How Well Does The Parkland Formula Estimate Actual Fluid Resuscitation Volumes?

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We had anecdotally observed that fluid resuscitation volumes often exceed those estimated by the Parkland Formula in adults with isolated cutaneous burns. The purpose of this study was to compare estimated and actual fluid resuscitation volumes using the Parkland Formula. We performed a retrospective study of fluid resuscitation in patients with burns ≥ 15% TBSA. Patients with inhalation injury, high voltage electrical injury, delayed resuscitation, or associated trauma were excluded. We studied 31 patients (mean age 51 ± 20 years, mean TBSA burn 27 ± 10%). The 24 hour resuscitation volume of 13 354 ± 7368 ml (6.7 ± 2.8 ml/kg/%TBSA) was significantly greater than predicted (P = 0.001) and exceeded estimated volume in 84% of the patients. The mean urine output in the first 24 hrs was 1.2 ± 0.6 ml/kg/hr. After the first 8 hours of resuscitation, the infusion rate decreased by 34% in 16 patients (DCR group), while in 15 patients the rate increased by 47% (INCR group). Both the DCR and INCR groups received significantly more fluid than predicted, (5.6 ± 2.1 ml/kg/%TBSA and 7.7 ± 3.1 ml/kg/%TBSA respectively). The INCR patients had significantly larger full thickness burns (14 ± 11% vs 3 ± 6%, P < 0.001). Our findings reveal that despite its effectiveness, the Parkland Formula underestimated the volume requirements in most adults with isolated cutaneous burns, and especially in those with large full thickness burns. (J Burn Care Rehabil 2002;23:258–265)

Dr. Charles Baxter has stated, in his description of the Parkland Formula, that the majority of burn patients will be adequately resuscitated if they receive 3.7 to 4.3 ml of Ringer’s lactate per kilogram of body weight per percent total body surface area burn (%TBSA) in the first 24 hours following an acute burn injury.1,2 Although it is recognized that burn patients with associated inhalation injury,3 high voltage electrical trauma, or delayed initiation of fluid resuscitation usually require more fluid than expected,5 questions continue to arise regarding the accuracy of the Parkland Formula in patients without these associated conditions. Most recently, Engrav et al6 have observed that current burn resuscitation delivers more fluid than recommended by the Parkland Formula in patients who have an isolated cutaneous burn. Appropriately, the authors of that study identified the need for confirmatory investigations. The purpose of this study was to examine the relationship between the resuscitation volume estimated by the Parkland Formula, and the actual resuscitation volume delivered to burn patients who had not sustained a smoke inhalation injury. We were also interested in examining the pattern of fluid resuscitation over the first 24 hours following injury.

MATERIALS AND METHODS

This was a retrospective cohort study. The hospital’s Research Ethics Board approved review of the patient’s records. The computerized database of an adult tertiary regional burn center was used to review all admissions between December 31, 1998, and May 31, 2000. Inclusion criteria were the presence of burns ≥ 15% TBSA, where fluid resuscitation had been started within 6 hours of injury and where the patient was transferred to our facility within 6 hours of injury. This was done to ensure that no delayed resuscitations were included, and to ensure that the
majority of the resuscitation was performed at our institution. Exclusion criteria were the diagnosis of smoke inhalation injury (based on bronchoscopic evaluation),^7^ concomitant trauma, high voltage electrical injury, incomplete records, or enrollment in any clinical trial involving fluid resuscitation. Patients who received compassionate care only were excluded from analysis.

The data collected from the patient’s records included age, sex, etiology of the burn, total body surface area burn size (%TBSA), full thickness burn size (%FTB), admission weight (kg) and the 24 hour Parkland estimated resuscitation volume. The hourly critical care nursing flow sheet was used to determine the actual crystalloid resuscitation volume received in the first 24 hours, the hourly urine output over the first 24 hours, and the mean arterial blood pressure (MAP) recorded for each hour during fluid resuscitation. Fluid administered prior to arrival at our facility was included in the calculation of total volume received by each patient.

Outcome measures included the minimum ratio of the arterial partial pressure of oxygen to the fractional inspired oxygen concentration (PaO2/FiO2) during fluid resuscitation (as an approximate reflection of pulmonary edema), ventilator days (the number of days from intubation to 24 hrs. of unassisted spontaneous breathing), the development of abdominal compartment syndrome requiring decompressive laparotomy, and in-hospital mortality.

