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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Contributions To The Literature:

- Implementation initiatives in the emergency setting can be challenging, and more research is needed into successful implementation strategies.

- This study provides an example of successful implementation of a complex multidisciplinary intervention in the acute emergency setting using behaviour change frameworks.
- Findings from this evaluation can inform the implementation of multidisciplinary interventions in the emergency/acute care context with high fidelity.

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 older patients where each additional rib fracture increases the risk of mortality by 19% and of 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 have 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, care for patients can be ad hoc, and clinician-dependent and compliance with guidelines varies due to patient complexity and organisational barriers and [11–13]. Improving the reliable and sustained uptake of evidence in practice requires a robust implementation strategy developed through a rigorous and systematic theory-informed process that considers local clinician behaviour and context [14].

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 Australian hospitals [15] (Fig. 1). The ChIP care bundle is an early notification system to notify clinician 'responders' to review the patient within 60 minutes 24 hours, seven days a week. Responders included a physiotherapist, the surgical, intensive care, pain teams, and if required, the general medicine or geriatric medical team. Responders tailored care to the individual patient needs in three main areas, including respiratory adjuncts, analgesia and complication prevention (Fig. 1). The level of clinical intervention prescribed was clinician-led and guided by patient acuity and need.

Implementation fidelity or process evaluation is important to determine the reliability and validity of implementation studies [16, 17] and consists of two components: 1) the degree to which the implementation strategy was implemented as intended, and 2) the degree to which the intervention was delivered as intended [18].

The fidelity to the *implementation strategy* for ChIP has been evaluated and reported as 97.6% fully or partially implemented as intended [19, 20]. The implementation strategy for ChIP was developed using the Behaviour Change Wheel (BCW) and is described elsewhere [21, 22]. The barriers and facilitators to implementation of ChIP were identified following a survey of 198 staff from the 12 impacted clinical

departments and developed based on the Theoretical Domains Framework [23]. Alongside a consultation process that included an APEASE assessment (affordability, practicability, effectiveness, acceptability, side-effects, and equity), a multi-method implementation strategy containing seven intervention functions and 15 behaviour change techniques (BCT) [24] was developed (Additional file 1) [22]. Resources for the delivery of the implementation, including a staff video https://youtu.be/woc4cJGjjQo and storyboard for the video development, have been provided (Additional file 2). A logic map depicts 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) [25].

The fidelity of the intervention (ChIP), also referred to as 'fidelity of delivery' or 'treatment fidelity' [26], has not yet been evaluated. The Medical Research Council (MRC) guideline for process evaluations of complex interventions recommends that '*fidelity', 'dose*' and '*reach*' are evaluated as appropriate to the specific study and intervention [27]. *Fidelity* will assess if ChIP was delivered as intended. *Reach* describes whether the intended audience came into contact with an intervention, so this is how many patients received a ChIP activation and if it was appropriate [27]. *Dose* is the quantity of the intervention implemented; this will assess the components of ChIP that were delivered [27, 28]. The purpose of this study was to evaluate the fidelity, dose and reach of an intervention (ChIP) to discern if ChIP was activated and delivered to patients as intended.

Methods

Study Design

This study was a pre-post implementation evaluation of the fidelity, dose and reach of the ChIP care bundle (intervention). The outcomes were to discern if ChIP was *delivered* as intended (fidelity of ChIP) and whether the intended patient group received the care bundle activation (reach) [27]; and adherence to the intervention components (dose).

This study was part of a larger study testing the efficacy of the care bundle (ChIP) (Figure 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 [29], 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 [30] (Additional file 3).

Setting

The *blunt chest injury care bundle* (ChIP) was implemented at two hospital sites in regional NSW, Australia. The two sites were within the same local health district with a 500-bed regional trauma centre (Site A) and a 200-bed rural/regional hospital (site B), representing diverse sites with differing resources.

Site A is a regional trauma centre seeing approximately 70,000 presentations annually, and Site B is a smaller district hospital with approximately 40,000 presentations to its ED annually [31]. Both sites have intensive care units (ICU), EDs, pain specialist teams, and physiotherapists on site.

