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Research paper

The effect of 20 minutes of cool running water first aid within three hours of thermal burn injury on patient outcomes: A systematic review and meta-analysis

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A B S T R A C T

Background: Burn injuries are a leading cause of morbidity that can result in devastating disability and poor quality of life for survivors. This systematic review aimed to synthesise evidence regarding the effect of 20 minutes of cool running water (CRW) within three hours of injury on outcomes of patients with thermal burn injuries.
Methods: This systematic review was conducted in reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Multiple databases (PubMed, EMBASE, CENTRAL, CINAHL Complete via EBSCO, PROQUEST Dissertations and Theses), and the Australia New Zealand Clinical Trial Registry were searched for eligible studies published in English and Chinese, without date restriction. Meta-analyses were undertaken Methodological quality of studies was assessed by using Downs and Black Checklist.
Results: Of 323 records, seven studies were included. The majority (67%) of studies were conducted in Australia and New Zealand. The methodological quality was ranked between 'fair' and 'good'. Twenty minutes of CRW within the first three hours of burn injury significantly decreased the odds of patients requiring skin grafting and surgical intervention for wound management.
Conclusions: There is considerable evidence suggesting the application of 20 min of CRW within the first three hours of injury improves outcomes for patients with burn injury. Consensus between burn organisations and collaborative efforts to translate evidence into practice are needed to optimise burn first aid care which can improve patient outcomes globally.

Introduction

"A man of wisdom delights in water." – Confucius

The use of cold water was first recommended to treat burn injuries by Galen almost 2000 years ago [1]. Now in the era of evidence-based medicine, the scientific evidence supporting Galen's recommendation is growing. Potential associations between cool running water (CRW) burn first aid and improved patient outcomes were first published in peer-reviewed research last century [2–4]. This early research identified potential associations between the use of water to cool burns and reduced mortality and morbidity, including less pain, infection and scar formation [2–4]. Nonetheless, the reliability of these early research findings was limited by poor methodology and small observational cohorts. At the turn of the 21st century, scientific research regarding the use of water for burns first aid was primarily focused on animal models, which limited the generalisability of the results to humans [5–8]. However, in the past decade there is an increasing body of scientific

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evidence to support the application of CRW for burns first aid to reduce the burden of burn injury in humans [2,9–11].

Galen's time old recommendation to use cool running water for burn first aid has evolved and been adopted by many professional burn associations worldwide [4,12,13]. However, recommendations regarding the duration and mechanism of cooling are inconsistent between jurisdictions [2,6,14,15]. This is contrary to the growing evidence that 20 min of CRW within the first 3 h of injury provides the most therapeutic benefit [2,9–11]. Inconsistencies in burn first aid messaging are also evident in the recommendations provided by wider health care peak bodies and organisations including the World Health Organisation and the European Resuscitation Council [15,16]. For example in Australia, New Zealand and the British Burns Associations, 20 min of CRW is recommended, however in the American Burns Association only suggests 5 min CRW [14]. Inconsistent first aid guidelines and messaging from peak bodies is likely to contribute to confusion regarding best practice, limiting the potential therapeutic benefits of a relatively simple and affordable intervention. Moreover, in some jurisdictions where 20 min of CRW has been incorporated into burns, pre-hospital and emergency department guidelines, implementation and adherence to the guidelines remain sub-optimal [17–19].

To optimise opportunities to reduce the burden of burn injury, clear and consistent messaging regarding first aid is required by peak bodies. It is paramount therefore to establish and synthesise available evidence on the effectiveness of 20 min of CRW first aid on the outcomes of patients with burn injury. Using systematic review methodology, we evaluated existing literature to quantify the effect of 20 min of CRW within three hours of thermal burn injury on patient outcomes to assist the international burns community in reaching consensus regarding evidence-based burns first aid best practice.

Review questions

What effect does the application of CRW for 20 min within three hours of burn injury have on patient outcomes, and is it more effective than alternative remedies, or no CRW?

Methods

This systematic review was conducted in reference to the Joanna Briggs Institute [20] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21]. The systematic review methodology is appropriate for this question as it facilitates the synthesis of existing studies reporting statistical analysis.

Inclusion criteria

Participants/population - Children (0–17 years old) and adults (18 years and older) with thermal burns (flame, scald, contact) with any thickness and total body surface area percentage involvement. Thermal burns are any skin burns that involve an external heat source (i.e. flame, scald, contact) [22].

Intervention - Any intervention where CRW was administered intermittently or collectively for a total of 20 min within three hours of injury were included (referred to as "CRW 20″ herein forward).

Comparator/control - The intervention was compared with alternative management (such as CRW less than 20 min, Aloe vera, toothpaste, butter, etc) or no first aid intervention at all within three hours of thermal burn injuries.

Outcomes – Primary outcomes of interest were: burn depth, a requirement for admission to hospital, skin grafting, time to re-epithelialisation and hospital length of stay. Any other relevant patient outcomes such as surgical intervention requirements, pain, wound temperature, outpatient visits, ICU admission and length of stay, and mortality were included as secondary outcomes.

