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Research paper

Implementation of a hospital-wide multidisciplinary blunt chest injury care bundle (ChIP): Fidelity of delivery evaluation

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ABSTRACT

Background: Ineffective intervention for patients with blunt chest wall injury results in high rates of morbidity and mortality. To address this, a blunt chest injury care bundle protocol (ChIP) was developed, and a multifaceted plan was implemented using the Behaviour Change Wheel.

Objective: The purpose of this study was to evaluate the reach, fidelity, and dose of the ChIP intervention to discern if it was activated and delivered to patients as intended at two regional Australian hospitals.

Methods: This is a pretest and post-test implementation evaluation study. The proportion of ChIP activations and adherence to ChIP components received by eligible patients were compared before and after intervention over a 4-year period. Sample medians were compared using the nonparametric median test,

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with 95% confidence intervals. Differences in proportions for categorical data were compared using the two-sample z-test.

Results/Findings: Over the 19-month postimplementation period, 97.1% (n = 440) of eligible patients received ChIP (reach). The median activation time was 134 min; there was no difference in time to activation between business hours and after-hours; time to activation was not associated with comorbidities and injury severity score. Compared with the preimplementation group, the postimplementation group were more likely to receive evidence-based treatments (dose), including high-flow nasal cannula use (odds ratio [OR] = 6.8 [95% confidence interval {CI} = 4.8–9.6]), incentive spirometry in the emergency department (OR = 7.5, [95% CI = 3.2–17.6]), regular analgesia (OR = 2.4 [95% CI = 1.5–3.8]), regional analgesia (OR = 2.8 [95% CI = 1.5–5.3]), patient-controlled analgesia (OR = 1.8 [95% CI = 1.3–2.4]), and multiple specialist team reviews, e.g., surgical review (OR = 9.9 [95% CI = 6.1–16.1]).

Conclusions: High fidelity of delivery was achieved and sustained over 19 months for implementation of a complex intervention in the acute context through a robust implementation plan based on theoretical frameworks. There were significant and sustained improvements in care practices known to result in better patient outcomes. Findings from this evaluation can inform future implementation programs such as ChIP and other multidisciplinary interventions in an emergency or acute care context.

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1. Introduction

Blunt chest wall injury is one of the most common injuries after blunt force trauma and includes rib fractures, sternal fractures, and chest wall contusions.¹ Up to 40% of injuries occur from low-velocity mechanisms such as falls.² Blunt chest injury is often painful and impairs normal respiratory function.^{1,3} Ineffective or delayed treatment for blunt chest injury results in high morbidity and mortality, especially for patients aged 65 years and older, where each additional rib fracture increases the risk of mortality by 19% and pneumonia by 27%.^{4,5} As such, there is a need to implement strategies to improve the care and outcomes of people with rib fractures.⁶

The use of guidelines for blunt chest injury has become more prevalent over recent years and has been shown to be effective in reducing pneumonia,^{7,8} hospital length of stay,^{9,10} and unplanned intensive care unit (ICU) admissions.⁷ However, hospital care can be ad hoc, often clinician or hospital dependent. Compliance with guidelines varies owing to patient complexity and organisational barriers,^{11–13} with studies reporting 55–58% compliance with recommended care protocols.^{12,14,15} Improving reliable and sustained uptake of evidence in practice requires an implementation plan developed through a rigorous and systematic theory-informed process that considers local clinician behaviour and context.^{16–18}

1.1. Intervention

An evidence-based blunt chest injury care bundle protocol (ChIP) was developed after an integrative review of the literature, which enabled tailored patient treatment and consideration of local context for use in two regional hospitals on the east coast of Australia¹⁹ (Supplementary file 1). ChIP is an early notification system, activated by emergency nurses or physicians in the emergency department, to alert ‘responders’ to review the patient within a suggested 60-min time frame. ChIP operates 24 h, 7 days a week. Once activated, the appropriate care is initiated in the emergency department by responders and maintained for the duration of clinical need. Responders included a physiotherapist and surgical, intensive care, and pain specialist teams. If required, the emergency or surgical teams can request the general medicine or geriatric medical team to review as per the patient’s clinical needs. Responders tailor care to the individual patient’s needs in three main areas: respiratory adjuncts, analgesia, and prevention of complications. Every potential ChIP clinical intervention is not mandatory but provided a guide to enable tailoring to each

individual patient. This acknowledges that each patient has individual needs dependent on their pre-morbid and clinical condition. The level of clinical intervention prescribed was clinician led and guided by patient acuity and need.

1.2. Implementation plan

The implementation plan for ChIP was developed using the Behaviour Change Wheel²¹ and is described in the study by Kourouche et al.²⁰ In brief, the barriers and facilitators to implementation of ChIP were identified after a survey of 198 staff, from the 12 impacted clinical departments of the two participating hospitals, and developed based on the Theoretical Domains Framework.²¹ Alongside a consultation process that included an APEASE assessment (i.e., affordability, practicability, effectiveness, acceptability, side-effects, and equity),²² a multifaceted implementation plan containing seven intervention functions and 15 behaviour change techniques (BCTs)²³ was developed as per the Behaviour Change Wheel (Supplementary file 2).²⁰ The implementation plan targeted the behaviour of multidisciplinary staff involved in the activation or response of ChIP including nurses from emergency wards, ICUs, and hospital wards and emergency, surgical, ICU, geriatric, and pain physicians. Resources for the delivery of the implementation, including a staff video <https://youtu.be/VIMz1PjzmBk> and storyboard for video development, have been provided (Supplementary file 3). The ChIP intervention commenced on November 22, 2017, and was introduced with a lead-up time with resources and training occurring in the 4 weeks before ChIP commencement and continuing after ChIP commencement.

