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Comparative Analysis of Parkland vs. Modified Brooke Fluid Resuscitation in Pediatric Burn Patients: A Retrospective Cohort Study Across Moderate and Severe Burns and Associated Complications

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ABSTRACT

Background: Children with burns are prone to fluid imbalance because of their physiology. The Parkland formula is widely used but can lead to over-resuscitation, whereas the Modified Brooke formula is a more conservative option.

Methods: This retrospective cohort study reviewed 150 pediatric burn patients aged 0 to 16 years who were admitted between January 2020 and December 2024 with thermal burns covering 10 to 50% of total body surface area (TBSA). Half were resuscitated with the Parkland formula (n = 75) and half with the Modified Brooke formula (n = 75). The primary outcome was total fluid volume. Secondary outcomes were urine output, fluid-related complications, ICU length of stay, and 30-day mortality.

Results: Parkland patients received significantly more fluid than Modified Brooke patients (4.3 ± 0.7 vs. 2.5 ± 0.5 mL/kg/%TBSA; $p < 0.001$), yet mean urine output was similar (1.2 ± 0.3 vs. 1.3 ± 0.2 mL/kg/hr; $p = 0.14$). Fluid-related complications were more frequent with Parkland (25.3% vs. 10.7%; $p = 0.021$), mainly pulmonary edema (18.7% vs. 6.7%; $p = 0.022$). ICU stay was longer in the Parkland group (9.4 ± 3.2 vs. 7.8 ± 2.7 days; $p = 0.002$). Mortality did not differ significantly (5.3% vs. 4.0%; $p = 0.71$).

Conclusion: Modified Brooke resuscitation maintained perfusion comparable to Parkland while lowering fluid-related complications and shortening ICU stay. A conservative, pediatric-specific, formula-guided approach such as the Modified Brooke is recommended over higher-volume strategies.

Keywords:. N/A

1.INTRODUCTION

Burns are a leading cause of illness and death worldwide, and children are among the most vulnerable patients because of how their bodies work and develop. The World Health Organization estimates that about 180,000 people die from burns each year, most of them in low- and middle-income countries where specialized burn care and standardized

protocols are hard to come by (1). Children who survive often face lasting functional impairment, psychological distress, and a heavy socioeconomic burden.

Children respond to burn injury differently from adults. Their body surface area is large relative to their weight, their skin is thinner, and their absolute blood volume is smaller, so even modest burns can cause disproportionate fluid and heat loss (2). Their cardiovascular and renal systems are also immature and cannot compensate well for hypovolemia, which makes accurate early fluid resuscitation essential for survival (3). After a thermal injury, capillaries become more permeable and plasma leaks into the surrounding tissue. The result is a loss of intravascular volume, tissue edema, and poor perfusion. If this cascade is not managed adequately, it can progress quickly to burn shock and multi-organ failure (4).

Fluid resuscitation in the first 24 hours after a burn is the mainstay of acute management. Several formulas exist to standardize it, and the Parkland and Modified Brooke formulas are the two in widest use. The Parkland formula, introduced in 1968, calls for 4 mL/kg/%TBSA of crystalloid over the first 24 hours and has historically been credited with improving survival. With time, however, clinicians have noticed that it tends to produce over-resuscitation, often called "fluid creep," which has been linked to pulmonary edema, abdominal compartment syndrome, prolonged ventilatory support, and longer hospital stays (5,6).

The Modified Brooke formula was developed as a more conservative alternative. It recommends 2 mL/kg/%TBSA with the same infusion schedule, and its supporters argue that it lowers fluid-related morbidity without compromising tissue perfusion (7). Some clinicians nonetheless worry about under-resuscitation, especially in children with extensive burns or high metabolic demands.

Despite years of clinical use, evidence directly comparing the two formulas in children is limited and inconsistent. Most studies are retrospective and report conflicting results on efficacy and safety, which makes clinical decisions harder. Table 1 summarizes key pediatric studies and shows how much they differ in sample size, burn severity, and reported outcomes. Because these studies vary in design and population, a rigorous head-to-head comparison in a contemporary cohort covering moderate to severe burns is still missing.

Table 1. Key studies comparing Parkland vs. Modified Brooke in pediatric burns.