Study designs – Quantitative studies: randomised controlled trials (RCTs), before and after, interrupted time series, case control studies, cohort studies, and cross-sectional studies were considered.

Table 1
Searching strategy in pubmed.

("burn*"[Title/Abstract] OR "scald*"[Title/Abstract] OR "thermal burn"[Title/Abstract] OR "sunburn*"[Title/Abstract] OR "heat burn"[Title/Abstract] OR "thermal injury"[Title/Abstract] OR "burns"[MeSH Terms])
AND
("emergency care"[All Fields] OR ("first aid"[MeSH Terms] OR ("first"[All Fields] AND "aid"[All Fields]) OR "first aid"[All Fields]) OR "pre:hospital care"[All Fields] OR "paramedicine"[All Fields] OR "household treatment"[All Fields] OR "emergency department"[All Fields] OR "emergency room"[All Fields] OR "first responder* "[All Fields] OR ("first aid"[MeSH Terms] OR "emergency treatment"[MeSH Terms] OR "emergency medical services"[MeSH Terms] OR "emergency service, hospital"[MeSH Terms] OR "ambulances"[MeSH Terms] OR "ambulances"[MeSH Terms])
AND
("cool running water"[Title/Abstract] OR "cold running water"[Title/Abstract] OR "running water"[Title/Abstract] OR "immediate cooling"[Title/Abstract] OR "water cooling"[Title/Abstract] OR "cold water"[Title/Abstract] OR "cool water"[Title/Abstract] OR "cooling"[Title/Abstract] OR "surface cooling"[Title/Abstract] OR "cold treatment"[Title/Abstract] OR "coolant"[Title/Abstract] OR "cooling therapy"[Title/Abstract])

Search strategy

A comprehensive literature search was conducted in health care databases [PubMed, EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL Complete via EBSCO, and PROQUEST Dissertations and Theses] and clinical trials registries [Australian New Zealand Clinical Trials Registry and ClinicalTrials.gov]. The search was conducted on 5th March 2021.

The search strategy was structured and systematic, which included keywords and subject headings from the study population (i.e. thermal burn, scald) intervention (i.e. cool running water, water cooling), context (i.e. first aid, pre-hospital care, emergency care), and/or outcomes (i.e. wound healing, burn depth, grafting, re-epithelialisation, length of hospital stay) (Table 1). The study was registered in PROSPERO (CRD42020185646). For completeness, the reviewers hand-searched the reference lists of relevant articles. No date restrictions were applied. Studies published or previously translated in English and Chinese language were included.

Study selection

All citations from the final search strategy were imported into Endnote and subsequently screened independently for relevance using title and abstract by two reviewers (CJC, BA). Studies not meeting the inclusion criteria were excluded. Full text of studies that met or could potentially meet the inclusion criteria was retrieved. Reasons for inclusion or exclusion were documented, and any discrepancies were discussed by two reviewers and a mediator (BG) until consensus was achieved.

Risk of bias assessment

Study quality was independently appraised by two reviewers (CJC, BA); and any disagreements were discussed with a mediator (BG). Studies for methodological quality were assessed using Downs and Black Checklist [23]. The maximum score was 28 suggesting: excellent (26–28); good (20–25); fair (15–19); and poor (≤14) [24]. Poor quality studies were excluded from the review.

