The Parkland Formula Under Fire: Is the Criticism Justified?

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Controversy has continued regarding the practicality and accuracy of the Parkland burn formula since its introduction over 35 years ago. The best guide for adequacy of resuscitation is urine output (UOP) per hour. A retrospective study of patients resuscitated with the Parkland formula was conducted to determine the accuracy (calculated vs. actual volume) based on UOP. A review of burn resuscitation from a single institution over 15 years was conducted. The Parkland formula was defined as fluid resuscitation of 3.7 to 4.3 ml/kg/% total body surface area (TBSA) burn in the first 24 hours. Adequate resuscitation was defined as UOP of 0.5 to 1.0 ml/kg/hr. Over-resuscitation was defined as UOP > 1.0 ml/kg/hr. Patients were stratified according to UOP. Burns more than 19% TBSA were included. Electrical burns, trauma, and children (<15 years) were excluded. Four hundred and eighty-three patients were reviewed. Forty-three percent (n = 210) received adequate resuscitation. Forty-eight percent (n = 233) received over-resuscitation. The mean fluid in the adequately and over-resuscitated groups was 5.8 and 6.1 ml/kg/%, respectively (*P* = .188). Mean TBSA and full thickness burns in the adequately and over-resuscitated groups were 38 and 43%, and 19 and 24%, respectively (*P* < .05). Inhalation injury was present in 12 and 18% (*P* = .1). Only 14% of adequately resuscitated and 12% of over-resuscitated patients met Parkland formula criteria. The mean Ivy index in the adequately and over-resuscitated groups was 216 and 259 ml/kg (*P* < .05). There was no significant difference in complication rates (80 vs. 82%) or mortality (14 vs. 17%). The actual burn resuscitation infrequently met the standard set forth by the Parkland formula. Patients commonly received fluid volumes higher than predicted by the Parkland formula. Emphasis should be placed not on calculated formula volumes, as these should represent the initial resuscitation volume only, but instead on parameters used to guide resuscitation. The Parkland formula only represents a resuscitation "starting" point. The UOP is the important parameter. (J Burn Care Res 2008;29:180–186)

The Parkland formula was first described in 1968 by Baxter and Shires.[1] In subsequent papers, Baxter stated that the majority of burn patients could be adequately resuscitated with 3.7 to 4.3 ml of lactated Ringer's solution per kilogram per percentage total body surface area (TBSA) burned.[2] Only 12% of 438 patients evaluated during a 5-year period required more fluid for adequate resuscitation.[3] Adequacy of resuscitation was guided by urine output (UOP), which was defined as greater than 40 ml/kg/hr.[3]

Since that time, the literature is replete with retrospective studies demonstrating that patients require greater amounts of fluid resuscitation volume than predicted by the Parkland formula.[4–7] Controversy has arisen over both the accuracy and the practicality of the Parkland formula in guiding resuscitation.[4–6] UOP per hour continues to be used as the best guide to monitor adequate resuscitation and end organ perfusion, regardless of the amount of fluid given. The purpose of this study was to review our experience with the Parkland formula using UOP as the guide for adequacy of resuscitation in the first 24 hours postburn.

METHODS

After IRB approval, a retrospective analysis of burn patients treated at Parkland Memorial Hospital Burn Center in Dallas, Texas, was conducted. Data were

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Table 1. Demographics of study patients

Demographics	n = 483
Age	40.7 ± 16.7
Mean % burn	40.2 ± 17
Full thickness	21.7 ± 20.3
Inhalation injury	15.7
Survival	83%
Mean fluids (ml)	19,061
Fluid (ml/kg/%)	6.07
% within PF	13

collected from hospital records during a 15-year period (1991–2005). Inclusion criteria were burns in adults greater than 19% TBSA. Children aged 14 years or younger were excluded. Burns associated with trauma or electrical injuries were excluded. All patients were resuscitated using the Parkland Burn formula of 4 ml/kg/% TBSA. Colloid was given in the form of 25% albumin at 24 hours postburn.

Patients were stratified according to their hourly UOP. For purposes of this study, adequate fluid resuscitation was defined as UOP of 0.5 to 1.0 ml/kg/hr. Over-resuscitation was defined as UOP >1.0 ml/kg/hr.

