Burn Resuscitation Index: A Simple Method For Calculating Fluid Resuscitation in the Burn Patient

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The Parkland formula is the standard for calculating the initial intravenous fluid rate for resuscutation after thermal injury. However, it is cumbersome when used by those with modest burn training. We propose an easier method to calculate fluid requirements that can be initiated by first-line providers. Burn size is estimated by using the Burn Size Score (BSS), which is then crossreferenced with the patient's weight on a preprinted Burn Resuscitation Index (BRI), based on the Parkland formula, to determine initial hourly fluid rate. Seventy-two residents and faculty in the Departments of Surgery and Emergency Medicine were surveyed. Participants were shown a diagram of a burn patient and asked to calculate the initial fluid rate using the Parkland formula from memory. The study was repeated with a different diagram, and the participants were asked to calculate the initial fluid rate using the BRI (a preprinted card with written instruction pertaining to its use). Statistical analysis was performed with the McNemar test. Using the Parkland formula, 33% of surgeons and 17% of emergency medicine physicians were able to calculate the initial fluid rate. Using the BRI, 56% of surgeons and 77% of emergency medicine physicians were able to calculate the fluid rate correctly ($P < .01$ and $P < .001$, respectively). Fifty-four percent of physicians surveyed believed that the BRI was easier to use. The accuracy of determining initial fluid rate was low using the Parkland formula and "rule of nines" from memory. Accuracy increased when the BRI was used. The BRI serves as a visual aid and provides some instruction, allowing the user to calculate fluid resuscitation with greater accuracy than with rote memorization of a formula. The BRI might be a useful tool for providers with minimal burn training. However, further investigation is warranted. (J Burn Care Res 2010;31:616–623)

Major burn injury causes a systemic response that initiates a fluid flux from the intravascular space into the interstitial space. A state of shock proportionate to the size of the body surface burn ensues.[1] Burn patients develop this shock more than 8 hours after the initial thermal injury. This differs from hemorrhagic shock seen in trauma patients, which, in contrast, develops rapidly and requires prompt fluid resuscitation within the first "golden" hour. The goal of burn resuscitation is to complete treatment of this shock state within the first 24 hours. Isotonic saline solutions have been shown to be an effective fluid replacement that maintains intravascular volume and tissue perfusion.[2] The Parkland formula, published by Baxter and Shires[3] in 1968, has since become the standard of care for resuscitating burn patients with isotonic saline solutions. The formula provides the burn patient with a volume of fluid of 4 mL/kg/%TBSA burned during the first 24 hours after the injury. The fluid needs follow first-order kinetics and can be approximated by giving half of the calculated volume during the first 8 hours and the second half given during the next 16 hours. An accurate estimate of the burn size is essential to calculate the volume needed for resuscitation. This estimation is typically performed using a commercially available Lund-Browder chart or the "rule of nines," which divides the body into eleven 9% regions.[4] However, physicians may overestimate burn size by 50 to 100% when using the rule of nines.[5] This study also demonstrated that 42% of transfers to a major burn center had pretransfer burn size calculated correctly by referring physicians. Evidence also suggests that the Lund-Browder chart, when available, is not used correctly in

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half the cases.[6] In rural areas, referring physicians often overestimate and overresuscitate small burns, whereas they underestimate and underresuscitate large burns.[7]

Approximately 700,000 people seek medical care in an emergency department for burn injuries annually. Approximately 45,000 of these patients necessitate admission to the hospital each year with half requiring admission to a specialized burn center.[8] Referring physicians often have minimal experience assessing and initiating resuscitation of burn victims. Compounded with inexperience is the inherent difficulty in estimating burn size and using the cumbersome Parkland formula that requires two multiplication and two division functions. A simpler and faster method to accurately calculate initial fluid resuscitation in the burn patient is necessary. Such a method would beneficial to physician with minimal experience in burn resuscitation.

The objective of this investigation was to develop an easier method to estimate burn size and the initial resuscitation fluid rate based on the Parkland formula. At our institution, we developed the Burn Resuscitation Index (BRI) (Table 1), a two-by-two table, which estimates the initial fluid rate by cross-referencing the patient's weight with the Burn Size Score (BSS) (Figure 1). The BSS is a simpler method of estimating burn size. We hypothesized that this method, used by care givers with limited experience, would be more accurate than long hand calculation of the resuscitation volume using the Parkland formula and the rule of nines. The BRI was tested among surgery and emergency medicine physicians to see whether it was easier to use and more accurate than the Parkland formula.

