours after injury compared to those performed between the second and sixteenth days after injury. Reduced blood loss was noted in the second 24-hour period after injury; however this was not significant compared to blood loss between postburn days 2 and 16. Blood loss in burns treated conservatively with grafting on granulating beds is also less when compared to blood loss from excision during postburn days 2 through 16.

We have previously demonstrated[22] that blood loss was significantly reduced with a more conservative approach in which grafting was performed after 16 days after injury than that observed in an early excision group. In this study the similarity of the blood loss noted in excisions performed on postburn days 0 and 1 and after postburn day 16 may be due to the differing methods of graft site preparation. Early excisions require the sharp removal of adherent eschar, whereas the preparation of a burn wound after 16 days after injury is a blunt debridement of the granulating bed. It is noteworthy that the amount of third-degree burn is significantly less in the patients with burns of more than 30% TBSA excised after 16 days postburn, even though the amount of TBSA burn is similar. This is possibly due to errors in early clinical assessment, in-

TABLE 5. *Blood Loss in Patients with ≥ 30% TBSA Burn and Robust Regression of Blood Loss* Versus *Area Excised*

| | Overall | | Preoperative Hct >30% <50% | | Pre- and Postoperative Hct Within + 5% | |
|---|---|---|---|---|---|---|
| Postburn Day of Excision | Blood Loss/$cm^2$ | Slope and R Value | Blood Loss/$cm^2$ | Slope and R Value | Blood Loss/$cm^2$ | Slope and R Value |
| 0–1 | 0.41 ± 0.06 | 0.45 (0.327, 0.57) $r^2 = 0.85$ | 0.37 ± 0.06 | 0.42 (0.29, 0.54) $r^2 = 0.85$ | 0.36 ± 0.09 | 0.36 (0.28, 0.44) $r^2 = 0.98$ |
| | (N = 15) | | (N = 11) | | (N = 4) | |
| 2–16 | 0.72 ± 0.03* | 0.63 (0.593, 0.671) $r^2 = 0.8$ | 0.75 ± 0.04† | 0.62 (0.576, 0.65) $r^2 = 0.79$ | 0.68 ± 0.04 | 0.62 (0.56, 0.66) $r^2 = 0.79$ |
| | (N = 262) | | (N = 250) | | (N = 145) | |
| >16 | 0.49 ± 0.07* | 0.36 (0.25, 0.46) $r^2 = 0.53$ | 0.49 ± 0.07* | 0.36 (0.26, 0.47) $r^2 = 0.73$ | 0.47 ± 0.07† | 0.36 (0.26, 0.45) $r^2 = 0.72$ |
| | (N = 41) | | (N = 38) | | (N = 25) | |

Data presented as Mean ± SEM for blood loss/$cm^2$; slope value with 95% confidence limits in ( ).

* $p < 0.01$; †$p < 0.05$.

dicating that these wounds would spontaneously heal, which would result in a significant number of patients requiring late surgical intervention, and in the early excision groups, in which areas that might have healed were undoubtedly removed.

The use of pre- and postoperative hematocrits as an indicator of adequate intraoperative blood volume replacement can lead to significant calculation errors in estimation of blood loss. Several authors[28,29] have noted that the hematocrits of burned patients may be in error as much as 10% to 20%, which could be due to the fluctuating vascular volume during the early postburn period. Intravascular fluid loss in the early postburn periods may alter the circulating volume and change the calculated red blood cell volume (RBCV), thereby introducing some error. In a series of 60 dogs with 50% TBSA full-thickness flame burns, Baxter and Shires[30] demonstrated a mean blood volume decrease of 8% during the first 24 hours after burn, while Pruitt described a 'modest' plasma volume decrease in a series of 10 adult men with a mean burn size of 65% TBSA.[31] Increased capillary permeability responsible for the extravascular fluid accumulation is reduced after the first 8 hours after injury, with maximal edema formation occuring within 18 hours.[30] No excisional procedures were performed during the first 8-hour postburn period, and most were performed after 12 hours after injury. When operative times, amounts of administered asanguinous fluid, and evaporative losses are similar, any aberration in fluid equilibration would be constant. When the central venous pressure, urine output, and mean arterial pressure are normalized, error due to vascular volume changes and hematocrit estimation can be minimized. The formula by which blood loss was calculated is based on the RBCV before operation, after operation, and on intraoperative blood transfusions, not simply on the hematocrit, and should improve the predictive accuracy of the formula used. It is possible, however, that this calculation may be in error when applied to patients in states of extreme hemoconcentration or hemodilution. When blood loss calculations were performed, excluding patients with preoperative hematocrits of $\leq$30% or $\geq$50%, the results demonstrated no differences from those obtained overall. In addition a series of patients with pre- and postoperative hematocrits within $\pm$5% also demonstrated no differences from those obtained for the group overall. The alternate methods of establishing blood loss, including serial volume determinations using various dyes or radiolabeled cells or plasma, and gravimetric evaluations have arguably not proved to be of any significant advantage compared to this technique.[32-34]

