

## Evaluation of Fluid Resuscitation Protocols and their Outcomes in Major Burns

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### Abstract:

**Background:** Due to significant capillary leakage and fluid sequestration, major burn injuries, particularly those involving more than 20% of the total body surface area (TBSA), cause hypovolemic shock. The Parkland formula is essential for effective management, but "fluid creep"—the phenomena where actual quantities provided surpass projections—has gained international attention.

**Objective:** In an Indian tertiary care context, this study sought to measure the prevalence of fluid creep, evaluate clinical outcomes, and assess adherence to standard fluid resuscitation regimens in adult patients with severe thermal burns.

**Methods:** Over the course of 18 months, 120 patients with 20–60% TBSA burns between the ages of 18 and 60 participated in a prospective observational study. In order to maintain urine output between 0.5 and 1.0 mL/kg/hr, patients were resuscitated using Ringer's Lactate (RL) based on the Parkland formula 4mL (4 mL/kg/%TBSA), with hourly titration.

**Results:** Predicted and delivered fluid quantities differed significantly, according to the study. In the first 24 hours, the mean real fluid volume was  $4.8 \pm 1.2$  [(mL/kg) / % TBSA], which was substantially greater than the projected 4.0 mL/kg/% TBSA ( $p < 0.05$ ). 10% of individuals experienced acute kidney injury (AKI), and 6.7% experienced pulmonary edema.

**Conclusion:** Although the Parkland formula is a useful starting point, real fluid requirements in this group were regularly higher than anticipated. In order to reduce the dangers of both under-resuscitation and fluid overload, the study emphasizes the need for dynamic, customized resuscitation.

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### Introduction

**Historical Context and Current Standards:** Burn injuries are a catastrophic trauma that sets off a complicated series of physiological reactions. Preventing burn shock, a particular kind of hypovolemic shock caused by extravascular fluid changes, is the main objective of early therapy. Prior to the development of established fluid procedures, burn shock mortality was high. The Parkland formula (4 mL × body weight (kg) × % TBSA), developed by Baxter and Shires in 1968, changed the emphasis from plasma-based resuscitation to the aggressive use of crystalloids, particularly Ringer's Lactate (RL) [1]. The "gold standard" for determining fluid requirements within the first 24 hours after a burn is still this formula.

But there has been a paradigm shift in recent decades. The problem known as "fluid creep," which Pruitt developed to characterize the sneaky administration of fluid amounts significantly in excess of predicted requirements, is increasingly reported in literature [2]. This excess is not benign; it is linked to "resuscitation morbidity," which includes pulmonary edema, ocular compartment syndrome, and abdominal compartment syndrome (ACS) [3].

**Pathophysiology of Burn Shock:** The disturbance of Starling forces is the physiological underpinning for large fluid demand. Capillary endothelial integrity rapidly deteriorates after a significant thermal damage, both at the burn site and throughout the body in cases of burns greater than 30% TBSA

[4]. Protein-rich plasma leaks into the interstitial space as a result, causing severe edema and hypovolemia. Concurrently, a "cytokine storm," which exacerbates vascular permeability, is produced by the production of inflammatory mediators like histamine, prostaglandins, and cytokines [5]. Before the patient moves into the hypermetabolic "flow phase" of shock, volume expansion is required to sustain organ perfusion during this "ebb phase" of shock, which is marked by lower cardiac output and metabolic rate [6].

**Rationale for the Study:** Compared to Western models, managing burn injuries in India has particular difficulties. These include a population with different baseline nutritional variance, restricted pre-hospital treatment, and delayed presentation because of transport constraints [7]. Although the Parkland formula is frequently taught and used, there is a dearth of prospective data examining the frequency of fluid creep in the Indian context or confirming its precise applicability. Additionally, advanced hemodynamic monitoring is frequently not possible due to financial limitations, therefore clinicians must rely mostly on urine output as a guidance. In a specialist burn center in North India, this study attempts to assess the fluid resuscitation patterns, the degree of departure from the Parkland formula, and the relationship between fluid amounts and clinical outcomes.