Patient identification

Patients were identified via two sources: 1) medical records of patients admitted to hospital with blunt chest injury identified using International Statistical Classification of Disease version 10 (ICD-10) codes and the Australian Refined Diagnosis Related Groups version 6 (AR-DRG v6) (Additional file 4) [32]; and 2) patients who had a ChIP call registered on the electronic medical record (eMR) system 'FirstNet' [33] (Figure 4) .

As part of the activation of ChIP, staff from the ED activated an icon on patients records to help other staff identify patients and to help staff 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 an icon logged.

The patient medical records were initially screened for eligibility against the following inclusion criteria:

- Any mechanism of chest trauma resulting in documented radiological or clinical blunt chest wall injury
- 18 years or over
- Presents via the ED
- No intubation in ED or prehospital

The records of patients identified through eMR who did not meet the above criteria but had a ChIP call were excluded from the primary analysis but had baseline data collected, and sub-analysis reported; as this was important for reach (Figure 4).

Medical records of patients meeting the above criteria underwent a second screening process, to assess if the patient met ChIP criteria and were eligible for a ChIP call. The ChIP eligibility criteria included patients who had recorded no improvement to chest pain or unable to deep breathe cough after analgesia and an injury that occurred within one week of ED presentation.

Sample

Four groups within the overall sample were analysed according to the outcome measure of interest (Figure 4). Group 1: The pre-group included admitted patients who presented in the pre-implementation period and met ChIP criteria. Group 2: The ChIP group were patients who met study eligibility criteria and had a ChIP activation, including both admitted and non-admitted patients. Group 3: The ChIP missed

group were patients who presented post-implementation, met ChIP eligibility criteria but did not get a ChIP activation. Group 4: The post-group included patients who presented after implementation and met ChIP eligibility criteria, including admitted patients who had activation of CHIP (admitted patients from group 2) or no activation (group 3).

Data collection

The study was conducted over four years. The pre-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 inpatient medical records and entered into a secure electronic database REDcap (Research Electronic Data Capture) [34]. Each data point 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 ten per cent 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. Inter-rater agreement rates were 97.8% for Site A (n=10) and 96.8% for Site B (n=20), both considered acceptable [35, 36].

Patient characteristics collected included age and gender. Clinical information included injury(s), mechanism of injury, injury date and time, Injury Severity Score (ISS) the Charlson Comorbidity Index (CCI). The ISS was used as an internationally recognised scoring system for the combined effects of trauma. The score ranges from 1 to 75, with ISS 15 or greater considered severe injuries. The CCI is a scoring system for mortality based on pre-existing comorbidities. ISS and CCI were considered confounding factors.

Data were also collected to identify adherence to the care bundle components (dose) in the areas of analgesia delivery, respiratory support and complication prevention. Data collected included whether vital signs, respiratory assessments, incentive spirometry and high flow nasal cannula use were documented. The dates and times of health service reviews were collected including physiotherapy, surgical, pain team or ICU. The admission team(s) were also collected.

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. There were two main analyses: 1) between-group analyses of ChIP call vs ChIP missed, and pre-ChIP implementation vs post-ChIP implementation and 2) within-group analyses involving the post group who received ChIP.

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 of the difference estimated using the Hodges-Lehmann estimate. Generalised Linear Models were also used for adjusted analyses of pre and post ChIP data: logistic regression with logit link was used for binary outcomes and for scale outcomes such as time to specific treatments the Gamma with log link model was used [37]. Correlation (Spearman's rho) 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 $p < 0.05$.

Outcome 1: Reach of ChIP intervention

The reach of ChIP activations was calculated as the proportion of eligible patients who got a ChIP call from all patients eligible for ChIP post-implementation (post-group). Hospital sites were compared for reach. ChIP and ChIP missed groups were described and compared on demographics, mechanisms, injuries, medical history and presentation in or out of hours to identify potential reasons for missed calls. Out of hours presentations were defined as before 8am and after 4pm on weekdays, and anytime on weekends and public holidays. Patients who got a ChIP call but were ineligible were described in sub-analysis; also indicating reach as an unintended patient group.

Outcome 2: Fidelity to ChIP intervention

Fidelity was assessed by analysis of the ChIP group. The ChIP group were analysed for patient discharges, discharges over time, and any issues with activation, including time to activation.

