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Impact of Reduced Resuscitation Fluid on Outcomes of children with 10-20% Body Surface Area scalds.

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Abstract

'Permissive hypovolaemia' fluid regimes in adult burn care are suggested to improve outcomes. The effect of reduced fluid resuscitation in paediatric burn care is less well understood.

In a retrospective audit, outcomes of children from the South West Children's Burn Centre (SWCBC) of less than 16 years of age with scalds of 10-20% Burn Surface Area (BSA) managed with a low volume fluid resuscitation regime (post 2007) were compared to two groups: an historical local protocol (pre 2007) and current regimes in burn services across England and Wales (E&W). Outcomes included length of stay per percent burn surface area (LOS/%BSA), skin graft requirement and re-admission rates.

92 SWCBC patients and 475 patients treated in 15 other E&W burn services were included. The reduced fluid resuscitation regime median LOS/%BSA was 0.27 days: significantly less than pre-2007 (0.54 days) and other E&W burn services (0.50 days, $p<0.001$). Skin grafting has reduced post-2007 compared to pre-2007 and remains comparable with other E&W services. Re-admission rates were comparable between all groups

A reduced fluid regime has significantly shortened LOS/%BSA without compromising burn depth. A prospective randomised control trial comparing permissive hypovolaemia resuscitation to current recommended regimes for moderate paediatric scald injuries would help clarify.

Introduction

International burn services are attempting to develop standardised clinical quality indicators to monitor outcomes [1]. The United Kingdom's National Health Service (NHS) is also striving for a system of healthcare focused on measurable clinical outcomes [2]. The change from a process-driven NHS system to one weighted towards clinical outcomes has evolved over the last three years in response to the 2010 Department of Health (DOH) White Paper, "Equity and Excellence: Liberating the NHS" which stressed that the effectiveness of the treatment and care provided to patients will be measured by clinical outcomes [2].

The development of appropriate clinical outcomes in burn care is an area of current controversy and has been highlighted as needing development in the United Kingdom *National Burn Care Review* (2001) [3]. Outcome measures need to be evidence-based, permit useful comparison, be clinically relevant, age-specific, consistently reliable, specific and sensitive enough to make comparisons and have an agreed definition [4]. The most commonly used indicators of clinical outcome in both adult and paediatric burn care are survival, time to return to pre-burn activity, length of hospital stay (LOS) per percent BSA (LOS/%BSA), need for secondary surgery and re-admission rates [5]. To date, there is no single, ratified outcome measure for moderate sized paediatric scald injuries as defined by a body surface area (BSA) of 10-20%.

Mortality in 10-20% BSA paediatric scald injuries is rare and therefore gives no indication of the quality of services provided to patients. Time taken to return to pre-burn activities often reflects the size of burn rather than the quality of care provided. There is a close correlation between LOS and extent of size of burn injury [6,7] and outcome in paediatric scalds can be better assessed by monitoring hospital LOS, with studies showing a link between improving quality of care and shortened LOS for similar burn sizes and depths [8].

The length of stay of patients sustaining burn injuries depends on the size of the burn. Using LOS/%BSA as an outcome measure will correct for size of burn injury [9]. It does not, however, correct for burn depth, children who have delays in discharge due to other co-morbidities, child protection issues or social care delays. With these provisos however, LOS has been found to be linearly associated with %BSA for small and moderately sized burn injuries. Despite advances in burn care, length of stay still remains consistent with the one day per percent model proposed by Dimick and Warden 20 years ago [10]. Although not a gold standard, use of one day per % BSA remains a helpful outcome target for burn care services assuming depth of burn and co-morbidity is standardised [11].

Adequate and timely fluid resuscitation is recognised as one of the most important therapeutic interventions in burn care [12]. Fluid is administered in order to prevent both burn shock and renal insufficiency (as a measure of vital organ perfusion). Over-resuscitation is common with conventional fluid resuscitation regimes and has been shown to increase complications such as respiratory compromise, sepsis, multi-

organ failure and death [13]. In adults, there is an emerging body of evidence confirming the risks of over-resuscitation and this has led to the development of the permissive hypovolaemic fluid resuscitation model [14]. Evidence supporting the effectiveness of permissive hypovolaemic resuscitation in children sustaining burn injuries is currently lacking.

