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Barriers and co-designed strategies for the implementation of negative pressure wound therapy in acute pediatric burn care in Australia: A mixed method study

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ABSTRACT

Purpose: Pediatric burn injuries are a global clinical issue causing significant morbidity. Early adjunctive negative pressure wound therapy improves re-epithelialization rates in children with burns, yet adoption in acute burn care is inconsistent. This investigation aimed to determine barriers to the implementation of adjunctive negative pressure wound therapy for the acute management of pediatric burns and co-design targeted implementation strategies.

Methods: A sequential mixed methods design was used to explore barriers to adjunctive negative pressure wound therapy implementation in acute pediatric burn care. An online questionnaire was disseminated to healthcare professionals within four major Australian pediatric hospitals, each with a dedicated burns service. Barriers were coded according to the Consolidated Framework for Implementation Research (CFIR). Semi-structured interviews with senior clinicians tailored implementation strategies to local contexts. A stakeholder consensus meeting consolidated implementation strategies and local processes.

Results: Sixty-three healthcare professionals participated in the questionnaire, and semi-structured interviews involved nine senior burn clinicians. We identified eight implementation barriers across all five CFIR domains then co-designed targeted strategies to address identified barriers. Barriers included lack of available resources, limited access to knowledge and information, individual stage of change, patient needs and resources, limited knowledge and beliefs about the intervention, lack of external policies, intervention complexity, and poor implementation planning.

Abbreviations: ANZCTR, Australian and New Zealand Clinical Trials Registry; AUD, Australian Dollars; BRANZ, Burns Registry of Australian and New Zealand; CFIR, Consolidated Framework for Implementation Research; CHQHHS, Children's Health Queensland Hospital and Health Service; CI, Confidence Intervals; ED, Emergency Departments; ERIC, Expert Recommendations for Implementing Change; GCP, Good Clinical Practice; HREC, Human Research Ethics Committee; NHMRC, National Health and Medical Research Council; NPWT, Negative Pressure Wound Therapy; RCT, Randomized Controlled Trial; REDCap, Research Electronic Data Capture; TBSA, Total Body Surface Area; USA, United States of America; VSM, Victorian Specific Module; WASM, Western Australian Specific Module.

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Conclusion: Multiple contextual factors affect negative pressure wound therapy uptake in acute pediatric burn settings. Results will inform a multi-state stepped-wedge cluster randomized controlled trial. Additional resources, education, training, updated policies, and guidelines are required for successful implementation. It is anticipated that adjunctive negative pressure wound therapy, in conjunction with tailored implementation strategies, will enhance adoption and sustainability.

Trial registration: Australian and New Zealand Clinical Trials Registry: ACTRN12622000166774. Registered 1 February 2022.

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Introduction

Burns rank among the top five most common causes of non-fatal childhood injuries worldwide (Peck, 2011; World Health Organization, 2018). In Australia, thousands of children present to Emergency Departments (EDs) each year with burn injuries that require acute management and definitive wound care (Burns Registry of Australia and New Zealand, 2022). Accidental scald and contact injuries are the most frequent causes of pediatric burns, often resulting from hot liquid and food spills and contact with hot surfaces (Burns Registry of Australia and New Zealand, 2022). A considerable proportion of childhood burn injuries are small to medium in size: the Burns Registry of Australia and New Zealand (BRANZ) reports nearly 90% of pediatric burn injuries were <10% total body surface area (TBSA). Burns <5% TBSA were recorded in 62% of pediatric cases (Burns Registry of Australia and New Zealand, 2022). While the majority of pediatric burns seen in Australia are relatively small, these injuries demand carefully planned treatment to reduce the risk of infection and improve time to re-epithelialization (Greenhalgh, 2019). Infection and scarring remain common problems for pediatric patients, even in those with smaller burns, despite advances in knowledge and treatment including evidence based first aid (Griffin et al., 2019), early debridement (Griffin et al., 2021), burn pain (Holbert et al., 2021), and silver-impregnated dressings (Nunez Lopez et al., 2017; Wang et al., 2018). Previous studies have shown the strongest predictor of scarring in pediatric burn patients is time to healing, defined as 95% burn wound re-epithelialization (Chipp et al., 2017). Burn wounds taking longer than 14–17 days to re-epithelialize are at significantly increased risk of hypertrophic scarring (Cubison et al., 2006), which affects between 16% and 35% of children who sustain burns [(Chipp et al., 2017) and (Cubison et al., 2006) respectively]. Therefore, a critical goal of burn care is to achieve more rapid re-epithelialization to reduce the impact of scarring.

Negative pressure wound therapy (NPWT) is a wound dressing system that provides sub-atmospheric pressure within a closed dressing. It is associated with improved patient outcomes in a wide range of complex chronic and acute wounds (Anghel & Kim, 2016; Kantak et al., 2017; Krug et al., 2011). Proposed mechanisms and benefits of NPWT include the induction of macrodeformation (i.e., wound contraction), microdeformation (i.e., tissue and dressing interactions on a microscopic level), stimulation of angiogenesis around the wound bed, promotion of granulation tissue, improved microvascular perfusion, oedema control, wound exudate control, and reduced risk of infection via decreasing bacterial loads (Borgquist et al., 2010; Daigle et al., 2013; Lalezari et al., 2017). There is strong evidence from experimental (Morykwas et al., 1999), randomized controlled trials (RCTs) (Frear et al., 2020; Zheng et al., 2019), and prospective cohort studies (Chen et al., 2010; Haslik et al., 2004; Kamolz et al., 2004; Molnar et al., 2004; Schrank et al., 2004) to support the benefits of adjunctive NPWT in acute burn care. Compared to standard silver-impregnated dressings alone, early adjunctive NPWT (i.e., applied over standard silver dressings) results in significant improvements in time to re-epithelialization in children with burns, and decreases dressing change

requirements and referrals for scar management (Frear et al., 2020). Early adjunctive treatment in this context refers to NPWT application within the first 48-h post-burn. Adjunctive NPWT applied within the first 48 h of the initial burn aims to reduce burn wound progression and the development of deeper injuries, as vascular compromise can worsen for up to 48 h post-burn (Krug et al., 2011).