Outcome 3: Adherence with ChIP components (dose)

Adherence with ChIP components was evaluated in two ways. Firstly, within the post-group, comparisons were made between ChIP and ChIP missed groups. Secondly, the pre-group was compared to the post-group to identify how the components were used before and after implementation, identifying changes in practice. ChIP components explored included time to analgesia, pain team and physiotherapist review, use of high flow nasal cannulae (HFNC), patient-controlled analgesia (PCA) or other modes of analgesia.

Results

A total 795 patients were included in the final data analysis (Fig. 4). There were 284 in the pre-implementation group and 453 in the post-implementation group. In the post-implementation period, 533 patients received a ChIP call in the ED. However, 33 patients did not meet study inclusion criteria; leaving 500 who had ChIP activated and met study eligibility criteria (ChIP). There were 13 patients identified who were eligible for ChIP but did not get a call (ChIP missed).

Outcome 1: Reach of ChIP intervention

Overall, the reach of ChIP in eligible patients was 97.1%, with 96.1% at Site A and 98.8% at Site B. Eligible patients that did not receive an activation (ChIP missed group, n = 13) were not different in age, ISS, CCI, comorbidities and in-hours presentation, compared to patients who were eligible and received an activation (ChIP group n = 440) (Table 1). However, participants in the ChIP missed group were more likely to be female, have a sternal injury, have less than three rib fractures, or have had a vehicle-related injury compared to the ChIP activated group (Table 1). None of the ChIP missed group had three or more ribs fractures or a flail chest (Table 1). 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

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	[63.7–88.8]	0.257	8.4 (-18.4, 1.4)[b]
Female	n % (95% CI)	169	38.4 (33.9, 42.9)	10	76.9 (54.0, 99.8)	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 % (95% CI)	68	15.5 (12.1, 18.9)	2	15.4 (-4.2, 35.0)	0.992	0.1 (-19.9, 20.1) [a]
Pneumonia on arrival	n % (95% CI)	35	8.0 (5.5, 10.5)	1	7.7 (-6.8, 22.2)	0.969	0.3 (-14.7, 15.3) [a]
Asthma	n % (95% CI)	37	8.4 (5.8, 11.0)	0	0 (0, 0)	0.276	8.4 (-6.7, 23.5) [a]
Smoking (past or current)	n % (95% CI)	205	46.5 (41.8, 51.2)	7	53.9 (26.8, 81.0)	0.598	7.4 (-20.1, 34.9) [a]
Trauma call	n % (95% CI)	79	18.0 (14.4, 21.6)	2	15.4 (-4.2, 35.0)	0.810	2.6 (-18.6, 23.8) [a]
Out of hours presentation [c]	n % (95% CI)	292	66.4 (62.0, 70.8)	8	61.5 (35.1, 88.0)	0.713	4.9 (-21.2, 31.0) [a]
Polytrauma	n % (95% CI)	8	1.8 (0.6, 3.0)	1	7.7 (-6.8, 22.2)	0.131	5.9 (-1.8, 13.6) [a]
Sternum injury	n % (95% CI)	46	10.4 (7.6, 13.3)	4	30.8 (5.7, 55.9)	0.020	20.4 (3.2, 37.7) [a]
Rib fractures < 3 (includes clinical) [d]	n % (95% CI)	209	47.5 (42.8, 52.2)	11	84.6 (65.0, 104.2)	0.008	37.1 (9.5, 64.7) [a]

n = 453		ChIP (n = 440)		CHIP missed (n = 13)		P value	Change score* (95% CI)
Rib fractures ≥ 3 ribs or flail	n % (95% CI)	209	47.5 (42.8, 52.2)	0	0 (0,0)	< 0.001	47.5 (20.0,75.0) [a]
Lung injury, any	n % (95% CI)	111	25.2 (21.1, 29.3)	1	7.7 (-6.8, 22.2)	0.149	17.5 (-6.3, 41.3) [a]
Fall [e]	n % (95% CI)	277	63.0 (58.5, 67.5)	5	38.5 (12.1, 65.0)	0.072	24.5 (-2.2, 51.2) [a]
Vehicle related injury	n % (95% CI)	124	28.2 (24.0, 32.4)	7	53.8 (26.7, 80.9)	0.045	25.6 (0.6, 50.6) [a]
Other mechanism [f]	n % (95% CI)	39	8.8 (6.2, 11.5)	1	7.7 (-6.8, 22.2)	0.890	1.1 (-14.5, 16.7) [a]

[a] p value, difference and 95% CI based on 2 sample z test

[b] P value based on test of sample medians, change score and 95% CIs based on 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 4 pm-8am, weekends and public holidays. Polytrauma = two or more abbreviated injury scores (AIS) greater than 2 in 2 or more body regions.

