Implementation Evaluation of a Multidisciplinary Blunt Chest Injury Care Bundle (ChIP): Fidelity of Delivery

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Research

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Abstract

Background: Ineffective or delayed treatment of patients with blunt chest wall injury results in high rates of morbidity and mortality. A blunt chest injury care bundle protocol (ChIP) was developed and implemented to improve evidence-based care for these patients at two regional hospitals in Australia. ChIP is an early notification system to notify specialist clinician 'responders' to prescribe and commence treatment for patients with blunt chest injury in the emergency department (ED). A multi-pronged implementation strategy developed using the Behaviour Change Wheel (BCW), including seven intervention functions and 15 behaviour change techniques, guided implementation. Fidelity to the implementation strategy was high, with 97.5% fully or partially implemented. Implementation fidelity is the extent to which an intervention has been implemented as intended; it affects the internal and external validity of implementation. This study evaluates the fidelity of intervention delivery (fidelity, dose and reach) at two hospitals.

Methods: Pre-post implementation evaluation study.

The characteristics of patients, rate of ChIP activations and components of ChIP received by eligible patients were compared pre (1 July 2015 to 21 November 2017) and post (22 November 2017 to 30 June 2019) intervention. Sample medians were compared using the non-parametric median test, with the 95% confidence of the difference estimated using the Hodges-Lehmann estimate. Differences in proportions for categorical data were compared with two-sample z-test. Logistic regression was used to adjust for group differences.

Results: Overall, 97.1% of eligible patients received ChIP over the 19-month post-implementation period. Compared to the pre-implementation group the post-implementation group, were more likely to receive evidence-based treatments including high flow nasal cannula (OR=6.8 (4.8,9.6)), incentive spirometry in ED (OR=7.5 (3.2,17.6)), regular analgesia (OR=2.4 (1.5,3.8)), regional analgesia (OR=2.8 (1.5, 5.3)), Patient controlled analgesia (OR=1.8 (1.3,2.4)), and multiple specialist team reviews e.g. ICU liaison (OR=10.7 (6.9,16.7)).

Conclusions: High fidelity of delivery was achieved and sustained for ChIP for the implementation of a complex intervention in the emergency context with a robust implementation plan based on theoretical frameworks. Findings from this evaluation can inform future implementation of ChIP and other multidisciplinary interventions in an emergency or acute care context.

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Introduction

Blunt chest wall injury is one of the most common injuries following 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 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 due 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].

Intervention

An evidence-based blunt chest injury care bundle protocol (ChIP) was developed following an integrative review of the literature, that enabled tailored patient treatment and consideration of local context for use in two regional hospitals on the east coast of Australia [19] (Fig 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 60 minutes. ChIP operates 24 hours, seven 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; 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. Responders tailor care to the individual patient 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.

Fig 1. The ChIP flowchart

Implementation plan

The implementation plan for ChIP was developed using the Behaviour Change Wheel [21] and is described elsewhere [20, 21]. In brief, the barriers and facilitators to implementation of ChIP were identified following a survey of 198 staff, from the 12 impacted clinical departments of the two participating hospitals, and developed based on the Theoretical Domains Framework [22]. Alongside a consultation process that included an APEASE assessment (i.e. affordability, practicability, effectiveness, acceptability, side-effects, and equity) [23], a multi-faceted implementation plan containing seven

intervention functions and 15 behaviour change techniques (BCT) [24] was developed per the Behaviour Change Wheel (S1. Appendix) [21]. The implementation plan targeted the behaviour of multidisciplinary staff involved in the activation or response of ChIP including nurses from emergency, ICU and hospital wards; emergency, surgical, ICU, geriatric and pain physicians. Resources for the delivery of the implementation, including a staff video <https://youtu.be/woc4cJGjjQo> and storyboard for the video development, have been provided (S2

Appendix). The ChIP intervention commenced on 22 November 2017 and was introduced with a lead-up time with resources and training occurring in the four weeks prior and continuing after ChIP commencement.