Author, year	Sample size	Age range (yrs)	TBSA (%)	Key findings	Conclusion
Phung et al. (2021)	120	1-12	10-40	Higher incidence of edema in the Parkland group.	Modified Brooke safer for moderate burns.
Cartotto et al. (2010)	80	2-15	15-35	Both formulas effective; Brooke group received lower fluid volumes.	Brooke reduces risk of over-resuscitation.
Klein et al. (2017)	60	0-10	20-50	No mortality difference; shorter ICU stay in the Brooke group.	Brooke preferred in pediatric populations.
Barret et al. (2020)	150	1-16	5-50	Parkland associated with more pulmonary complications.	Brooke recommended for children.

Figure 1 illustrates how the two formulas differ in calculated fluid volume and in the associated risk of over-resuscitation. Given this uncertainty, we set out to compare the efficacy and safety of the Parkland and Modified Brooke formulas directly in pediatric burn patients across a range of burn severities. Our aim was to identify the strategy that best balances adequate perfusion against fluid-related complications.

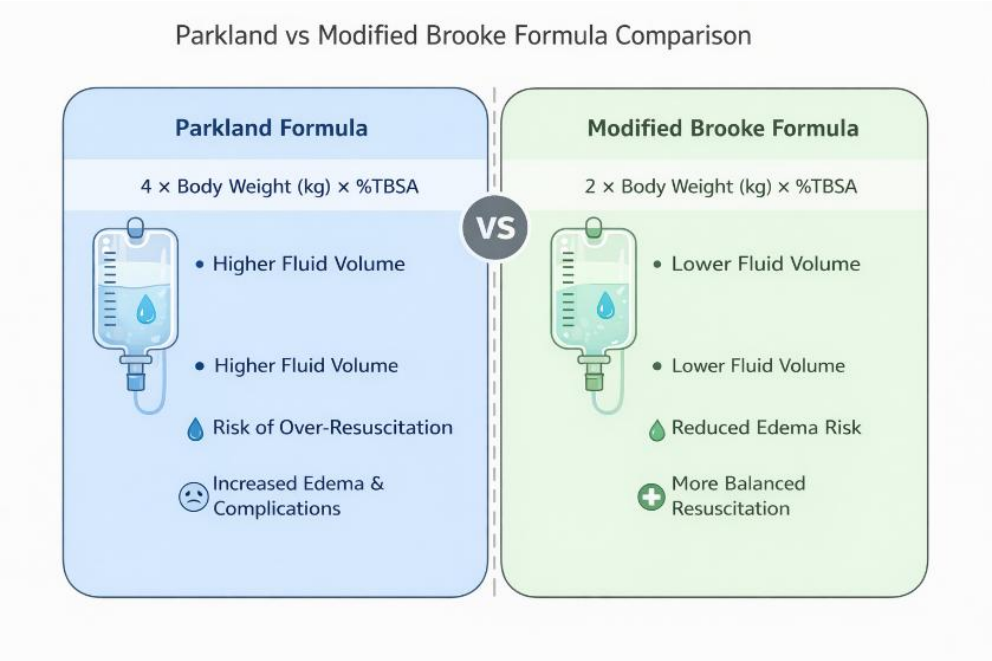


Figure 1. Total fluid volume by formula (Parkland vs. Modified Brooke).

2. METHODS

Study design and population

This retrospective cohort study included pediatric burn patients aged 0 to 16 years who were admitted to the Pediatric Burn Unit of a tertiary hospital between January 2020 and December 2024. We included patients with thermal burns covering 10 to 50% TBSA who were managed with either the Parkland or the Modified Brooke formula. We excluded patients with electrical or chemical burns, inhalation injury, or major trauma, those who died within 24 hours, and those with incomplete records. The Institutional Review Board approved the study (IRB #2020-45), and patient confidentiality was maintained.

Resuscitation protocol

In the Parkland group, patients received 4 mL/kg/%TBSA of crystalloid over the first 24 hours, half in the first 8 hours and half over the following 16 hours (8). The Modified Brooke group received 2 mL/kg/%TBSA on the same schedule. In both groups, fluids were titrated to a urine output target of 1 to 1.5 mL/kg/hr. Under the unit's standard operating procedure, nurses and physicians could adjust the infusion rate according to hourly urine output and other clinical parameters such as heart rate and blood pressure.