Due to the inadvisability of using radioactive isotopes in children and the unavailability of Evans blue in pharmacologic grades due to its demonstrated carcinogenic effects, gravimetric analysis was used to evaluate the validity of the blood loss formula. Gravimetric analysis of blood loss was found to be within a mean of 15% of those calculated by the blood loss formula used in this study. The difference between the determined postoperative weight (*i.e.*, preoperative weight corrected for tissue excised and fluid balance) and direct 4-day postoperative nude weights was only 3%.

References to lower blood losses associated with burn wound excision performed within the first 48 hours after burn have been made by several authors.[13,35] Although general surgical tradition advocates correction of hemodynamics and stabilization of the patient before a major surgical procedure, technologic advances have enabled early excision of the burn wound within 48 hours of the time of injury, with hemodynamic stability achieved concurrently, thus optimizing the removal of necrotic tissue, altering humoral responses, infection rate, hospital stay, and mortality.[22]

The release of systemic and local mediators in response to thermal injury has been well described. Hilton et al.[24] have shown that vasopressin plasma levels increase five times within 30 minutes after a 15% TBSA full-thickness thermal injury. They have further shown that the subsequent increase in systemic vascular resistance that occurs after burn injury results in a myocardial depression that can be reversed by nonspecific vasodilators such as verapamil and nitroprusside.[36] Herndon et al.[25] demonstrated elevated thromboxane $A_2$ metabolite levels in patients with burn injuries. Early postburn plasma samples from patients have showed thromboxane $B_2$ (the stable metabolite of the potent vasoconstrictor thromboxane $A_2$) levels at $2.6 \pm 0.85$ picomoles/mL. This represents an elevation of 86 times that found in the control group. They have also shown that plasma 6-keto-PGF levels do not change after thermal injury, resulting in an imbalance of opposing physiologic mediators. The ratio of thromboxane $A_2$ to prostacycline would result in vasoconstriction, which can contribute to further ischemia as well as to the redistribution of blood flow from central organs, particularly the gut. Catecholamines[26] and many other systemic and local mediators, which have been demonstrated to be elevated in burned patients, also have vasoconstrictive effects on the circulatory system. Surgical removal of coagulative necrotic tissue from thermal injury may reduce such early vasoconstrictive humoral responses, bacteria, endotoxin, and even perhaps decrease the early immunosuppressive effects[37] of acute-phase mediators such as IL-1, IL-2, TNF, or the burn toxin described by Allgower et al.[38] The resulting exchange transfusion may also dilute these acute-phase mediators, thus encouraging an early recovery.[39]

Data presented have demonstrated that near-total excision of large ($58 \pm 3$% TBSA) burns can be safely performed in operations lasting 3 hours or less while maintaining hemodynamic stability and core temperatures.

Less blood loss is associated with burn wound excision when performed within 24 hours or when delayed grafting on granulating beds is performed after 16 days after burn. No significant difference in blood loss could be shown in burns of less than 30% TBSA at any excision time, but too few patients were excised within the first 24 hours after burn or after 16 days after injury to make a valid comparison. Predictive formulae for blood loss have been constructed for burns more than 30% TBSA excised during the first 24 hours or after the 16th day after burn, excised between the second and sixteenth day after burn, and for patients with less than 30% TBSA burns. Near-total primary excision of large burn wounds can be performed during the resuscitative phase of burn injury resulting in less blood replacement and without adversely affecting hemodynamic stability or mortality. Blood loss can also be reduced by conservatively treating patients and grafting after the 16th day after burn and this approach reduces the amount of wound excised and grafted, but has other previously described disadvantages related to pain and extent of morbidity.

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### Discussion

DR. ARNOLD LUTERMAN (Mobile, Alabama): Dr. Herndon and his colleagues have evaluated the hypothesis that burns can be excised *in toto* and that blood resulting from burn wound excision would be less if excision was performed earlier in the postburn course than is currently advocated, without increased morbidity and mortality rates.

The management of burn injuries continues to change, approaching closer and closer the most logical end point, which is treatment consistent with that of any other trauma case. Absolutely central to the basic thesis