METHODS

This study was conducted at an academic institution that contains a level one trauma center and an American Burn Association verified burn center. Participants in the study consisted of residents and faculty in the Department of Emergency Medicine and the Department of Surgery. The accuracy standard rule of nines/Parkland formula method of calculation was compared with the BRI when physicians were asked to calculate fluid requirements using both methods.

Development of BSS

The BSS is based on the rule of nines where each nine is now replaced with a one (Figure 1). The head and arms are each assigned 1 point, whereas the legs, anterior torso, and posterior torso are assigned 2 points for a total of 11 points for the entire body. Essentially, each estimate of 9% TBSA is replaced with a value of 1. If an area is burned more than 50%, it is assigned the full point value. An area burned less than 50% is assigned half the point value. All points are added and then rounded up to determine the BSS. Once the BSS is obtained, the initial fluid resuscitation rate is found quickly by using the BRI.

Development of the BRI

The BRI is based on the Parkland formula and has the patient's weight on the horizontal axis and the BSS on the vertical axis (Table 1). The number at the intersection of the patient's weight and BSS is the initial hourly infusion rate of Lactated Ringer's. The initial fluid rate is obtained by crossreferencing the BSS with the patient's weight on a printed BRI card instead of using

Table 1. The Burn Resuscitation Index

	Weight (kg)											
Total BSS Score	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
1	90	113	135	158	180	203	225	248	270	293	315	338
2	180	225	270	315	360	405	450	495	540	585	630	675
3	270	338	405	473	540	608	675	743	810	878	945	1013
4	360	450	540	630	720	810	900	990	1080	1170	1260	1350
5	450	563	675	788	900	1013	1125	1238	1350	1463	1575	1688
6	540	675	810	945	1080	1215	1350	1485	1620	1755	1890	2025
7	630	768	945	1103	1260	1418	1575	1733	1890	2048	2205	2363
8	720	900	1080	1260	1140	1620	1800	1980	2160	2340	2520	2700
9	810	1013	1215	1418	1620	1823	2025	2228	2430	2633	2835	3038
10	900	1125	1350	1575	1800	2025	2250	2475	2700	2925	3150	3375
11	990	1238	1485	1733	1980	2228	2475	2723	2970	3218	3465	3713

Once the Burn Size Score (BSS) is added up, it is crossreferenced on the table with the patient's weight. The intersecting box between the BSS and weight is the initial fluid rate of Lactated Ringer's in mL/hr. Adult Burn Resuscitation Index: initial fluid rate (mL/hr).

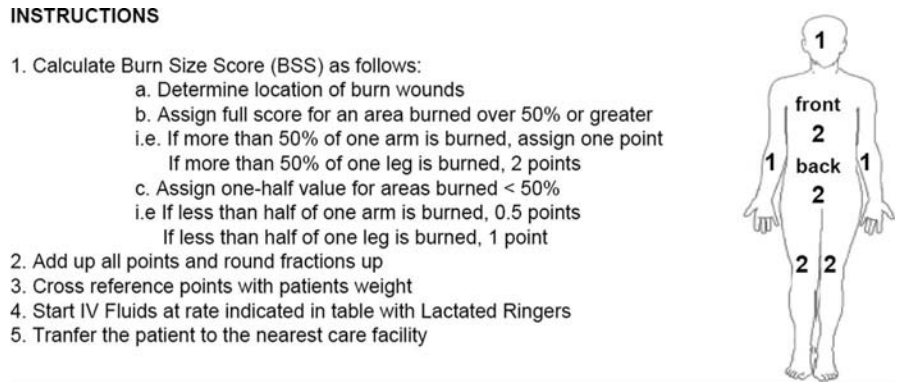

Figure 1. Burn Size Score. The Burn Size Score is calculated using this chart. Each 9% TBSA used in the traditional Lund-Browder Chart is substituted with a point value of 1.

the Parkland formula. The values for the initial fluid rate in each cell were calculated by multiplying the column weight by the row BSS × 9 and then multiplying the product by 0.25.