Implementation fidelity, or process evaluation, is vital to determine the reliability and validity of implementation studies [25, 26]. It consists of two components: 1) the degree to which the *implementation plan* was implemented as intended, and 2) the degree to which *the intervention* was delivered as intended [27]. The fidelity to the *implementation plan* for ChIP has been evaluated and previously reported as 97.6% fully or partially implemented as intended [28]. A logic map depicts the intervention functions, BCTs and modes of delivery used across the two sites (Fig 2); partially shaded areas represent BCTs partially implemented (21.4%), filled boxes represent BCTs and modes that were fully implemented (76.2%) (Fig 2) [28].

Fig 2. Logic map showing the intervention functions linked to behaviour change techniques (BCTs) and modes of delivery which are shaded (partially-implemented) or full colour (fully-implemented) [28]

The fidelity of the intervention (ChIP), also referred to as ‘fidelity of delivery’ or ‘treatment fidelity’ [29], has not yet been evaluated. The Medical Research Council (MRC) guideline for process evaluations of complex interventions recommends that ‘*reach*’, ‘*fidelity*’, and ‘*dose*’ are evaluated as appropriate to the specific study and intervention [30]. *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 [30]. *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 [30, 31]. 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.

Methods

Study Design

This study was a pre-test/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 (Fig 3). 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 Council [32], and

was approved by the NSW Population & Health Services Research Ethics Committee (HREC/17/CIPHS/56). The Standards for Reporting Implementation Studies (STaRI) guidelines were used to guide the reporting of this evaluation [33] (S3 Appendix).

Fig 3. Overall study design evaluating the implementation and efficacy of ChIP, this study indicated in orange

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 [34]. Both sites have ICU, 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 at the next possible time.

Patient identification

Patients were identified via two sources: firstly, medical records of all patients admitted to 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 (AR-DRG v6) (S4 Appendix) [35]; or, secondly, patients who had a ChIP call registered on the electronic medical record (eMR) system 'FirstNet' [36]. To be eligible for a ChIP call, patients had to have: i) an injury that occurred within one week of emergency department presentation; ii) recorded no improvement to chest pain or were unable to deep breathe or cough 30 minutes after analgesia administration.

To assess the need for ChIP activation, emergency department staff were required to do a respiratory assessment 30 minutes after analgesia. As part of the activation of ChIP, staff from the emergency department activated an icon on patients' electronic medical record (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 patient 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 prehospital. The records of patients identified through eMR who did not meet the case ascertainment criteria but had a ChIP activation were excluded from the primary analysis but had baseline data collected, and sub-analysis 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 were eligible for a ChIP call.

Data collection

The study was conducted over four years. The pre-test-implementation data period was between 1 July 2015 to 21 November 2017, and post-implementation between 22 November 2017 to 30 June 2019.

Data were extracted from in-patient medical records and entered into a secure electronic database REDcap (Research Electronic Data Capture) [37]. 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 analysed for inter-rater agreement. Records were chosen at random using a random number generator. Inter-rater agreement was checked across 12 pre-agreed 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 15 or greater 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 as 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 cannulae use were documented, and the times these were commenced. Initial, regular and as required charted analgesia within 24 hours 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 admission. The admitting in-patient team(s) was also collected. Data was collected for documented patient education on chest injury.

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 (dose [30]) as shown below.

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

Data analysis

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

Medians and 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 non-parametric median test, with the 95% confidence intervals of the difference estimated using the Hodges-Lehmann estimate. Generalised Linear Models were used for adjusted analyses of pre- 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 [38]. Correlation (Spearman's rho [rs]) 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 according to the outcome measure of interest are discussed below.

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 post-implementation (1 July 2015 to 21 November 2017). The two groups used in this analysis were the ChIP and ChIP-missed groups. The ChIP group were patients who met study eligibility criteria and had a ChIP activation, including both admitted and non-admitted patients (22 November 2017 to 30 June 2019). The ChIP-missed group were patients who presented post-implementation (22 November 2017 to 30 June 2019), met ChIP eligibility criteria but did not get a ChIP activation. Hospital sites were compared for reach. 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 8am and after 4pm on weekdays, or anytime on weekends and public holidays. Patients who received a ChIP call but were ineligible were described in a sub-analysis; also indicating reach as an unintended patient group.