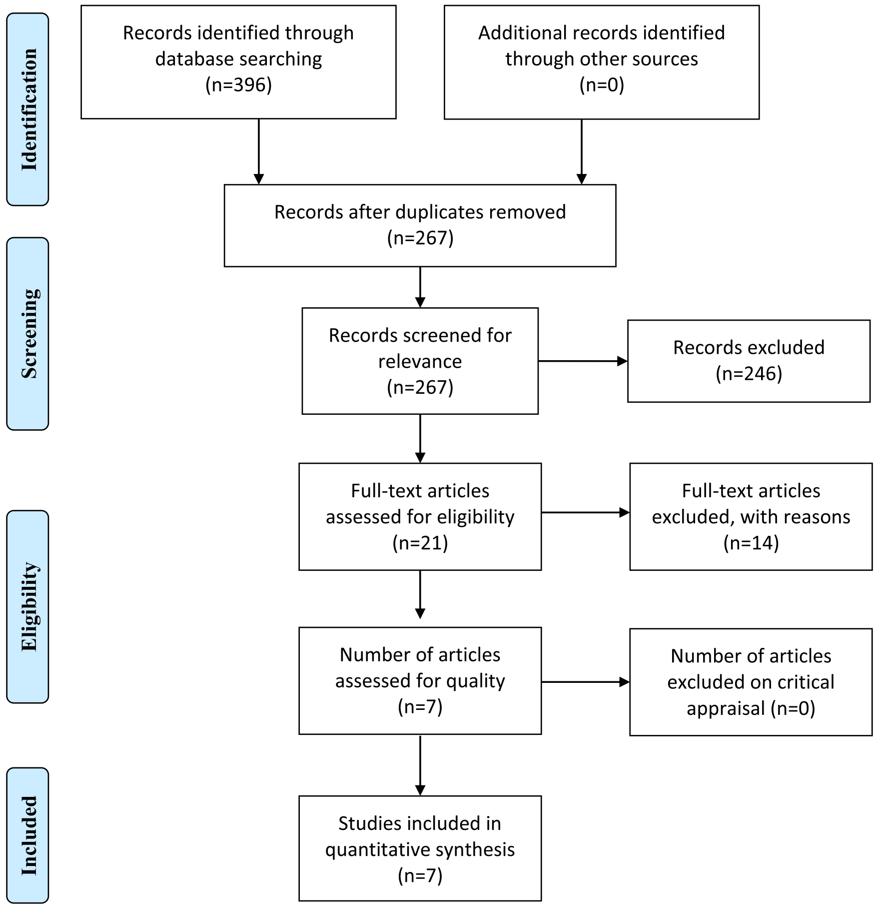

Fig. 1. Study selection flow diagram[21].

Data synthesis

Data from the studies were extracted and cross-checked for accuracy by two reviewers (CJC, BA). When data were presented graphically or as effect sizes, authors were contacted to provide actual values required for statistical pooling. Meta-analyses were conducted in Review Manager (RevMan) [Computer programme] Version 5.4 . Continuous outcomes were presented as mean difference (MD); while dichotomous outcomes were presented as odds ratio (OR) using Mantel-Haenszel random effects model [25]. Heterogeneity was assessed statistically using the standard I^2 statistic, where (approximately) 1–25 %, 26–75 %, 76–100 % was interpreted as low, moderate, and high respectively [26]. Where statistical pooling was not possible, the findings were presented in a narrative form with tables.

Results

Description of included studies

There were 396 citations found on initial search (See Fig. 1). After the removal of duplicates, 267 studies were screened for relevance. The full text of 21 relevant papers was retrieved and appraised for methodological quality. Of these, 14 were excluded because no full text could be located (n = 3) [27–29], the intervention was not cool running water (n = 6) [18,29–33], no patient outcomes were reported (n = 1) [34], English translation was unavailable (n = 1) [35], or was of poor methodological quality (n = 3) [36–38].

Table 2 describes included studies. Seven studies [2,9–11,39–41] with a total study population of N = 11,383 were included in this review. The majority (n = 6/7) of the studies were either case control or cohort studies utilising data from burns registries between 2004 and 2018. Geographical location was not diverse, with 6/7 studies representing the Australian population and two of these studies sampling both Australian and New Zealand populations. The quality of all studies was fair to good (range 16–21) (Table 2). Due to the nature of observational studies, they were downrated for risks of selection bias, inaccurate or missing data, and confounders.

Patient and injury characteristics

Of the entire burn population, 67.8 % were adults (n = 7722), and 32.2 % (n = 3661) were paediatrics. The mean age range for the adult population was 37–42.7 years, while the paediatric population mean age range was 2 months to 14 years. Scald, flame, and contact burns were the most common mechanism of thermal burns. All but one study, Harish et al. [9] had a study population with TBSA of less than 10 %. Wound depth at presentation to Emergency Departments or Burns Units were mainly superficial to partial thickness burns as reported in five studies. [2,10,39–41].

Cool running water for 20 minutes

Of the n = 11,383 included in this review, n = 5782 (50.8 %) received CRW 20. Where indicated, first aid was provided by either family members, bystanders, paramedics, emergency department clinicians or a combination. [39–41] Comparators were other forms of first aid, [2,9–11,40,41] such as Burn Cool Spray ® or Burnshield®, [39] cool running water for less than 20 min [41] or no first aid.

Table 2
Characteristics of included studies and the study population.

Studies	Study design	Methodological quality		Country	Data collection period	Setting	Description of the intervention and comparator	Intervention provider (primary)	Sample size (n)	Population characteristics					
		Score	Rating							Age in years (mean ± sd or median, range)	Female: Male (% Female)	Burn mechanisms (primary)	TBSA%	Burn site (primary)	Burn depth at presentation (primary)
Paediatric population															
Cuttle et al., 2009 [39]	Case control	16	Fair	Australia	Jan-Dec 2005	Burns unit	Cold water 20 min	Family members	25	2 months to 14.5 years	Not reported	Scald, n = 224 (48.8 %) Contact, n = 128 (28.3 %)	2.8 (sd 4.2)	Limbs, n = 266 (58 %)	Superficialto partial-thickness burns (% not reported)
							Cold water > 20 min	x	28						
							Nothing	x	40						
							Cold water < 10 min	x	56						
							Cold water 10–15 min	x	72						
							Cold water unknown duration	x	168						
							First aid applied, but not cold water	x	47						
Griffin et al., 2020[2]	Cohort study	20	Good	Australia	Jul 2013 to Jun 2016	Burns unit	≥ 20 min of cool running water delivered either cumulatively or continuously within 3 h of injury	Not reported	1780	2 (range 1–6)	1033:1462 (41.4 %F)	Scald n = 1224 (49.1 %) Contact, n = 1116 (44.7 %)	1 (range 0.5–2)	Upper limb, n = 993 (40.3 %)	Partial thickness, n = 1604 (65.7 %)
							Any other form of first aid		715						
Riedlinger et al., 2015[38]	Case control	20	Good	Australia and New Zealand	October 1, 2009 to September 30, 2011	Burns Unit	≥ 20 min of cool running water delivered either cumulatively or continuously within 3 h of injury	Caregivers orbystanders	129	1 (range 1–3)	311:419 (42.6 %F)	Scald, n = 730 (100 %)	TBSA less than 10%, n = 627 (85.9 %)	Not reported	Full thickness 39/93 (41.9 %)
							Any other form of first aid	x	601						Partial thickness 132/ 351 (37.6 %)
Adult population															
Cho et al., 2017[37]	RCT	21	Good	South Korea	June to October 2015	Emergency department	Tap water for 20 min, temperature of 23.9–27.3 degrees Celsius	Emergency department staff	33	40.2 (sd 12)	17:16 (51.5 % F)	Scald, n = 24 (72.7 %)	1 (1–2)	Upper extremity, n = 22 (66.7%)	Partial thickness, n = 22 (66.7%)
							Comparator 1: Burn Cool Spray		31	42.7 (sd 13.8)	22:9 (71 % F)	Scald, n = 18 (58.1 %)	1 (0.5–2)	Upper extremity, n = 19 (61.3 %)	Partial thickness,l, n = 22 (71 %)
							Comparator 2: Burnshield		30	42.3 (sd 12.5)	21:9 (70 % F)	Scald, n = 22 (73.3 %)	1 (1–2)	Upper extremity, n = 18 (60 %)	Partial thickness, n = 21 (70 %)