$$\text{tPFV} = 4 \times \text{Wt} \times \%\text{TBSA}$$

$$\text{ihPF} = 1/2 \times 1/8 \times \text{tPFV}$$

$$\text{ihPF} = 1/4 \times \text{Wt} \times \%\text{TBSA}$$

$$\text{cBRI} = 1/4 \times \text{eWt} \times \text{cBBS} \times 9$$

Wt = patient's actual weight
cWt = estimate of patients weight from column on BRI
%TBSA = percent TBSA burned
BSS = BSS estimated by "rule of one's"
cBSS ~ calculated BSS = %TBSA/9
tPFV = total Parkland formula volume (mL)
ihPF = initial hourly Parkland formula rate (mL/hr)
cBRI = initial hourly Parkland formula rate in BRI table cells

Testing the BRI

Forty-eight surgeons (38 residents and 10 faculty members) and 28 emergency department physicians (24 residents and 4 faculty members) were asked to evaluate a hypothetical burn. This group was selected because the authors believed that it adequately represented the population of physicians who typically refer patients to our burn center. None of the physicians tested in this study were fellowship-trained burn surgeons. The participants were given a pictorial diagram of a burn patient with the patient's weight. For the first part of the investigation, the participants were asked to calculate initial intravenous (IV) fluid therapy rate in milliliters per hour using the Parkland formula with the assumption that there was no delay between injury and start of IV fluids. The actual Parkland formula was not provided because it was assumed that this was basic knowledge of this group of physicians. After the first questionnaire was completed, the study participants were given a new pictorial diagram of a burn patient and asked to compute the initial hourly fluid rate applying the BRI with the assumption that there was also no delay between time of injury and start of IV fluids.

Methods of Measurement

Examinations were collected and graded anonymously. The results were stratified according to the level of training and specialty. Answers were deemed correct if they were within 10% of the correct fluid resuscitation rate in milliliters per hour.

Primary Data Analysis

Statistical analysis was performed with the McNemar test. Statistical significance was assumed with a P value $< .05$.

RESULTS

Seventy-four examinations were collected, graded, and analyzed. However, two emergency medicine physicians did not complete both portions of the examination. Using the Parkland formula, 35% of surgeons were able to accurately calculate the correct initial IV fluid resuscitation rate. Using the BRI, this number increased to 56% ($P < .01$). When stratified by level of training, all residents, except for third year, had improved accuracy with the BRI (Figure 2). An additional six surgical faculty members were surveyed; four were correct with the Parkland formula, and five were correct with the BRI. Of the emergency medicine physicians, 17% calculated the initial IV fluid rate correctly with the Parkland formula. This percentage improved to 79% when using the BRI ($P < .001$). All levels of emergency medicine resi-

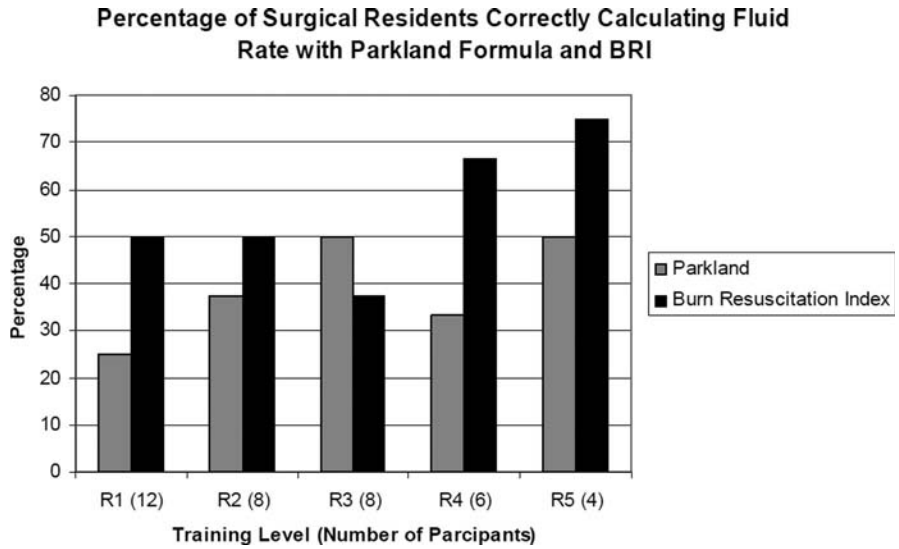

Figure 2. Comparison of Parkland formula and Burn Resuscitation Index to calculate initial fluid resuscitation in surgical resident group, stratified for level of training. Percentage of surgical trainees who correctly calculated initial fluid requirements with the Parkland formula are depicted in gray and those correct with the Burn Resuscitation Index (BRI) are depicted in black. Trainees are stratified by postgraduate year of training. Accuracy of all resident levels except postgraduate year 3 increased with the BRI.