The percentage of patients within the Parkland formula burn resuscitation recommendations was determined. Patients with a fluid resuscitation of 3.7 to 4.3 ml/kg/% TBSA burn in the first 24 hours were considered to have met criteria of the Parkland formula. Fluid volumes were evaluated as per the Parkland formula (ml/kg/%) and also in ml/kg as described by Ivy.[8] Ivy described that resuscitation volumes in excess of 250 ml/kg resulted in intraabdominal hypertension, which could then lead to abdominal compartment syndrome. Therefore appropriate monitoring for these conditions should be employed once this volume has been given.

Inhalation injuries were diagnosed by bronchoscopy with direct visualization in those patients stable enough to undergo this procedure. In patients too unstable to undergo bronchoscopy, clinical suspicion and signs such as soot around nares, in mouth, or in the endotracheal tube are used for diagnosis.

Fluid volumes, survival, and complication rates were examined using independent samples *t*-tests and χ^2 tests. Results are presented as mean ± SD and percentages. The correlation between fluid input and TBSA was measured using Pearson correlation coefficient. Results are presented as medians with interquartile ranges and Pearson *r*. A $P < .05$ was considered significant for all statistical analyses. Statistical software SPSS (SPSS Inc., Chicago, IL) was used for all statistical analyses.

RESULTS

A total of 483 patients constituted the study population. Study patient demographics are shown in Table 1. The percent of patients within the Parkland formula recommendation was consistently low across stratified TBSA groups (Table 2). Fluid input (ml/kg) correlated with percent TBSA ($r = .665$; $P < .001$). Median fluids for burns more than 40% was greater than or equal to the Ivy index of 250 ml/kg (Figure 1).

Stratification based on UOP revealed that 43% of patients (n = 210) received adequate resuscitation. Forty-eight percent of patients (n = 233) received over-resuscitation. Nine percent of patients (n = 40) were under-resuscitated. This last group was not evaluated. Characteristics of the two evaluated groups are listed in Table 3. Mean TBSA in the two groups (adequate vs. over-resuscitated) was 38 vs. 43% ($P = .001$), mean full thickness was 19 vs. 24% ($P = .023$), mean with an inhalation injury was 12 vs. 18% ($P = .100$). The mean Ivy index in the adequate fluid resuscitation and over-resuscitation was 216 and 259 ml/kg ($P < .05$).

There was no significant difference between the adequately resuscitated and over-resuscitated groups in the percentage meeting the Parkland formula (14 vs. 12%). The mean milliliter per kilogram per percent TBSA (5.8 vs. 6.1) and frequency of colloid use (87 vs. 84%) were similar between the two groups. Overall length of stay (35 vs. 43 days), intubation status

Table 2. Percentage of patients within the Parkland formula by TBSA groups

	TBSA							
	20–29% (n = 153)	30–39% (n = 132)	40–49% (n = 75)	50–59% (n = 49)	60–69% (n = 33)	70–79% (n = 20)	80–89% (n = 16)	90–99% (n = 5)
Patients within PF	15.7%	12.1%	14.7%	8.2%	9.1%	10.0%	0.0%	20.0%