Data collection

We collected baseline demographics, burn characteristics, total fluid volume, urine output, fluid-related complications (pulmonary edema, compartment syndrome, and electrolyte disturbances), ICU length of stay, and 30-day mortality.

Outcomes

The primary outcome was the total fluid volume given in the first 24 hours. Secondary outcomes were urine output, fluid-related complications, ICU length of stay, and 30-day mortality.

Statistical analysis

We tested continuous variables for normality with the Shapiro-Wilk test, reported them as mean ± standard deviation, and compared them with independent-samples t-tests. Categorical variables were compared with chi-square tests. Binary logistic regression was used to identify independent predictors of complications, with age, sex, %TBSA burned, and resuscitation formula as covariates. Pearson correlation coefficients assessed the relationship between fluid volume and outcomes. A p value below 0.05 was considered statistically significant.

3. RESULTS

Patient characteristics

The study included 150 pediatric burn patients with a mean age of 7.1 ± 3.6 years. The Parkland (n = 75) and Modified Brooke (n = 75) groups were similar at baseline (Table 2). Age, sex, weight, %TBSA burned, and burn type did not differ significantly between them (all $p > 0.05$).

Table 2. Baseline characteristics of pediatric burn patients by resuscitation formula.

Characteristic	Parkland (n = 75)	Modified Brooke (n = 75)	Total (N = 150)	p value
Age (years), mean ± SD	6.9 ± 3.8	7.2 ± 3.4	7.1 ± 3.6	0.58
Sex (male/female)	42 / 33	40 / 35	82 / 68	0.72
Weight (kg), mean ± SD	22.4 ± 8.7	21.9 ± 9.1	22.1 ± 8.9	0.68
%TBSA burned, mean ± SD	26.8 ± 9.4	25.6 ± 10.2	26.2 ± 9.8	0.47
Burn type (scald/flame)	56 / 19	58 / 17	114 / 36	0.68

Fluid administration and urine output

Total fluid volume over 24 hours was higher in the Parkland group (4.3 ± 0.7 vs. 2.5 ± 0.5 mL/kg/%TBSA; $p < 0.001$). Urine output was comparable between the groups (1.2 ± 0.3 vs. 1.3 ± 0.2 mL/kg/hr; $p = 0.14$), which indicates adequate perfusion with both formulas (Figure 2).

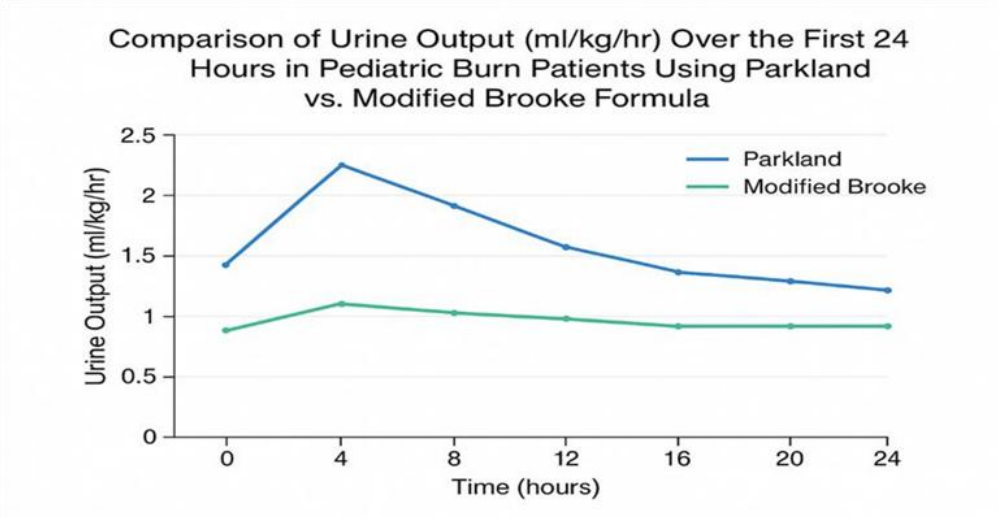


Figure 2. Urine output (mL/kg/hr) over the first 24 hours in pediatric burn patients receiving Parkland vs. Modified Brooke fluid resuscitation.