Adjunctive NPWT can also offer a cost-effective solution for the acute treatment of pediatric burns. One recent investigation evaluated the healthcare costs of adjunctive NPWT in small-area pediatric burns, and found the mean total cost was \$765 AUD less per person for those treated with adjunctive NPWT compared to standard silver dressings alone [\$904 AUD (95% CI 671–1235) compared to \$1669 AUD (95% CI 659–3269)] (Frear et al., 2021). NPWT has been used for decades as a non-invasive treatment to bolster skin grafts in burn and non-burn patients to reduce shearing forces and promote graft take (Blackburn 2nd et al., 1998; Fischer et al., 2016; Jiang et al., 2021; Singh et al., 2021; Teng, 2016). Whilst some specialist burn services make selected or ad hoc use of adjunctive NPWT in children during the acute burn phase (i.e., within 48-h post-burn or after initial wound debridement), a wider and more systematic application informed by evidence-based guidelines is lacking. Any intervention which reliably improves time to re-epithelialization in pediatric burn patients warrants further consideration for implementation into recommended best practice.

Within healthcare research, considerable time lags from the identification of evidence-based treatments to their widespread implementation into clinical practice are well recognized (Morris et al., 2011; Munro & Savel, 2016). This investigation aimed to identify barriers to the application and use of adjunctive NPWT for the acute management of pediatric burn injuries in a hospital setting and co-design implementation strategies to address identified barriers. Co-design in healthcare research is a collaborative and iterative process aiming to bring together relevant stakeholders to address implementation issues, develop targeted solutions, and improve patient outcomes. Our co-design process targeted experienced burn surgeons, burn nurses and nurse practitioners, burn allied health staff, ED doctors, ED nurses, and ED nurse practitioners with a focus on identification of NPWT implementation barriers within their local hospital and health service. In this paper, we discuss themes and strategies relating to barriers to the implementation of adjunctive NPWT into acute burn care at four pediatric hospitals with dedicated burns centers.

Aim and objectives

This investigation aimed to determine barriers to the implementation of adjunctive NPWT for the acute management of pediatric burn injuries and co-design targeted implementation strategies. To achieve this aim, the following research objectives were completed:

- I. Determine barriers to acute adjunctive NPWT implementation via a purpose-built electronic questionnaire and semi-structured interviews with relevant clinical stakeholders.
- II. Co-design tailored strategies to overcome the identified barriers in acute adjunctive NPWT implementation. These strategies will

serve as the foundation for an NPWT implementation toolkit specifically designed for the acute care of pediatric burn patients.

The co-designed implementation strategies will inform the “Implementation of Negative Pressure for acute Paediatric burns” (INPREP) toolkit. The INPREP toolkit will subsequently undergo testing in a type III hybrid implementation–effectiveness study, utilizing a stepped-wedge cluster randomized controlled trial (SW-RCT) (Curran et al., 2012; Hemming et al., 2015; Hemming et al., 2019; Hemming & Taljaard, 2020) design with results to be reported separately.

Methods

Study design

A sequential mixed methods qualitative approach was used to address the study aims comprising: i) electronic questionnaires, ii) semi-structured interviews, and iii) a stakeholder consensus meeting. Procedures for each are outlined below.

Study setting

Participating sites were distributed across four tertiary children's hospitals, each the nominated statewide burns referral center for their respective Australian states (New South Wales, Queensland, Victoria, and Western Australia).

Participants

Participants recruited for this investigation comprised of healthcare professionals involved in the acute treatment and management of pediatric burn injuries across four participating pediatric hospitals. Participants included medical consultants, junior medical officers, registered nurses, clinical nurse consultants, nurse practitioners, and allied health staff from burns and ED departments across the four participating sites. As aforementioned, parents and caregivers of pediatric burn patients who had received adjunctive NPWT within the last 12-months were also invited to participate in a semi-structured interview.

Procedures

Electronic questionnaires

A purpose-built electronic questionnaire was developed and managed using REDCap (Research Electronic Data Capture, Vanderbilt, USA, hosted at Griffith University). REDCap is a secure, web-based software platform designed to support data capture for research studies (Harris et al., 2009; Harris et al., 2019). The questionnaire was disseminated to healthcare professionals involved in the acute treatment of burn injuries at the four participating hospitals. The questionnaire focused on engagement with clinical stakeholders in the identification, specification, and prioritization of NPWT implementation barriers. The questionnaire contained three pediatric burn clinical case scenarios, and asked participants to record perceived barriers to the application and use of early adjunctive NPWT for that specific patient (via a free text-response box in the online questionnaire). The three clinical case scenarios were developed by a multidisciplinary team of burns experts and piloted on 12 healthcare professionals and burns researchers. The scenarios aimed to capture a variety of clinical and contextual variables, which cover the scope of projected future adjunctive use of NPWT in acute pediatric burn care. Using a free text response box, participants were also prompted to list barriers perceived to impact their ability to deliver optimal, evidence-based acute pediatric burn care at their local hospital and health service.

Electronic questionnaire data analysis

Deductive coding based on the Consolidated Framework for Implementation Research (CFIR) was used to evaluate free text data on barriers to NPWT implementation gathered from the electronic REDCap questionnaires (Damschroder et al., 2009). The CFIR is a determinant framework and uses five domains (inner setting, outer setting, intervention characteristics, characteristics of individuals, and planning) to understand barriers to implementation in complex systems (Kirk et al., 2016). The CFIR was used to develop a comprehensive understanding of the complex contextual characteristics of acute burn care (EDs/burn centers) across multiple Australian states and contexts so that early adjunctive NPWT implementation strategies can be better targeted. Identified CFIR barriers from questionnaire data were used to generate matched implementation strategies using the Expert Recommendations for Implementing Change (ERIC) matching tool (Powell et al., 2015).