[d] Clinical rib fractures include injuries where there is no documented rib fracture on imaging; however, patient has significant pain

[e] Fall includes standing, height and ladder.

[f] Other mechanism includes blunt impact from objects or animals, and other mechanisms such as from cough or CPR

Abbreviations: CCI = Charlson Comorbidity Index, ChIP = blunt chest injury care bundle protocol, COPD = Chronic obstructive pulmonary Disease, ISS = injury severity score

Among those who had a ChIP call activated, but did not meet predetermined eligibility criteria (n = 33), 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 electronic medical record 19 (57.6%), potentially indicating they were placed in error. Three patients (9%) 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 under 18 years and therefore ineligible for inclusion in this study. (Additional file 5).

Thirty patients had ChIP activations that occurred on the hospital ward; occurring between 6 hours and 5.4 days after ED presentation (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 ED. (Additional file 5)

Outcome 2: Fidelity to ChIP intervention

Sub-analysis of patients with ChIP activations (n = 500) demonstrated median [IQR] time to ChIP activation was 134 [58–249.5] minutes with 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 [60–259] vs 117 [56–239], p = 0.048). There was no difference in time to activation after-hours compared to during hours (147 [67–255] vs 114 [52.5-236.5], p = 0.15). Time to activation was not associated with CCI (rho = 0.08, p = 0.08), age (rho = 0.02, p = 0.62), or ISS (rho = 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). Further results for sub-analysis are available in Additional file 5.

Of the 500 patients who received a ChIP call, 440 (88%) were admitted to hospital and 60 (12%) discharged from the ED. 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 ChIP patients from ED reduced over the post-implementation study, p = 0.04 (Additional file 5).

Outcome 3: Dose - adherence of ChIP activations

Post-implementation comparisons: adherence

The ChIP and ChIP missed groups were similar in relation to receiving initial vital sign assessment, respiratory assessment or initial analgesia in the ED (Table 2). In regards to analgesia, the ChIP group were more likely to be seen by the pain service and have a PCA (Table 2). In regards to respiratory support and complication prevention, the ChIP group were more likely to have had a physiotherapy review, HFNC, incentive spirometry, and education for deep breathing compared to the ChIP missed group (Table 3). Of patients that got 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 (Additional file 5).

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

n = 453	CHIP n = 440		ChIP missed n = 13		P value	Change Score* (95% CI)
	n	% (95% CI)	n	% (95% CI)		
Initial vital signs	434	98.6 (97.5, 99.7)	13	100 (100, 100)	0.668	1.4 (-5.0, 7.8)
Respiratory assessment prior to analgesia	311	72.0 (67.8, 76.2)	8	61.5 (35.1, 88.0)	0.408	10.5 (-14.4, 35.4)
Analgesia in emergency department	385	87.5 (84.4, 90.6)	11	84.6 (65.0, 104.2)	0.756	2.9 (-15.4, 21.2)
Vital signs (15–90 min post-analgesia)	270	61.4 (56.9, 66.0)	6	46.2 (19.1,73.3)	0.268	15.2 (-11.7, 42.1)
Respiratory assessment post-analgesia (15–90 min)	137	32.1 (27.7, 36.5)	1	7.7 (-6.8, 22.2)	0.062	24.4 (-1.2, 5.0)
Analgesia plan (regular, PRN, regional, IV or PCA)	432	98.2 (97.0, 99.4)	13	100 (100, 100)	0.626	1.8 (-5.4, 9.0)
Reviewed by acute pain service	380	86.4 (83.2, 89.6)	5	38.5 (12.1, 65.0)	< 0.001	47.9 (28.2, 67.6)
Regular analgesia charted day 1	404	91.8 (89.2, 94.4)	12	92.3 (77.8, 106.8)	0.948	0.5 (-14.6, 15.6)
As needed (PRN) Analgesia charted	362	82.3 (78.7, 85.9)	12	92.3 (77.8, 106.8)	0.349	10.0 (-10.9, 30.9)
Regional analgesia	54	20.2 (16.5, 24.0)	0	0 (0, 0)	0.071	20.2 (-1.7, 42.1)