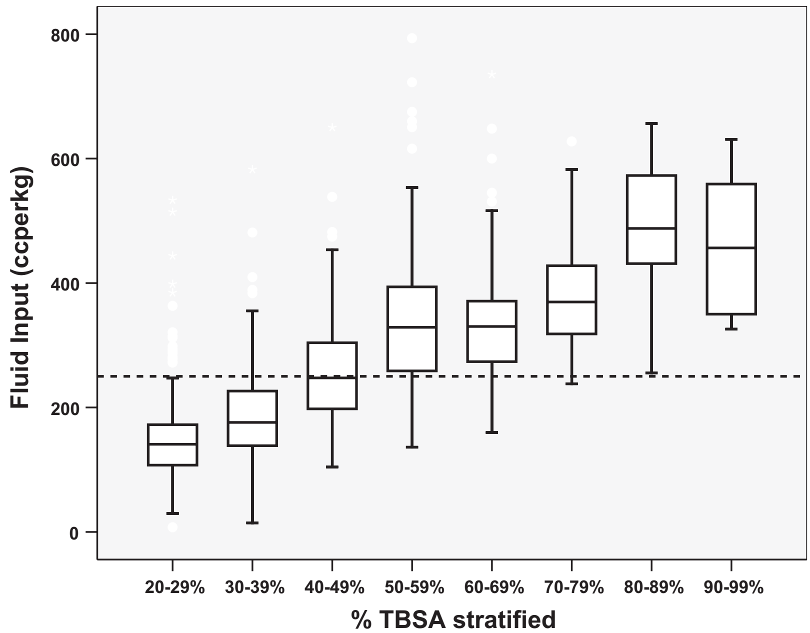

Figure 1. This box-and-whiskers plot shows the median and interquartiles of fluid resuscitation by total body surface area burned groups. Boxes represent the interquartile range depicted as the difference between the 75th and 25th percentiles. The line within the box represents the median. The IVY score, which is equal to 250 ml/kg, is represented by the dotted reference line.

(33 vs. 35%), and time on ventilator (15 vs. 21 days) were not significantly different. Length of ICU stay was significantly lower for the adequately resuscitated group (17 vs. 26 days; $P = .038$). Survival (86 vs. 83%) and complication rates were not different between the two groups (Table 4).

The differences between patients receiving and exceeding the Parkland formula are demonstrated in Tables 5 and 6. In the adequately resuscitated group (Table 5), patients who received more than the Parkland formula had significantly larger full thickness components. There was no significant difference in complication rates. However, patients within the Parkland formula had higher survival rates (Table 5).

In the over-resuscitated group (Table 6), despite significant differences in volume of fluid given, no differences existed in age, burn size or % full thickness, complication rates or survival.

DISCUSSION

Underhill and Blalock were among the first to describe the extensive loss of fluids in the burned patient.[9,10] After this, the appropriate resuscitation

Table 3. Patient characteristics by urine output

	Urine ml/hr/kg		
	0.5–1.0 (n = 210)	>1.0 (n = 233)	Significance
Mean age	42.6 ± 17.1	37.8 ± 15.6	.002
Mean weight (kg)	83.3 ± 17.4	77.5 ± 16.7	<.001
Mean % TBSA	37.7 ± 15.6	43.0 ± 17.8	.001
Mean % full thickness	19.2 ± 18.2	23.5 ± 21.5	.023
% Inhalation injury	12.4%	18.0%	.100
% Survival	85.7%	83.3%	.477
Mean input (ml)	17,560 ± 9,519	19,699 ± 11,671	.036
Mean ml/kg/% TBSA burn	5.8 ± 2.3	6.1 ± 2.7	.188
Mean ml/kg	216.2 ± 117.9	258.7 ± 142.8	.001
% Patients w/in PHHS formula	13.8%	12.0%	.574

Table 4. Complication rates stratified by urine output groups

	Urine ml/hr/kg		
	0.5–1.0 (n = 210)	>1.0 (n = 233)	*P*
Any complication	79.5%	82.4%	.440
Sepsis	11.0%	17.2%	.061
Hypotension	17.1%	14.6%	.462
Cardiac arrest	1.4%	3.9%	.115
Pneumonia	25.7%	33.0%	.091
ARDS	7.6%	8.2%	.835
CHF/overload	12.9%	14.2%	.688
Abdominal compartment syndrome	1.0%	0.4%	.503

of the acutely burned patient, including the amount and type of fluid given, was debated in the literature.[11–14] A number of resuscitation formulas have been proposed during the last 60 years. Evans in 1951 described the use of 1 ml/kg/% TBSA each of normal saline and colloid, in addition to 2 L of 5% dextrose in water for the first 24 hours postburn. The Brooke formula, initially described in 1953, used 1.5 ml/kg/% TBSA of lactated Ringer's solution plus 0.5 ml/kg/% TBSA of colloid and 2 L of 5% dextrose in water.[14] This formula was later modified to 2 ml/kg/% TBSA of lactated Ringer's solution. Colloid is not given in the first 24 hours postburn.