Semi-structured interviews

Semi-structured interviews were then conducted with senior clinicians at each participating hospital, using interview questions derived from the electronic questionnaire data; The CFIR Interview Tool Guide (*Consolidated Framework for Implementation Research Interview Guide Tool, n.d.*) was used to generate interview questions based on identified CFIR domains and constructs from questionnaire data. Interview questions were open-ended and designed to generate detailed responses from clinicians. Semi-structured interviews aimed to determine clinicians' level of agreement and consensus with adjunctive NPWT implementation barriers identified in the initial questionnaire, and to further develop the matched implementation strategies tailored to local needs. In addition, these interviews examined for consensus or divergence of clinician opinion on other key clinical aspects of adjunctive NPWT use in acute pediatric burn care. Site principal investigators identified senior clinicians within their local hospitals. Potential participants were emailed information about the research and invited to partake in a semi-structured interview (hosted online via Microsoft Teams or in-person). Interviews were recorded and transcribed verbatim. To gain relevant consumer feedback and involvement, two semi-structured telephone interviews were conducted with parents and caregivers of pediatric burn patients who had received adjunctive NPWT as part of their acute burn treatment within the last 12-months. Interviews were conducted with one parent-caregiver of a child treated as an inpatient receiving adjunctive NPWT, and one parent-caregiver of a pediatric patient treated as an outpatient receiving adjunctive NPWT.

Semi structured interview data analysis

Semi-structured interview data were analyzed using framework-guided rapid analysis methods (Gale et al., 2019; Nevedal et al., 2021). Verbatim transcripts were summarized using a structured template based on the five CFIR domains and matched ERIC strategies, and then consolidated into matrices with actionable and tailored recommendations for adjunctive NPWT implementation into acute burn care based on hospital sites. This allowed for group comparisons of consolidated data across the four sites to determine core components and themes, and components that need to be tailored to local contexts.

Consensus meeting

Following the dissemination of electronic questionnaires and semi-structured interviews with burn and ED clinicians across the four participating sites, a consensus meeting was held to present questionnaire and interview data back to the consensus group – to ensure relevant stakeholders at participating hospitals were satisfied with the tailored implementation strategies. The consensus meeting was conducted using informal consensus development panel methods (Waggoner et al., 2016). An online meeting was held via Microsoft Teams in April 2023. The stakeholder consensus group comprised of experts in burn

care, chief investigators, and site principal investigators from New South Wales, Queensland, Victoria, and Western Australia. On meeting commencement, stakeholders were reintroduced to the aims of the consensus meeting (i.e., gaining final consensus tailored implementation strategies). Questionnaire and interview data were presented and whole group discussions occurred until final consensus was reached. Following the consensus meeting, detailed minutes of the discussions were documented and disseminated out to the consensus group participants (see Fig. 1.).

Ethics approval and consent to participate

Human Research Ethics Committee (HREC) approval has been obtained for this investigation (HREC/21/QCHQ/81002) from Children's Health Queensland Hospital and Health Service HREC. This research was also approved by the Griffith University Human Research Ethics Committee (GU Ref No: 2022/157). Written informed consent was obtained from all participants following detailed explanation of the research before semi-structured interviews were conducted. For online questionnaire participation, implied consent was used following provision of the purpose of the questionnaire, what will be asked, how long it will take, how the data will be used and stored, and potential risks or benefits of participation.

Results

Results presented below are an integration of findings from electronic questionnaires, semi-structured interviews, and stakeholder consensus meeting data.

CFIR domains and constructs – Barriers to NPWT implementation

The following barriers regarding the implementation of NPWT for acute pediatric burn injuries were generated from $N = 63$ healthcare professionals who responded to the electronic REDCap questionnaire:

$n = 18$ from New South Wales, $n = 20$ from Queensland, $n = 16$ from Victoria, and $n = 9$ from Western Australia. Participant's professional streams are presented below in Table 1.

Eight barriers (CFIR constructs) covering five CFIR domains were identified:

Inner setting

Lack of available resources. Resources (e.g., operating theatre access, bed availability, staff availability, time constraints, and number of available NPWT devices) are insufficient to support implementation of adjunctive NPWT into acute pediatric burn care. Lack of available resources as a barrier to adjunctive NPWT implementation was reported across all four participating hospitals.

"Sometimes in peak burn seasons (e.g., school holidays), we run out of NPWT pumps, which prevents us from being able to apply NPWT..." (Participant 23).

"Time, staff, non-specialty staff, high ED turnover with an already significant learning need, storage of supply, emergent nature of department requiring nurses to be pulled at a moment's notice" (Participant 34).

"...if operating theatre not available, attempting a NPWT dressing in a burn of this size on a child of this age is going to be very difficult in an ED setting without a GA so may be more prudent to opt for non-NPWT options." (Participant 55).

Lacking access to knowledge and information. Stakeholders lack adequate access to digestible information and knowledge about adjunctive NPWT and how to best incorporate adjunctive NPWT into acute burn care at their hospital and health service (e.g., lack of clinical guidelines surrounding early adjunctive NPWT use, lack of NPWT troubleshooting