dents were able to calculate initial fluid rates better using the BRI. Percentage of correct answers stratified by level of emergency medicine training is shown in Figure 3. An additional four emergency department (ED) faculty members were surveyed; two were correct with the Parkland formula, and three were correct with the BRI. The majority of physicians in both groups believed that the BRI was easier to use than the Parkland formula. Of note, everyone who was able to use the Parkland formula correctly was also able to use the BRI correctly as well. Fifty-four percent of surgeons believed the BRI was easier, whereas 61% of emergency department physicians believed it was easier.

DISCUSSION

Resuscitation of thermally injured patients begins at the scene of injury and continues *en route* to and at

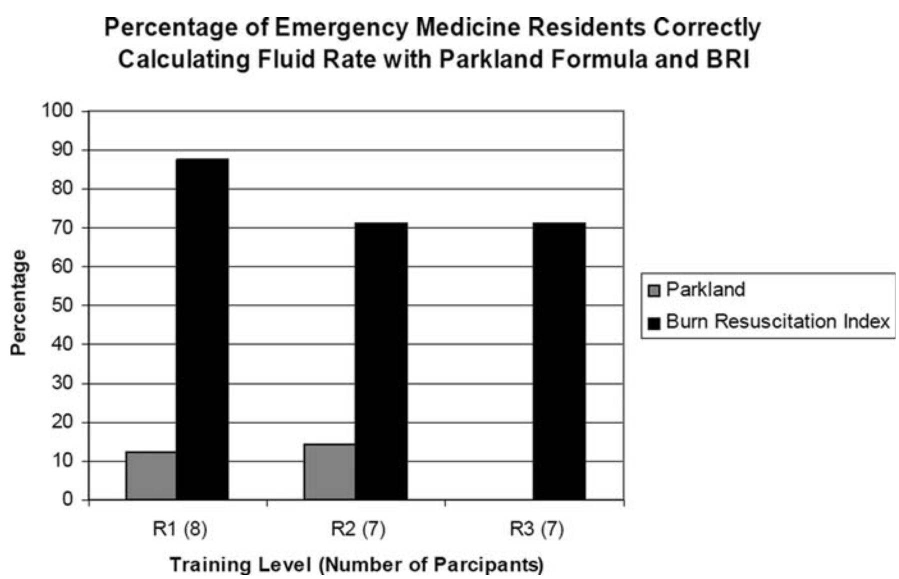

Figure 3. Percentage of emergency medicine trainees who correctly calculated initial fluid requirements with the Parkland formula are depicted in gray and those correct with the Burn Resuscitation Index (BRI) are depicted in black. Trainees are stratified by postgraduate year of training. Accuracy increased using the BRI.

the emergency room. Care is often delivered by those with modest training in burn resuscitation, and errors are frequent. Hence, a simpler method of calculating burn resuscitation fluid rates is needed. Mass casualty situations also warrant the need for a quick and accurate method to calculate initial burn resuscitation fluid rate. One such example is the Rhode Island nightclub fire, in which 40 critically injured burn patients were thrust on a small 350-bed community hospital in 1 hour.