(continued on next page)

Table 2 (*continued*)

Studies	Study design	Methodological quality		Country	Data collection period	Setting	Description of the intervention and comparator	Intervention provider (primary)	Sample size (n)	Population characteristics					
		Score	Rating							Age in years (mean ± sd or median, range)	Female: Male (% Female)	Burn mechanisms (primary)	TBSA%	Burn site (primary)	Burn depth at presentation (primary)
Harishet al., 2019[10]	Cohort study	21	Good	Australia	2007–2012	Burns unit	≥ 20 min of cool running water delivered either cumulatively or continuously within 3 h of injury	Not reported	2859	37 (sd 15.1)	1122:1737 (39.2 %F)	Scald, 1546 (54.1 %) Flame, 685 (24 %)	1.9 (sd 2.1)	Not reported	Superficial, 1158 (40.5 %) Partial thickness, 1351 (47.3 %)
							Any other form of first aid		2059	40 (sd 17.9)	800:1259 (38.8 %F)	Scald, 941 (45.7 %) Flame, 391 (19 %)	1.8 (sd 2)	Not reported	Superficial, 724 (25.3 %) Partial thickness, 850 (29.7 %)
Harishet al., 2019[9]	Cohort study	21	Good	Australia	2004–2018	Burns unit	≥ 20 min of cool running tap water (8–25 deg C) delivered within 3 h of injury	Not reported	139	40 (sd 17)	22:117 (15.8 %F)	Flame, n = 88 (62.3 %)	31.5 (sd 14.2)	Not reported	41.7 (37.4) (percentage of TBSA that was full thickness injury)
							Any other form of first aid		251	42.7 (sd 18.9)	62:189 (24.7 %F)	Flame,n = 188 (74.9 %)	40.8 (sd 20.6)	Not reported	64.2 (38.4) (percentage of TBSA that was full thickness injury)
Wood et al., 2016[11]	Case control	21	Good	Australia and New Zealand	July 1, 2009 to March 30, 2012	Burn Centres	1–9 within 3hrs	Not reported	286	40.37 (sd 18.06)	580:1740 (25 %F)	Flame, n = 1313 (56.5 %)Scald, n = 667 (28.8 %)	5.5 (IQR 3–10)	Multiple sites, n = 1492 (64.45)	Not reported
							10–19 within 3hrs		351						
							20–39 min of water within 3 h of injury		525						
							40 + within 3hrs		228						
							No water or other first aid		930						

