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Fluid requirements of patients with burns and inhalation injuries in an intensive care unit

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Abstract. We have studied 9 patients with burns (20%–75%) who had inhalation injuries and compared their actual fluid requirements with their requirements calculated from the Muir and Barclay formula. All patients were resuscitated with plasma protein fraction at a rate sufficient to keep their physiological variables within the following range: heart rate <120/min, central venous pressure 8–12 cm H_2O, urine output >30–50 ml/h, systolic blood pressure >90 mm Hg and diastolic blood pressure >60 mm Hg. The amount of plasma protein fraction needed was 4.38 ± 1.26 ml/kg/% burn in the first 24 h and 2.15 ± 0.97 ml/kg/% burn in the second 24 h. This is an increase of 75% and 110% respectively above values predicted from the formula. We suggest that the observed difference is due to a combination of the presence of an inhalation injury which increases fluid requirements by approximately 30% in the first 24 h and the use of plasma protein fraction rather than the dried plasma used in the original Muir and Barclay formula.

Key words: Burns – Inhalation injury – Resuscitation – Fluid Replacement

The mortality and morbidity associated with severe cutaneous burns has been significantly reduced with improvements in fluid resuscitation, nutrition and antibiotic therapy [1]. The mortality rate in patients with inhalation injuries and burns covering over 30% of their total body surface area shows little improvement and remains at approximately 70% [2, 3]. Many formulae have been devised to aid calculation of the fluid requirements of burned patients [4–7]. In Great Britain the most commonly used formula is that of Muir and Barclay [8, 9]. These formulae do not specifically allow for a coexistent inhalation injury. It is thought that the presence of an inhalation injury increases the fluid requirements by as much as 37%–44% [10, 11].

This study describes patients with inhalation injuries and cutaneous burns, admitted to the intensive care unit (ICU) at University College Hospital (UCH) between January 1986 and January 1988. It compares their actual fluid requirements with predicted requirements calculated from the Muir and Barclay (M&B) formula.

Methods

Nine patients with burns were studied. Their details are given in Table 1. Inhalation injury was considered to have occured if the following criteria were fulfilled:

1) History of a burn in an enclosed space
2) Wheezing or hoarseness of voice
3) Carbonaceous sputum production
4) Facial burns with oedema of the lips and palate
5) Stridor

Inhalation injury was confirmed on laryngoscopy or bronchoscopy and by the enventual need for intubation and intermittent positive pressure ventilation (IPPV). On admission an estimate was made of each patient's total percentage cutaneous burned area and body weight. The volume of plasma to be infused was calculated by the M&B formula:

$$\frac{\text{total area of burn (\%)} \times \text{weight (kg)}}{2}$$

The plasma was administered over successive periods of 4, 4, 4, 6, 6 and 12 h [8, 9]. Metabolic fluid requirements were met with approximately 2 l of 5% dextrose in water over 24 h. Some patients did not receive the desired amount of crystalloid because of protocol trans-

Table 1. Patient details

Patients	1	2	3	4	5	6	7	8	9
Age	23	30	21	50	20	55	35	45	32
Sex	F	F	F	M	F	M	M	M	F
Burn size (%)	50	40	42	75	70	20	50	20	20
No. of days on ventilator	17	17	24	9	6	7	17	7	4
PaO_2/FiO_2 (worst)	22.5	14.2	14	8.3	22	31	21.5	12.8	24
Predicted mortality %	78	50	58	100	100	11	78	11	11
Death				+		+		+	

(PaO_2/FiO_2 is the arterial oxygen (tension) divided by the inspired oxygen concentration. Predicted mortality calculated using method of Venus et al. [14]

Table 2. Plasma requirements of patients in the first 24 hours

Patient	1	2	3	4	5	6	7	8	9
Calculated requirements (ml)	7500	7000	6200	13125	10500	4500	8750	3500	2500
Actual requirements (ml)	12360	20600	13711	17450	17500	7760	12199	4800	400
Difference (ml)	4860	13600	7511	4325	6500	32600	3449	1300	1500
Difference %	64	194	121	32.9	61.9	72	39.4	37	60
	4.12	7.3	5.4	3.3	4.2	4.0	3.48	3.4	4.0

gression. Serial recordings were made of heart rate (HR), blood pressure (BP), central venous pressure (CVP), temperature (T) and urine output (UO).

The predicted colloid regime was adjusted in order to achieve the following physiological goals (7, 10, 11).

$$HR < 120/\text{min}$$

$$CVP = 8-12\ \text{cm}\ H_2O$$

$$UO > 30-50\ \text{ml/h}$$

$$BP > \frac{90}{60}\ \text{mmHg}$$

These goals were successfully achieved in over 80% of the measurements taken hourly in the first 2 days. Comparisons were made between actual fluid requirements and predicted values. Statistical analysis was performed with the Minitab program release 5.1 using linear regression and visual examination of the scatter diagrams of the data and residuals.