**Fluid Resuscitation Protocol**

The % TBSA burn was determined using a Lund and Browder chart. Patients were weighed on admission to our facility. For the purpose of this study, the period of resuscitation was defined as the first 24 hours following injury. The initial fluid resuscitation rate for all patients was determined by the Parkland Formula. The rate of fluid administration was then subsequently titrated by the attending physician to maintain urine output between 0.5 to 1 ml/kg/hr. We did not attempt to achieve a predefined or calculated maintenance fluid infusion rate. Rather, the main endpoint for successful resuscitation was a urine output between 0.5 and 1.0 ml/kg/hr during the first 24 hours. Central venous pressure measurements and pulmonary artery catheters were not used to guide the initial resuscitation. As recommended by the Parkland Formula, an attempt was made in all cases to infuse one half of the estimated 24-hour volume in the first eight hours, and to infuse the remaining half over the subsequent 16 hours. In this sense, reduction of the infusion rate by 50% after 8 hours while maintaining urine output in the desired range was a defined resuscitation goal. The reduction in the infusion rate was never made abruptly at 8 hours, but rather, as a gradual titration of the infusion rate as described by Warden,^8,9^ while at all times attempting to maintain urine output between 0.5 to 1 ml/kg/hr. The resuscitation fluid consisted entirely of Ringer’s Lactate. Colloids were never administered during the first 24 hours following injury.

Since the Parkland Formula recommends that the rate of fluid administration be decreased by half after 8 hours, we decided to examine whether patients in the study group followed this pattern. The mean fluid infusion rate during the first 8 hours of the resuscitation was compared to the mean infusion rate during the subsequent 16 hours for each patient. Patients whose fluid infusion rate increased were assigned to the INC group, and patients whose infusion rate decreased were assigned to the DCR group.

Statistical analysis was performed using paired and unpaired 2 tailed Student’s t-tests for comparison of continuous data. The chi square test was used for comparison of categorical data. Two-way analysis of variance (ANOVA) was used to compare the pattern of actual fluid volume received versus the Parkland estimate between the INC group and the DCR groups. All values are expressed as the mean ± SD, unless otherwise indicated. Statistical significance was ascribed to a P value < 0.05.

**RESULTS**

Between December 31, 1998, and May 31, 2000, a total of 256 patients were admitted to our burn center. Of these, 50/256 cases met the inclusion criteria of having burns ≥ 15% TBSA, and of receiving fluid resuscitation and arriving at our facility within 6 hours of injury. From this group, 19/50 cases were excluded; 12 due to the presence of inhalation injury, 6 because of incomplete records, and 1 because of enrollment in a clinical trial involving fluid resuscitation.

This left a study population of 31 patients with a mean age of 51 ± 20 years, a mean %TBSA of 27 ± 10%, with a mean %FTB of 8 ± 10%. The mean delay between injury and arrival at our facility was 2.8 ± 1.7 hours. During this period (ie, prior to arrival at our institution), the patients received a mean of 2546 ± 1888 ml of Ringer’s lactate.

The actual total resuscitation volume for the first 24 hours, (including fluid administered prior to transfer to our facility), was 13 354 ± 7 386 ml, which was significantly greater than the Parkland estimate of 8 227 ± 3 239 ml (P < 0.001). This translates to an actual 24-hour resuscitation volume of 6.7 ± 2.8 ml/kg/%TBSA. Only four patients (13%) fell...
within the Parkland Formula’s anticipated range of 3.7 to 4.3 ml/kg/%TBSA. Twenty-six patients (84%) exceeded 4.3 ml/kg/%TBSA, and one patient (3%) required less than 3.7 ml/kg/%TBSA.

Table 1 shows that the actual resuscitation volume was very similar to the estimated volume during the first 8 hours of resuscitation. However, the resuscitation volume became significantly greater than estimated during both the second 8 hour interval \((P < 0.001)\), and the third 8 hour interval \((P < 0.001)\) of resuscitation.