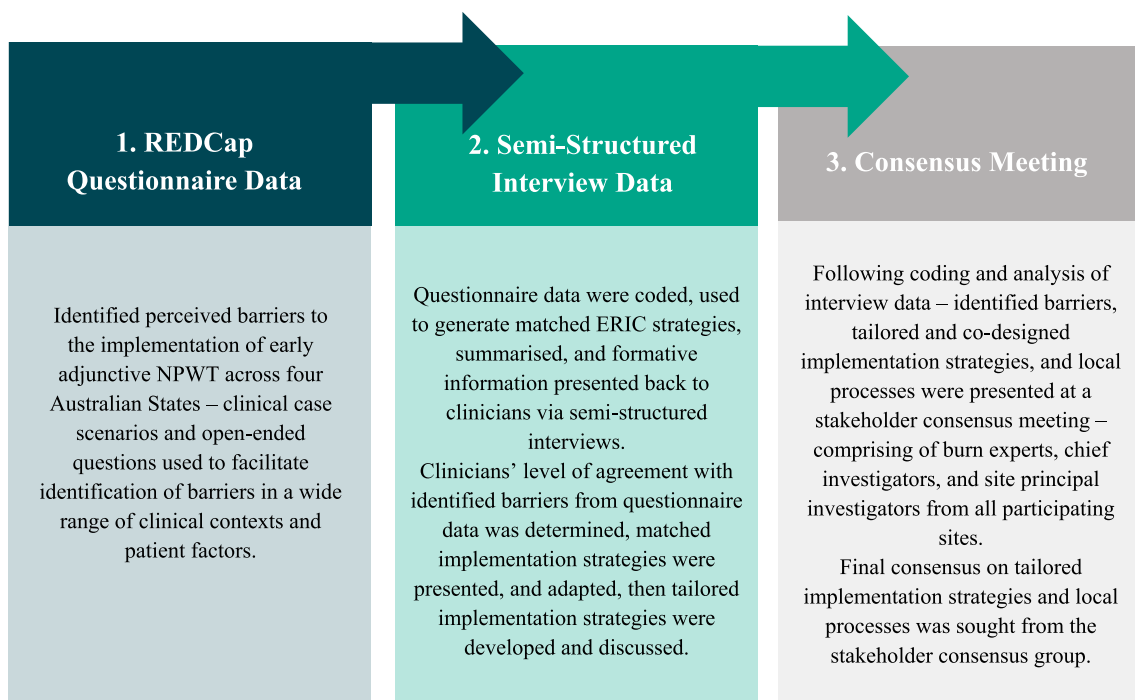


Fig. 1. Data Synthesis and Implementation Strategy Development. Generation of initial barrier data perceived to impact the implementation of adjunctive NPWT into acute pediatric burn care across participating sites, generation of matched implementation strategies (non-tailored), tailoring of implementation strategies, and consolidation and consensus of strategies and processes to form the evidence-based intervention and INPREP toolkit.

Table 1
Participant professional stream.

Professional Stream	N %
Nursing (ED)	10 (16)
Nursing (Burns)	15 (24)
Medical (ED)	13 (21)
Medical (Burns/Surgery)	19 (30)
Burns Physiotherapist/Occupational Therapist	6 (10)

resources for clinicians and families; lack of trained and experienced staff).

“Not all [Participating Hospital Site] ED Nursing staff are proficient in the application of NPWT dressings. Currently ED would rely on Burns Nursing staff for support and education” (Participant 18).

“No idea what NPWT is” (Participant 42).

“I’ve never heard of NPWT” (Participant 44).

Characteristics of individuals

Individual stage of change. Stakeholders acknowledged a lack of skills or enthusiasm about using NPWT in a sustained way (e.g., clinicians view it as extra work).

“Nursing concerns over additional time and resources to both apply and monitor NPWT as well as patient discomfort” (Participant 10).

“A VAC dressing is time consuming for an ED Department – takes regular skill from the user to apply” (Participant 35).

“...Concerned burden of increased workload of new dressings and associated staffing and sedation will fall onto the emergency department” (Participant 30).

Knowledge & beliefs about the intervention. Clinical stakeholders have negative attitudes toward early adjunctive NPWT, place low value on implementing adjunctive NPWT into acute pediatric burn care, and/or are not familiar with current evidence supporting early adjunctive NPWT (e.g., clinicians are unsure or skeptical about the benefits of adjunctive NPWT compared to standard care and other adjunctive treatments).

“Logistical barriers – dressing takes longer to place, more difficult for parents to manage at home. Clinician preference – I am interested in being involved in trials for NPWT and partial thickness burns but I am not aware of enough evidence to change my standard practice, particularly for burns away from limbs” (Participant 57).

“There is evidence for improved outcomes with the application of Biobrane within 24-hours of mid-dermal burns” (Participant 16).

“Want to know that significant improvement in wound healing timeframes to make a difference and justify use and change in practice...” (Participant 19).

“Unclear evidence for better outcome in this age group” [(Participant 50)]

Outer setting

Patient needs and resources. Patient needs, including barriers and enablers to meet those needs, are not accurately known (e.g., clinicians suspect NPWT will cause issues with mobilization and walking when applied to foot burns, cause pain and discomfort for pediatric patients, and place an additional burden on parents and caregivers).

“...Parents already have a lot of things going on with an active toddler they are less likely to want to use it...” (Participant 3).

“...Does standard Acticoat dressing provide similar healing results and timeframes, less costly, and easier for patient and family to manage?” (Participant 19).

“Patient reluctance to carry the machine, restriction on schooling, and whether parents are able to take time off to care for [the] patient” (Participant 32).

“Age – would unlikely tolerate the pump device. Parents – they would find keeping the kid away from the pump difficult” (Participant 49).

Lack of external policy & incentives. External policies, regulations, mandates, recommendations, or guidelines do not exist to implement the innovation into acute burn care (e.g., lack of hospital policies surrounding use of adjunctive NPWT for acute pediatric burn management, clinician do not view early adjunctive NPWT as standard treatment for acute burn injuries).

“Lack of current policy for NPWT, lack of training, lack of availability” (Participant 12).

“...decision makers need to update their approaches to burn wound management to prioritize early(ier) debridement AND primary application of NPWT – new dressing skills need to be learned by a broader population of staff – health service has to increase financial outlay at the front end of patient care with the prospect (but not guarantee) of a later saving” (Participant 55).

Intervention characteristics

Complexity. Clinical stakeholders hold the belief that NPWT is complex, based on their perception of duration, scope, disruptiveness, intricacy, and the number of steps involved in its implementation. For instance, clinicians commonly perceive adjunctive NPWT as challenging and time consuming to apply, anticipating an increased need for analgesia and sedation for patients that receive early adjunctive NPWT in comparison to standard care.

“Intricacy of application, benefit versus standard dressing, obtaining and maintaining a seal, requirement for analgesia and sedation” (Participant 19).

“Application is already difficult on tiny toes and feet. I honestly cannot even imagine how negative pressure would work in this way. NPWT would be better suited to a flat surface burn in my experience. Also, you can’t even get a sats probe on a 2-year-old without them having a tantrum so I don’t think a machine connected to their feet would stay on for very long” (Participant 27).