*p value, difference and 95% CI based on 2 sample z test

Abbreviations: ChIP = blunt chest injury care bundle protocol, HFNC = High flow nasal cannula, ICU = intensive care unit, PCA = Patient controlled analgesia

n = 453	CHIP n = 440		ChIP missed n = 13		P value	Change Score* (95% CI)
	n	% (95% CI)	n	% (95% CI)		
Patient controlled analgesia (PCA) charted	201	45.7 (41.1, 50.4)	1	7.7 (-6.8, 22.2)	0.007	38 (10.6, 65.4)
Intravenous (IV) continuous analgesia used	18	4.1 (2.3, 6.0)	0	0 (0, 0)	0.456	4.1 (-6.7, 14.9)
Reviewed by surgery	417	94.8 (92.7, 96.9)	6	46.2 (19.1, 73.3)	< 0.001	48.6 (34.9, 62.3)
Admit general surgery	391	88.9 (86.0, 91.8)	6	46.2 (19.1, 73.3)	< 0.001	42.7 (24.6, 60.8)
ICU liaison nurse review	242	55.0 (50.4, 60.0)	1	7.7 (-6.8, 22.2)	< 0.001	47.3 (19.8, 74.8)
ICU doctor review	267	60.7 (56.1, 65.3)	1	7.7 (-6.8, 22.2)	< 0.001	53.0 (25.9, 80.1)
Physiotherapy review (chest)	422	96.0 (94.1, 97.8)	9	69.2 (44.1, 94.3)	< 0.001	26.8 (15.0, 38.6)
High flow nasal cannula (HFNC)	315	71.6 (67.4, 75.8)	3	23.1 (0.2, 46.0)	< 0.001	48.5 (23.3, 73.7)
Incentive spirometry	187	42.6 (38.0, 47.2)	2	15.4 (-4.2, 35.0)	0.050	27.2 (-0.04, 54.4)
Education	408	92.7 (90.3, 95.1)	6	46.2 (19.1, 73.3)	< 0.001	46.5 (31.0,62.0)
*p value, difference and 95% CI based on 2 sample z test						
Abbreviations: ChIP = blunt chest injury care bundle protocol, HFNC = High flow nasal cannula, ICU = intensive care unit, PCA = Patient controlled analgesia						

Comparison of pre and post groups: adherence

Age, sex, CCI, or mechanism of injury did not differ between the pre-implementation (n = 282) and post-implementation groups (n = 453) (Table 3). There were more trauma calls in the pre-group compared to the post-group; however, the ISS 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 characteristic mechanism, injuries

Total **n = 737**	**PRE** **n = 282**		**POST** **n = 453**		**p value**	**Change Score (95% CI)**
	n % (95%CI) (unless otherwise specified*)		**n % (95%CI)** (unless otherwise specified*)			
Female n %	103	36.5 (30.9, 42.1)	179	39.5 (35.0, 44.0)	0.416	3.0 (-4.2, 10.2)[a]
Age median [IQR]	67.9	[50.6–81.4]*	69.3	[54.6–81.3]*	0.51	-1.8 (-4.5, 1.1)[b]
CCI median [IQR]	3	[1.0–6.0]*	3	[1.0–5.0]*	0.642	0 (0, 0)[b]
ISS median [IQR]	5	[3.0–10.0]*	9	[4.0–10.0]*	0.005	0 (-1.0, 0)[b]
Chronic Obstructive Pulmonary Disease	60	21.3 (16.5, 26.1)	70	15.5 (12.2, 18.8)	0.045	5.8 (0.1, 11.5) [a]
Asthma	28	9.9 (6.4, 13.4)	37	8.2 (5.7, 10.7)	0.430	1.7 (-2.5, 5.9) [a]
Smoking (current or past)	143	50.7 (44.9, 56.5)	212	46.8 (42.2, 51.4)	0.304	3.9 (-3.5, 11.3) [a]
Recent pneumonia	23	8.2 (5.0, 11.4)	36	7.9 (5.4, 10.4)	0.884	0.3 (-3.7, 4.3) [a]
Trauma call	89	31.6 (26.2, 37.0)	81	17.9 (14.4, 21.4)	< 0.001	13.7 (7.4, 20.0) [a]
Out of hours presentation	179	63.5 (57.9, 69.1)	300	66.2 (61.8, 70.6)	0.455	2.7 (-4.4, 9.8) [a]
Polytrauma	5	1.8 (0.3, 3.4)	9	2.0 (0.7, 3.3)	0.848	0.2 (-1.8, 2.2) [a]