The urine output over the first 24 hours was 1.2 ± 0.6 ml/kg/hr \((89 ± 39 \text{ ml/hr})\). In the first and second 8 hour intervals of resuscitation the urine output was 1.3 ± 1.2 ml/kg/hr and 1.3 ± 0.8 ml/kg/hr, respectively. Urine output decreased to 1.0 ± 0.9 ml/kg/hr during the final 8-hour interval of resuscitation. No diuretics were given to any of the patients during the first 24 hours. The MAP during the first, second, and third 8-hour intervals of the resuscitation was 92 ± 18 mmHg, respectively.

The INCR group consisted of 15 patients whose infusion rate decreased by a mean of 47% (range 1% to 110%) after the first eight hours. The DCR group consisted of 16 patients whose infusion rate decreased by a mean of 54% (range 1% to 85%) after the first eight hours. The two groups did not differ significantly with respect to age, burn etiology, %TBSA burn, or delay in resuscitation. However, the %FTB of 14 ± 11% in the INCR group was significantly greater than the %FTB of 3 ± 6% in the DCR group \((P < 0.001)\).

The INCR group received 15 917 ± 8397 ml \((7.7 ± 3.1 \text{ ml/kg/%TBSA})\) over the first 24 hours which was significantly greater than the Parkland estimate of 8 609 ± 3 958 ml \((P = 0.002)\). The DCR group received 10 951 ± 5 134 ml \((5.6 ± 2.1 \text{ ml/kg/%TBSA})\) over 24 hours which was also significantly greater than the Parkland estimate of 7 869 ± 2 466 ml \((P = 0.017)\).

Figure 1 compares the pattern of actual vs estimated fluid volumes in the first, second, and third 8-hour intervals of the resuscitation in the INCR and DCR groups. During the first 8 hours of resuscitation, the actual volume received closely matched the estimated volume in both the INCR and DCR groups. During the second and third 8-hour intervals, the actual resuscitation volume was significantly greater than estimated in both the INCR and DCR groups. However, the magnitude of the discrepancy between actual and estimated fluid volumes was significantly greater in the INCR group than in the DCR group \((P < 0.001)\) by 2-way ANOVA.

Table 1 compares the pattern of actual vs estimated fluid volumes during the first, second, and third 8-hour intervals of resuscitation.

<table>
<thead>
<tr>
<th></th>
<th>First 8-Hour Volume (ml)</th>
<th>Second 8-Hour Volume (ml)</th>
<th>Third 8-Hour Volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated</td>
<td>4113 ± 1619</td>
<td>2057 ± 810</td>
<td>2057 ± 810</td>
</tr>
<tr>
<td>Actual</td>
<td>4365 ± 1930</td>
<td>4651 ± 3458</td>
<td>4338 ± 2827</td>
</tr>
<tr>
<td>(P) value*</td>
<td>NS</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

NS, not significant.

*Two-tailed paired student’s \(t\)-test.
deaths resulted from Multiple Organ Dysfunction Syndromes (MODS) on post burn days 13, 15, and 19 and 22. Among the four patients who died in the DCR group, the mean age was 74 ± 14 years, and the mean %TBSA burn was 26 ± 11%. One death followed withdrawal of care (an 87-year-old with a 20% TBSA burn on post burn day 8). The other 3 deaths resulted from MODS and occurred on post burn days 2, 9, and 10.

In Engrav et al’s study, the mean age of the patients was 36 years. Since our population was substantially older than this, we decided to analyze the patients who were ≤ 36 years of age. There were 9 patients in this sub-group, with a mean age of 30 years (range 22–36 years), who had a TBSA burn of 28 ± 12%, and a %FTB of 6 ± 8%. This group received 11 657 ± 4926 ml (5.3 ml/kg/%TBSA) over the first 24 hours, which was significantly greater than the estimated Parkland volume of 8 802 ± 4 124 ml (P < 0.001) using 2-way ANOVA.

Figure 1. Comparison of the estimated and actual fluid resuscitation volumes in the first, second, and third 8-hour intervals of resuscitation, in the decrease (DCR) and increase (INCR) groups. P values reflect comparison of estimated to actual volumes using two-tailed paired Student’s t-tests. The DCR and INCR were significantly different from each other (P < 0.001 using 2-way ANOVA).