The South West Children's Burns Centre (SWCBC) uses the biosynthetic dressing Biobrane™ for the wound dressing management for partial thickness scalds. This biosynthetic dressing is effective in reducing fluid loss directly from the burn injury and has been demonstrated to reduce pain levels, healing time, inpatient stay and nursing requirements in the management of moderate to large area superficial and partial thickness depth burns [15].

Prior to January 2007, the SWCBC used a fluid resuscitation regime based on the traditional Parkland Formula. The protocol recommended starting fluid resuscitation at 10% BSA with an initial rate of between 3 ml/kg/%BSA with 100% maintenance fluid requirements and the application of biosynthetic dressings.

Since January 2007, in response to an on-going audit of complications of over-resuscitation in children with moderate partial thickness scald injuries, the SWCBC has changed to a permissive hypovolaemic fluid resuscitation regime. In children with moderate-sized partial thickness scalds, this protocol recommends starting fluid resuscitation at 15% BSA with a rate of 2ml/kg/%BSA with 80% maintenance fluid requirements and the application of biosynthetic dressings.

Our aim is to investigate whether a permissive hypovolaemic fluid resuscitation regime has an affect on patient outcome in children sustaining scalds of 10-20%BSA. The primary outcome is defined by hospital LOS/%BSA. Secondary outcomes include skin graft rate, re-admission rate, renal impairment incidence, intensive care unit (ICU) admission, ventilator use and total length of stay.

We have also summarised the current fluid regimes used in other England and Wales burns services and compared outcomes of moderate sized scald injuries in these services to those from children treated at the SWCBC pre and post 2007 in order to attempt to clarify the link between fluid management and outcome in these injuries.

Methods

It was deemed by the Local Research Ethics Committee that ethical permission was not required for this study.

The International Burns Injury Database (iBID) created in 1996, is a registry of data from all burn services in England and Wales (E&W) [16]. The iBID allows information on burn injury causation, clinical data, service data and quality of service to be collated and analysed.

Data was obtained from the iBID and local databases from 1st January 2004 to 31st December 2011 for children from the South West Children's Burns Centre.

Inclusion criteria used were age less than 16 years at time of injury, a scald (burn due to hot liquid) mechanism recorded, depth defined as partial thickness and of surface area between 10-20% inclusive. Clinical notes for children managed at SWCBC were reviewed for the child's age and burn surface area as a % of the total body (%BSA) as documented in the initial operation note. The number of skin-graft procedures performed from the time of injury to the time of discharge was recorded, along with any admissions to the intensive care unit. Any evidence of renal dysfunction as defined by the paediatric modified RIFLE criteria (RIFLE) (estimated creatinine clearance reduction by 25% or urine output <0.5ml/kg/hr for 8hrs) at any point during the acute admission was also noted. As an indirect measure of the incidence of pulmonary oedema, the number of patients who received respiratory support was noted. Hospital admission and discharge dates were reviewed to calculate length of hospital stay. It was also recorded whether the patient was re-admitted at any point after discharge.

Anonymised demographic and outcome data for children fulfilling the same inclusion criteria was also obtained from the iBID database for all E&W burns services (excluding SWCBC) for the same time period.

Finally, an email questionnaire was sent to 15 services leads in E&W who provide specialist burn care services for children. The survey was divided into two sections. The first asked whether biosynthetic dressings were used for managing paediatric scald injuries and at what %BSA scald were they considered. The second section requested information regarding fluid resuscitation in paediatric scalds including at what %BSA formal fluid resuscitation was routinely started, which fluid resuscitation formula was used and at what initial volume and rate. Details of fluid resuscitation regime volumes and rates were collated. Those services that did not respond to the email questionnaire were followed up with a telephone call to the duty senior member of staff by one author (TW).

Statistical analyses

For categorical outcomes we used Fisher's exact test to compare SWCBC outcomes to the data from the other E&W burn services. The demographic variable patient age

was log-transformed to conform to residual normality and variance heteroskedasticity and differences between groups analysed using ANOVA. Total % BSA, length of stay and LOS/%BSA were skewed and differences between groups analysed using Kruskal-Wallis tests. Length of stay and LOS/%BSA were also investigated using survival analysis to produce a Kaplan Meyer plot and 95% confidence intervals for the median time to discharge (analysed in SPSS for Windows v. 18; SPSS, Chicago, IL, USA). All other analyses were performed in Stata v. 12 (StataCorp LP, USA). Depending on data distribution, variables were described using mean ± SD or median (inter quartile range IQR). All tests were two-tailed and the level of statistical significance was set at $P \leq 0.05$.