“...Unless staff in ED get regular support from these services, we cannot take on a more complicated dressing technique such as NPWT” (Participant 35).

Process

Planning. A structured scheme or sequence of tasks necessary to implement adjunctive NPWT into acute burn care has yet to be developed. This is exemplified by the absence of adjunctive NPWT application within the ED processes of certain participating hospitals.

“NPWT not historically an ED treatment. No exposure to education in this space. No idea of how to access NPWT resources or experienced staff” (Participant 42).

Implementation strategies – Matched ERIC strategies and tailored strategies

The following implementation strategies presented below in Fig. 2 were selected from the CFIR-ERIC Barrier Buster V0.53 tool (CFIR-ERIC Implementation Strategy Matching Tool, n.d.) to address identified barriers and challenges to adjunctive NPWT implementation into acute burn care. This tool generates and selects implementation strategies using identified CFIR constructs. Semi-structured interviews were conducted with nine clinicians across New South Wales, Queensland, Victoria, and Western Australia, which were then used to tailor the generated CFIR-ERIC matched implementation strategies to local contexts. Interviews aimed to extrapolate details of identified barriers to define the INPREP toolkit and matched implementation strategies for each participating site. Table 2 below presents the initial matched implementation strategies (generic and non-tailored) and the tailored implementation strategies, which incorporated data and feedback from semi-structured clinician interviews.

Table 2. Initial CFIR-ERIC matched implementation strategies were refined and tailored to local needs and contexts during semi-structured interviews with clinicians, and then consolidated in a consensus group meeting with clinical investigators.

Discussion

There is a substantial and growing volume of evidence to support the use of NPWT for the treatment of acute and chronic complex wounds (Anghel & Kim, 2016; Bruwer et al., 2021; Kantak et al., 2017; Krug et al., 2011). A prospective randomized controlled trial conducted in pediatric burn patients demonstrated a 22% reduction in time to re-epithelialization in children who received NPWT compared to standard care alone (Frear et al., 2020). However, it is important to note that demonstrating the effectiveness of an intervention does not equate to its implementation and translation into clinical practice (Green et al., 2009). Research investigating the implementation of evidence-based practices in hospital and health services have indicated that even after an intervention has been proven effective – less than half of them are adopted and incorporated as part of standard clinical care (Bauer & Kirchner, 2020). Furthermore, it takes an average of 17–20 years for evidence-based practices and interventions to be implemented into clinical practice (Bauer & Kirchner, 2020; Morris et al., 2011; Munro & Savel, 2016). Barriers to research translation and implementation often lie in the clinical context, and the challenges posed by the environments in which the intervention will be used, rather than a lack of supporting evidence for the intervention (Bauer & Kirchner, 2020).

Therefore, the purpose of this research was to explore and describe barriers to the implementation of adjunctive NPWT for incorporation into acute pediatric burn care. This investigation identified eight barriers to the implementation of adjunctive NPWT into acute pediatric burn care covering five CFIR domains. In addition, this study has co-designed tailored strategies to address identified barriers to adjunctive NPWT implementation including the following: development of a NPWT implementation toolkit (INPREP toolkit) tailored to participating site’s local hospital guidelines and standards of care for the acute management of pediatric burn injuries; development and distribution of a