Outcome 2: Fidelity - ChIP intervention delivered as intended

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

Outcome 3: Dose - Adherence with ChIP components

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

Adherence with ChIP components was evaluated in two ways to identify practice change. Firstly, the pre-implementation group was compared to the post-implementation group to identify how adherence to the ChIP components before and after implementation. ChIP components explored were: time to analgesia, pain team and physiotherapist review, use of high flow nasal cannulae, patient-controlled analgesia or other modes of analgesia. Secondly, within the post-group, comparisons were made between ChIP and ChIP-missed groups as a sub-analysis.

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 [39].

There were 795 patients included in the final data analysis (Fig 4). There were 282 in the pre-implementation and 453 in the post-implementation group. In the post-implementation 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). Of the 500 with ChIP

activations, 440 (88%) patients were admitted (ChIP-group). There were 13 (2.9%) of 453 patients in the post-implementation group identified who were eligible for ChIP but did not get a call (ChIP-missed).

Fig 4. Patient identification, inclusion and groups (blue) for analysis

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 that did not receive an activation (ChIP-missed group, n=13, 2.9%) were no different in age, injury severity score, Charlson comorbidity index, comorbidities and in-hours presentation, compared to 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 female, have a sternal injury, have less than three rib fractures, or had a vehicle-related injury compared to the ChIP activated group. None of the ChIP-missed group had three or more ribs fractures or a flail chest. Reach was consistent over the implementation period as follows: 6 (46.2%) in the first 6-months post-implementation, 2 (15.4%) in the next six months and 5 (38.5%) in the final seven months.

Table 1. Characteristics of ChIP activated (admitted patients), and ChIP-missed groups including baseline data, mechanism and injuries

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. Just over 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 non-traumatic causes such as prolonged steroid use or malignancy. Two patients (6.1%) were aged less than 18 years and therefore, ineligible for inclusion in this study.

Thirty patients had ChIP activations that occurred while on the hospital ward, which was not the initial intent of the implementation. These activations occurred between 6 hours and 5.4 days after presentation to the emergency department (median 19.2 hours [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 they met eligibility criteria while in the emergency department.

Outcome 2: Fidelity to ChIP intervention

Sub-analysis of patients with ChIP activations (n=500) in the post-implementation group demonstrated median [IQR] time to ChIP activation was 134 [58.0 – 249.5] minutes with 127 (25.4%) of activations occurring within 60 minutes of arrival. The median [IQR] time to activation was 29 minutes earlier at Site B compared to 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 to during hours (147 [67.0 - 255.0] vs 114 [52.5 - 236.5], $p=0.15$). Time to activation was not associated with 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 health care facility (46.0 [19.0 – 115.5] vs 155.0 [76.0 – 272.0] $p<0.001$) and for patients who had analgesia pre-hospital (111.0 [49.0 – 226.0] vs 165.0 [85.0 – 282.5], $p<0.001$); though no significant difference for transfer to hospital by ambulance. Further results for sub-analysis are available in S5 Appendix.

Of the 500 patients who received a ChIP call, 440 (88%) were admitted to hospital, and 60 (12%) 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 assess adherence to the components of ChIP reliably; therefore, they were excluded from the adherence specific analysis. Discharge of ChIP patients from the emergency department reduced in the post-implementation group by 10% over time, $p=0.04$.

Outcome 3: Dose - adherence of ChIP activations

Post-implementation comparisons: adherence

There was no significant difference between the ChIP and ChIP-missed groups for initial vital sign assessment, respiratory assessment or initial analgesia in the emergency department. With respect to the analgesia component of ChIP, the ChIP group were more likely to be seen by the pain service and have patient-controlled analgesia (Table 2). In terms of the respiratory support and complication prevention components of ChIP, the ChIP group were more likely to have had a physiotherapy review, high flow nasal cannulae, incentive spirometry, and education for deep breathing compared to the ChIP-missed group (Table 3). Of patients that received a physiotherapy review, the review was also earlier in the ChIP group 960.5 [416.0 – 1238.0] minutes compared to 1492 [1102.0 – 2760.5] minutes in the ChIP-missed group, $p=0.04$.