Implementation fidelity is vital to determine the reliability and validity of implementation studies.^{24,25} It consists of two components: (i) the degree to which the *implementation plan* was implemented as intended and (ii) the degree to which *the intervention* was delivered as intended.²⁶ The fidelity to the *implementation plan* for ChIP has been evaluated and previously reported as 97.6% fully or partially implemented as intended.²⁷ A logic map depicts the intervention functions, BCTs, and modes of delivery used across the two sites; partially shaded areas represent BCTs partially implemented (21.4%), and filled boxes represent BCTs and modes that were fully implemented (76.2%) (Supplementary file 4).²⁷

The fidelity of the intervention (ChIP), also referred to as ‘fidelity of delivery’ or ‘treatment fidelity’,²⁸ has not yet been evaluated. The Medical Research Council guideline for process evaluations of complex interventions recommends that ‘reach’, ‘fidelity’, and ‘dose’

are evaluated as appropriate to the specific study and intervention.²⁹ *Reach* describes whether the intended audience came into contact with an intervention, i.e., how many patients received a ChIP activation and if it was appropriate.²⁹ *Fidelity* assesses if the intervention (ChIP) was delivered as intended. *Dose* refers to the quantity of the intervention implemented; this will assess the care bundle components of ChIP that were delivered.^{29,30} The purpose of this study was to evaluate the reach, fidelity, and dose of the implementation of the ChIP intervention to discern if it was activated and delivered to patients as intended.

2. Methods

2.1. Study design

This study was a pretest/post-test implementation evaluation of the reach, fidelity, and dose of the ChIP care bundle (intervention). This study was part of a larger study testing the efficacy of ChIP on patient outcomes (Supplementary file 5). Research conducted as part of this study adhered to the National Statement on Ethical Conduct in Human Research by the Australian National Health and Medical Research Council³¹ and was approved by the NSW Population and Health Services Research Ethics Committee (HREC/17/CIPHS/56). Data were collected without identifiers from medical records accessed from September 2018 to December 2019. Trail registration number is ANZCTR: ACTRN12618001548224. The Standards for Reporting Implementation Studies guidelines were used to guide the reporting of this evaluation³² (Supplementary file 6).

2.2. Setting

ChIP was implemented hospital-wide at two hospitals in regional NSW, Australia, with activation occurring in the emergency department and treatment continuing on through the hospital. The two sites were within the same local health district, with a 500-bed regional trauma centre treating approximately 70,000 emergency presentations annually (site A) and a 200-bed rural/regional hospital treating approximately 40,000 emergency presentations annually (site B), representing diverse sites with differing resources.³³ Both sites have ICUs, emergency departments, pain specialist teams, and physiotherapists on-site. Pain specialist teams were covered by anaesthetics out of hours. There was no physiotherapy coverage outside of hours; patients were seen as soon as possible the next day.

2.3. Patient identification

Patients were identified via two sources: (i) medical records of all patients admitted to the hospital with blunt chest injury identified using International Statistical Classification of Disease version 10 Australian modification (ICD-10-AM) codes and the Australian Refined Diagnosis Related Groups version 6 (Supplementary file 7)³⁴ or (ii) patients who had a ChIP call registered on the electronic medical record (eMR) system 'FirstNet'.³⁵ To be eligible for a ChIP call, patients had to (i) have an injury that occurred within 1 week of emergency department presentation or (ii) have recorded no improvement in chest pain or be unable to breathe deep or cough 30 min after analgesia administration (this enabled filtering of patients who were able to be safely discharged on oral analgesia). The choice of analgesia administered was at the clinician's discretion.

To assess the need for ChIP activation, emergency department staff members were required to do a respiratory assessment 30 min after analgesia administration. As part of the activation of ChIP, staff

from the emergency department activated an icon on patients' eMR to enable other staff to identify the patient and to prompt staff to remember to use ChIP. These icons were able to be tracked using the eMR and were used to generate a list of all patients who had a ChIP icon logged.

The patients' eMRs were initially screened for eligibility and were included if they had any chest trauma resulting in documented radiological or clinical blunt chest wall injury, were 18 years or older, presented via the emergency department, and were not intubated in the emergency department or before hospital admission. The records of patients identified through the eMR who did not meet the case ascertainment criteria but had a ChIP activation were excluded from the primary analysis, but baseline data were collected and subanalysis was reported as this was important to evaluate the reach of the intervention.

Medical records of patients meeting the case ascertainment criteria underwent a second screening process to assess if the patient met ChIP criteria and was eligible for a ChIP call.

2.4. Outcome measures

The outcomes were to discern whether the intended patient group received the care bundle activation (reach), if ChIP was delivered as intended (fidelity of ChIP), and the adherence to the intervention components (dose²⁹) as shown in the following list.

1. *Reach of ChIP intervention*: the proportion of eligible patients who received a ChIP call from all patients eligible for ChIP after implementation, which is calculated as the proportion of eligible patients who received a ChIP activation from all patients eligible for ChIP after implementation (November 22, 2017 to June 30, 2019).
2. *Fidelity – ChIP intervention delivered as intended*: analysis of all patients who received a ChIP activation in the post-implementation period (November 22, 2017 to June 30, 2019).
3. *Dose – adherence to ChIP components*: Pretest and post-test comparison of care bundle components and between-groups analysis of ChIP and ChIP-missed patient groups.

2.5. Data collection

The study was conducted over 4 years. The pretest implementation data period was between July 1, 2015, and November 21, 2017, and postimplementation data period was between November 22, 2017, and June 30, 2019. To reliably evaluate the dose, a pre-implementation group was needed to compare patient characteristics with the postimplementation group and ascertain any major clinical differences that may have influenced practice change.

Data were extracted from inpatient medical records and entered into a secure electronic database Research Electronic Data Capture.³⁶ Each data point was defined within a data dictionary, and the database was constructed with automatic outlier detection to alert data collectors of outliers. Regular quality checks were performed, and 10% of records were analysed for inter-rater agreement. Records were chosen at random using a random number generator. Inter-rater agreement was checked across 12 preagreed items, totalling 60 data points.