Figure 2. Comparison of the mean hourly urine output for each of the three 8-hour resuscitation intervals in the decrease (DCR) group (dark bars) and the increase (INCR) group (light bars).
mates seem to have been reproduced in several stud-
ies, but accurate values are still lacking. Our results
are approximate and within Baxter's guidelines.

If we make the assumption that the Parkland For-
mula is an accurate predictor of fluid requirements,
then we must first consider whether there are any
factors in our study that might explain why our pa-
tients routinely deviated from the estimated resusci-
tation requirements. The most obvious possibility is
that our patients were overresuscitated. The mean
urine output over the first 24 hours for the entire
study population was 1.2 ± 0.6 ml/kg/hr and there-
fore was marginally above the desired range of 0.5 to
1.0 ml/kg/hr. However, it is important to note that
the mean urine output was brought to just within the
desired range by the third 8 hour period of resuscita-
tion. Presumably, this occurred as a result of appro-
priate titration of the infusion rate. This belief is sup-
ported by specifically examining the urine output
patterns of the INCR and DCR groups (figure 2). In
the DCR group, urine output was initially high, and
clearly in excess of the desired range. However, with
reduction of the infusion rate, an appropriate urine
output was achieved as resuscitation proceeded. In
the INCR group, increasing infusion rates were asso-
ciated with maintenance of the urine output within
the range of 0.5 to 1.0 ml/kg/hr. We believe that this
reflects correct titration of the formula which resulted
in an appropriate and desired clinical response. In
the original descriptions of the Parkland Formula, the
actual urine output obtained with 3.7 to 4.3 ml/kg/
%TBSA was not reported. Baxter has suggested that
the “desired” or “recommended” urine output
should be 50 to 70 ml/hr,12 50 to 100 ml/hr,15
more than 40 ml/hr,11 and 40 to 70 ml/hr.1 Based
on these figures, our patients’ mean 24 hour urine
output of 89 ± 39 ml/hr would be considered ap-
propriate and generally within Baxter’s guidelines.
Therefore, it is difficult to conclude that our results
are due to gratuitous over-resuscitation or incorrect
use of the formula. Conversely, we do not believe that
ey early underresuscitation played a major role. The pa-
tients in this analysis received adequate volumes of
fluid relatively soon after their injuries.

It is not clear in Baxter’s original study on the Park-
land Formula10 whether the fluid infusion rate should
be gradually or suddenly reduced after 8 hours. Baxter
determined that the optimum response in a canine burn
model occurred when half of the 24-hour resuscitation
volume was administered within the first 8 hours after
the burn, giving the remaining half over the next 16
hours. Although unclear and not specified, it would ap-

### Table 2. Comparison of survivors and nonsurvivors with respect to age, % TBSA burn, % full-thickness burn (% FTB), 24-hour resuscitation volume, and mean urine output during the first 24 hours

<table>
<thead>
<tr>
<th></th>
<th>Survivors</th>
<th>Nonsurvivors</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>21</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>42 ± 14</td>
<td>72 ± 13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>% TBSA</td>
<td>26 ± 9</td>
<td>29 ± 12</td>
<td>NS</td>
</tr>
<tr>
<td>% FTB</td>
<td>6 ± 8</td>
<td>13 ± 12</td>
<td>NS</td>
</tr>
<tr>
<td>Resuscitation volume (ml/kg/%TBSA)</td>
<td>5.9 ± 2.3</td>
<td>8.1 ± 3.3</td>
<td>0.03</td>
</tr>
<tr>
<td>Urine output (ml/kg/hr)</td>
<td>1.3 ± 0.7</td>
<td>1.1 ± 0.4</td>
<td>NS</td>
</tr>
</tbody>
</table>

Figures are number or percent (± SD) unless otherwise specified.