Results

Demographics

E&W iBID data revealed that between 1st January 2007 and 31st December 2011, 541 children had scald injuries of 10-20% BSA inclusive. Of the 541 total patients, 482 (89%) were under five years of age, 525 (97%) under 10 years of age and 308 patients (57%) were male. Sixty-six of these patients were managed at the SWCBC and 475 were managed in other E&W burns services. There were 26 patients identified as fulfilling inclusion criteria between January 2004 and December 2006 inclusive managed at the SWCBC.

The children managed at the SWCBC (pre and post 2007) were statistically similar in age to those in other E&W burn services: mean age in years (±SD): SWCBC pre-2007 = 2.2 (±3.1), SWCBC post-2007 = 2.3 (±2.1), other services = 2.6 (±2.6); $F_{2, 561} = 0.66$, p=0.51. All groups were comparable in terms of total % BSA: median (IQR): SWCBC pre-2007 = 12 (4), SWCBC post-2007 = 12 (4), other E&W services = 12 (5); p=0.46.

Comparison with national guidelines

From January 2007 the SWCBC used a lower initial rate of fluid resuscitation, starting at a higher BSA and with lower maintenance fluid rates than currently recommended by national guidelines (table 1).

Survey

Of the 15 burn services identified as accepting children with this severity of burn injury, 12 (80%) replied to the survey. All 12 services that took part in survey use biosynthetic dressings routinely as part of their management of 10-20% scald injuries during the period of this study. All services would apply biosynthetic dressings for scalds between 10-20% under general anaesthesia. All 12 (100%) services begin resuscitation fluid protocols at BSA scalds of over 10% BSA.

All services use crystalloid as the primary resuscitation fluid. The rate at which this resuscitation fluid is administered varies between services (see table 2). The mean rate of fluid administration for all services except the SWCBC was 3.41ml/kg/%BSA. Three services (25%) give an initial rate of 4ml/kg/%BSA, five (42%) give an initial rate of 3ml/kg/%BSA, three (25%) give between 3-4ml/kg/BSA and one service (8%) had no fluid resuscitation rate standard. Three services (25%) give 100% maintenance fluid, four (33%) give maintenance fluid based on clinical parameters and 5 (42%) give no routine maintenance fluid. Maintenance fluid, when given is crystalloid in all cases. The SWCBC uses 41% less fluid than the mean rate in other burn services.

Key Outcomes

Table 3 gives comparison of SWCBC to other England and Wales services by key outcomes.

LOS and LOS/%BSA were found to be significantly shorter in the SWCBC group post 2007: median length of stay (IQR) in SWCBC of 3 days (7) compared with 7 days (8) in

other burn services (p<0.001) and median LOS/%BSA in SWCBC 0.27 days/%BSA (0.50) compared to 0.50 days/%BSA (0.6) in other services (p<0.001) (table 3).

There was a comparable and significant reducing in LOS and LOS/%BSA after implementation of local low fluid volume resuscitation protocol within our own department. Median length of stay of 3 days (7) post-2007 compared with 7.5 days (11) prior to January 2007 (p<0.001). Median LOS/%BSA of 0.27 days/%BSA (0.50) from January 2007, compared to 0.54 days/%BSA (0.75) prior to this date (p<0.001) (table 3).

Complications

None of the patients managed at SWCBC pre- and post-2007 or those managed in other services had any biochemical evidence of renal dysfunction during their inpatient stay. During the time period after 2007, SWCBC had statistically significantly fewer patients managed on intensive care compared to SWCBC pre-2007 and other England and Wales services (p=0.005, table 3). Fewer patients required skin graft operations post 2007 compared to pre 2007 (<0.001). Skin graft rates are comparable with other E&W services (table 3). Number of patients requiring ventilated care and readmission rates were comparable between those patients managed at SWBC (pre and post 2007) and those managed in other services in E&W (Table 3).

Table 1. Comparison of fluid resuscitation protocols

Protocol	**SWCBC post 2007**	**SWCBC Pre 2007**	**Emergency Management of Severe Burns (EMSB)**
Commences at %BSA	>15%	>10%	>10%
Initial fluid rate	2ml/kg/hr	3 ml/kg/%BSA	4ml/kg/%BSA
Additional maintenance fluid requirement	80%	100%	100%
Target urine output	0.5ml/kg/hr	1ml/kg/hr.	1ml/kg/hr.