[a] p value, difference and 95% CI based on 2 sample z test

[b] P value based on test of sample medians, change score and 95% CIs based on 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)

*Median [IQR]

Abbreviations: CCI = Charlson comorbidity Index, ISS = injury severity score

Total n = 737	PRE n = 282		POST n = 453		p value	Change Score (95% CI)
Sternum injury	34	12.0 (8.2, 15.8)	50	11.1 (8.2, 14.0)	0.709	0.9 (-3.8, 5.6) [a]
Rib fractures < 3 (includes clinical)	169	60.0 (54.3, 65.7)	220	48.6 (44.0, 53.2)	0.003	11.4 (4.0, 18.8) [a]
Rib fractures > = 3 ribs or flail	104	37.0 (31.4, 42.6)	209	46.1 (41.5, 50.7)	0.015	9.1 (1.8, 16.5) [a]
Lung injury, any	70	24.8 (19.8, 29.8)	112	24.7 (20.7, 28.7)	0.976	0.1 (-6.3, 6.5) [a]
Fall	157	55.7 (49.9, 61.5)	282	62.3 (57.8, 66.8)	0.076	6.6 (-0.7, 13.9) [a]
Vehicle related injury	95	33.7 (28.2, 39.2)	131	28.9 (24.7, 33.1)	0.170	4.8 (-2.1, 11.7) [a]
Other mechanism	30	10.7 (7.1, 14.3)	40	8.8 (6.2, 11.4)	0.394	1.9 (-2.5, 6.3) [a]
[a] p value, difference and 95% CI based on 2 sample z test						
[b] P value based on test of sample medians, change score and 95% CIs based on 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)						
*Median [IQR]						
Abbreviations: CCI = Charlson comorbidity Index, ISS = injury severity score						

The post-group were more likely to have regular analgesia charted (day one of admission), regional analgesia, and PCA in compared to the pre-group (Table 4). The post-group had greater odds of receiving HFNC, incentive spirometry and education regarding their injury (Table 4). The post-group received more reviews by surgery, ICU liaison, ICU, chest physiotherapists and pain team (Table 4). The post-group also had faster times to initial analgesia, regular analgesia, pain review, physiotherapist review, and ICU review (Table 5). The rates of ChIP component delivery over the study period are presented in Fig. 5.

Table 4
Comparison of pre ChIP and post ChIP groups on components relating to ChIP implementation

	PRE n = 282		POST n = 453		OR (95% CI)	p value[a]	Nagelkerke R^2
	n % (95% CI)		n % (95% CI)				
Components Before Activation							
Initial vital signs	278	98.6 (97.2, 100.0)	447	98.7 (97.7, 99.7)	1.1 (0.3, 4.1)	0.887	.073
Initial respiratory assessment	195	70.1 (64.8, 75.4)	319	71.7 (67.6, 75.9)	1.1 (0.8, 1.5)	0.627	.007
Initial analgesia in emergency	251	89.0 (85.4, 92.7)	396	87.4 (84.3, 90.5)	1.0 (0.6, 1.7)	0.869	.022
Vital signs attended post analgesia (15–90 minutes)	187	66.3 (60.8, 71.8)	276	60.9 (56.4, 65.4)	0.9 (0.7, 1.2)	0.542	.062
Respiratory assessment post analgesia	146	52.1 (46.3, 57.9)	138	31.4 (27.1, 35.7)	0.4 (0.3, 0.6)	< 0.001	.061
After activation							
Analgesia							
Regular analgesia charted	235	83.3 (79.0, 87.7)	416	91.8 (89.3, 94.3)	2.4 (1.5, 3.8)	< 0.001	.037
PRN analgesia	239	84.8 (80.6, 89.0)	374	82.6 (79.1, 86.1)	0.8 (0.5, 1.2)	0.201	.019
Regional analgesia	14	7.4 (4.3, 10.5)	54	19.3 (15.7, 22.9)	2.8 (1.5, 5.3)	0.001	.084