**DISCUSSION**

The Parkland Formula, and other crystalloid based
formulas are effective approaches to the resuscita-
tion of an acutely burned patient. However, the vast ma-
jority of the patients in our study received signifi-
cantly more fluid than the Parkland estimate. One
half of the patients did not follow the pattern anticipat-
ed by the Parkland Formula, and received increasing
amounts of fluid after the first 8 hours of resuscita-
tion. Engrav et al6 recently reported that fluid vol-
umes administered during burn resuscitation fre-
quently are in excess of what was estimated by the
Parkland Formula. In that study, the authors found that
the resuscitation volume exceeded the Parkland estimate in 45% of their 11 most recent cases involving
patients with burns larger than 40% TBSA. The au-
thors then reviewed data involving 50 resuscita-
tions surveyed from 7 burn centers, and reported that
58% of the sample received more than the upper limit
of 4.3 ml/kg/%TBSA predicted by the Parkland For-
mula, and that the mean (± SD) fluid resuscitation
was 5.2 ± 2.3 ml/kg/%TBSA. When patients with
smoke inhalation injury were excluded, the actual re-
suscitation volume ranged between 4.4 ± 1.8 ml/
kg/%TBSA for patients with partial thickness burns, to
5.3 ± 2.2 ml/kg/%TBSA in patients with full
thickness burns.

Our findings concur with those of Engrav et al6 and stand in stark contrast to what has been published in
the literature since the original description of the
Parkland formula in 1968.10 Baxter reported that ap-
proximately 70% of adult patients were adequately resuscitated with 3.7 to 4.3 ml/kg/%TBSA of Ringer’s lactate, and that only 12% of patients required
more than 4.3 ml/kg/%TBSA.1,2,11,12 Baxter’s esti-
mates seem to have been reproduced in several stud-
ies where fluid requirements for burn patients with-

out smoke inhalation injury have ranged between 2.3
± 0.8 ml/kg/%TBSA to 4.0 ± 0.19 ml/kg/
%TBSA.3,13,14 Why do the resuscitation requirements
of the patients in our study vary so significantly from
these commonly accepted values?

If we make the assumption that the Parkland For-
mula is an accurate predictor of fluid requirements,
then we must first consider whether there are any
factors in our study that might explain why our pa-
tients routinely deviated from the estimated resusci-
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volume was administered within the first 8 hours after
the burn, giving the remaining half over the next 16
hours. Although unclear and not specified, it would ap-
pear that the rate was suddenly decreased after 8 hours. Similarly, Baxter’s recommendations for human burn resuscitation suggest that the infusion rate drop by half at 8 hours.\textsuperscript{12,15} In contrast to this, Warden has stated that “abrupt changes in the fluid infusion rate as prescribed by the (Parkland) formula” are not physiological during the resuscitation of individual patients.\textsuperscript{8,9} It is conceivable that our method of gradual or tapered reduction in the infusion rate may have contributed to volumes in excess of the Parkland prediction. However, our gradual rate reduction strategy follows previously published recommendations,\textsuperscript{8,9} as well as the American Burn Association’s current practice guidelines on fluid resuscitation.\textsuperscript{16}

Could the demographics of our study population account for our findings? The mean age of our patients was relatively advanced. It has been recognized that the elderly often do not respond to resuscitation in the anticipated manner, and frequently require fluid volumes well beyond what was estimated.\textsuperscript{17} While this might partially account for our findings, it does not give us a complete explanation. If age had played a major role, we would have expected to see that the INCR group, who deviated most profoundly from the formula, to have consisted of significantly older patients. Furthermore, in the analysis of patients younger than 36 years, the resuscitation volume was still significantly greater than estimated.

Engrav et al.\textsuperscript{6} questioned whether the nature of the burn injury might be responsible for the increased fluid requirements. This is probably not the case in our study since the injuries consisted solely of the usual spectrum of flame, scald, and flash injuries. Burns associated with extensive tissue damage and myonecrosis, such as high voltage electrical injuries were specifically excluded. Chemical burns may require more fluid than anticipated, either because of underestimation of the extent of injury or because of ongoing progressive tissue destruction. While there were two chemical burns in this study, both were in the DCR group, which tended to follow the anticipated pattern of resuscitation more closely.