IQR = interquartile range; sd = standard deviation

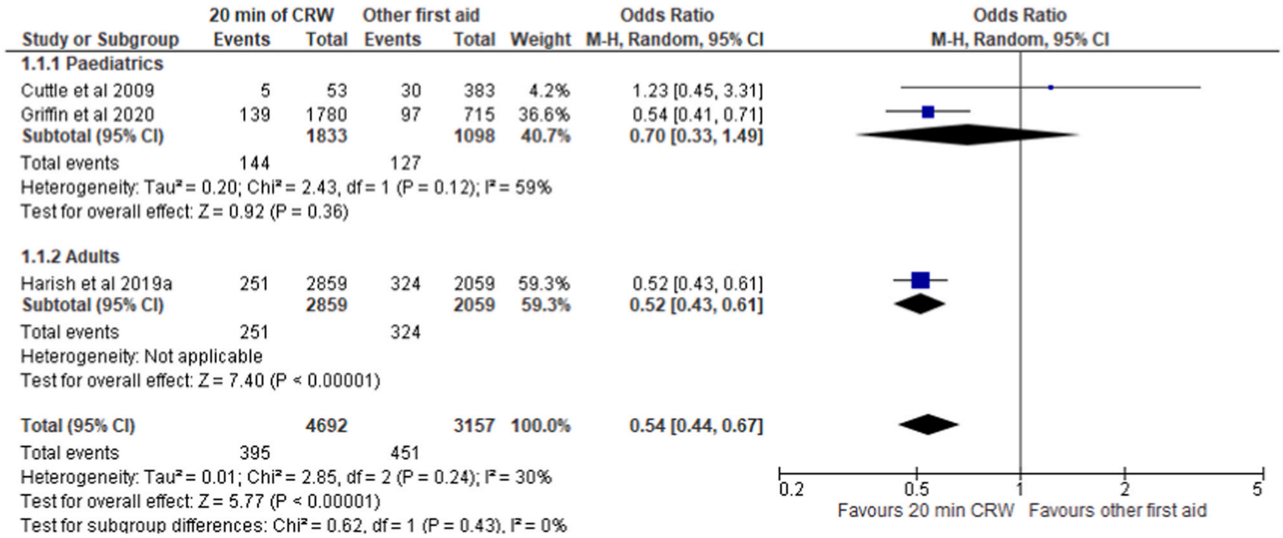

Fig. 2. Comparison between ≥ 20 min of cool running water and other forms of first aid. Outcome: Skin grafting.

Outcomes

Primary outcomes measured in the selected studies were:

- hospital admission and length of stay (LOS) [2,11,40]
- burn depth [2,10]
- requirement for skin grafting [2,9–11,41]
- time to re-epithelialisation [2,10,39,41]

Secondary outcomes were:

- pain [39]
- skin temperature [39]
- surgical interventions [2,40]
- ICU admission and LOS [9,11]
- mortality [9,11]

Primary outcomes

Hospital admission and length of stay (HLOS)

The incidence of hospital admission was only reported by Griffin et al. [2] in the paediatric population. Those who received CRW 20 had a 31% decreased likelihood of hospital admission (OR 0.69, 95 % CI 0.54–0.87, $p = 0.002$).

HLOS in days was reported in three studies: two in paediatrics [2,40] and one in adults. [11] Results varied in the paediatric population, Griffin et al. [2] reported no statistically significant differences in HLOS. Contrarily, Riedlinger [40] found that HLOS was statistically significantly shorter for those who received CRW 20 first aid (2 days (range 0.9–3.9) vs. 2.9 days (range 1.6–6.9), $p = 0.0001$).

In the adult population, Wood et al. [11] demonstrated CRW given up to 19 min was associated with a significant reduction of HLOS, but CRW 20 min or greater did not yield significant decreases to HLOS. For example, the constant HLOS of those who did not receive CRW 20 was 12.3 days. When this is compared with the median HLOS (7.95 days) of those who had 10–19 min of CRW, the difference was statistically significant ($p = 0.04$). However, the median HLOS of 9.13 and 12.1 days for those who received 20–39 min and ≥ 40 min of CRW (respectively) were not statistically significant.

Burn depth

Harish et al. [10] found that those who received CRW 20 were 39 % more likely to have wound depth reduction within 21 days after the injury (OR 1.39, 95% CI 1.24–1.55, $p < 0.001$). Griffin et al. [2] reported that CRW 20 was associated with a 63 % decreased likelihood of acquiring a full thickness depth at the first dressing change (adjusted OR 0.37, 95 % CI 0.24–0.59, $p < 0.001$).

Time to re-epithelialisation

Time to re-epithelialisation was reported in four studies. [2,10,39,41] In the paediatric population, Cuttle et al. [41] showed a trend towards shorter time to re-epithelialisation in patients who received CRW 20 compared to patients who received cool running water for less than 20 min or patients who did not have any first aid. Griffin et al. [2] identified that time to re-epithelialisation were very similar between those who received CRW 20 and those who received other forms of first aid. When stratifying for burns requiring ≥ 10 days to re-epithelialise, time-to-re-epithelialisation was significantly faster in people who received CRW 20 (HR= 1.2; 95 % CI 1 – 1.3; $p = 0.04$), with a reduction in median time to re-epithelialisation of 1 day from 14 to 13 days.

In the adult population, Cho [39] found no statistically significant difference in healing time (presumed re-epithelialisation) between those who received CRW 20 and those who received topical coolants (Burn Cool Spray® and Burnshield®). Whereas Harish [10] showed that re-epithelialisation was shorter with CRW 20 (MD −3.5 days, 95 % CI −4.49 to −2.41, $p < 0.001$).

Skin grafting

Requirement for skin grafting was reported in five studies. [2,9–11,41] Pooled data from three studies [2,10,41] produced an overall effect of a 46 % decreased likelihood of skin grafting (OR 0.54, 95 % CI 0.44–0.67, $p < 0.001$; $I^2 = 30$ %) (Fig. 2) for those who received CRW 20 compared to alternatives. In addition, results from Wood [11] indicated that any duration of CRW was associated with a decreased likelihood of skin grafting. Fig. 3.