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

Comparison of pre and post groups: adherence

There was no significant difference in age, sex, Charlson Comorbidity Index, or mechanism of injury between the pre-implementation ($n=282$) and post-implementation groups ($n=453$). There were significantly more trauma calls in the pre-group compared to the post-group; however, the injury severity score was higher, and the rib fractures more severe in the post-group (Table 3).

Table 3. Comparison of pre and post-implementation groups for patient characteristics, mechanism, injuries

The post-group were significantly more likely to have regular analgesia charted (day one of admission), regional analgesia, and patient-controlled analgesia compared to the pre-group. The post-group had a significantly higher likelihood of receiving high flow nasal cannulae, incentive spirometry and education regarding their injury and had a higher

likelihood of receiving reviews by surgery, ICU liaison, ICU, chest physiotherapists and pain team (Table 4). The post-group also had significantly shorter times to initial analgesia, regular analgesia, pain review, physiotherapist review, and ICU review (Table 5). The proportion of ChIP component delivery over the study period is presented in Fig 5.

Table 4. Comparison of pre and post-implementation groups on components relating to blunt chest injury care bundle (ChIP) implementation

Table 5. Time in minutes to receipt of components of the blunt chest injury care bundle (ChIP) for pre and post patient groups

Fig 5. Blunt chest injury care bundle (ChIP) components and multidisciplinary review over the study period

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 functions [20] resulted in a high and sustained reach (97.1%), fidelity to delivery and dose of the ChIP components over the 19-month post-implementation evaluation period.

Reach

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 which would have seen staff and policy changes. There were few erroneous activations of ChIP in the emergency department (5.8%).

Fidelity

Discharges after a ChIP activation decreased in the post-implementation period; this may suggest an improvement in the identification of patients that were eligible for ChIP activation by emergency staff and a need to admit the patient to better manage their pain. It may also suggest that emergency staff required support from the entire team for the decision to admit.

Dose

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 post-implementation period. This result was evident in both the comparisons for the ChIP and ChIP-missed groups and also in the pre-implementation and post-implementation comparisons. The prolonged improvement in care delivery across the extended post-implementation period (19 months) demonstrates sustained uptake and embedment of ChIP into clinical practice.

There were fewer patients in the post-group who received a respiratory assessment post-analgesia compared to the pre-group. This may be due to delayed documentation as data was only collected for the 90 minutes post-analgesia; healthcare workers may not always record their assessment or intervention as they have other competing priorities [40].

The smaller, rural hospital (Site B) had similar reach and slightly earlier activation times compared to the bigger metropolitan hospital (Site A). Rural implementation is known to be challenging due to fewer resources and staff availability [41]. However, this study has demonstrated it can be successful with strategic theory-based planning [42].

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 [43]. The implementation plan included multi-modal 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 being reminders, educational meetings, educational materials and clinical practice guidelines [44]. The ChIP implementation included a combination of all of these strategies. The implementation strategies were associated with high fidelity for care bundle implementation [45]. Minimal costs were incurred for the enactment of the implementation plan, aside from the hiring of one implementation nurse for four weeks.

Methodological considerations and limitations

A limitation is that there may have been some patients missed during the medical records screening. However, the eMR screening identified patients who were not initially picked up by the ICD-10-AM and DRG codes. The initial intent for the eMR screening was to determine the time that the ChIP call was

activated; however, the screening also identified some patients that 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. Whilst a strength of the intervention reach, this did lead to limiting power of statistical analysis in comparison to ChIP. There were fewer patients in the pre-intervention group; this may have been due to insufficient documentation of chest injury symptoms such as ongoing pain post-analgesia in the pre-group 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 [46]. 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 [47]. The impact of ChIP on patient outcomes is also important and will be presented separately [48].

Implementation of complex interventions in the emergency context have not had successful results in some cases [49-52], perhaps needing greater use of behaviour change theories to improve implementation design [53]. Further, this is one of few studies to examine behaviour change over an extended period (19 months).

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 scale of ChIP, including for research or clinical implications [54]. Further, it can improve the validity of the ChIP patient outcome studies [55].