Thus, we cannot easily explain our results on the basis of incorrect use of the Parkland Formula, over-resuscitation, delayed resuscitation, advanced patient age, or nature of the burn injury. This leads us to an alternative approach which is to challenge the assumed accuracy of the Parkland Formula itself. The first step is to examine how closely actual resuscitation volumes matched the estimated volumes reported in Baxter’s original publications. In the original description of the Parkland Formula\textsuperscript{10} the optimal fluid resuscitation regime was determined from an animal model, and was found to be 4 ml/kg/%TBSA. This was initially used in 11 patients with burns varying from 30 to 85% TBSA. The clinical response was not clearly described and Baxter reported only that urine output greater than 50 ml/hr was “usually achieved” within 2 to 6 hours after injury. The actual volume of crystalloid fluid administered is difficult to determine. The 24 hour volume of Ringer’s lactate administered was expressed as a percentage of body weight, yet the weights of the patients were not reported making it impossible to identify whether the patients received more or less fluid than predicted. In this same study, a clinical series of 277 burn patients of indeterminate mean age (range 2 years to > 60 years), with burns ranging from 20% TBSA to > 70% TBSA were estimated to require 3 ml/kg/%TBSA burn for resuscitation. These patients received Ringer’s lactate based on clinical signs of “adequate resuscitation” (which were not identified). The urine output in response to this resuscitation was not reported. Calculated and actual resuscitation volumes were again expressed as a percentage of body weight, and were reported as a 48-hour volume rather than a 24-hour volume. The administered volume was in excess of calculated volume for all categories of burn size but it is impossible to discern when the excess volume was given over the first 48 hours. Although the mean volume of crystalloid administered over 48 hours was reported as 3.5 ml/kg/%TBSA burn with two-thirds of this total volume “usually” being given in the first 24 hours, it is impossible to accurately compare predicted versus actual fluid volumes, or the response to resuscitation, from this data. Subsequently, Baxter reported that among 438 adult burn patients, resuscitation volumes exceeded the range of 3.7 to 4.3 ml/kg/%TBSA burn in only 12% of cases.\textsuperscript{11} However, the actual endpoint of resuscitation that was achieved with this regimen was only suggested to be a urine output which averaged more than 40 ml/hr. The actual mean urine output, and deviation around this were never reported. Hence, the absence of a consistent and clearly defined resuscitation endpoint, along with insufficient description of actual fluid volumes received make it impossible to be fully confident in the accuracy of the Parkland Formula as it was originally described.

This is by no means meant to be a condemnation of the Parkland Formula. Clearly, the Parkland Formula and other crystalloid based formulas produce adequate resuscitation of most burn patients. In particular, when these formulas are used to identify a starting point for resuscitation, with subsequent titration of the fluid infusion rate based on clinical response, successful resuscitation is usually achieved. While the clinical application of the Parkland Formula is not in
question, the accuracy of the formula in estimating actual fluid requirements is.

Surprisingly, there are only a few studies which have directly assessed actual versus predicted volumes during acute burn resuscitation in adults. Navar et al determined that 3.98 ± 0.19 ml/kg/% TBSA burn was required for the resuscitation of burn patients without smoke inhalation, in order to achieve urine output of 30–50 ml/hr in adults, and 1 ml/kg/hr in children. The study population was heterogeneous and included patients ranging in age from 1 to 59 years. Several patients with massive volume requirements were switched from Ringer’s lactate to hypertonic saline solution in an attempt to minimize overall fluid intake. Finally some of the resuscitations were guided by information obtained from pulmonary artery catheters. Thus, the reported fluid volume requirement of 3.98 ± 0.19 ml/kg/% TBSA burn may not have been representative of the typical needs of an adult who is being resuscitated purely with isotonic crystalloids to clinical endpoints without the use of invasive monitoring. In a study by Dai et al involving 36 adult burn patients without inhalation injury, the mean 24 hour resuscitation requirement was found to be 2.3 ± 0.8 ml/kg/% TBSA burn. These patients were resuscitated according to the Parkland Formula with titration of the infusion based on a desire to maintain urine output between 0.5 and 1.0 ml/kg/hr. However, the actual urine output was not reported and it is not clear whether 2.3 ± 0.8 ml/kg/% TBSA burn successfully achieved the desired endpoint of 0.5 to 1.0 ml/kg/hr of urine output. Furthermore the incidence of acute renal failure was 6% in patients without inhalation injury and 12% in those with inhalation injury, resulting in an overall incidence of 8%. This is relatively higher than has been reported in most of the recent studies and suggests that the patients may not have been adequately resuscitated. Thus, while the patients reported in these two studies required somewhere between 2.3 and 3.98 ml/kg/% TBSA burn, this cannot be interpreted as evidence of the accuracy of the Parkland Formula.