Patient characteristics collected included age and gender. Clinical information included injury(s), mechanism of injury, injury date and time, injury severity score, Charlson Comorbidity Index, and whether patients received a trauma call activation. The injury severity score was used as an internationally recognised scoring system for the combined effects of trauma. The score ranges from 1 to 75, with an injury severity score of 15 or higher being considered

severe injuries. The Charlson Comorbidity Index is a scoring system for mortality based on 17 pre-existing comorbidities. The injury severity score and the Charlson Comorbidity Index were considered confounding factors.

Data were collected to identify which patients had a ChIP activation and whether patients met ChIP criteria. Data were also collected to identify adherence to the care bundle components in the areas of analgesia delivery, respiratory support, and complication prevention. Data collected were whether vital signs, respiratory assessments, incentive spirometry, and high-flow nasal cannula use were documented and the times these were commenced. Initial, regular, and as-required charted analgesia within 24 h were collected including the times commenced. Data on regional analgesia, patient-controlled analgesia, and/or continuous analgesia were collected for the hospital stay, including the times commenced. The dates and times of health service reviews were collected including physiotherapy, surgical, pain team or ICU reviews. Reviews that were for another reason other than chest injury or did not include an assessment and plan were not collected. The admitting inpatient team(s) was also collected. Admission to ICU was also collected. Data were collected for documented patient education on chest injury.

2.6. Data analysis

Statistical analysis was performed using SPSS v25 (SPSS Statistics for Windows, version 25.0; IBM Corp., Armonk, NY), and EpiTools (<https://epitools.ausvet.com.au/>). Baseline characteristics (age, sex, and so on) were analysed using descriptive statistics.

Medians and the associated interquartile range (IQR) are reported for outcome data such as length of stay, time-based variables, and variables based on an ordinal scale. Differences between sample medians were compared using the nonparametric median test, with 95% confidence intervals of the difference estimated using the Hodges–Lehmann estimate. Generalised linear models were used for adjusted analyses of pretest and post-test ChIP data: logistic regression with logit link was used for binary outcomes, and for continuous outcomes such as time to specific treatments, the Gamma with log link model was used.³⁷ Correlation (Spearman's rho [r_s]) was used to explore the relationship between continuous variables and time to ChIP activation (post-group only), and differences in proportions for categorical data were compared using a two-sample z-test available in EpiTools (<https://epitools.ausvet.com.au/ztesttwo>). The z-test has the advantage of providing a 95% confidence interval around the difference in proportions. All other tests were performed using SPSS, version 25. P-values were considered statistically significant at $p < 0.05$. Four groups within the overall sample were analysed based on the outcome measure of interest, which are discussed in the following sections.

2.6.1. Outcome 1: reach of ChIP intervention

The reach of ChIP activations was calculated as the proportion of eligible patients who received a ChIP activation from all patients eligible for ChIP after implementation (July 1, 2015, to November 21, 2017). The two groups used in this analysis were the ChIP and ChIP-missed groups. The ChIP group consisted of patients who met study eligibility criteria and had a ChIP activation, including both admitted and nonadmitted patients (November 22, 2017, to June 30, 2019). The ChIP-missed group consisted of patients who presented after implementation (November 22, 2017, to June 30, 2019) and met ChIP eligibility criteria but did not get a ChIP activation. Hospital sites were compared for reach. The ChIP and ChIP-missed groups were described and compared by demographics, mechanism of injury, injuries, medical history, and presentation in or out

of hours to identify potential reasons for missed calls. Out-of-hours presentations arrived before 8 am and after 4 pm on weekdays or anytime on weekends and public holidays. Patients who received a ChIP call but were ineligible were described in a subanalysis, also indicating reach as an unintended patient group.

2.6.2. Outcome 2: fidelity – ChIP intervention delivered as intended

Fidelity was assessed by analysis of the ChIP group from the postimplementation period (November 22, 2017, to June 30, 2019), including admitted and nonadmitted patients. The ChIP activation group was analysed for time to ChIP activation, by site, transfers, in hours (8 am to 4 pm, Monday to Friday) versus out of hours, comorbidities, age, injury severity, and mode of hospital arrival. In addition, analyses were undertaken examining the length of emergency stay, and patient discharges from the emergency department.

2.6.3. Outcome 3: dose – adherence to ChIP components

There were two groups included in the analysis of the dose. The pre-group included admitted patients who presented in the preimplementation period (July 1, 2015, to November 21, 2017) and met ChIP criteria. The post-group included patients who presented after implementation commencement (November 22, 2017, to June 30, 2019) and met ChIP eligibility criteria, including admitted patients who had activation of ChIP or no ChIP activation.

Adherence to ChIP components was evaluated in two ways to identify practice change. First, the preimplementation group was compared with the postimplementation group to identify how adherence to the ChIP components occurred before and after implementation. ChIP components explored were time to analgesia, pain team and physiotherapist review, use of the high-flow nasal cannula, patient-controlled analgesia, or other modes of analgesia. Second, within the post-group, comparisons were made between the ChIP and ChIP-missed groups as a subanalysis.

3. Results

The inter-rater percent agreement rates were 97.8% for site A ($n = 10$) and 96.8% for site B ($n = 20$), both considered in the 'almost perfect' range.³⁸ There were 795 patients included in the final data analysis (Supplementary file 8). There were 282 patients in the preimplementation group and 453 in the postimplementation group. In the postimplementation group, 533 patients received a ChIP call in the emergency department. However, 33 (6.2%) patients did not meet study inclusion criteria, leaving 500 who had ChIP activated and met study eligibility criteria (ChIP-activated group). Of the 500 with ChIP activations, 440 (88%) patients were admitted (ChIP group). Thirteen (2.9%) of 453 patients were identified in the postimplementation group who were eligible for ChIP but did not get a call (ChIP-missed group).