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. Following a robust theoretical- based implementation plan is associated with high implementation delivery. Implementation evaluation of complex health interventions comprising of multidisciplinary teams may require multi- modal 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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References

1. Ursic C, Curtis K. Thoracic and neck trauma. Part two. *Int Emerg Nurs*. 2010;18(2):99-108. doi: 1016/j.ienj.2008.11.011.
2. Ingoe HMA, Eardley W, McDaid C, Rangan A, Lawrence T, Hewitt C. Epidemiology of adult rib fracture and factors associated with surgical fixation: Analysis of a chest wall injury dataset from England and Wales. *Injury*. 2020;51(2):218-23. doi: <https://doi.org/10.1016/j.injury.2019.10.030>.
3. Chiumello D, Coppola S, Froio S, Gregoretti C, Consonni D. Noninvasive ventilation in chest trauma: systematic review and meta-analysis. *Intensive Care Med*. 2013;39(7):1171-80. Epub 2013/04/11. doi: 10.1007/s00134-013-2901-4. PubMed PMID:
4. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. *Injury*. 2012;43(1):8-17. Epub 2011/01/25. doi: 10.1016/j.injury.2011.01.004. PubMed PMID:
5. Sawa J, Green RS, Thoma B, Erdogan M, Davis PJ. Risk factors for adverse outcomes in older adults with blunt chest trauma: A systematic review. *CJEM*. 2018;20(4):614-22. Epub 2018/08/11. doi: 1017/cem.2017.377.
6. Unsworth A, Curtis K, Asha SE. Treatments for blunt chest trauma and their impact on patient outcomes and health service delivery. *Scand J Trauma Resusc Emerg Med*. 2015;23:17. doi: 10.1186/s13049-015-0091-5. PubMed PMID:
7. Kelley KM, Burgess J, Weireter L, Novosel TJ, Parks K, Aseuga M, et al. Early Use of a Chest Trauma Protocol in Elderly Patients with Rib Fractures Improves Pulmonary Outcomes. *Am Surg*. 2019;85(3):288-91. Epub 2019/04/06. PubMed PMID:

8. Curtis K, Asha SE, Unsworth A, Lam M, Goldsmith H, Langcake M, et al. ChIP: An early activation protocol for isolated blunt chest injury improves outcomes, a retrospective cohort Australasian Emergency Nurses Journal. 2016;19(3):127-32. Epub 2016/07/28. doi: 10.1016/j.aenj.2016.06.002. PubMed PMID: 27448460.

9. Flarity K, Rhodes WC, Berson AJ, Leininger BE, Reckard PE, Riley KD, et al. Guideline-Driven Care Improves Outcomes in Patients with Traumatic Rib Fractures. Am Surg. 2017;83(9):1012-7. Epub 2017/09/30. PubMed PMID:

10. Macheel C, Reicks P, Sybrant C, Evans C, Farhat J, West MA, et al. Clinical Decision Support Intervention for Rib Fracture Treatment. J Am Coll Surg. 2020. doi: <https://doi.org/10.1016/j.jamcollsurg.2020.04.023>.

11. Tignanelli C, Rix A, Napolitano L, Hemmila M, Ma S, Kummerfeld E. Association Between Adherence to Evidence-Based Practices for Treatment of Patients With Traumatic Rib Fractures and Mortality Rates Among US Trauma Centers. JAMA Network Open. 2020;3:e201316. doi: 10.1001/jamanetworkopen.2020.1316.

12. Rayan N, Barnes S, Fleming N, Kudryakov R, Ballard D, Gentilello LM, et al. Barriers to compliance with evidence-based care in trauma. J Trauma Acute Care Surg. 2012;72(3):585-93. doi: 10.1097/TA.0b013e318243da4d. PubMed PMID: 01586154-201203000-00006.

13. Shafi S, Barnes SA, Rayan N, Kudryakov R, Foreman M, Cryer HG, et al. Compliance with recommended care at trauma centers: association with patient outcomes. J Am Coll Surg. 2014;219(2):189-98. Epub 2014/07/21. doi: 10.1016/j.jamcollsurg.2014.04.005. PubMed PMID: 25038959.