Baxter originally described the Parkland Burn formula in 1968.[1] According to his studies, the fluid requirements of acutely burned patients were between 3.7 and 4.3 ml/kg/% TBSA of lactated Ringer's solution.[2] At the time, this was a significantly larger amount of fluid than had been previously been recommended, and was the first to be based on both experimental and clinical research.[1,11–14] The endpoints of resuscitation were based on clinical signs including a normal sensorium and UOP of greater than 40 ml/hr, although this volume varied throughout Baxters's descriptions.[1–3] Baxter stated that only 12% of patients required more fluid than that predicted by the Parkland formula.[3] The formula as used today consists of 4 ml/kg/% TBSA burn of lactated Ringer's solution, one half of which is given during the first 8 hours, and the remainder divided equally during the next 16 hours. At the authors' institution, the fluid rate is adjusted to keep UOP between 0.5 and 1 ml/kg/hr. Although this volume differs from the original description by Baxter, this standardized volume has been used in studies in the recent literature.[4,8,15] Colloid is typically given at 24 hours postburn. Our use of colloid differs from Baxter's original description in that it may be given earlier in difficult resuscitations at the provider's discretion.

Retrospective review of the patients in the study revealed that the actual burn fluid resuscitation infrequently met the standard set by the Parkland formula. The majority of patients, even if adequately resuscitated using UOP as a guide, received significantly higher fluids than predicted by the Parkland formula. Only 13% of patients were within the Parkland formula, with a mean fluid resuscitation of 6 ml/kg/% burn. This is consistent with recent studies in the literature showing increased fluid resuscitation volumes in burn patients. Cartotto in 2002 studied 31 patients with cutaneous burns. He demonstrated that 84% received greater than predicted amounts of fluid resuscitation with a mean of 6.7 ml/kg/% TBSA. Also, the amount of fluid given in the 2nd and 3rd

Table 5. Comparison between those within PF and those not within PF based on UOP

	0.5–1.0 ml/kg/hr n = 210		
	Within Formula?		
	Yes (n = 29)	No (n = 181)	Significance
Mean age	34.8 ± 12.4	43.9 ± 17.4	.001
Mean weight (kg)	86.7 ± 13.7	82.8 ± 17.9	.259
Mean % TBSA	34.4 ± 9.5	38.3 ± 16.3	.076
Mean % full thickness	10.7 ± 11.7	20.6 ± 18.7	<.001
% Inhalation injury	3.4	13.8	.116
Mean input	12027 ± 3757	18447 ± 9863	<.001
Mean ml/kg/% TBSA burn	4.0 ± 0.2	6.1 ± 2.4	<.001
Mean ml/kg	138.7 ± 38.2	228.6 ± 121.6	<.001
% Survival	100	83.4	.018
% Any complication	79.3	79.6	.976

Table 6. Comparison between those within PF and those not within PF based on UOP

	>1.0 ml/kg/hr n = 233 Within Formula?		
	Yes (n = 28)	**No (n = 205)**	**Significance**
Mean age	36.6 ± 16.8	38.0 ± 15.5	.659
Mean weight (kg)	80.0 ± 19.9	77.1 ± 16.3	.391
Mean % TBSA	41.3 ± 19.3	43.2 ± 17.6	.598
Mean % full thickness	19.4 ± 23.3	24.1 ± 21.2	.276
% Inhalation injury	10.7	19.0	.283
Mean input	13476 ± 7574	20549 ± 11885	.002
Mean ml/kg/% TBSA burn	4.0 ± 0.2	6.4 ± 2.8	<.001
Mean ml/kg	166.5 ± 75.4	271.3 ± 145.3	<.001
% Survival	92.9	82.0	.147
% Any complication	75.0	83.4	.273

8-hour intervals was also significantly higher than that predicted by the formula.[4] Engrav and associates found similar results when they evaluated 11 acutely burned patients. They found that 45% of patients received more fluid than predicted at their center. A survey of six additional burn centers provided a total of 50 patients and revealed that 58% of patients received greater than predicted amounts of fluid.[6]