### Methodology

**Study Design and Setting:** The Department of Plastic and Reconstructive Surgery and the specialized Burn Unit of a tertiary care teaching hospital in North India were the sites of this prospective observational study. Patients admitted between January 2024 and June 2025 were recruited for the 18-month research. Upon admission, all patients or their legal guardians gave their informed consent, and the protocol was approved by the hospital ethics committee.

**Study Population and Sample Size:** There were 120 adult patients in the research group. To guarantee a uniform study group, the selection procedure was strict. Patients between the ages of 18 and 60 who had thermal burns that covered 20% to 60% of their total body surface area (TBSA) were screened. We deliberately eliminated patients with electrical or chemical burns in order to reduce confounding factors related to resuscitation physiology. This is because these injuries frequently include deep tissue damage that is not represented in surface area calculations, necessitating drastically different fluid procedures. Additionally, because the inflammatory response in the lungs greatly modifies fluid requirements, individuals with concurrent inhalation injuries were eliminated. To make sure that outcomes like Acute Kidney Injury (AKI) might be linked to burn pathology and resuscitation rather

than chronic illness, we additionally excluded people with pre-existing cardiac or renal comorbidities.

**Resuscitation Protocol:** A senior resident used the Lund and Browder chart, which provides better accuracy than the "Rule of Nines" by taking anatomical variances into account, to determine the extent of the burn when the patient arrived at the emergency room. A Foley catheter was placed to track hourly urine output once peripheral venous access was established.

Ringer's lactate (RL) was the only crystalloid used in the resuscitation protocol. The Parkland formula was used to calculate the initial fluid infusion rate. The timing of administration was a crucial component of our approach; the computed volume was split so that the first 50% was scheduled for the first eight hours after the injury rather than after admission. This meant that the infusion rate had to be increased for patients who arrived late in order to make up for the lost time, which we predicted would lead to fluid creep.

A dynamic titration protocol was followed by the resident physicians and nursing staff. The computed rate was merely a starting point. Maintaining a urine production of 0.5 to 1.0 mL/kg/hr was the physiological goal. The fluid rate was raised by 20% if the hourly output fell below this threshold for two straight hours. On the other hand, the rate was lowered by 20% if the output surpassed the goal. After the first 24 hours of this hourly adjustment, maintenance fluids were started.

**Data Collection and Analysis:** A dedicated proforma was used to record comprehensive clinical data. The exact moment of the injury, the time of admission, and the "fluid debt" accrued prior to hospital arrival were all monitored. At precisely defined periods of 0–8 hours, 8–16 hours, and 16–24 hours, fluid volumes were measured. The development of AKI (as defined by KDIGO criteria), respiratory distress necessitating mechanical ventilation, and compartment syndrome symptoms were among the clinical outcomes of interest. SPSS version 26.0 was used to analyze the data. We compared anticipated and real fluid quantities using the paired t-test, with a p-value of less than 0.05 being considered statistically significant.

### Results

**Demographic and Clinical Characteristics:** The average age of the 120 patients in the research population was  $(34.5 \pm 12.2)$  years. Males predominated (65%), which is in line with the region's industrial and occupational burn patterns. The cohort with severe but manageable injuries had an average Total Body Surface Area (TBSA) burnt of  $(38.4\% \pm 10.5\%)$ . The delay in presentation the

average time from injury to admission was (4.2 ± 1.8) hours was a significant finding. This suggests that fast catch-up infusion rates were required because the majority of patients came almost