Table 2: Rate of fluid administration in services across England and Wales excluding the SWCBC

Rate of Fluid Administration	**Number of services in England and Wales (%)**
4ml/kg/%BSA	3 (25)
3ml/kg/%BSA	5 (42)
3-4ml/kg/%BSA	3 (25)
2ml/kg/%BSA	0 (0)
No standard	1 (8)

Table 3: Comparison of SWCBC to other England and Wales services by key outcomes:

Outcomes	SWCBC post 2007 n=66	SWCBC pre 2007 n=26	Other E&W Services n=475	P-value
Total number of graft operations median (IQR)	0 (1)	1.5 (2)	0 (0)	<0.001
Total length of stay median (IQR)	3 (7)	7.5 (11)	7 (8)	P<0.001
Length of stay per percent burn median (IQR)	0.27 (0.5)	0.54 (0.8)	0.50 (0.6)	P<0.001
ICU stay (%)	1.5% (1/66)	7.7% (2/26)	13.7% (65/475)	0.005 [F]
Readmission rate (%)	3% (2/66)	3.8% (1/26)	4.6% (22/475)	0.91[F]
Ventilator use (%)	1.5% (1/66)	0% (0/26)	2.1% (10/475)	1.000 [F]

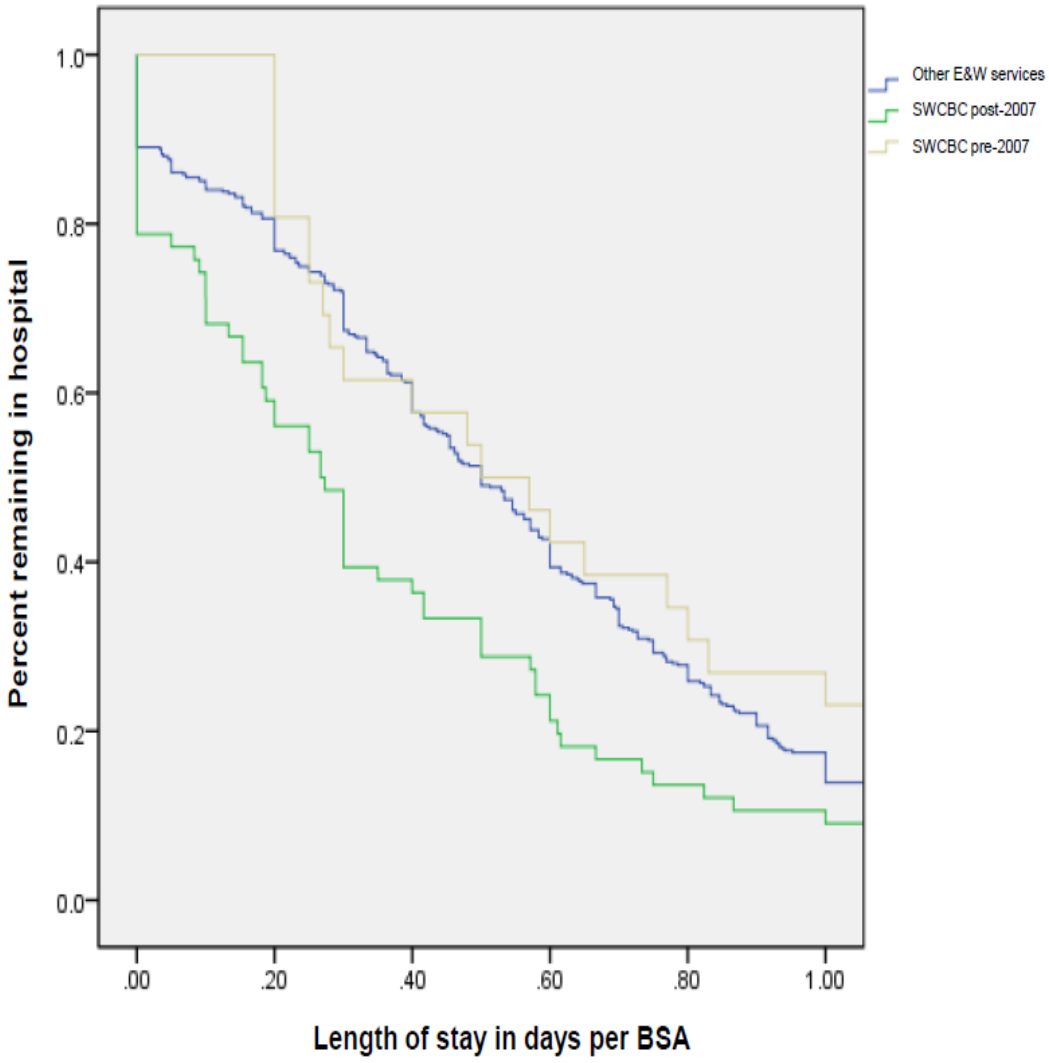
[F] =Fisher's exact test (2 tailed) comparing all groups – all others are Kruskal Wallis tests.