3.1. Outcome 1: reach of ChIP intervention

Overall, the reach of ChIP for eligible patients was 97.1% ($n = 440$), with 96.1% at site A ($n = 270$) and 98.8% at site B ($n = 170$). Eligible patients who did not receive an activation (ChIP-missed group, $n = 13$, 2.9%) showed no difference in age, injury severity scores, Charlson Comorbidity Index, comorbidities, and in-hours presentation, compared with patients who were eligible and received an activation (ChIP group, $n = 440$, 97.1%) (Table 1). However, a higher proportion of participants in the ChIP-missed group were women, had a sternal injury, had fewer than three rib fractures, or had a vehicle-related injury compared with the ChIP-activated group. None of the patients in the ChIP-missed group had three or more rib fractures or flail chest. Reach was consistent over

the implementation period as follows: 6 (46.2%) in the first 6 months after implementation, 2 (15.4%) in the next 6 months, and 5 (38.5%) in the final 7 months.

Among those who had a ChIP call activation but did not meet predetermined eligibility criteria ($n = 33$, 6.2%), the majority 29 (87.9%) did not have a history of trauma. More than half of these ineligible calls were activated and then cancelled on the eMR (19 [57.6%]), potentially indicating they were placed in error. Three patients (9.1%) had a documented chest injury; however, they were all due to nontraumatic causes such as prolonged steroid use or malignancy. Two patients (6.1%) were under 18 years of age and therefore ineligible for inclusion in this study.

Thirty patients had ChIP activations that occurred while in the hospital ward, which was not the initial intent of the implementation. These activations occurred between 6 h and 5.4 days after presentation to the emergency department (median = 19.2 h [IQR = 13.65–32.6]), calculated from 22 activations with a recorded time. One of these patients was included in the ChIP-missed group as the patient met the eligibility criteria while in the emergency department.

3.2. Outcome 2: fidelity to ChIP intervention

Subanalysis of patients with ChIP activations ($n = 500$) in the postimplementation group demonstrated the median [IQR] time to ChIP activation was 134 [58.0–249.5] minutes, with 127 (25.4%) activations occurring within 60 min of arrival. The median [IQR] time to activation was 29 min earlier at site B than at site A (146 [60.0–259.0] vs 117 [56.0–239.0], $p = 0.048$). There was no difference in time to activation after-hours compared with during hours (147 [67.0–255.0] vs 114 [52.5–236.5], $p = 0.15$). Time to activation was not associated with the presence of comorbidities ($r_s = 0.08$, $p = 0.08$), age ($r_s = 0.02$, $p = 0.62$), or the injury severity score ($r_s = 0.088$, $p = 0.06$). The time to activation was earlier for patients who were transferred to the study sites from another healthcare facility (46.0 [19.0–115.5] vs 155.0 [76.0–272.0]

$p < 0.001$) and for patients who had analgesia before hospital admission (111.0 [49.0–226.0] vs 165.0 [85.0–282.5], $p < 0.001$), although there was no significant difference in transfer to the hospital by the ambulance. Further results of subanalysis are available in [Supplementary file 9](#).

Of the 500 patients who received a ChIP call, 440 (88%) were admitted to the hospital, and 60 (12%) were discharged from the emergency department. Length of stay was too short for discharged patients (median [IQR] = 5.0 [3.3–8.0] hours) to be able to reliably assess adherence to the components of ChIP; therefore, they were excluded from the adherence-specific analysis. Discharge of patients in the ChIP group from the emergency department reduced in the postimplementation group by 10% over time ($p = 0.04$).

3.3. Outcome 3: dose – adherence to ChIP activations

3.3.1. Postimplementation comparisons: adherence

There was no significant difference between the ChIP and ChIP-missed groups for initial vital signs assessment, respiratory assessment, or initial analgesia in the emergency department. With respect to the analgesia component of ChIP, the ChIP group was more likely to be seen by the pain service and have patient-controlled analgesia ([Table 2](#)).

In terms of respiratory support and complication prevention components of ChIP, the ChIP group was more likely to have had a physiotherapy review, used the high-flow nasal cannula, had incentive spirometry, and had education for deep breathing than the ChIP-missed group ([Table 3](#)).

Of patients who received a physiotherapy review, the review was also earlier in the ChIP group (960.5 [416.0–1238.0] minutes) than in the ChIP-missed group (1492 [1102.0–2760.5] minutes) ($p = 0.04$).

3.3.2. Comparison of the pre-group and post-group: adherence

There was no significant difference in age, sex, Charlson Comorbidity Index, or mechanism of injury between the

Table 1

Characteristics of the ChIP-activated (admitted patients) and ChIP-missed groups including baseline data, mechanism, and injuries.