14. McGlynn EA, Asch SM, Adams J, Keesey J, Hicks J, DeCristofaro A, et al. The quality of health care delivered to adults in the United States. N Engl J Med. 2003;348(26):2635-45. Epub 2003/06/27. doi: 10.1056/NEJMs022615. PubMed PMID:

15. Runciman WB, Hunt TD, Hannaford NA, Hibbert PD, Westbrook JI, Coiera EW. CareTrack: assessing the appropriateness of health care delivery in Australia. *Med J Aust.* 2012;197. doi: 10.5694/mja12.11210.
16. Handley MA, Gorukanti A, Cattamanchi A. Strategies for implementing implementation science: a methodological overview. *Emerg Med J.* 2016;33(9):660. doi: 10.1136/emered-2015-205461.
17. Straus SE, Tetroe J, Graham ID. Knowledge translation in health care: moving from evidence to practice. 2nd ed. Chichester, West Sussex: John Wiley & Sons;
18. Tricco AC, Ashoor HM, Cardoso R, MacDonald H, Cogo E, Kastner M, et al. Sustainability of knowledge translation interventions in healthcare decision-making: a scoping review. *Implement Sci.* 2016;11(1):55. doi: 1186/s13012-016-0421-7.
19. Kourouche S, Buckley T, Munroe B, Curtis K. Development of a blunt chest injury care bundle: An integrative review. *Injury.* 2018;49(6):1008-23. doi: <https://doi.org/10.1016/j.injury.2018.03.037>.
20. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011;6(1):42-. doi: 10.1186/1748-5908-6-42.
21. Kourouche S, Buckley T, Van C, Munroe B, Curtis K. Designing strategies to implement a blunt chest injury care bundle using the behaviour change wheel: a multi-site mixed methods study. *BMC Health Serv Res.* 2019;19(1):461. doi: 1186/s12913-019-4177-z.
22. Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science.* 2012;7(1):37. PubMed PMID: doi:10.1186/1748-5908-7-37.

23. Atkins L. Using the Behaviour Change Wheel in infection prevention and control practice. *J Infect Prev.* 2016;17(2):74-8. doi: 1177/1757177415615952.
24. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med.* 2013;46. doi: 10.1007/s12160-013-9486-6.
25. Slaughter SE, Hill JN, Snelgrove-Clarke E. What is the extent and quality of documentation and reporting of fidelity to implementation strategies: a scoping review. *Implement Sci.* 2015;10(1):129. doi: 1186/s13012-015-0320-3.
26. Stockdale SE, Hamilton AB, Bergman AA, Rose DE, Giannitrapani KF, Dresselhaus TR, et al. Assessing fidelity to evidence-based quality improvement as an implementation strategy for patient-centered medical home transformation in the Veterans Health Administration. *Implement Sci.* 2020;15(1):18. doi: 10.1186/s13012-020-0979-y.
27. Roy R, Colquhoun H, Byrne M, Lorencatto F, Matvienko-Sikar K, McCleary N, et al. Addressing fidelity within complex health behaviour change interventions: A protocol of a scoping review of intervention fidelity frameworks and models. *HRB Open Research.* 2018;1(25). doi: 10.12688/hrbopenres.12892.1.
28. Kourouche S, Curtis K, Munroe B, Watts M, Balzer S, Buckley T. Implementation strategy fidelity evaluation for a multidisciplinary blunt chest injury care bundle [under review]. *Implementation Science Communications.* 2020;[PREPRINT](Available at Research Square).
29. Walton H, Spector A, Tombor I, Michie S. Measures of fidelity of delivery of, and engagement with, complex, face-to-face health behaviour change interventions: A systematic review of measure quality. *Br J Health Psychol.* 2017;22(4):872-903. doi: 1111/bjhp.12260.

30. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. *Bmj*. 2015;350:h1258. doi: 10.1136/bmj.h1258.
31. Carroll C, Patterson M, Wood S, Booth A, Rick J, Balain S. A conceptual framework for implementation fidelity. *Implement Sci*. 2007;2(1):40. doi: 1186/1748-5908-2-40.
32. National Health and Medical Research Council (NHMRC). The National Statement on Ethical Conduct in Human Research 2017 (updated 2018). Australia: Australian government,
33. Pinnock H, Barwick M, Carpenter CR, Eldridge S, Grandes G, Griffiths CJ, et al. Standards for Reporting Implementation Studies (StaRI) *Bmj*. 2017;356:i6795. doi: 10.1136/bmj.i6795.
34. The Bureau of Health Information. Healthcare observer 2019 [updated 07/11/19]10 March 2020]. Available from: http://www.bhi.nsw.gov.au/Healthcare_Observer.
35. Independent Hospital Pricing Authority. ICD-10-AM/ACHI/ACS previous editions 2019 [30/07/20]. Available from: <https://www.ihoa.gov.au/what-we-do/icd-10-am-achi-acg-previous-editions>.
36. Emergency Care Institute. Electronic Medical Record 2017 [updated 25/09/1730/07/20].
37. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Informatics*. 2009;42(2):377-81. doi: <https://doi.org/10.1016/j.jbi.2008.08.010>.
38. Ng VKY, Cribbie RA. Using the Gamma Generalized Linear Model for Modeling Continuous, Skewed and Heteroscedastic Outcomes in Psychology. *Curr Psychol*. 2017;36(2):225-35. doi: 10.1007/s12144-015-9404-0.

39. McHugh ML. Interrater reliability: the kappa statistic. *Biochemical Medicine*. 2012;22(3):276-
82. Epub 2012/10/25. PubMed PMID: 23092060; PubMed Central PMCID: PMCPMC3900052.
40. Chesworth BM, Leathley MJ, Thomas LH, Sutton CJ, Forshaw D, Watkins CL, et al. Assessing fidelity to treatment delivery in the ICONS (Identifying Continence Options after Stroke) cluster randomised feasibility trial. *BMC Med Res Methodol*. 2015;15(1):68. doi: 10.1186/s12874-015-0051-9.
41. Fulop N, Walters R, Perri, Spurgeon P. Implementing changes to hospital services: Factors influencing the process and 'results' of reconfiguration. *Health Policy*. 2012;104(2):128-35. doi: <https://doi.org/10.1016/j.healthpol.2011.05.015>.
42. Morgan D, Kosteniuk J, O'Connell ME, Kirk A, Stewart NJ, Seitz D, et al. Barriers and facilitators to development and implementation of a rural primary health care intervention for dementia: a process evaluation. *BMC Health Serv Res*. 2019;19(1):709. doi: 10.1186/s12913-019-4548-5.
43. Baker E, Woolley A, Xyrichis A, Norton C, Hopkins P, Lee G. How does the implementation of a patient pathway-based intervention in the acute care of blunt thoracic injury impact on patient outcomes? A systematic review of the literature. *Injury*. 2020. Epub 2020/06/25. doi: 10.1016/j.injury.2020.06.002. PubMed PMID:
44. de Wit K, Curran J, Thoma B, Dowling S, Lang E, Kuljic N, et al. Review of implementation strategies to change healthcare provider behaviour in the emergency department. *CJEM*. 2018;20(3):453-60. doi: 10.1017/cem.2017.432. PubMed PMID: 1100981992.
45. Gilhooly D, Green SA, McCann C, Black N, Moonesinghe SR. Barriers and facilitators to the successful development, implementation and evaluation of care bundles in acute care in hospital: a scoping review. *Implement Sci*. 2019;14(1):47. doi: 1186/s13012-019-0894-2.