Other authors have proposed techniques to aid health care workers in calculating burn fluid rates. Jenkinson[9] proposed the use of a special slide rule that would calculate fluid resuscitation based on the Muir and Barclay formula when the patient's weight and burn size were known. In addition to their protocol for war burns, Milner *et al*[10] proposed a simplified guide for burn resuscitation, which they called "The Burns Calculator" in 1993. Their burn resuscitation protocol consisted of a circular card that contained tables for burns from 10 to 100%. The user crossreferences the patient's weight and time since burn injury for a given burn size to yield the fluid deficit. In addition to fluid deficit, the hourly maintenance volume can also be determined from the burns calculator card. The intent of this simplified method was to aid the primary caregivers in calculating the fluid deficit that would need to be replaced in the first 8 hours after initial injury until expert burn care could be obtained. The authors believed that the burns calculator was straightforward enough that paramedics and nurses could use it in the field. However, the burns calculator requires the user to estimate the burn size with the Lund-Browder chart or using the rule of nines, which as previously mentioned is frequently inaccurately applied in referring emergency rooms. Recently, several authors have attempted to develop computer simulation models to calculate fluid resuscitation based on multiple physiologic parameters.[11–13] Although some of these simulations have been validated on patients, their complexity and learning curve limit their widespread use in clinical practice, particularly with respect to community emergency physicians, surgeons, and generalists.

Similar to Milner et al, we have developed a simple method for calculating initial fluid resuscitation in burn patients. The main advantage to our method is that it further simplifies the burn size estimate calculation by eliminating the rule of nines. Additionally, our data show that the BSS and BRI is more accurate method of estimating hourly fluid requirements than the classically taught rule of nines estimate of burn size combined with the Parkland formula. Both surgery and emergency medicine physicians were able to calculate the initial fluid resuscitation more readily and accurately using the BRI than the Parkland formula. However, there are some limitations to the conclusions that can be drawn about the efficacy of the BRI from this data set. The subjects were asked to use the Parkland formula from memory, but they had a card with instructions and a visual aid to help them with the BRI. A card with a standard Lund-Browder diagram and instructions about use of the Parkland formula might improve accuracy as well. However, physicians were able to use the BRI successfully with little instruction. With training, paramedics and emergency medicine technicians should be able to master the use of the BRI. This method could potentially be valuable in mass casualty situations where initial fluid resuscitation could be calculated by first responders at the scene of injury and started without delay. However, testing the hypothesis that the BRI is easier to use than the Parkland formula in a mass casualty or disaster situation would be difficult. Although the Parkland formula can be calculated without any instruments in the field, our study shows that physicians have difficulty calculating the initial fluid rate even in the controlled setting of a classroom. First-line response personnel in civilian and military sectors often carry laminated cards with ACLS algorithms and treatment protocols on their person. Therefore, the BRI could be carried and be easily accessible to these personnel at critical times to calculate the initial fluid resuscitation rate. As small cards have the tendency to disappear from white-coat pockets, we have also provided posters with the BRI to the emergency departments in our referral area. In addition, the information is also available on the burn center's website.

One limitation to the use of the BRI is that the clinician must possess the BRI card to apply it to the care of a burned patient. In today's age, most cellular phones allow internet access, so a card might not even be necessary. If the initial provider does not have access to the BRI (no card, poster, or internet available), a simple alternative is to multiply the BSS by the patient's weight in pounds for an estimation of initial fluid requirements. As previously stated:

Total Parkland formula volume (tPFV)

$$\begin{aligned} \text{tPFV} &= 4 \times \text{Wt} \times \%\text{TBSA} \\ &= 4 \times \text{Wt} \times (\text{BSS} \times 9) \end{aligned}$$

and

Initial hourly Parkland formula volume (ihPF)

$$\begin{aligned} \text{ihPF} &= 1/2 \times 1/8 \times \text{tPFV} \\ &= 1/2 \times 1/8 \times (4 \times \text{Wt} \times (\text{BSS} \times 9)) \end{aligned}$$

$$= 2 \times 1/8 \times \mathrm{Wt} \times (\mathrm{BSS} \times 9)$$

$$= 1/4 \times \mathrm{Wt} \times (\mathrm{BSS} \times 9)$$

$$= 2.25 \times \mathrm{Wt} \times (\mathrm{BSS})$$

Using weight in pounds (Wtp) for weight in kilograms (Wt), the initial hourly Parkland formula (ihPF) rate calculation is even easier.

$$\mathrm{Wt_p} = 2.2\ \mathrm{Wt}$$

$$\mathrm{ihPF} = 2.25 \times \mathrm{Wt_p}/2.2 \times \mathrm{BSS}$$

$$= 1.02 \times \mathrm{Wt_p} \times \mathrm{BSS}$$

$$\sim \mathrm{Wt_p} \times \mathrm{BSS}$$

Therefore, an alternative to the BRI is to multiply the weight in lbs by the BSS if the card is not present. This method underestimates the BRI by only 2%. This simplified formula has not yet been tested in the field or in a classroom setting.