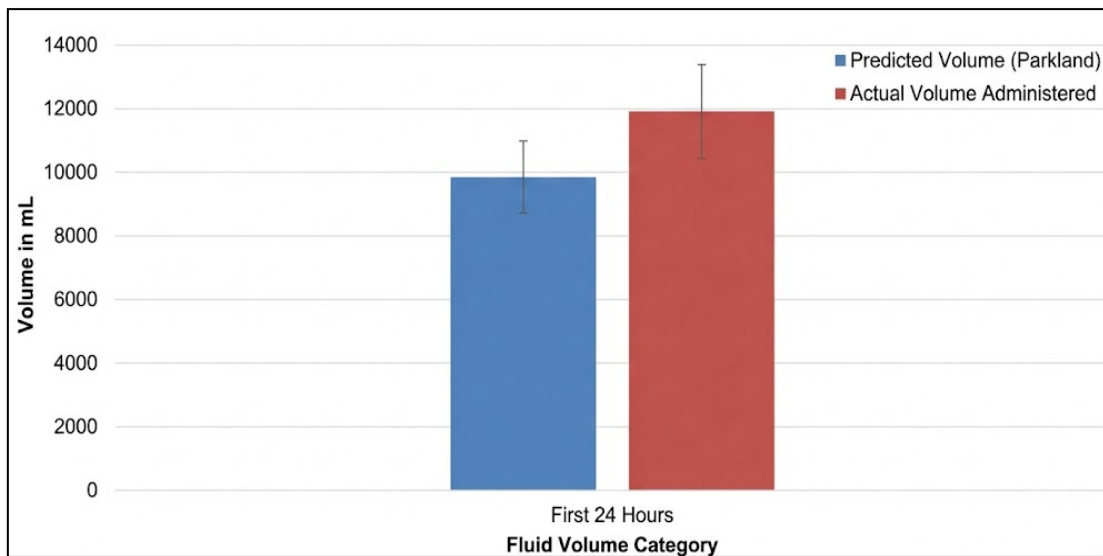
halfway through the first crucial 8-hour resuscitation window. Table 1 provides a full description of the baseline characteristics.

**Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (N=120)**

Characteristic	Value (Mean ± SD or n%)
Age (years)	34.5 ± 12.2
Gender (Male/Female)	78 (65%) / 42 (35%)
Weight (kg)	62.4 ± 8.5
Total Body Surface Area (TBSA) Burned (%)	38.4 ± 10.5
<b>Type of Burn</b>	
Flame	98 (81.6%)
Scald	22 (18.4%)
Time from Injury to Admission (hours)	4.2 ± 1.8
Inhalation Injury	0 (Excluded)

**Fluid Resuscitation Volumes:** The fluid volumes needed to maintain hemodynamic stability and the fluid volumes predicted by the Parkland formula differed statistically significantly, according to our data. The actual volume delivered averaged 11,920 ± 1,850 mL (p < 0.001), whereas the Parkland formula projected a mean 24-hour volume of (9,850 ± 1,200 mL). The patients received

about (4.8 mL/kg/%TBSA) when adjusted for body weight and burn size, which is 20% more than the recommended 4.0 mL. This surplus was most noticeable in the second and third 8-hour blocks, indicating that continued fluid loading long after the first bolus was needed to maintain urine production.