Harish [10] reported that the TBSA% grafted was the same between those who received CRW 20 and other forms of first aid (2.2 ± 1.6 vs. 2.2 ± 1.6, $p = 0.86$). In their other study [9] including

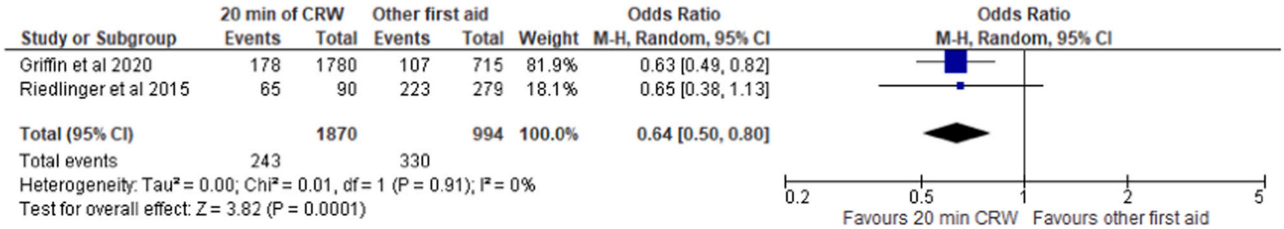

Fig. 3. Comparison between ≥ 20 min of cool running water and other forms of first aid. Outcome: Surgical intervention for burn management.

population with burns ≥ 20 % TBSA, TBSA % grafted was lesser in those who received CRW 20 (11.9 ± 12.5 vs. 16.4 ± 6.4, $p = 0.06$).

Any surgical intervention

Meta-analysis was possible from two paediatric studies. [2,40] Pooled results show that there was a 36% lower likelihood of undergoing surgical intervention (i.e. grafting, debridement, reconstruction) for burn management with CRW 20 compared to alternative (OR 0.64, 95 % CI 0.50–0.80, $p = 0.0001$; $I^2 = 0$ %).

Secondary outcomes

Pain

A single study [39] in adult patients showed that pain, measured by visual analogue scale within 20 min of receiving first aid, was significantly higher amongst patients who received CRW 20 compared to Burnshield® as first aid (p < 0.001).

Burn wound temperature

One study involving adult patients [39] demonstrated a reduction in burn wound temperature, when measured within 20 min of receiving first aid, was significantly greater amongst patients who received CRW 20 compared to patients who received topical coolants (Burn Cool Spray® and Burnshield®) as first aid (no *p* value given).

ICU admission and length of stay

ICU admission and ICU LOS were reported in two studies [9,11] involving adult populations. After accounting for confounders (e.g. TBSA, TBSA grafted) Harish [9] did not find a significant association between CRW 20 and ICU admission (OR 0.77, 95 % CI 0.42–1.40, $p = 0.39$). Similarly, Wood [11] reported that CRW 20 was not associated with a reduced likelihood of ICU admission (OR 0.91, 95 % CI 0.70–1.37, $p = 0.58$).

However, for ICU LOS, CRW 20 was associated with a shorter ICU LOS of 4.8 days (95 %CI −7.7 to −1.9, p = 0.01). [9].

Outpatient visits

Outpatient visits were reported in two studies, one each representing the paediatric [41] and adult [10] populations. Both studies [10,41] showed a similar number of outpatient visits made by those who received CRW 20 and who received other first aid.

Mortality

Mortality was reported in two studies [9,11] involving adult populations. After accounting for confounders, Harish [9] reported that CRW 20 was not associated with a reduced likelihood of mortality (OR 0.37, 95 % CI 0.12–1.13, $p = 0.08$). Wood [11] also reported similar findings (OR 0.67, 95 % CI 0.37–1.29, $p = 0.30$).

Discussion

This systematic review explored the effects of 20 mins of CRW < 3 h of a burn injury on patient outcomes. In this review of both paediatric and adult populations, approximately half of the patients received 20 mins of CRW < 3 h of thermal burn injury. Patients who received 20 mins of CRW < 3 h of burn injury had better outcomes compared to patients who did not. This was evidenced by a statistically significant reduction in burn depth; decreased likelihood of skin grafting; shorter re-epithelialisation time; and decreased likelihood of surgical intervention for wound management. The impacts of 20 mins of CRW < 3 h on pain, burn wound temperature, hospitalisation and HLOS, ICU admission and LOS, outpatient visits, and mortality are unclear.

Our findings of decreased risk of skin grafting, occasions of theatre and admission rates are consistent with many studies in the area of interest [38,41–44]. Time to re-epithelialisation, a critical goal of burn care to be minimised [44], was not found to be significantly different between groups by Griffin et al. [2]. However, when Griffin et al. concentrated only on those with longer re-epithelialisation times (> 10 days), CRW 20 was found to be significantly effective, similar to findings by Harish et al. [9,10]. It is widely accepted that time to re-epithelialisation can be significantly influenced by several factors, such as parental distress [45], pain [46], early debridements [47], dressing choice [48,49]. These factors may have influenced Griffin et al. [2] results.

Each of the studies reporting the risk of skin grafting [2,9,10,41] in relation to CRW 20, adjusted for burn depth and size in their models to account for the influence of burn severity bias. Even after adjustment, all studies consistently found the risk of skin grafting was significantly reduced in the CRW 20 group. Likewise, models adjusted for burn severity showed decreased risks of patients requiring hospital admission in CRW 20 patients.