Table 4: Median length of stay with 95% confidence intervals derived from a Kaplan Meier analysis of length of stay and length of stay per percent burn.

Variable	**SWCBC post 2007 n=66**	**SWCBC pre 2007 N = 26**	**Other E&W Services n=475**	**P Value***
Length of stay	3 (2.2, 3.8)	7 (4.0, 10.0)	7 (6.3, 7.7)	0.002
Length of stay per percent burn	0.27 (0.19, 0.34)	0.50 (0.25, 0.75)	0.50 (0.45, 0.55)	0.01

*P-value is log rank (Mantel Cox) p value.

Figure 1: Comparison between SWCBC pre-and post-2007 with other E&W services. Kaplan Meier curve for length of stay per percent BSA burned – truncated at 1 day per percent burn.



Discussion

In order to improve clinical outcomes in line with NHS reforms as specified in the 2011 white paper "Equity and Excellence: Liberating the NHS", moderate sized scald injuries in children represent a significant challenge to burns services [2]. Fluid resuscitation is an essential part of paediatric burn care and will affect outcome [13, 17]. Too much or too little fluid during the acute phase results in higher complication rates and increases mortality in larger burns [12].

The SWCBC recommends commencing fluid resuscitation at BSA burns of 15% using a modified Parkland formula at a rate of 2ml/kg/%BSA along with 80% (of traditionally calculated) maintenance fluid. Urine output rates in this protocol are accepted down to 0.5ml/kg/hr as long as the child remains well perfused and not acidotic (pH > 7.25). All partial thickness scalds of 10-20% BSA are managed using biosynthetic dressings applied within the first 24 hrs.

We believe that this permissive hypovolaemic resuscitation protocol is having an effect on patient outcome as measured by LOS/%BSA. LOS/%BSA at the SWCBC is significantly less after introduction of this protocol in 2007 in comparison to both our own department data pre 2007 and other burns services in England and Wales currently using more traditional fluid resuscitation regimes.

Currently, the Emergency Management of Severe Burns paediatric guideline, endorsed by the British Burns Association, uses the Parkland formula as the recommended fluid resuscitation protocol. The advice is to commence fluid resuscitation at burns of BSA of more than 10% and to administer fluid at 4ml/kg/hr, with half of the fluid administered within the first eight hours following injury and half in the subsequent 16 hours, along with 100% of maintenance fluid requirement (table 1). The main physiological parameter to determine the adequacy of this resuscitation is stated to be urine output. The current accepted urine output for children using this guideline is 1-2 ml/kg/hr depending on age. As with any fluid resuscitation protocol the goal in the initial resuscitation period is to correct intravascular deletion and therefore prevent end organ damage [18].

There is a growing body of evidence to suggest that the Parkland formula can lead to over-resuscitation and end organ dysfunction in moderate sized burn injuries. Using measurements of intra-thoracic blood volume and cardiac output, a 2007 study showed that that the Parkland formula did not correct the intravascular volume deficit in the first 48 hours post burn as expected. Indeed, any increase in fluid administration during the first 12 hour period after thermal injury only added to extracellular fluid accumulation rather than achieve sufficient vital organ perfusion [14].

Caution is needed if using urine output as a measure of the adequacy of fluid resuscitation in children. In 1961, it was found that despite adequate resuscitation children remain oliguric for several hours after a burn injury [19]. This finding has been attributed to a surge in anti-diuretic hormone (ADH) production seen in

children who have sustained trauma [20]. This is also the case after minor burn injuries in children [21]. Oliguria caused by raised plasma levels of ADH may persist for 48-72 hours. This phenomenon is seen to occur despite adequate fluid resuscitation. Importantly, the target urine output in our current reduced fluid resuscitation regime is half than that recommended by the Parkland Formula. Forcing a diuresis in order to achieve urine output of 1-2ml/kg/hr during fluid resuscitation post-burn may contribute to problems related to over-resuscitation [13].