The Parkland formula may in some situations underestimate the fluid volume requirement (eg, in adults with large burns or smoke inhalation).[14] As the BRI is based on the Parkland formula, it poses similar risks of underestimation. Serendipitously, an overestimation of fluid volume is built into the BRI, as the BSS is rounded up to a whole number, which raises the hourly infusion rate slightly. One caveat is that this poses a risk of overresuscitation. However, the BRI has been successfully used by referring Emergency Medicine providers during the past several years in our service area without major problems with under or overresuscitation. Fortunately, patients usually arrive at our burn center from the outside hospital (or the field) within several hours of injury. Before use of the BRI, patients transferred in from outside centers were at times woefully underresuscitated. Since instituting use of the BRI approximately 4 years ago, neither underresuscitation or overresuscitation has been problematic. One must keep in mind that overresuscitation is still harmful; so it is important to pay close attention to the patient's urine output when using the BRI and titrate fluids as quickly as tolerated, just as with the Parkland formula. Therefore, it is recommended that the BRI be used only as a guide for an initial starting rate that can later be titrated to maintain urine output and other resuscitation endpoints. Once an accurate measurement of the patient's burn size can be calculated (and a precise weight can be obtained) at the burn center, the actual Parkland fluid rate can be used. The BRI is intended to be used by first responders to initiate appropriate initial fluids and not for providers performing ongoing resuscitation. If a long delay in transfer to the burn center is imminent, then the fluid rate should be modified as needed for each individual patient to avoid overresuscitation. As an additional safeguard against overresuscitation, referring providers are instructed to "not count" areas that have a burn less than the size of the patient's hand (1% TBSA) on areas with a BSS of 1 (eg, arm) and less than the size of two hands on areas with a BSS of 2 (eg, leg). This prevents a small, insignificant burn being counted as a half point, thus lowering the risk of overresuscitation.

The BRI is also not designed to calculate fluid resuscitation for children less than 30 kg. Therefore, a separate pediatric BRI card has been constructed for resuscitation of children less than 30 kg (Table 2). In calculating the BSS for a child less than 30 kg, the head, which is disproportionately large, is assigned a

Table 2. The Pediatric Burn Resuscitation Index

	Weight (kg)											
Total BSS Score	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**
1	39	58	73	86	99	111	120	129	138	148	157	166
2	52	78	100	120	139	158	174	190	206	222	238	254
3	66	98	127	153	180	205	228	251	273	296	319	342
4	79	119	154	187	220	252	282	311	341	370	400	429
5	92	139	181	221	261	300	336	372	408	445	481	517
6	106	159	208	255	301	347	390	433	476	519	562	605
7	120	179	235	288	342	394	444	494	543	593	643	693
8	133	200	262	292	382	441	498	554	611	667	724	780
9	147	220	289	356	423	489	552	615	678	742	805	868
10	160	240	316	390	463	536	606	676	746	816	886	956
11	174	260	343	423	504	583	660	737	813	890	967	1044

The Burn Size Score (BSS) is added just as in an adult except children <30 kg have 2 points assigned to the head (Figure 4). The intersecting box between the BSS and weight is the initial fluid rate of Lactated Ringer's in mL/hr. Pediatric Burn Resuscitation Index: initial fluid rate (mL/hr).

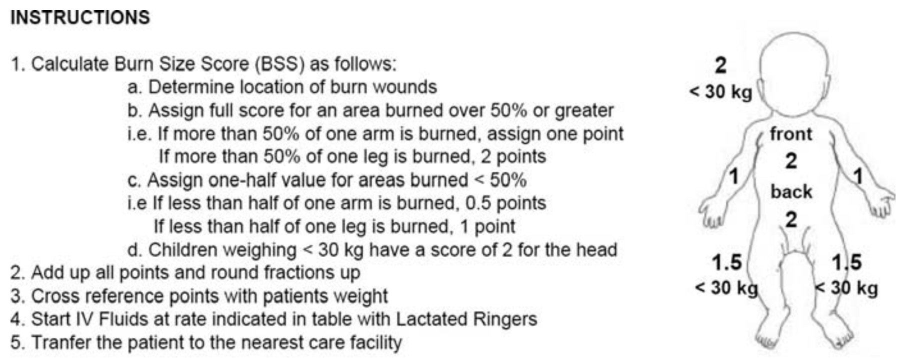

Figure 4. Pediatric Burn Size Score (BSS) similar to the adult BSS (Figure 1); however, children <30 kg have 2 points assigned to the head and 1.5 points assigned to each leg.