Positive associations between burn depth wound and CRW 20 were found by both Harish and Griffin. [2,9,10]. The applied theory of Jackson's "zone of coagulation" means that burn depth is acutely dynamic especially within the three days of the burn injury. Future studies may consider measuring burn depth at multiple time points (i.e., before and after the application of the CRW 20 intervention, and three days after injury) to more accurately understand burn depth progression in relation to CRW 20.

It is important to note our research findings did differ from a recent publication by the International Liaison Committee on Resuscitation (ILCOR), who reviewed the dosage of CRW and found indecisive conclusions [50]. There are several potential reasons resulting in these differences. Firstly, the ILCOR publication used GRADE quality assessment, not the Downs and Black tool used in this study. The downgrading of good evidence in observational studies has been documented as a reason for not using GRADE for rating quality [51–53]. Secondly, objectives, inclusion and exclusion criteria differed between our study and the ILCOR review. For example, three papers, included in this study, were excluded from the ILCOR study based on methodology. The inclusion of these extra studies, combined with the different ratings of the quality of evidence, is likely to be the reason our review reached a different conclusion on the impact of 20 min of cool running water on burn patient outcomes.

The effect of CRW 20 on mortality, ICU admission and HLOS remains uncertain. These outcomes were only investigated in studies that included patients with severe burns [9,11,40]. Whilst all three studies found no associations between mortality and adequate first aid, mortality was so rare, especially in paediatric populations, only large associations could be found. Importantly, death following burn injury is heterogenous and multifactorial, it is not possible to fully risk adjust. It is possible, the effect of adequate first aid was confounded by other factors that were not investigated in the three studies. For example, inhalation injury is an independent predictor of mortality in people with flame burn injuries but was not included in the studies [54,55]. It is also possible that inhalation injury confounded ICU admission and ICU LOS findings, as intubation is often necessary to protect the airway and provide ventilatory support. Intubation necessitates an ICU admission, and the severity of inhalation injury will influence ventilatory requirements, which subsequently influence ICU LOS.

When reporting burn pain, Choi and colleagues cooled the burn for 20 min, measuring temperature and pain at five minute intervals [39]. However, inspection of photographs of the Burn Shield™ group showed that at least some of the hydrogel remained on the burn, possibly confounding this observation A study by Cuttle et al. [56] found a similar hydrogel dressing provided no benefit to healing (in terms of time to re-epithelialisation, scar thickness and cosmetic appearance), when compared with no CRW. Cho and Choi's [39] report of the impact of CRW 20 on skin temperature aligns to conclusions derived by Cuttle et al. [42] Cuttle et al. hypothesise this is due to continuous temperature and pressure of CRW reduces injury severity by dissipating thermal energy [42].

CRW first aid has now been shown to provide analgesia, reduce wound temperature, stabilise vasculature, and modulate the inflammatory response [42]. The plausible mechanisms of adequate first aid have mainly been studied in animal models. It is posited, albeit, with inconsistent findings, that a beneficial mechanism of adequate first aid is achieved through heat dissipation, oedema reduction, and/or histamine suppression [5]. In human models, cooling thermal burns with 16 °C water for 20 min led to decreased blistering, redness, and oedema of the affected skin [5]. These mechanisms could explain the benefits observed in improved re-epithelialisation and reduced skin grafting requirements, and additional surgical interventions for wound management.

Inadequate burns first aid is a common problem worldwide [36,57,58]. In our review, only one in two people received 20 min of CRW < 3 h of burn injury. The challenge of translating first aid evidence into clinical practice is multifactorial. Firstly, the uptake of first aid evidence into clinical practice guidelines varies across jurisdictions. In Australia and New Zealand, where the majority of the studies included in this review were conducted, 20 min of CRW were endorsed by the national burn care organisations as the recommended first aid practice [13]. In comparison, studies conducted in other countries including the United States do not endorse 20 min CRW in their burn first aid guidelines. The need to standardise burn first aid guidelines globally is evident. Furthermore, it is necessary to understand and address barriers that limit first aid efficacy. Although 20 min of CRW is recommended in Australia and New Zealand, guideline adherence remains an issue as only 35–68% of burn patients received adequate first aid [9–11]. There is also a knowledge deficit of adequate first aid for burn injuries in the general population [59–62], and patients from socioeconomically disadvantaged backgrounds, and remote locations are less likely to receive adequate first aid [17,19,44].

Cuttle et al. identified that full-thickness burns are unlikely to respond to adequate first aid [7]. However, this should not preclude the need to apply first aid. Burn injuries can have mixed depths. Full-thickness thermal burns, especially scalds and flame burns, can be interspersed with or surrounded by areas of superficial burns [63]. Adequate first aid can preserve the damaged but viable tissue prevents extension of full-thickness areas and minimising surgical requirements. Moreover, because of the evolving nature of burn wound progression, full-thickness burns are rarely manifested within the first 3 h of injury.