**Figure 1 Comparison between Parkland predicted fluid volumes and actual volumes**

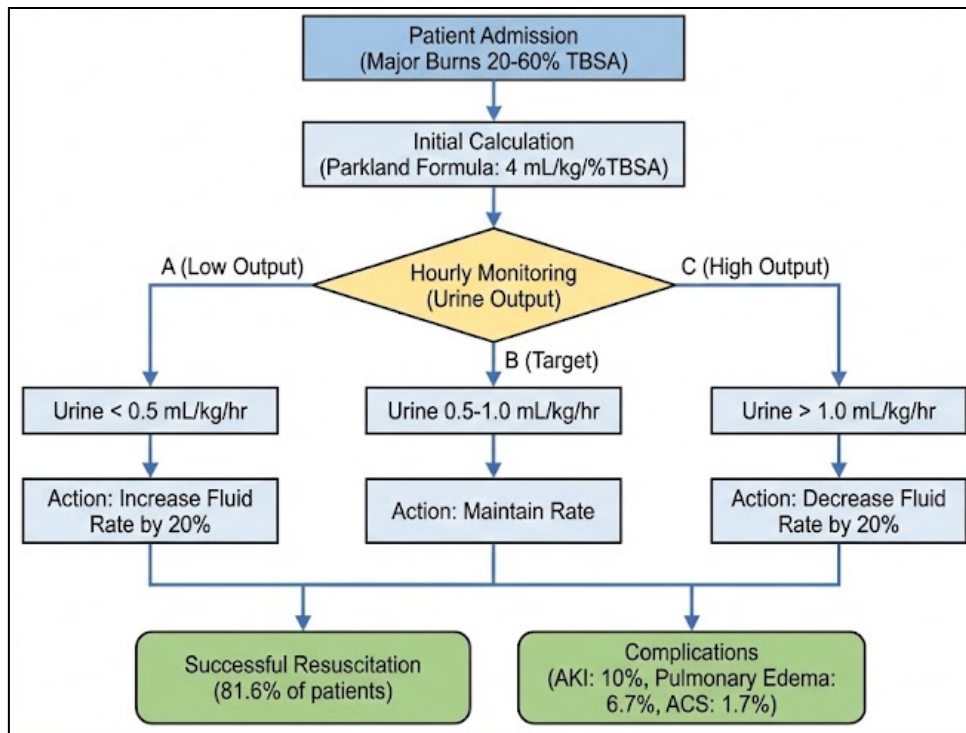
**Urine Output and Clinical Outcomes:** Most patients met the primary resuscitation goal of hourly urine output, with a mean output of (0.85 ± 0.3 mL/kg/hr). But the resuscitation process's unpredictability is hidden by this average. During the first eight hours, almost 15% of patients had temporary oliguria (< 0.5 mL/kg/hr), which prompted protocol-driven increases in fluid rates. On the other hand, some patients showed "fluid responsiveness," which resulted in supranormal urine production. However, fluid rates were not always reduced right away, which added to the total overload.

In terms of consequences, 12 individuals (10%) had Acute Kidney Injury (AKI). The subset of patients who arrived more than six hours after injury had all incidences of AKI, underscoring the negative effects of delayed resuscitation. 6.7% of the group experienced pulmonary problems, including pulmonary edema and pleural effusions visible on a chest X-ray or ultrasound. Two patients (1.7%) experienced Abdominal Compartment Syndrome (ACS), a feared consequence of significant volume expansion. Both patients had burns more than 50% TBSA and had received fluids greater than 6 mL/

kg/%TBSA. Table 2 provides a summary of these results.

**Table 2: Resuscitation Parameters and Clinical Outcomes**

Parameter	Result
Mean Urine Output (mL/kg/hr)	0.85 ± 0.3
Actual Fluid Coefficient (mL/kg/%TBSA)	4.8 ± 1.2
<b>Complications</b>	
Acute Kidney Injury (AKI)	12 (10.0%)
Respiratory Distress / Pulmonary Edema	8 (6.7%)
Abdominal Compartment Syndrome (ACS)	2 (1.7%)
Electrolyte Imbalance (Hyponatremia < 130 mEq/L)	18 (15.0%)
Mortality (within first 7 days)	5 (4.2%)



**Figure 2: Algorithmic approach to fluid resuscitation and observed clinical outcomes**

**Discussion**

**The Reality of Fluid Creep:** Our research demonstrates that "fluid creep" is a common occurrence in Indian tertiary care settings and is not just a Western phenomenon. Strict adherence to the conventional 4 mL guideline is severely contradicted by the fact that patients received an average of 4.8 mL/kg/%TBSA. This is consistent with worldwide patterns shown by Saffle et al. [8], who observed that contemporary resuscitation volumes frequently surpass historical projections. This creep is caused by a number of variables. In younger patients, who made up the majority of our study, the hypermetabolic response, which is fueled by increased cortisol and catecholamines, is significant [9]. Furthermore, according to McClellan et al. [10], the use of high-dose opioids for analgesia in our unit may have resulted in systemic

vasodilation, requiring greater fluid quantities to maintain mean arterial pressure.