point value of two instead of one, and each lower extremity is assigned a value of one instead of two (Figure 4). Maintenance fluid has been included in the rate displayed in each cell in the pediatric table. The maintenance fluid estimate for pediatric patients less than 30 kg is approximated by the Holliday-Segar method,[15] also known as the "100/50/20 rule" (100 mL/kg/d of fluid for the first 10 kg of body weight, 1000 mL + 50 mL/kg/d for every kilogram if the weight is 11–20 kg, and 1500 mL + 20 mL/kg/d for every kilogram if the weight is greater than 20 kg). This maintenance fluid rate is divided by 24 and then added to the initial hourly Parkland fluid rate. The use of 5% dextrose Lactated Ringer's was not addressed in the pediatric BRI for simplicity alone. However, the hourly fluid rate in each cell could be given as half Lactated Ringer's and half 5% dextrose Lactated Ringer's.

The authors believe that first responders and providers should not become completely dependent on a card, because they may find themselves in a situation where they do not have access to it, and would need to use the Parkland formula from memory. This new method, if used correctly, provides an accurate estimate of initial hourly Parkland fluid rates for the resuscitation of burn shock without multiple calculations from memory and complex burn size approximations.

The Parkland formula, and the estimation of burn size using either the rule of nines or Lund-Browder charts, are classically taught to calculate initial fluid resuscitation in the burn patient. It is generally accepted that physicians can apply the Parkland formula from memory in an accurate manner. This study shows that physicians were surprisingly inaccurate when using the Parkland formula from memory. The authors believe that this is one of the most important although distressing points that this study demonstrates. Incorrect application of the Parkland formula can result in either under or overresuscitation, both of which can be detrimental. Although physicians in this study had some difficulty applying the Parkland formula from memory, the accuracy of determining initial fluid rate greatly increased with the BRI. The authors believe this is due to deficits in education and training rather than an inherent defect in the Parkland formula. The Parkland formula is a tried and true method of resuscitation. However, this study shows that physicians were not able to apply it from memory with accuracy. Despite the aid of the simpler BRI, approximately ⅓ of the test group failed to calculate fluid requirements correctly, the incorrect group even included attendings. The BRI is not a magic bullet, but it did improve accuracy. The increased accuracy may possibly be attributed to the simple fact that the trainees had an aid, and other aids that contain instruction on calculating fluid requirements might be just as effective as the BRI. Physicians should continue to receive education regarding the initial care of the burn patient through Advanced Burn Life Support, Advanced Trauma Life Support, residency education, and surgical textbooks. The emergency medicine residents in this study performed more poorly than the surgery residents; so a particular need for additional training in burn care exists for the emergency medicine residents.

In summary, physicians in this study were not able to use the Parkland formula from memory with consistency. Eliminating calculations and providing a visual aid in the form of a BRI improved their ability to calculate initial fluid requirements for the burn patient. However, the BRI has limitations, a risk of overresuscitation, and is by no means a universal substitute for the Parkland formula. The BRI is simply another method of fluid calculation that might be advantageous in certain situations. For example, the BRI might be a useful supplement for medical providers that have minimal education pertaining to burn care. Furthermore, the BRI might potentially be an accurate way for first responders to determine fluid resuscitation rapidly in a mass casualty situation. Although the BRI has had anecdotal success in outlying emergency rooms, further large trials are warranted. When using the BRI, it is crucial to pay close attention to resuscitation endpoints. The BRI is imperfect as it slightly sacrifices accuracy for simplicity. However, it is impossible to create a brainless method of resuscitating burn victims with current technology. In the end, regardless of the method or tool used to calculate fluid resuscitation, there is no substitute to experience and a true understanding of the principles taught by the rule of nines and Parkland formula.

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