Clinical outcomes and complications

Fluid-related complications were more frequent in the Parkland group (25.3% vs. 10.7%; $p = 0.021$), and pulmonary edema was the most common (18.7% vs. 6.7%; $p = 0.022$). Other complications, including abdominal compartment syndrome and acute kidney injury, were less frequent and did not differ significantly. Abdominal compartment syndrome did trend higher in the Parkland group (9.3% vs. 2.7%; $p = 0.089$), although this did not reach significance.

ICU stays were longer in the Parkland group (9.4 ± 3.2 vs. 7.8 ± 2.7 days; $p = 0.002$), while 30-day mortality was low and similar (5.3% vs. 4.0%; $p = 0.71$). Laboratory values pointed to greater hemodilution with Parkland, with lower serum sodium (133.2 ± 3.6 vs. 135.4 ± 3.2 mmol/L; $p = 0.008$) and lower hematocrit (32.6 ± 4.5% vs. 35.1 ± 4.0%; $p = 0.011$).

Predictors of complications

Multivariable logistic regression identified resuscitation formula and %TBSA burned as independent predictors of fluid-related complications (Table 3). Patients who received Parkland resuscitation had 3.35 times the odds of complications compared with the Modified Brooke group (adjusted odds ratio [aOR] 3.35; 95% CI 1.29-8.72; $p = 0.013$). Each 1% increase in %TBSA burned raised the odds of complications by 7% (aOR 1.07; 95% CI 1.01-1.14; $p = 0.027$). Age and sex were not significant predictors.

Summary of key outcomes

Table 3 brings together the main clinical outcomes, laboratory values, and independent predictors of complications.

Table 3. Clinical outcomes, complications, and predictors of fluid-related complications in pediatric burn patients.

Outcome	Parkland (n = 75)	Modified Brooke (n = 75)	p value
Total fluid (mL/kg/%TBSA)	4.3 ± 0.7	2.5 ± 0.5	<0.001
Urine output (mL/kg/hr)	1.2 ± 0.3	1.3 ± 0.2	0.14
Pulmonary edema (%)	18.7	6.7	0.022
Abdominal compartment syndrome (%)	9.3	2.7	0.089
Acute kidney injury (%)	4.0	2.7	0.650
Any complication (%)	25.3	10.7	0.021
ICU stay (days)	9.4 ± 3.2	7.8 ± 2.7	0.002
30-day mortality (%)	5.3	4.0	0.71
Serum sodium (mmol/L)	133.2 ± 3.6	135.4 ± 3.2	0.008
Hematocrit (%)	32.6 ± 4.5	35.1 ± 4.0	0.011
Independent predictors of fluid-related complications (adjusted OR, 95% CI)			
Parkland vs. Modified Brooke	3.35 (1.29-8.72)		0.013
%TBSA burned (per 1% increase)	1.07 (1.01-1.14)		0.027

Fluid volume and outcomes correlation

Pearson correlation analysis showed a positive correlation between total fluid volume and ICU length of stay ($r = 0.52$; $p < 0.001$). Total fluid volume also correlated moderately with any complication ($r = 0.43$; $p < 0.001$), as did ICU length of stay ($r = 0.39$; $p < 0.001$). Higher fluid administration was therefore associated with poorer clinical outcomes (Figure 3).