**Impact of Delayed Admission:** One important factor influencing the results of our investigation was the "time to needle." The 4.2-hour average admission delay results in a substantial fluid debt. 50% of the 24-hour fluid volume must be given within the first eight hours following the accident, according to the Parkland formula. The full 8-hour volume must be compressed into the final 4 hours for a patient who arrives at hour 4. The cardiopulmonary system may be overloaded as a result of the high, quick infusion rates required. We saw this "catch-up" phenomena in 6.7% of our patients, which is a recognized risk factor for pulmonary edema. This result is consistent with results from Greenhalgh et al. [11], who highlighted the linear correlation between higher fluid

requirements and problems with delayed resuscitation.

**AKI and Mortality Patterns:** Our cohort's 10% AKI incidence is in line with previous research from poor countries, including Legrand et al.'s study [12]. Interestingly, those who presented late were the only ones who had AKI. This implies that even with intensive subsequent fluid loading, the first period of untreated hypovolemia causes renal tubular ischemia that may not be completely reversible. This highlights the potential advantages of pre-hospital oral rehydration treatments (ORT) in areas with limited resources where intravenous access is delayed during transport [13].

**The Role of Colloids:** For the first 24 hours, our treatment only included crystalloids. However, the large amounts needed imply that fast extravasation may render crystalloid-only resuscitation ineffective. The American Burn Association's guidelines and other recent consensus indicate that adding colloids, such as albumin, can reduce fluid creep [14]. It has been demonstrated that the "Rescue Colloid" approach introducing albumin when fluid requirements surpass 6 mL/kg/%TBSA maintains intravascular volume more successfully than crystalloids by themselves [15]. The larger total volumes observed were probably caused by the lack of colloids in our first phase, mainly because of the financial limitations common to Indian public sector hospitals.

**Limitations:** The intrinsic limitations of this study have an impact on its generalizability. The demographic profile mostly young males with industrial burns may not be representative of larger burn populations because this was a single-center study conducted in North India. Hourly urine output is an inadequate physiological surrogate for perfusion. Even in euvolemic conditions, oliguria can be caused by the stress-induced production of aldosterone and antidiuretic hormone (ADH). It was difficult to differentiate between real hypovolemia and fluid responsiveness without sophisticated hemodynamic monitoring instruments like transpulmonary thermodilution or Central Venous Pressure (CVP), which may have contributed to the observed "fluid creep."

Furthermore, the stated "time of injury," which was frequently approximated by onlookers, was used to calculate resuscitation windows. The crucial first 8-hour infusion rates can be distorted by errors in this area. Additionally, a "best-case" scenario is presented by the rigorous exclusion of patients with serious comorbidities and inhalation injuries, which probably underestimates the complication rates observed in ordinary, unselected clinical practice. Lastly, "hidden fluids" that are used to dilute medications and add to the cumulative fluid burden were not taken into consideration in the study.

## Conclusion

With real fluid requirements averaging 4.8 mL/kg/%TBSA much higher than the Parkland prediction this review verifies that "fluid creep" is active in the Indian tertiary care context. Strict adherence without dynamic titration runs the risk of under-resuscitation, even though the formula is still an essential starting point. According to the study, a significant vulnerability is delayed hospital admission. The consequent fluid debt requires quick "catch-up" infusions, which are directly linked to renal stress and pulmonary problems.

The strategy of hourly titration based on urine output was mainly successful in reducing death (4.2%) in spite of these difficulties. However, the frequency of iatrogenic consequences indicates that protocol modification is necessary. Pre-hospital fluid commencement should be given priority in order to minimize the initial deficit, and future treatment in resource-constrained settings should take into account the earlier integration of "rescue colloids" to decrease volume overload. In order to maximize survival while reducing resuscitation morbidity, the Parkland formula must ultimately be seen as a guide rather than a strict regulation.

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