n = 453	ChIP (n = 440)	CHIP-missed (n = 13)	P-value	Change score (95% CI)
Age, median (IQR)	69.1 (52.5–82.0)	81.6 (3.7–88.8)	0.257	8.4 (–18.4, 1.4) ^b
Female (n, %)	169 (38.4)	10 (76.9)	0.005	38.5 (11.5, 65.5) ^a
ISS, median (IQR)	9 (4.0–10.0)	4 (1.0–5.5)	0.181	4.0 (0, 6.0) ^b
CCI score, median (IQR)	3 (1.0–5.0)	4 (2.5–5.0)	0.444	–1.0 (–2.0, 1.0) ^b
COPD (n, %)	68 (15.5)	2 (15.4)	0.992	0.1 (–19.9, 20.1) ^a
Pneumonia on arrival (n, %)	35 (8.0)	1 (7.7)	0.969	0.3 (–14.7, 15.3) ^a
Asthma (n, %)	37 (8.4)	0 (0)	0.276	8.4 (–6.7, 23.5) ^a
Smoking (past or current) (n, %)	205 (46.5)	7 (53.9)	0.598	7.4 (–20.1, 34.9) ^a
Trauma call (n, %)	79 (18.0)	2 (15.4)	0.810	2.6 (–18.6, 23.8) ^a
Out-of-hours presentation ^c (n, %)	292 (66.4)	8 (61.5)	0.713	4.9 (–21.2, 31.0) ^a
Polytrauma ^d (n, %)	8 (1.8)	1 (7.7)	0.131	5.9 (–1.8, 13.6) ^a
Sternum injury (n, %)	46 (10.4)	4 (30.8)	0.020	20.4 (3.2, 37.7) ^a
Rib fractures <three (includes clinical) ^e (n, %)	209 (47.5)	11 (84.6)	0.008	37.1 (9.5, 64.7) ^a
Rib fractures ≥three ribs or flail (n, %)	209 (47.5)	0 (0)	<0.001	47.5 (20.0, 75.0) ^a
Lung injury, any (n, %)	111 (25.2)	1 (7.7)	0.149	17.5 (–6.3, 41.3) ^a
Fall ^f (n, %)	277 (63.0)	5 (38.5)	0.072	24.5 (–2.2, 51.2) ^a
Vehicle-related injury (n, %)	124 (28.2)	7 (53.8)	0.045	25.6 (0.6, 50.6) ^a
Other mechanism ^g (n, %)	39 (8.8)	1 (7.7)	0.890	1.1 (–14.5, 16.7) ^a

Abbreviations: CCI = Charlson Comorbidity Index, ChIP = blunt chest injury care bundle protocol, COPD = chronic obstructive pulmonary disease, CPR = cardiopulmonary resuscitation, ISS = injury severity score, IQR = interquartile range, CI = confidence interval.

^a P-value, difference, and 95% CI based on the two-sample z-test.

^b P-value based on the test of sample medians and change scores and 95% CIs based on the Hodges–Lehmann estimator, which is the median of the set of differences between each value in the first group and each value in the second group and may diverge from the difference obtained by sample median 1 – sample median 2 (Klotz, 2006).

^c Out-of-hours presentations include weekdays from 4 pm to 8 am, weekends, and public holidays.

^d Polytrauma = two or more abbreviated injury scores (AISs) greater than 2 in two or more body regions.

^e Clinical rib fractures include injuries wherein there is no documented rib fracture on imaging; however, the patient has significant pain.

^f Fall includes standing, height, and ladder.

^g Other mechanism includes blunt impact from objects or animals and other mechanisms such as from cough or CPR.

preimplementation (n = 282) and postimplementation groups (n = 453). There were significantly more trauma calls in the pre-group than in the post-group; however, the injury severity score was higher and the rib fractures more severe in the post-group (Table 3).

The post-group was significantly more likely to have regular analgesia charted (day 1 of admission), regional analgesia, and patient-controlled analgesia than the pre-group. The patients in the post-group had a significantly higher likelihood of receiving high-flow nasal cannula treatment, incentive spirometry, and education with regard to their injury and had a higher likelihood of receiving reviews by surgery, ICU liaisons, ICUs, chest physiotherapists, and pain teams (Table 4). The post-group also had significantly shorter times to regular analgesia (p < 0.001), pain review (p < 0.001), physiotherapist review (p < 0.001), and ICU doctor review (p < 0.001) (Supplementary file 9). The proportion of ChIP component delivery over the study period is presented in Fig. 1, demonstrating elevated and sustained implementation over the 19 months.

4. Discussion

This study evaluated the implementation of a blunt chest injury care bundle (ChIP) by assessing the implementation of delivery (i.e., reach, fidelity, and dose). The implementation plan based on the Behaviour Change Wheel functions³⁹ resulted in a high and sustained reach (97.1%), fidelity to delivery, and dose of the ChIP components over the 19-month postimplementation evaluation period.

Reach was extremely high at 97.1% at both sites with only 13 patients missed over the implementation period, demonstrating the target audience was reached with the implementation plan. Most importantly, this high reach was sustained over the 19-month implementation period, which is a considerable amount of time that would have seen staff and policy changes.⁴⁰ There was a slight increase before the implementation date; this may reflect the implementation strategies that were in place before the 'go-live' date of implementation. There were few erroneous activations of ChIP in the emergency department (5.8%). Discharges after a ChIP activation decreased in the postimplementation period; this may

suggest an improvement in the identification of patients who were eligible for ChIP activation by emergency staff. It may also suggest that emergency staff required support from the entire team for the decision to admit.⁴¹

Implementation was successful with significant improvements to care delivery demonstrated across the ChIP components of analgesia administration, respiratory support, and complication prevention and in the multidisciplinary response for the duration of the postimplementation period. This result was evident in both the comparisons of the ChIP and ChIP-missed groups and also in the preimplementation and postimplementation comparisons. The prolonged improvement in care delivery across the extended postimplementation period (19 months) demonstrates sustained uptake and embedment of ChIP into clinical practice.¹⁸

There were fewer patients in the post-group who received a respiratory assessment after analgesia administration compared with the pre-group. This may be due to delayed documentation as data were only collected for the 90 min after analgesia administration; healthcare workers may not always record their assessment or intervention as they have other competing priorities.⁴²

The smaller, rural hospital (site B) had similar reach and slightly earlier activation times than the bigger metropolitan hospital (site A). Rural implementation is known to be challenging owing to fewer resources and staff availability.⁴³ However, this study has demonstrated that it can be successful with strategic theory-based planning.⁴⁴

The implementation of ChIP resulted in a significant increase in the number of patients receiving evidence-based interventions over a sustained period. This is in contrast with other studies of fidelity in the acute care environment, which have had limited success in clinician behaviour change.^{45,46} Bosch et al.⁴⁵ were successful in the implementation of only one of the three practice recommendations, although supported by theory-based implementation. The large number of sites involved may have influenced the strength of implementation in both these studies as implementation efforts were then diluted.^{45,46} Furthermore, the implementation plans lacked facilitators on-site to drive the implementation and were minimal in their delivery, for example, only one 60-min workshop at each site, which may have affected fidelity.^{45,46}