There is some indirect evidence in the literature which supports the concept that the Parkland Formula is inaccurate and underestimates the actual resuscitation requirements of adult burn patients. Kaups et al reviewed the fluid resuscitation data of 83 adult burn patients (mean ± SD TBSA of 25 ± 2%), of whom 72% did not have an accompanying inhalation injury. These patients were resuscitated according to the Parkland Formula to maintain urine output greater than 0.5 ml/kg/hr. While the authors were primarily interested in the role of the base deficit as a predictor of fluid requirements, it was noted that the actual 24 hour volume requirements were significantly greater than the Parkland prediction in all patients. This was especially so in patients with abnormally elevated admission base deficits. Because actual urine output was not reported, it is impossible to be sure that these patients were not resuscitated to an endpoint outside of the commonly accepted range of 0.5 to 1.0 ml/kg/hr. Also, 28% of the study population had sustained an inhalation injury, which may have partially contributed to the elevated fluid requirements. Nonetheless, the findings in this study suggest that the Parkland Formula did not provide an accurate estimate of the actual resuscitation requirements of the patients.

Half of the patients in our study did not follow the expected pattern of resuscitation and required increasing amounts of fluid (INCR group), rather than decreasing amounts (DCR group), after the first 8 hours. The only difference between the patients in these groups was that the patients in the INCR group had more extensive full thickness burns. The larger amount of tissue destruction, and more importantly, the greater magnitude of wound progression that would be expected in the INCR group may explain why they required increasing amounts of resuscitation fluid. This is supported by the observation that the Parkland Formula correctly predicted requirements during the first 8 hours of resuscitation, but failed over the remaining 16 hours, during which time wound progression was maximal in the zone of stasis. We hypothesize that progression of the burn wound, which would be expected to be maximal in the tissues surrounding full thickness wounds, is responsible for our findings.

We do not believe that the Parkland Formula should be amended based on these results. The Parkland Formula is a time honored and effective approach to fluid resuscitation of an acutely burned patient. The critical aspect to the formula is not the absolute numerical fluid rate that it generates, but rather, that this initial fluid rate be used as a starting point with adjustment of the rate based on clinical response. Paradoxically, although our results suggest that the Parkland Formula is inaccurate, our results also validate the effectiveness of the Parkland Formula as an approach to fluid resuscitation. The Parkland Formula made an accurate estimate of the initial fluid resuscitation requirements in our patients, and only began to fail as an estimator of requirements after 8 hours. Successful resuscitation was achieved through appropriate titration of the initial fluid resuscitation rate which had been dictated by the Parkland Formula.
Although we found that patients required significantly more fluid than 4 ml/kg/% TBSA, starting the resuscitation based on an estimate greater than this could be detrimental to the patient, and might result in volume overload during the first 8 hours. The risks of too much fluid are well recognized and include abdominal compartment syndrome, limb compartment syndrome, and pulmonary edema. Notwithstanding the risks of over-resuscitation, our results do raise one interesting hypothetical question. Would use of an estimation more than 4 ml/kg/% TBSA (such as an estimate between 5.6 and 7.7 ml/kg/% TBSA) in patients with large full thickness burns result in less fluid requirements after 8 hours through more aggressive volume loading during the first 8 hours? This question can only be answered by a randomized prospective study where resuscitation was meticulously titrated to a strictly defined set of end points.

In conclusion, while the Parkland Formula provides an effective approach to fluid resuscitation, we have found that it underestimates the actual fluid requirements in adult burn patients who have not sustained an inhalation injury. Although the formula was accurate during the first 8 hours of resuscitation, it significantly underestimated fluid requirements during the second and third 8 hour periods, especially in patients with larger full thickness burns. Also, deviation from the anticipated pattern of a decreasing fluid infusion rate after the first 8 hours was frequently observed in patients with large full thickness injuries. Despite its inaccuracy as an estimator of actual fluid resuscitation volumes, successful resuscitation was achieved in our patients through appropriate use of the formula.

REFERENCES