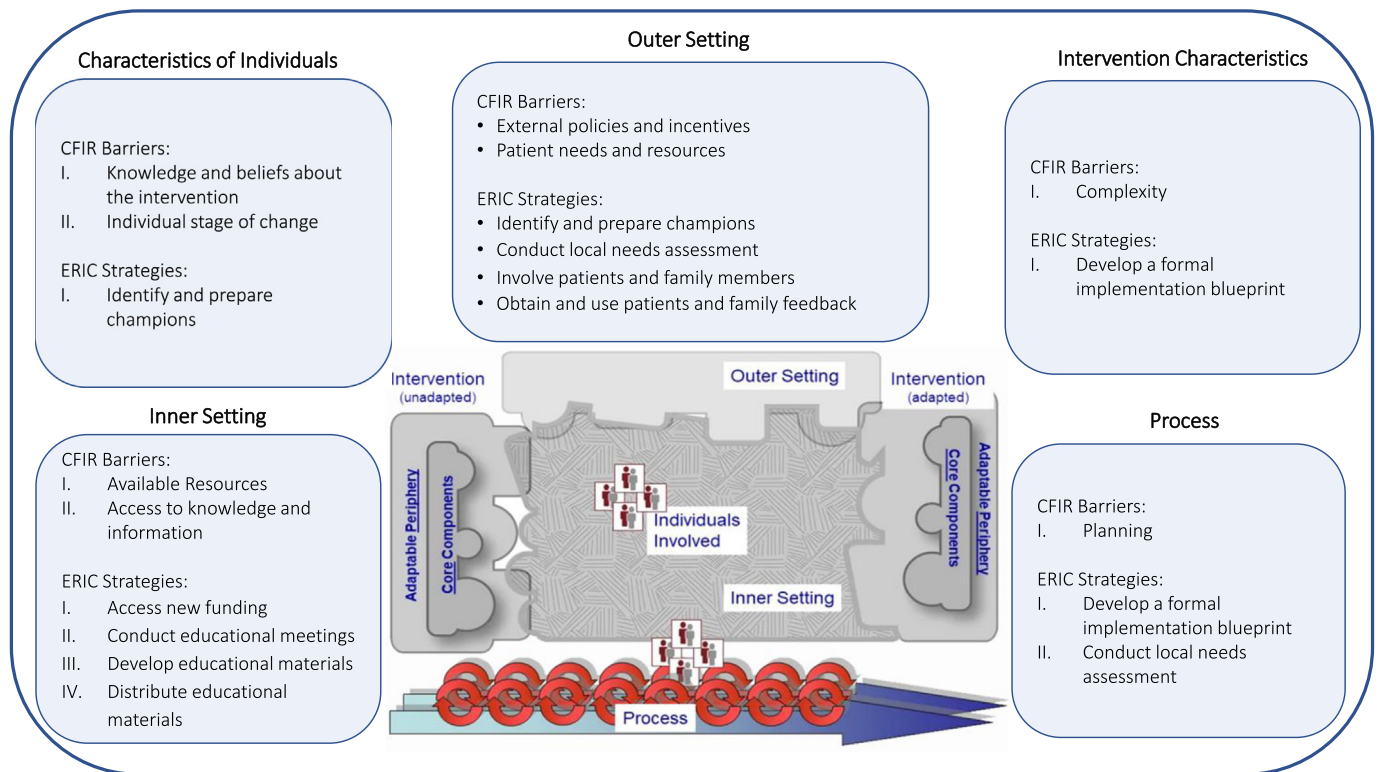


Fig. 2. CFIR Barriers & Matched ERIC Implementation Strategies. CFIR domains and implementation barriers (constructs) that emerged from online questionnaire data, the associated matched ERIC strategies, and their influence on implementation into clinical practice. Fig. 2 has been adapted from Damschroder et al. Figure: Major Domains of the CFIR (Damschroder et al., 2009).

Table 2
Tailored Implementation Strategies.

Matched ERIC Implementation Strategies	Tailored NPWT Implementation Strategies
I. Identify and prepare champions	<ul style="list-style-type: none"> In-person site visits from the coordinating principal investigator were performed to promote engagement of local opinion leaders Identification of NPWT champion/s at each participating site
II. Conduct local needs assessment	<ul style="list-style-type: none"> Conducted local needs assessment to determine areas of concern relating to NPWT implementation and use at their local hospital and health service. This was performed via semi-structured interviews with clinical stakeholders across participating sites Semi-structured interviews were conducted with ED and burns clinicians from the four participating hospitals to gain further information on needed resources for NPWT implementation, how these should be delivered, clinical consensus discussions surrounding exclusion criteria for NPWT, and how best to provide continued education and training at each hospital. Feedback from these interviews were used to develop and tailor resources and material to local needs
III. Involve patients, consumers, and family members	<ul style="list-style-type: none"> Semi-structured interviews were conducted with parents and caregivers of pediatric burn patients who received NPWT within the last 12 months
IV. Obtain and use patients, consumers, and family feedback	<ul style="list-style-type: none"> Feedback from parents and caregivers regarding their experiences with NPWT as part of their child's treatment acute burn treatment were used to develop additional resources for parents and caregivers.
V. Develop a formal implementation blueprint	<ul style="list-style-type: none"> Development and tailoring of the INPREP toolkit to local hospital guidelines and standards of care for the acute management of pediatric burn injuries Development of a NPWT Decision Pathway Poster – targeted for clinicians at participating hospitals Tailoring of implementation strategies to local contexts, and the development of a NPWT implementation protocol Development of troubleshooting resources for parents and caregivers of children who receive NPWT – based on feedback from semi-structured interviews with families
VI. Access new funding	<ul style="list-style-type: none"> Research funding obtained to employ researchers and clinical facilitators within New South Wales, Western Australia, Queensland, and Victoria to assist with implementation of the INPREP toolkit and data collection within the SW-RCT
VII. Conduct educational meetings	<ul style="list-style-type: none"> Regular education meetings and in-person NPWT training to be provided to all sites – a senior burns nurse practitioner will travel to sites to provide in-person, in-service education
VIII. Develop educational materials	<ul style="list-style-type: none"> Development of educational resources including a NPWT clinician handout document, which contains a QR code linking to a detailed instructional video demonstrating NPWT application using two different NPWT devices Development and dissemination of electronic educational material to relevant clinical stakeholders
IX. Conduct local needs assessment	<ul style="list-style-type: none"> Conducted local needs assessment to determine areas of concern relating to NPWT use and management from a parent-caregiver perspective. This was performed via semi-structured interviews with parents-caregivers of children who received NPWT as part of their acute burn treatment

suite of educational material and resources (i.e., NPWT education and troubleshooting guide for caregivers, and a NPWT clinician handout document containing a QR code linking to a detailed instructional video demonstrating adjunctive NPWT application using two different NPWT devices); established and conducted regular educational meetings; and identified and prepared NPWT champions at participating sites. These strategies will also address ambiguities regarding supporting evidence and the relative advantage of adjunctive NPWT for acute burn injuries.

Resource availability, or lack thereof, was identified as a significant barrier to the implementation of adjunctive NPWT into acute burn care at participating hospitals. This was one of the most commonly reported barriers in online questionnaire data across participating sites and is consistent with previous reported studies as a significant barrier to implementation in healthcare settings (Jabbour et al., 2018; Silver et al., 2023). Limited resources include access to operating theatres, staff time constraints (within EDs, Wards, and Burns Outpatient Departments), number of hospital beds, and number of NPWT devices available. Additional funding has been obtained to help address this barrier, however the power to influence some of these resource limitations are outside the scope of this investigation. Whilst initial staff time and expenses might increase with the implementation of adjunctive NPWT for acute pediatric burns, the potential reduction in time to re-epithelialization and subsequent reduction in total number of dressings changes required for children, as well as reducing referrals to scar managements and skin grafting requirements, might reduce overall hospital costs and staff time constraints down the line.

Lack of, or limited access to, knowledge and information regarding NPWT use was also a common reported barrier. This CFIR construct is often described as a significant barrier in implementation science research – however this barrier is seldom reported in studies assessing NPWT use in burn wound care (Frear et al., 2020). Matched and tailored implementation strategies to address this barrier include the provision

of in-person, in-service education and training sessions to improve clinical competence and understanding of the benefits of acute adjunctive NPWT for burn injuries. Education and training sessions will encompass practical exercises in NPWT application, how to achieve a seal in different anatomical regions, troubleshooting for different NPWT devices, and summaries of NPWT evidence. Even in clinical settings where NPWT is part of routine standard care, adult patients receiving NPWT for complex wound management reported perceived inconsistencies in hospital staff's skills and knowledge of NPWT (Apelqvist et al., 2017; Bolas & Holloway, 2012). In the 2012 investigation, authors emphasized the need for continued professional development and education in NPWT skills.