46. Tavender EJ, Bosch M, Fiander M, Knott JC, Gruen RL, Connor D. Implementation research in emergency medicine: a systematic scoping review. *Emerg Med J*. 2016;33(9):652. doi:10.1136/emered-2015-205053.
47. Lavallée JF, Gray TA, Dumville J, Russell W, Cullum N. The effects of care bundles on patient outcomes: a systematic review and meta-analysis. *Implement Sci*. 2017;12(1):142. doi: 10.1186/s13012-017-0670-0.
48. Curtis K. Trial registration: Retrospective pre-post evaluation of the impact of an evidence- based protocol for management of patients with blunt chest injury under real-world conditions: Chest Injury bundle of care Protocol (ChIP).
49. Scott PA, Meurer WJ, Frederiksen SM, Kalbfleisch JD, Xu Z, Haan MN, et al. A multilevel intervention to increase community hospital use of alteplase for acute stroke (INSTINCT): a cluster- randomised controlled trial. *Lancet Neurol*. 2013;12(2):139-48. doi: [https://doi.org/10.1016/S1474-4422\(12\)70311-3](https://doi.org/10.1016/S1474-4422(12)70311-3).
50. Campbell JC, Coben JH, McLoughlin E, Dearwater S, Nah G, Glass N, et al. An Evaluation of a System-change Training Model to Improve Emergency Department Response to Battered Women. *AEM*. 2001;8(2):131-8. doi: 1111/j.1553-2712.2001.tb01277.x.
51. Dexheimer JW, Abramo TJ, Arnold DH, Johnson K, Shyr Y, Ye F, et al. Implementation and evaluation of an integrated computerized asthma management system in a pediatric emergency department: A randomized clinical trial. *Int J Med Inform*. 2014;83(11):805-13. doi: <https://doi.org/10.1016/j.ijmedinf.2014.07.008>.
52. Middleton S, Dale S, Cheung NW, Cadilhac DA, Grimshaw JM, Levi C, et al. Nurse-Initiated Acute Stroke Care in Emergency Departments. *Stroke*. 2019;Strokeaha118020701. Epub 2019/05/17. doi: 10.1161/strokeaha.118.020701. PubMed PMID:

53. Zamboni K, Baker U, Tyagi M, Schellenberg J, Hill Z, Hanson C. How and under what circumstances do quality improvement collaboratives lead to better outcomes? A systematic review. *Implement Sci.* 2020;15(1):27. doi: 1186/s13012-020-0978-z.
54. Graham I, Tetroe JM. The Knowledge to Action Framework. In: Rycroft-Malone J, Bucknall T, editors. *Models and frameworks for implementing evidence-based practice: linking evidence to action.* Chichester, England: Wiley-Blackwell;
55. Bellg AJ, Borrelli B, Resnick B, Hecht J, Minicucci DS, Ory M, et al. Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. *Health Psychol.* 2004;23(5):443-51. Epub 2004/09/16. doi: 10.1037/0278-6133.23.5.443. PubMed PMID:

List Of Abbreviations

BCT – behaviour change technique

BCW – Behaviour change wheel

CCI – Charlson Comorbidity Index

ChIP – Chest Injury Protocol

CNC – Clinical nurse consultant

ED – emergency department

eMR - electronic medical record

HFNC - high flow nasal cannulae

ICU – intensive care unit

ISS – injury severity score

PCA - patient-controlled analgesia

TDF – theoretical domains framework

Declarations

Ethics approval

This study is part of a larger study testing the efficacy of the care bundle (ChIP). 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 Council (NHMRC, 2018), and was approved by the NSW Population & Health Services Research Ethics Committee (HREC/17/CIPHS/56).

Consent for publication

N/A

Availability of data and materials

The data supporting the conclusions of this article are included within the article. The individual data sets used in the evaluation are available from the corresponding author on reasonable request.

Competing interests

All authors declare that they have no competing interests.

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Authors' contributions

All authors made substantial contributions to conception and design of the study. SK, BM, TB and KC were involved in the study design. SK, BM, TB and KC were involved in the database design. SK, JL, IC did the data collection. SK did the quantitative analysis. SK drafted the manuscript, and all authors have been involved in revising it critically. All authors have read and approved the final manuscript for publication.

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Tables

Please see the supplementary files section to view the tables.

Figures

Figure 1

The ChIP flowchart

Figure 2

Logic map showing the intervention functions linked to behaviour change techniques (BCTs) and modes of delivery which are shaded (partially-implemented) or full colour (fully-implemented) [28]

Figure 3

Overall study design evaluating the implementation and efficacy of ChIP, this study indicated in orange

Figure 5

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

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [S4Appendix.ICD10DRG.pdf](#)
- [S3Appendix.Stari.docx](#)
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