Over-resuscitation in children sustaining trauma and burns most commonly leads to oedema as fluid is administered above the level whereby cells are restored to normal function. Fluid accumulates more readily in children, in comparison to adults, due to less compliant heart muscle and increased capillary permeability in immediate post burn period [22]. Oedema forming as a consequence of fluid over-resuscitation increases the likelihood of organ dysfunction and with increasing volumes of fluid administered the risk of pneumonia, sepsis, Acute Respiratory Distress Syndrome (ARDS), Multi-organ failure and death increases [13].

Following published results from studies investigating haemodynamic orientated burn shock resuscitation monitoring techniques [14, 23, 24] and repeated local clinical audits a protocol of permissive hypovolaemic resuscitation was developed at SWCBC. We believe that children with partial thickness scalds of between 10-20% BSA, resuscitated at a lower rate of fluid administration than the Parkland formula suggests (table 1), especially if managed with biosynthetic dressings, may be less likely to develop complications attributable to over-resuscitation. Reduced incidence of oedema is likely to effect LOS/%BSA by reducing the incidence of pneumonia, sepsis, Acute Respiratory Distress Syndrome and Multiple Organ Failure. Commencing fluid resuscitation at higher %BSA scalds also means that fewer children will require invasive monitoring techniques and less children will be managed in intensive care. Subsequently, with less monitoring there will be fewer complications attributable to catheters, invasive haemodynamic adjuncts and naso-gastric tubes. Children are less constrained by wires and tubing and mobilization, physiotherapy and nutrition will be easier in the acute phase of burn care. This will positively effect the amount of time taken to return to normal activity and expedite discharge from acute care services.

The trend towards lower ventilator use in SWCBC and the significant difference in intensive care stay between SWCBC and other E&W services is likely to represent a reduced incidence of pulmonary oedema in moderate sized scald injuries managed with a reduced fluid resuscitation regime.

Importantly, outcomes reported suggest that a reduced fluid resuscitation regime is not leading to problems seen with under-resuscitation. Skin graft rates were higher pre-2007 at SWCBC and those reported post 2007 are comparable to those in other E&W burn services. Readmission rates are comparable with those seen prior to 2007 at SWCBC and those reported in other E&W burn services. Both of these outcomes suggest that the low volume resuscitation protocol is not compromising burn depth.

Biochemical markers of renal function have also shown that permissive hypovolaemia resuscitation regime did not cause any adverse physiological effects during the audit period.

The variability of fluid resuscitation protocols between burn services in E&W in the amount of fluid given during the initial resuscitation period represent a continued lack of consensus regarding paediatric fluid resuscitation in burns and highlights the need for further investigation to draw evidence-based links between a permissive hypovolaemic resuscitation regime and improved outcomes as measured by LOS/%BSA.

We recognise several limitations to this investigation. There are limitations due to retrospective design and lack of objective burn depth measurement. Inconsistencies can occur as iBID data is routinely collected data and as such may not be complete. In the process of analysis, it is possible that variables lacking data entry may be interpreted as lack of events. This data inaccuracy is less likely to occur for variables, which require date entry or %BSA where the omission cannot be mistaken for a real value. Therefore, although data inaccuracy may explain some of the differences between Bristol and other E&W burns services, this cannot explain the difference in length of stay per percentage burn.

This audit has highlighted differences in the resuscitation protocols throughout E&W. We suggest that the hypovolaemic fluid resuscitation protocol used in the SWCBC after 2007 is improving patient outcome and reducing morbidity due to over-resuscitation. In addition, there are no increased complications relating to under-resuscitation such as renal dysfunction or increased burn depth.

Conclusion

The length of stay /%BSA at the SWCBC is significantly less after the implementation of a hypovolaemic fluid resuscitation regime in 2007. LOS/%BSA is also significantly less than in other burn services in England and Wales. We suggest that this is due in part to our conservative fluid resuscitation regime resulting in fewer complications from over-resuscitation and less intensive care admissions for children sustaining 10-20% scald injuries.

A multicenter randomized control trial to compare permissive hypovolaemia to current resuscitation fluid protocols in the management of scald injuries in children would clarify the issue.

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Conflict of interest statement

None