Table 2
Documented components of the blunt chest injury care bundle (ChIP) performed for the ChIP-activated vs ChIP-missed groups.

n = 453	ChIP, n = 440		ChIP- missed, n = 13		P-value	Change score ^a (95% CI)
	n	%	n	%		
Initial vital signs	434	98.6	13	100	0.668	1.4 (-5.0, 7.8)
Respiratory assessment before analgesia	311	72.0	8	61.5	0.408	10.5 (-14.4, 35.4)
Analgesia in the emergency department	385	87.5	11	84.6	0.756	2.9 (-15.4, 21.2)
Vital signs (15–90 min after analgesia administration)	270	61.4	6	46.2	0.268	15.2 (-11.7, 42.1)
Respiratory assessment after analgesia administration (15–90 min)	137	32.1	1	7.7	0.062	24.4 (-1.2, 50.0)
Analgesia plan (regular, as-required, regional, intravenous [IV], or patient-controlled analgesia [PCA])	432	98.2	13	100	0.626	1.8 (-5.4, 9.0)
Reviewed by acute pain service	380	86.4	5	38.5	<0.001	47.9 (28.2, 67.6)
Regular analgesia charted day 1	404	91.8	12	92.3	0.948	0.5 (-14.6, 15.6)
As-required (PRN) analgesia charted	362	82.3	12	92.3	0.349	10.0 (-10.9, 30.9)
Regional analgesia	54	20.2	0	0	0.071	20.2 (-1.7, 42.1)
PCA charted	201	45.7	1	7.7	0.007	38 (10.6, 65.4)
IV continuous analgesia used	18	4.1	0	0	0.456	4.1 (-6.7, 14.9)
Reviewed by surgery	417	94.8	6	46.2	<0.001	48.6 (34.9, 62.3)
Admit general surgery	391	88.9	6	46.2	<0.001	42.7 (24.6, 60.8)
ICU liaison nurse review	242	55.0	1	7.7	<0.001	47.3 (19.8, 74.8)
ICU doctor review	267	60.7	1	7.7	<0.001	53.0 (25.9, 80.1)
Physiotherapy review (chest)	422	96.0	9	69.2	<0.001	26.8 (15.0, 38.6)
High-flow nasal cannula	315	71.6	3	23.1	<0.001	48.5 (23.3, 73.7)
Incentive spirometry	187	42.6	2	15.4	0.050	27.2 (-0.04, 54.4)
Education	408	92.7	6	46.2	<0.001	46.5 (31.0, 62.0)

Abbreviations: ChIP = blunt chest injury care bundle protocol, ICU = intensive care unit, CI = confidence interval, PRN = pro re nata.

^a P-value, difference, and 95% CI based on the two-sample z-test.

Table 3

Comparison of the preimplementation and postimplementation groups for patient characteristics, mechanism, and injuries.

Total, n = 735	Preimplementation, n = 282		Postimplementation, n = 453		P-value	Change score (95% CI)
	n	% (unless otherwise specified) ^c	n	% (unless otherwise specified) ^c		
Female	103	36.5	179	39.5	0.416	3.0 (-4.2, 10.2) ^a
Age median (IQR)	67.9	[50.6–81.4] ^c	69.3	[54.6–81.3] ^c	0.51	-1.8 (-4.5, 1.1) ^b
CCI median (IQR)	3	[1.0–6.0] ^c	3	[1.0–5.0] ^c	0.642	0 (0, 0) ^b
ISS median (IQR)	5	[3.0–10.0] ^c	9	[4.0–10.0] ^c	0.005	0 (-1.0, 0) ^b
Chronic obstructive pulmonary disease	60	21.3	70	15.5	0.045	5.8 (0.1, 11.5) ^a
Asthma	28	9.9	37	8.2	0.430	1.7 (-2.5, 5.9) ^a
Smoking (current or past)	143	50.7	212	46.8	0.304	3.9 (-3.5, 11.3) ^a
Recent pneumonia	23	8.2	36	7.9	0.884	0.3 (-3.7, 4.3) ^a
Trauma call	89	31.6	81	17.9	<0.001	13.7 (7.4, 20.0) ^a
Out-of-hours presentation	179	63.5	300	66.2	0.455	2.7 (-4.4, 9.8) ^a
Polytrauma	5	1.8	9	2.0	0.848	0.2 (-1.8, 2.2) ^a
Sternum injury	34	12.0	50	11.1	0.709	0.9 (-3.8, 5.6) ^a
Rib fractures <three (includes clinical)	169	60.0	220	48.6	0.003	11.4 (4.0, 18.8) ^a
Rib fractures ≥three ribs or flail	104	37.0	209	46.1	0.015	9.1 (1.8, 16.5) ^a
Lung injury, any	70	24.8	112	24.7	0.976	0.1 (-6.3, 6.5) ^a
Fall	157	55.7	282	62.3	0.076	6.6 (-0.7, 13.9) ^a
Vehicle-related injury	95	33.7	131	28.9	0.170	4.8 (-2.1, 11.7) ^a
Other mechanism	30	10.7	40	8.8	0.394	1.9 (-2.5, 6.3) ^a

Abbreviations: CCI = Charlson Comorbidity Index, IQR = interquartile range, ISS = injury severity score, CI = confidence interval.

^a P-value, difference, and 95% CI based on the two-sample z-test.^b P-value based on the test of sample medians and change scores and 95% CIs based on the Hodges–Lehmann estimator, which is the median of the set of differences between each value in the first group and each value in the second group and may diverge from the difference obtained by sample median 1 – sample median 2 (Klotz, 2006).^c Median (IQR).