It is possible that prolonged cooling (> 20 min) increases the risk of hypothermia. Hypothermia in burn patients on admission to hospital is associated with increased mortality, longer HLOS and early sepsis [64,65]. Risk factors for hypothermia include the size of the burn, inhalation injury, pre-hospital intubation, higher Abbreviated Burn Severity Index, the number of resuscitation fluids and interventions such as the use of blankets [66,67]. To date, no associations have been found between burn wound cooling and hypothermia [66,67]. However, these studies had small sample populations, the length of time CRW was applied was not specified, and the effects of prolonged cooling were not investigated. Furthermore, in the context of Wood et. al findings, that there were no significant benefits from applying CRW to burns for more than 20 min [11], and its unknown effects on hypothermia risk, future first aid guidelines must emphasise not overcooling burn wounds for more than 20 min, especially in those most at risk. Until there is evidence, it would be ideal to stop CRW first aid in patients if severe hypothermia (< 35 C), is suspected, because of hypothermia's deleterious effects.

This paper was not able to compare CRW for 20 min with shorter time periods due to limited papers and heterogeneity. However both Wood et al. [11] and Griffin et al. [2], found linear associations with increasing duration up to 20 min with improved clinical outcomes.

The significant advantages of 20 min of CRW first aid are its accessibility, affordability, and simplicity. Products such as hydrogel dressings are not easily accessible and with reported compromise of clinical outcomes would not make it a reasonable option [42,68]. The initiation of CRW needs to be within three hours of injury to be effective, therefore bystanders or paramedics at the scene have a unique opportunity to positively influence patient outcomes through the application of CRW. This window of opportunity has often passed, by the time they arrive at the Emergency Department. One recent study [18] assessed the adequacy of first aid practice provided by healthcare workers in paediatric burn management. The authors found a higher percentage of inadequate burn first aid was provided by paramedics (25 %) and GPs (24.2 %) compared with hospitals (56.3–76 %). However it is impracticable to expect first aiders to assess the depth of a burn at the scene of an injury, nor overly complicate the intervention according to depth severity.

There is considerable evidence to support 20 min of CRW within three hours of injury as the gold standard of adequate first aid for thermal burns. The international burns community must work across inter-professional boundaries with pre-hospital, emergency and community stakeholder groups and organisations to provide clear and unified first aid messaging. Whilst the most practical way to achieve CRW 20 is to use tap water [13] or a bucket of water if tap water is not feasible [69], in many prehospital environments access to clean water may be difficult. Researchers have identified that people who are injured in rural or remote settings [17,19] are at higher risk of receiving inadequate first aid. Understanding the unique contextual characteristics of challenging pre-hospital environments, such as remote areas and/or bushfire scenarios, could help with the design of local guidelines that can address unique contextual characteristics, increasing the likelihood that adequate first aid will be provided.

Strengths and limitations of the review

Results from this review have important limitations. First, there is bias inherent with observational studies such as selection bias, inaccurate or missing data, and confounders. Most studies [2,9–11,40] utilised data from burns registries wherein we can presume accuracy, completeness, and generalisability [70]. Second, there is a lack of geographical diversity of studies as they mainly represent the Australian and New Zealander population; thus, there is justification for studies to be done outside these countries. Third, there could be English language bias in the context of the inclusion criterion. Consequently, a non-English language study [35] was excluded but the reviewers believe that the exclusion of one study is unlikely to change the review findings. Fourth, reporting bias is plausible given the exclusion of low-quality studies [36–38]. This decision was justified to improve our confidence that the evidence stems from good quality studies. Fifth, this paper has not tested 20 min of CRW against shorted time periods, instead compares CRW20 with all other methods, potentially compromising validity of conclusions. Finally, data from one large Australian cohort study exploring the efficacy of CRW in adult burn patients could not be included for metanalysis due to the categorisation of the timing of burn first aid [11]. Nonetheless, this review was conducted by following a registered protocol and adopting a systematic approach without the restriction of publication year and the inclusion of a methodological quality review using the Downs and Black tool, adding to the strength of the review.

Implications for research and practice

With the clear benefits of 20 min of CRW burn first aid, international burn care organisations and other stakeholder groups must develop consensus regarding the evidence-based burn first aid. Clear consistent messaging will facilitate adequate first aid and subsequently minimise the burden of injury.

It is necessary to identify and address barriers that inhibit, and enablers that facilitate, the translation of first aid evidence into clinical practice. The use of implementation science frameworks could help to understand the unique contextual characteristics of pre-hospital and emergency environments, ultimately developing appropriate, acceptable and sustainable implementation strategies.

Conclusion

This systematic review explored the impact of 20 min of CRW first aid on patient outcomes. The review demonstrated that 20 min of CRW first aid was associated with substantial improvements to patient morbidity, including significant reductions in burn wound temperature and depth, hospital admissions, skin grafting or other surgical interventions requirements and infection rates. Moreover, from a practical sense, CRW first aid is mostly accessible, simple and can be applied by conscious patients, bystanders and pre-hospital responders. There is considerable evidence to recommend 20 min of CRW within three hours of injury as the gold standard of first aid for thermal burns. International consensus is required.

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Conflict of interest

We have no conflicts of interest to declare.

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