Patient needs and resources was another implementation barrier to emerge from the data. Clinicians anticipate that NPWT will cause issues with mobilization and walking when applied to foot burns, cause additional pain and discomfort for patients, require additional analgesia and sedation for patients, and place high levels of treatment burden on patients and their families. This is consistent with broader literature.

In a sample of $N = 25$ adult inpatients undergoing NPWT for non-burn wounds, patients reported increased pain with the treatment (Apostoli & Caula, 2008). However, pain and discomfort associated with wound care treatment in general is a well-documented issue, with other studies proposing that pain levels experienced with NPWT are comparable to those of alternative treatments and standard care (Moffatt et al., 2011; Upton & Andrews, 2015). In a qualitative investigation of $N = 50$ adult patients receiving NPWT for chronic or surgical wound management, a significant proportion of patients (94%) reported a beneficial effect of NPWT on their wounds, and 88% had an overall positive experience. Despite these positive aspects, participants also highlighted several difficulties related to NPWT, including limitations in movement, noise-related burdens, and disruptions to sleep (Upton & Andrews, 2013).

In a recent randomized trial investigating adjunctive NPWT for acute pediatric burns – children treated with NPWT healed significantly faster compared to children who received standard care, but significant associated treatment burden related to NPWT use was identified (Frear et al., 2020). Parents and caregivers of burn patients (aged <8 years) treated with adjunctive NPWT reported movement and at-home management of the device to be more difficult in comparison to the standard care group. Ten families (out of $n = 47$ in the intervention arm) in the aforementioned randomized trial requested premature removal and discontinuation of adjunctive NPWT due to issues with alarms (e.g., loss of pressure, air leaks in dressing, device charging abnormalities), difficulties attending school with the device, and the physical burden of carrying the NPWT pump (Frear et al., 2020).

Following the conclusion of this aforementioned trial, an informal telephone interview was conducted with approximately 60% of parents and caregivers of children in the adjunctive NPWT arm (including families who requested premature NPWT removal). When parents and caregivers were informed of the results of the investigation, and the 22% reduction in time to re-epithelialization for children treated with adjunctive NPWT, all parents and caregivers reported that they would recommend this treatment to other families (Frear, 2021). Whilst data indicates increased treatment burden with NPWT for children and their families, there is inconclusive evidence to suggest that acute adjunctive NPWT application and removal causes additional pain and discomfort for pediatric burn patients (Frear, 2021; Frear et al., 2020). Application and removal of NPWT was not found to be significantly more painful than standard silver dressing changes, in accordance with burns clinicians, parents and caregivers, and patients (Frear et al., 2020). Despite this, healthcare professionals often report fear of increased pain in children during NPWT procedures (Santosa et al., 2019).

In addition to developing implementation resources for clinicians, we created NPWT resources for patients, parents, and caregivers using data from interviews with families of burn patients who received NPWT within the last 12-months. Parents and caregivers reported wanting more information about adjunctive NPWT, how it works, the proposed benefits, and clear guidelines on when to return to hospital. Parents and caregivers also indicated that the information sheet provided to them following hospital discharge was for a NPWT device that was different to the device their child received (as hospital and health services can often have multiple NPWT devices from different manufacturers). Furthermore, parents and caregivers indicated a preference to have both electronic and paper versions of the NPWT handout and troubleshooting guide. We developed a NPWT handout and troubleshooting guide incorporating all components requested from parents and caregivers. This resource included detailed information on NPWT in plain English, fall prevention tips, images of NPWT devices, what different alarms and alerts look like (with images) and how to resolve them, in-hours and after-hours hospital contact details, and information on when to present to the hospital. Patient and caregiver education on NPWT was highlighted as a critical component of care from the European Wound Management Association (EWMA) within their 2017 publication on NPWT (Apelqvist et al., 2017). Recommendations from the EWMA to be included in patient and caregiver NPWT education material include detailed instructions regarding safe operation of the device, how to troubleshoot device alarms, how to reinforce dressings, information on signs of wound complications, and when to seek medical attention (Apelqvist et al., 2017). These recommendations strongly align with included information in our developed NPWT resources for patients, parents, and caregivers.

Lack of hospital policies and guidelines, indicating an absence of government policies and/or local hospital and health service guidelines for the use and management of adjunctive NPWT for acute burn care, was reported as a barrier to NPWT implementation. At present, all participating hospitals involved in this research use NPWT – but not all sites use adjunctive NPWT in acute burn care. There are also conflicting guidelines for NPWT between participating sites and the maximum

application timeframe for NPWT varies. Some hospitals have strict treatment duration timeframes – mandating NPWT removal after 72 h (and reapplication of NPWT if required) whereas other sites permit continuous NPWT application for up to one week. To address these identified barriers, guidelines should encompass the appropriate use and management of NPWT for acute burn care, defining the optimal application timeframe for NPWT and establishing a consensus on its duration, ensuring consistent and evidence-based NPWT practices. Previous implementation studies exploring successful determinates of research translation into clinical practice discuss the vital role policies and guidelines play in promoting research utilization. The development of organizational policies, procedures, and guidelines have been suggested as a successful strategy for moving research evidence into practice among nursing staff in hospitals (Squires et al., 2007).

The level of complexity and intricacy to apply adjunctive NPWT to pediatric burn patients was also reported as an implementation barrier. Clinicians perceive adjunctive NPWT application to be complex and difficult. Moreover, NPWT application is believed to be more time consuming when compared to current standard care. This is also consistent with broader literature. Burns clinicians, comprising surgeons and senior burns nurses, reported acute adjunctive NPWT to be more difficult to manage in pediatric patients in comparison to standard care alone (i.e., silver impregnated dressings) (Frear et al., 2020). In addition, burns clinicians reported adjunctive NPWT application and removal to be more time consuming compared to standard care (Frear et al., 2020). Individual stage of change, indicating that clinicians are not enthusiastic about using NPWT or might prefer to use a different intervention, as well as knowledge and beliefs about NPWT were identified as significant barriers to the implementation of adjunctive NPWT for acute burn care in the current investigation. This CFIR construct ties in well with the previous reported construct (complexity). It is not surprising that clinicians are not enthusiastic about implementing a treatment they perceived to be more complex, intricate, and time consuming to use.