4.1. Implementation plan scalability

The ChIP intervention and implementation plan were adaptable and were tailored for implementation at the sites for this study. In a recent systematic review of the blunt chest injury pathways, it was highlighted that pathways need to be highly adaptable to the patient and context.⁴⁷ The implementation plan included multimodal

hospital-wide implementation strategies, including educational sessions, a support video, clinical champions, audit and feedback, environmental changes, and advertisements, which are common, accessible strategies that can be adapted and used at other sites. Other emergency department implementation studies have included multiple strategies, with the most common strategies reported in a systematic review of emergency behaviour change

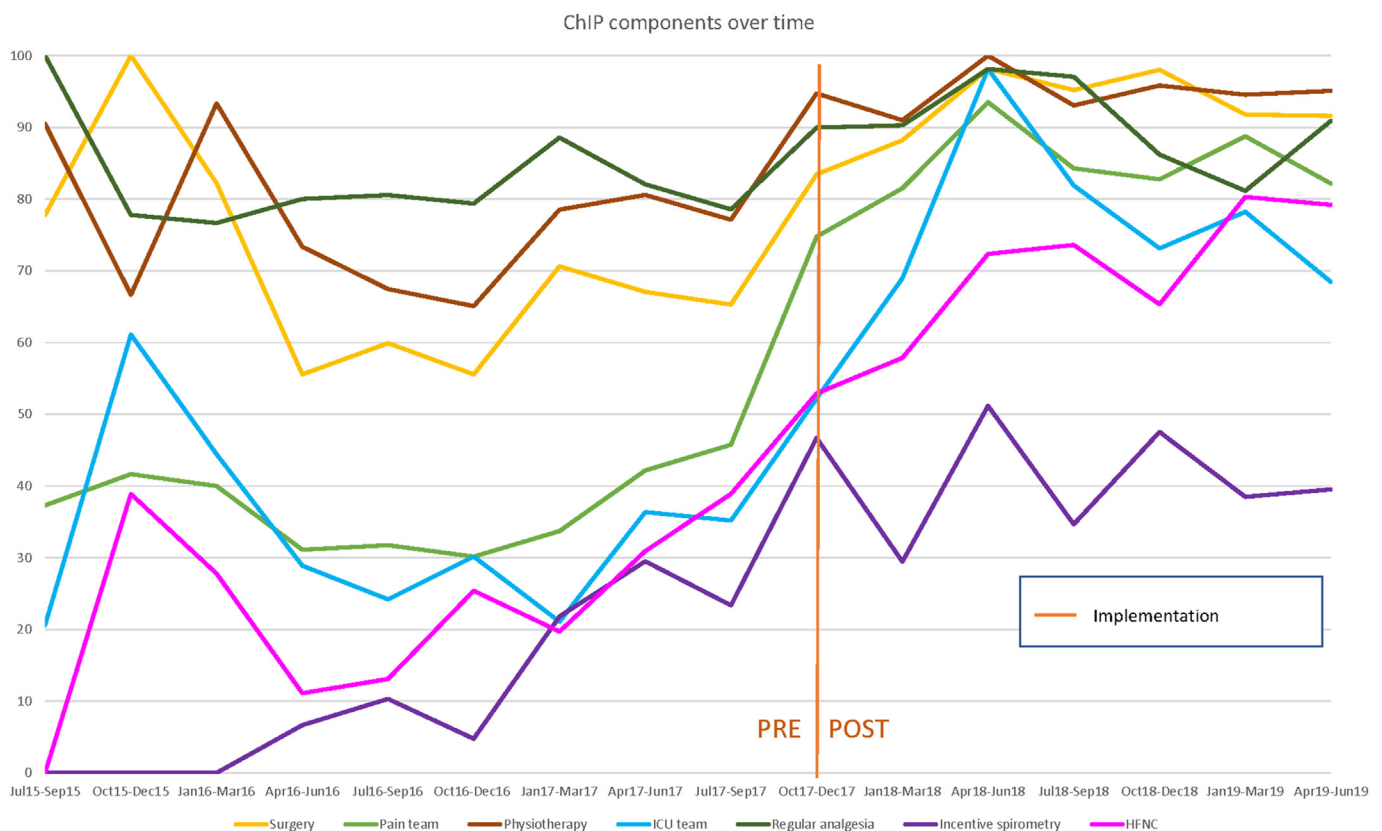
**Figure 1.** Blunt chest injury care bundle (ChIP) components and multidisciplinary review over the study period.

Table 4
Comparison of the preimplementation and postimplementation groups on components relating to ChIP implementation.

ChIP components	Preimplementation, n = 282		Postimplementation, n = 453		OR (95% CI)	P-value ^a
	n	%	n	%		
Components before activation						
Initial vital signs	278	98.6	447	98.7	1.1 (0.3, 4.1)	0.887
Initial respiratory assessment	195	70.1	319	71.7	1.1 (0.8, 1.5)	0.627
Initial analgesia in emergency	251	89.0	396	87.4	1.0 (0.6, 1.7)	0.869
Vital signs attended after analgesia administration (15–90 min)	187	66.3	276	60.9	0.9 (0.7, 1.2)	0.542
Respiratory assessment after analgesia administration	146	52.1	138	31.4	0.4 (0.3, 0.6)	<0.001
After activation						
Analgesia						
Regular analgesia charted	235	83.3	416	91.8	2.4 (1.5, 3.8)	<0.001
PRN analgesia	239	84.8	374	82.6	0.8 (0.5, 1.2)	0.201
Regional analgesia	14	7.4	54	19.3	2.8 (1.5, 5.3)	0.001
PCA	94	33.3	202	44.6	1.8 (1.3, 2.4)	0.001
Any analgesia	269	95.4	445	98.2	2.5 (1.0, 6.4)	0.049
Team review						
Surgical review	193	68.4	417	92.1	9.9 (6.1, 16.1)	<0.001
Pain team review	113	40.1	385	84.9	9.0 (6.2, 12.9)	<0.001
Physiotherapist review	218	77.3	431	95.1	4.8 (2.9, 8.1)	<0.001
ICU liaison	27	9.6	237	52.3	10.7 (6.9, 16.7)	<0.001
ICU doctor review	72	25.6	268	59.2	4.5 (3.2, 6.3)	<0.001
Respiratory support						
HFNC	73	25.9	318	70.2	6.8 (4.8, 9.6)	<0.001
Incentive spirometry	54	19.1	189	41.8	3.0 (2.1, 4.3)	<0.001
Incentive spirometry commenced in the ED	7	12.7	98	51.9	7.5 (3.2, 17.6)	<0.001
Education	168	59.6	414	91.4	6.8 (4.5, 10.3)	<0.001