The endpoint of burn resuscitation has traditionally been the UOP.[3] In the paper by Engrav, 64% of patients had greater than 1 ml/kg/hr of UOP, with a mean fluid input of 5.2 ml/kg/% TBSA. In Cartotto's paper, the mean UOP was 1.2 ml/kg/hr, with fluids of 6.7 ml/kg/% TBSA. In the present study, we have chosen to evaluate adequacy of resuscitation using UOP, in addition to comparing the amount of fluid based on the Parkland formula. Even in patients who were adequately resuscitated (based on a UOP between 0.5 and 1 ml/kg/hr), the amount of fluids received significantly exceeded the Parkland formula. In this group, it is implied that the formula was used appropriately, with fluid volume adjusted to keep UOP at goal. Despite the increased amount of fluids given, there were no significant differences in complication rates between the adequately or over-resuscitated groups. However, the rates of complication were still high at 79.5 and 82.4%, demonstrating that the deleterious effects of excessive fluid resuscitation, or "fluid creep" as coined by Pruitt, are valid, and excessive fluid volumes, although commonly given, do result in complications. Adequately resuscitated patients who received greater than the Parkland formula had significantly more full thickness burns than those whose fluids were within the Parkland formula. Of note inhalation injury did not appear to be a factor (Table 5). The amount of full thickness burns may have contributed to the increased fluid received and decreased survival in this group, but there are likely other factors contributing, which were not elucidated in this retrospective review. Additional factors such as a delay of onset of resuscitation or inadequate fluids given before admission to the burn center may also contribute; however, this data are not available for all patients.

Over-resuscitation in burn patients has been proposed as the cause of complications such as increased need for mechanical ventilation and resultant ventilator associated pneumonia, increased ICU stay, and abdominal compartment syndrome.[4,8] Over-resuscitation in the present study was defined by the endpoint of UOP per hour, rather than fluid input, and both groups received more than Parkland formula calculations. The present review identified no significant differences in length of stay, complication rates, ventilator days, or abdominal compartment syndrome between the adequately resuscitated and over-resuscitated groups. The length of ICU stay was longer for the over-resuscitated group, despite having no increase in inhalation injuries, pneumonia, or ventilator days, which have typically been associated with longer ICU stay; however, these patients also had significantly larger burns with a significantly more full thickness component, which may have contributed, although other factors not demonstrated in this study are likely involved.

Ivy in 2000 demonstrated that intraabdominal hypertension and resultant abdominal compartment syndrome commonly occurred in the acutely burned patient.[8] He recommended routinely measuring bladder pressures in patients when volume resuscitation reached 250 ml/kg. In the present study, the median fluid resuscitation for burns exceeding 40% was 250 ml/kg or greater (Figure 1). Despite this, there was a low incidence (1%) of abdominal compartment syndrome in these patients. There was no difference in the incidence of abdominal compartment syndrome between the adequately and over-resuscitated groups. It is important to note that present study is limited in evaluating abdominal compartment syndrome because there was no uniform protocol for measuring and monitoring intraabdominal hypertension in this retrospective review.

The reasons for the increase in burn fluid resuscitation volumes are multifactorial. In this review, increased burn size was associated with increased resuscitation volumes. This was also demonstrated by Cancio and associates.[16] In that study, the authors reviewed 89 patients resuscitated with the modified Brooke Formula during a 10-year period. Thirty-seven percentage of patients received less than 4 ml/kg/% TBSA, and 63% received more. The average resuscitation volume was 4.9 ml/kg/% TBSA. They then performed multivariate analysis, which showed that both increased TBSA burn and decreased weight were independently associated with increased fluid given. They also demonstrated that patients received on average larger amounts of fluid than predicted, with the average fluid given surpassing the Parkland formula volumes, despite the lower starting resuscitation volume.