Limitations and strengths

Strengths of this research include the involvement of relevant clinical stakeholders and end users. Identified barriers and resulting co-designed implementation strategies are evidence-based and acceptable to participating healthcare professionals across four Australian States. To promote trustworthiness, initial barrier data derived from electronic questionnaires were triangulated with participants in the subsequent semi-structured interviews. The co-designed strategies, however, require further testing to examine feasibility, acceptability, and appropriateness for adjunctive NPWT implementation into acute pediatric burn care. This will be examined in future studies.

Findings from this investigation must also be interpreted with consideration of several limitation. Limitations include the use qualitative mixed methods and self-report nature of the data. Verbatim semi-structured interview data were analyzed using framework-guided rapid analysis methods over traditional in-depth thematic analysis. Rapid data analysis can be less rigorous and less trustworthy when compared to thematic data analysis (Gale et al., 2019). Moreover, qualitative methods such as these are susceptible to influence from researchers' own expectations, assumptions, and views. However, to address this limitation, data coding was grounded in a theoretical framework (i.e., the CFIR), which contained predetermined and predefined barriers that helped minimize coding inaccuracies. In addition, healthcare professionals who participated in electronic questionnaires and semi-structured interviews volunteered to do so. This might have elicited a self-selection bias from clinicians who hold strong positive or negative feelings about adjunctive NPWT implementation into acute pediatric burn care. Moreover, this research did not include healthcare professionals from mixed hospitals that treat adult and pediatric patients, or

rural and remote settings, and thus results might not be generalizable nationwide. It is recommended that future studies investigate adjunctive NPWT implementation into acute burn care in mixed adult and pediatric hospitals, as well as in rural, regional, and remote Australian healthcare contexts. Lastly, the electronic REDCap questionnaire used was purposely-built for the investigation. This questionnaire has not been validated or undergoing reliability testing, and therefore might not measure the intended concepts or produce consistent and reliable results across different settings, populations, or timepoints.

Implications to practice

Findings from this investigation have significant implications for the integration of adjunctive NPWT into acute pediatric burn care. The identification of implementation barriers from relevant clinical stakeholders involved in the acute management of pediatric burn patients, as well as the co-design of tailored strategies to address these barriers, provide a robust foundation for the successful implementation of NPWT and long-term sustainment of this adjunctive treatment as part of acute standard care. Moreover, results from this investigation provide a comprehensive understanding of the challenges faced in implementing NPWT in this context. The development of the NPWT implementation toolkit (INPREP toolkit), educational materials, and adapted resources specific to each study site, as well as the establishment of regular educational meetings and NPWT champions at participating sites, are practical steps toward overcoming the identified barriers. By implementing these strategies, we aim to streamline the integration of evidence, specifically focusing on the proven clinical and cost effectiveness of NPWT for acute pediatric burns. Through this approach, we not only dispel uncertainties surrounding supporting evidence and the comparative advantages of NPWT, but also empower healthcare professionals with enhanced skills and understanding for its application. Despite the constraints posed by limited resources, the potential long-term benefits of NPWT, including faster re-epithelialization, reduced need for dressing changes, and decreased referrals to scar management, promise substantial savings in both cost and time. However, ongoing evaluation is crucial to ensure the efficacy of these strategies across various healthcare settings to ensure their sustained effectiveness and adaptability.

Conclusion

The time lag in evidence-to-practice implementation is a well-recognized issue in clinical and healthcare research. This investigation is one of the first to define barriers and co-design tailored strategies and treatment plans for the implementation of adjunctive NPWT for acute pediatric burns. Furthermore, findings from this research can help inform and guide other acute burn related implementation studies in the future, the implementation of other technologies, devices, or treatment pathways for pediatric patients in a healthcare setting. This investigation identified several barriers to adjunctive NPWT implementation in the acute management of pediatric burn injuries and co-designed targeted implementation strategies to address these barriers. The mixed methods co-design approach used in this investigation enabled detailed contextualization and identification of factors affecting implementation and adoption of early adjunctive NPWT across four Australian states. This ensured that implementation strategies were relevant, comprehensive, and tailored to the specific contexts of each participating hospital. The implementation strategies developed as part of this investigation will be adopted as part of a type III hybrid implementation-effectiveness SW-RCT. Findings and implementation strategies from this research can help inform and guide the implementation of adjunctive NPWT in other acute care settings, leading to improved patient outcomes and quality of care for children who have acquired a burn injury.

Consent for publication

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Maleea D. Holbert: Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Data curation. **Jed Duff:** Writing – review & editing, Methodology, Investigation. **Fiona Wood:** Writing – review & editing, Conceptualization. **Andrew J.A. Holland:** Writing – review & editing, Conceptualization. **Warwick Teague:** Writing – review & editing, Conceptualization. **Cody Frear:** Writing – review & editing. **Dianne Crellin:** Writing – review & editing, Project administration, Conceptualization. **Natalie Phillips:** Writing – review & editing, Conceptualization. **Kristen Storey:** Writing – review & editing, Resources. **Lisa Martin:** Writing – review & editing, Project administration. **Yvonne Singer:** Writing – review & editing. **Tanisha A. Dimanopoulos:** Writing – review & editing, Formal analysis. **Leila Cuttle:** Writing – review & editing, Resources, Conceptualization. **Dimitrios Vagenas:** Writing – review & editing, Conceptualization. **Steven McPhail:** Writing – review & editing, Conceptualization. **Pauline Calleja:** Writing – review & editing, Conceptualization. **Alexandra De Young:** Writing – review & editing, Conceptualization. **Roy M. Kimble:** Writing – review & editing, Conceptualization. **Bronwyn R. Griffin:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of competing interest

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