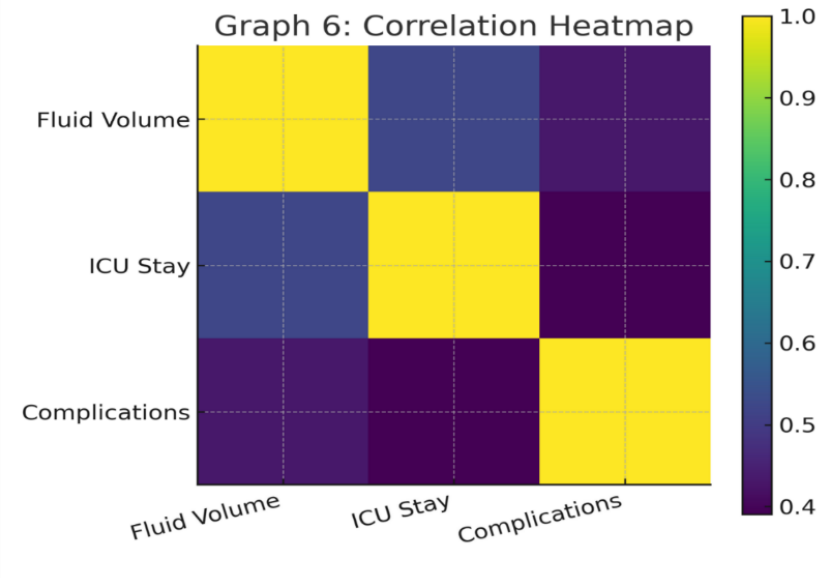


Figure 3. Correlation heatmap of fluid volume and clinical outcomes.

Subgroup analysis by burn severity

We divided patients into moderate burns (10-30% TBSA; n = 92) and severe burns (>30% TBSA; n = 58). Severe burns needed more fluid and had more complications and longer ICU stays (9.8 ± 3.6 vs. 7.1 ± 2.5 days for severe vs. moderate burns; $p < 0.001$). Urine output targets were met in both groups.

Qualitative notes pointed the same way. Edema was more common with Parkland, and Modified Brooke patients reached

milestones such as ambulation and enteral feeding sooner, which suggests a clinical benefit from conservative fluid resuscitation.

4. DISCUSSION

In this study, the Parkland formula led to substantially higher fluid administration (Table 3) with no physiological or clinical advantage over the more conservative Modified Brooke formula. This agrees with earlier work showing that Parkland predisposes children to fluid overload, the phenomenon known as "fluid creep" (9,10). Over-resuscitation contributes to pulmonary complications, longer ICU stays, and systemic edema, especially in children, who have a higher body surface area-to-mass ratio and limited cardiopulmonary reserve (6,11). Our results fit this pattern: pulmonary edema was more common and ICU stays were longer in the Parkland group (Table 3).

Even with lower fluid volumes (Table 3), the Modified Brooke group reached adequate resuscitation endpoints, with mean urine output consistently above 1 mL/kg/hr (Figure 2). Conservative dosing therefore did not compromise perfusion. The correlation analysis added that higher fluid volumes went along with longer ICU stays and more complications (Figure 3), which supports the view that individualized, physiology-guided resuscitation is safer and more effective than strict adherence to a formula (12,13). Because the Modified Brooke formula starts from a lower volume, it may offer a safer baseline for that individualized adjustment and limit the risk of fluid creep. Pulmonary edema and overall fluid-related complications were significantly less common in the Modified Brooke group, which translated into shorter ICU stays and potentially lower healthcare costs (Table 3). Mortality was similar in the two groups, so conservative resuscitation appears to reduce morbidity rather than change survival (9,14).

Our findings also point to the limits of applying adult-derived formulas to children. Although the Parkland formula was transformative in adult burn care, it does not account for pediatric differences such as smaller circulating volume, immature renal function, and a higher surface area-to-body mass ratio (8,15). That mismatch may explain the greater hemodilution (lower serum sodium and hematocrit) and the pulmonary edema we saw in the Parkland group. Pediatric-specific protocols like the Modified Brooke formula lower the risk of over-resuscitation while still maintaining perfusion, in keeping with current principles of individualized, physiology-guided burn care (5,16).

Strengths. The study focused exclusively on children, used a direct comparative design, and measured clinically meaningful outcomes.

5. LIMITATIONS

The study was retrospective and single-center, which may limit how far its practice patterns generalize. Unmeasured factors, such as small differences in burn depth or in the timing of fluid initiation, could have confounded the results, and no long-term functional outcome data were available. Patients were not randomized to a formula. Assignment followed a change in unit protocol over time, which could introduce selection bias despite well-matched baseline characteristics.

Conclusion

In pediatric burn patients, the Modified Brooke formula achieved resuscitation adequacy equivalent to Parkland while reducing fluid-related complications and ICU stay. Conservative, physiology-guided, pediatric-specific strategies are recommended over rigid adult-derived formulas. Prospective multicenter studies are needed to refine pediatric burn resuscitation further.

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