Abbreviations: ChIP = blunt chest injury care bundle protocol, ED = emergency department, HFNC = high-flow nasal cannula, ICU = intensive care unit, PCA = patient-controlled analgesia, PRN = pro re nata (as needed), CI = confidence interval, ISS = injury severity score, OR = odds ratio, VIF = variance inflation factor.

No multicollinearity detected for each test: all tolerance >0.1, all VIF <5.0 (Field, 2017).

Independence of errors for each test assessed using scatterplot of standardised residuals and predicted values and found to be appropriate.

Abbreviations: ChIP = blunt chest injury care bundle protocol, ED = emergency department, HFNC = High flow nasal cannulae, ICU = intensive care unit, PCA = Patient-controlled analgesia, PRN = pro re nata (as needed).

^a OR, 95% CI, and P-value adjusted for ISS and trauma call.

being reminders, educational meetings, educational materials, and clinical practice guidelines.⁴⁸ The ChIP implementation included a combination of all of these strategies. The implementation strategies were associated with high fidelity for care bundle implementation.⁴⁹ Minimal costs were incurred for enactment of the implementation plan, aside from hiring of one implementation nurse for 4 weeks.

4.2. Methodological considerations and limitations

A limitation is that there may have been some patients missed during the medical record screening. However, eMR screening identified patients who were not initially picked by the ICD-10-AM and DRG codes. The initial intent for eMR screening was to determine the time that the ChIP call was activated; however, the screening also identified some patients who were not identified by the medical record coding screen. The ICD-10-AM codes were retrospectively checked for the records that were missed. Some examples of the ICD-10-AM codes given to the missed patients were 'chest pain, unspecified' and 'injury, unspecified'. These codes were not included in the ICD-10-AM case ascertainment criteria as they were considered medical related or vague as to blunt chest trauma. Another limitation is that the ChIP-missed group was relatively small. Although a strength of the reach of the

intervention, this did lead to limiting the power of statistical analysis in comparison with ChIP. There were fewer patients in the preintervention group; this may have been due to insufficient documentation of chest injury symptoms such as ongoing pain after analgesia administration in the medical records. This evaluation did not examine if components were delivered appropriately or missed, for example, if a patient should have had a regional block. However, the design of ChIP is that it relies on clinician judgement to deliver the most appropriate treatment at the time in relation to the clinical context.

A strength is that this study provides a unique view of implementation in the emergency context. There are limited studies reporting on the implementation evaluation in an emergency context, with most focusing on facilitators and barriers.⁵⁰ A lack of fidelity to the intervention may be associated with poorer outcomes, with a systematic review of care bundles reporting that implementation treatment fidelity needed to be as high as 95% for improved patient outcomes.⁵¹ The impact of ChIP on patient outcomes is also important and will be presented separately.⁵² Implementation of complex interventions in the emergency context has not had successful results in some cases,^{46,53–55} perhaps needing greater use of behaviour change theories to improve implementation design.⁵⁶ Furthermore, this is one of the few studies to examine behaviour change over an extended period

(19 months). This research provides an example of how implementation science theories can be used to develop a robust implementation plan with high fidelity of delivery.

Ongoing compliance and clinical monitoring of ChIP has been embedded in the site trauma registry and emergency department processes to maintain sustainability. The health district clinical governance unit mandates second yearly updates of clinical guidelines, which ensures ongoing evidence updates to ChIP.⁴⁰ Further research will examine the learning and decay effect of implementation over the duration of the implementation period. This implementation evaluation can inform future spread and the scale of ChIP, including research or clinical implications.⁵⁷ Furthermore, the evaluation of the implementation can improve the validity of the results of the ChIP patient outcome studies.⁵⁸

5. Conclusion

This study reported on the evaluation of the reach, fidelity, and dose of the ChIP intervention to discern if it was activated and delivered to patients as intended. Using a robust theoretical-based implementation plan is associated with high implementation delivery. Implementation evaluation of complex health interventions comprising of multidisciplinary teams may require multimodal implementation strategies to be successful. The results of this study can inform future implementation of clinical practice change efforts in the acute care environment, such as the emergency department.

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CRedit authorship contribution statement

Sarah Kourouche: Conceptualisation, Methodology, Software, Formal analysis, Writing – original draft, Visualisation, Project administration. **Kate Curtis:** Conceptualisation, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition. **Belinda Munroe:** Conceptualisation, Methodology, Writing – review & editing, Supervision. **Stephen Edward Asha:** Conceptualisation, Writing – review & editing, Funding acquisition. **Ian Carey:** Investigation, Writing – review & editing. **Julie Considine:** Conceptualisation, Writing – review & editing, Funding acquisition. **Margaret Fry:** Conceptualisation, Writing – review & editing, Funding acquisition. **Jack Lyons:** Investigation, Writing – review & editing. **Sandy Middleton:** Conceptualisation, Writing – review & editing, Funding acquisition. **Rebecca Mitchell:** Conceptualisation, Writing – review & editing, Funding acquisition. **Ramon Z. Shaban:** Conceptualisation, Writing – review & editing, Funding acquisition. **Annalise Unsworth:** Investigation, Writing – review & editing. **Thomas Buckley:** Conceptualisation, Methodology, Writing – review & editing, Supervision

Conflict of Interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

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