In their studies, Navar et al and Dai et al demonstrated that inhalation injury increased the amount of fluid resuscitation volumes in burn patients.[15,17] The retrospective review by Navar evaluated 171 patients with greater than 25% TBSA burn. Fifty-one of these patients had inhalation injuries confirmed by bronchoscopy, xenon scan, or both. Patients with an inhalation injury received significantly more fluid than those without inhalation injury (5.76 vs. 3.98 ml/kg/%, $P < .05$). Dai in 1998 showed similar results in a retrospective review of 62 patients. Twenty-six patients with inhalation injury received significantly more fluid than 36 patients without inhalation (3.1 vs. 2.3 ml/kg/%, $P < 0.05$), although all received less than the Parkland formula. In the present study, there were no significant differences in the incidence of inhalation injury between the groups who were adequately resuscitated or over-resuscitated based on UOP. When these patients were further stratified by fluid resuscitation volume (Tables 5 and 6), there were no differences in the incidence of inhalation injury between those who were within the Parkland formula or not. This was true for both the adequately and over-resuscitated groups. Therefore, inhalation injury appears not to be a significant cause of increased fluid resuscitation volume in this study, which is contrary to the findings in the previous studies.

The reasons for the large proportion of patients who were over-resuscitated (based on UOP) are unclear. These patients were younger, weighed less, and had larger burns with larger full thickness components. The burn size may contribute to receiving more fluid overall. However, these patients were over-resuscitated based on UOP, which implies that the fluids could have been decreased based on this endpoint. It has been suggested by Cancio that clinicians may be more likely to increase rather than decrease fluids.[16] His study found that fluids were appropriately increased (that is, when UOP was less than 30 ml/hr) only 37% of the time, and appropriately decreased (when UOP exceeded 50 ml/hr) only 27% of the time. This reluctance to change fluid rate based on the UOP may also be true in this review as well.

The limitations of the present study include the following: First, it is a retrospective review. Data regarding delay in resuscitation, associated comorbidities, and glycosuria, all of which contribute to increased fluid requirements, were not available for most patients. Second, this study also excluded 40 patients, or 9% of the study population, who were "under resuscitated" defined by UOP less than 0.5 ml/kg/hr. Some of these patients may have been truly given less fluid than required to keep their UOP appropriate. However, patients with causes for low UOP other than receiving too little fluid, such as abdominal compartment syndrome (5% of these patients) were included in this group, and the majority in this group received significantly more fluid than predicted (mean 7.3 ml/kg/% TBSA and 265 ml/kg, with only 10% within the Parkland formula). In this group of patients, the linear relationship between fluid input and UOP did not apply, and the endpoint of UOP could not be used to monitor these patients, so they were excluded from the review. Further studies would be necessary to determine the cause for the low UOP despite the large volume of fluid in this particular group. Children were also excluded as the fluid resuscitation as well as the endpoint of resuscitation (UOP of at least 1 ml/kg/hr) for children differs from adults, and conclusions made for adults may not apply to children. Third, although the majority of patients (84 and 87% of the study groups) received some colloid, data regarding timing was incomplete. Colloid is typically given at 24 hours postburn, but in a patient with a difficult resuscitation (receiving much larger volumes than anticipated) colloid was often given as early as 8 hours postburn. The volume and timing of colloid was varied throughout the 15 years of the study and between the study groups, and no conclusions can be therefore drawn regarding the effect of colloid on resuscitation. Fourth, although Baxter's original description of adequate UOP was greater than 40 ml/hr, studies in the recent literature have used UOPs varying from 0.5 to 1 ml/kg/hr[4,8,15] and 30 to 50 ml/hr.[16,17] At this institution, UOP of 0.5 to 1 ml/kg/hr is typically used, and was therefore included in the study definitions. There were no differences in the study outcomes when 30 to 50 ml/hr was used as the endpoint; however, the endpoint of greater than 40 ml/hr was not evaluated, and potential changes in the outcome could be possible if this volume was used. Fifth, although the authors have chosen to evaluate UOP as the endpoint of resuscitation as in Baxter's original descriptions, it is important to note that reliance on UOP alone is not adequate. Mental status and vital signs are also closely monitored, and patients deviating significantly from calculated resuscitation volumes or having unstable vital signs, are considered for further invasive monitoring, such as pulmonary artery catheterization. The data on the more invasive monitoring are limited, and therefore not included in this review.

CONCLUSION

Criticism should not be directed the Parkland formula because it commonly exceeds what was predicted. The formula provides an excellent resuscitation starting point. Hourly UOP is the best guide for determining adequacy of resuscitation. The criticism should be directed at failure to implement management of the formula, using UOP to control the resuscitation volume.

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