Results

Details of the 9 patients studied are given in Table 1. There were 5 females and 4 males, they had an age range of 23–55 years. The burn size varied from 20%–75%. All patients had an inhalation injury confirmed on laryngoscopy or bronchoscopy and needed IPPV for between 4–24 days. The worst PaO_2/FiO_2 ratio recorded for each patient ranged from 8.3–31 (normal 65–75). [A patient with a PaO_2 of 10 KPa on a FiO_2 of 0.4 has a PaO_2/FiO_2 ratio of 25. Ratios below 20 indicate severe parenchymal lung disease.] [12, 13] Three of the patients died (overall mortality = 33%). The predicted mortality in this group would have been 55% [14]. The results shown in Table 2 indicate that the range of fluid requirements in the first 24 h period was 3.3–7.3 ml/kg/% burn with a mean of 4.38±1.26 ml/kg/% burn, compared with 2.5 ml/kg/% burn calculated from the M&B formula, which is an increase of 75%. The range of fluid requirements in the second 24 h was between 1.06 and 3.54 ml/kg/% burn, with a mean of 2.15±0.98 ml/kg/% burn, compared with 1 ml/kg/% burn as calculated for this period, using the M&B formula, which represents an increase of 110% (Table 3).

There was no evidence of a linear relationship between:

1) The amount of fluid transfused and the worst PaO_2/FiO_2 ratio. (Slope = −0.025, SE = 0.058)
2) The number of days on the ventilator and the amount of fluid transfused. (Slope = 0.47, SE = 0.051).

Discussion

The presence of an inhalation injury complicates the intensive care of thermally injured patients and greatly increases the mortality in patients with all sizes of thermal injury [2, 3]. The mortality in this series was 33% (predicted mortality 55%). This figure would be lower if patient 6, who had a cerebro-vascular accident (CVA) before admission, was excluded. While on the ICU he had a further CVA and was declared brainstem dead on day seven of his admission. At this time his respiratory function was improving.

The other two deaths occurred in patients 4 and 8. Patient 4 did not achieve the therapeutic goals described, showed little response to inotropes (dopamine

Table 3. Plasma requirements of patients in the second 24 hours

Patient	1	2	3	4	5	6	7	8	9
Calculated requirements (ml)	3000	2800	2480	5250	4200	1800	3500	1400	1000
Actual requirements (ml)	4690	8350	8780	5570	10070	2310	5100	4900	1600
Difference (ml)	1690	5550	6300	320	5870	510	1600	3500	600
Difference %	56	198	254	6	139	28	45	250	60
Actual requirements ml/kg/%	1.56	2.98	3.54	1.06	2.39	1.28	1.45	3.5	1.6

and dobutamine) and eventually died with renal failure, heart failure, septicaemia, clotting abnormalities, adult respiratory distress syndrome and liver failure. In retrospect his clinical indices (low CVP and urine output) suggested the need for more fluid in the first 48 h. Patient 8 died on day 7 from septicaemia and respiratory failure. It is interesting to note that the two patients who died as a direct consequence of their burns had the worst PaO_2/FiO_2 ratios.

In this study we found that fluid requirements in the first 24 h were 75% greater and in the second 24 h 110% greater than those calculated from the M&B formula. There are 2 possible reasons for this;

1) The use of the M&B formula. This was originally derived at a time when pooled freze-dried plasma (dried plasma) was used rather than human plasma protein fraction (PPF). PPF is made from pooled human blood from which the cellular constituents and most of the globulin have been removed. It therefore contains less protein, less globulin but more albumin than dried plasma. It has been suggested that in adults, the M&B formula should be increased by 30% in the first 24 h and 80–100% in the second 24 h to allow for the change from dried plasma to PPF [15]. Allowing for this factor the predicted volume of PPF would be 3.3 ml/kg/% burn in the first 24 h and 2 ml/kg/% burn in the secnd 24 h.

2) All the patients had an inhalation injury. Other studies have demonstrated that patients with an inhalation injury require between 37%–44% more fluid in the initial resuscitation perion [3, 11, 16]. These increased requirements may be due to an increase in pulmonary microvascular permeability [2, 3]. The modified M&B formula gives a predicted fluid requirement of 3.3 ml/kg/% burn in the first 24 h. The patients in this study actually required 4.38 ml/kg/% burn. This represents a 30% increase in fluid requirements, possibly due to the presence of an inhalation injury. Studies in the United States have shown that patients with inhalation injuries, resuscitated with crystalloid, required 5.6–6 ml/kg/% burn in the first 24 h, compared with patients in our study who required 4.38 ml of colloid [2, 9].

This study suggests that patients with cutaneous burns and inhalation injuries require 30% more fluid in the initial 24 h period. If the M&B formula is used to calculate fluid requirements it should be remembered that this formula refers to the use of dried plasma. If PPF is used the fluid requirements in adults may be increased by 30% in the first 24 h and 90%–100% in the second 24 h.

We would suggest that adults with inhalation injuries and burns require more fluid in the first 24 h than patients who only have a cutaneous injury. As a result of this study we recommend that PPF requirements for adults with inhalation injuries and cutaneous burns are 4.0–4.5 ml/kg/% burn in the first 24 h and 2 ml/kg/% burn in the second 24 h, as well as 2 l per day of 5% dextrose in water for their metabolic requirements. These formulae should only be used as a guideline for planning fluid therapy and must be adjusted according to the patient's clinical response and measured parameters.

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