[a] odds ratio (OR), 95% CI, and p value adjusted for ISS and trauma call

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, HFNC = High flow nasal cannulae, ICU = intensive care unit, PCA = Patient controlled analgesia

	PRE n = 282		POST n = 453		OR (95% CI)	p value[a]	Nagelkerke R^2
	n	% (95% CI)	n	% (95% CI)			
PCA	94	33.3 (27.8, 38.8)	202	44.6 (40.0, 49.2)	1.8 (1.3, 2.4)	0.001	.144
Any analgesia	269	95.4 (93.0, 97.8)	445	98.2 (97.0, 99.4)	2.5 (1.0, 6.4)	0.049	.150
Team review							
Surgical review	193	68.4 (63.0, 73.8)	417	92.1 (89.6, 94.6)	9.9 (6.1, 16.1)	< 0.001	.375
Pain team review	113	40.1 (34.4, 45.8)	385	84.9 (81.6, 88.2)	9.0 (6.2, 12.9)	< 0.001	.316
Physiotherapist review	218	77.3 (72.4, 82.2)	431	95.1 (93.1, 97.1)	4.8 (2.9, 8.1)	< 0.001	.204
ICU liaison	27	9.6 (6.2, 13.0)	237	52.3 (47.7, 56.9)	10.7 (6.9, 16.7)	< 0.001	.278
ICU doctor review	72	25.6 (20.5, 30.7)	268	59.2 (54.7, 63.7)	4.5 (3.2, 6.3)	< 0.001	.188
Respiratory Support							
HFNC	73	25.9 (20.8, 31.0)	318	70.2 (66.0, 74.4)	6.8 (4.8, 9.6)	< 0.001	.270
Incentive spirometry	54	19.1 (14.5, 23.7)	189	41.8 (37.3, 46.3)	3.0 (2.1, 4.3)	< 0.001	.092

[a] odds ratio (OR), 95% CI, and p value adjusted for ISS and trauma call

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, HFNC = High flow nasal cannulae, ICU = intensive care unit, PCA = Patient controlled analgesia

	PRE n = 282		POST n = 453		OR (95% CI)	p value[a]	Nagelkerke R^2
	n % (95% CI)		n % (95% CI)				
Incentive spirometry commenced in ED	7	12.7 (8.8, 16.6)	98	51.9 (47.3, 56.5)	7.5 (3.2, 17.6)	< 0.001	.179
Education	168	59.6 (53.9, 65.3)	414	91.4 (88.8, 94.0)	6.8 (4.5, 10.3)	< 0.001	.214
[a] odds ratio (OR), 95% CI, and p value adjusted for ISS and trauma call							
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, HFNC = High flow nasal cannulae, ICU = intensive care unit, PCA = Patient controlled analgesia							

Table 5
Time in minutes to receipt of components of the blunt chest injury care bundle (ChIP) for pre and post patient groups [32]

Time (minutes)	PRE		POST		P value	Change Score (95% CI)[a]
	Estimated Marginal Mean (SE)		Estimated Marginal Mean (SE)			
Time to initial analgesia	87.6	(5.15)	76.0	(4.0)	0.060	11.6 (-.4, 23.5)
Time to regular analgesia	542.1	(27.1)	425.5	(18.4)	< 0.001	116.5 (56.6, 176.4)
Time to PCA	689.6	(60.9)	482.2	(31.3)	0.002	207.4 (75.0, 339.8)
Time to Surgical review	347.6	(23.4)	204.3	(10.2)	< 0.001	143.3 (94.9, 191.6)
Time to Pain team	1394.7	(117.3)	680.7	(36.7)	< 0.001	714.0 (480.7, 947.3)
Time to Physiotherapist review	1801.6	(92.9)	975.4	(40.0)	< 0.001	826.2 (641.7, 1010.7)
Time to ICU doctor	770.0	(85.6)	343.0	(23.2)	< 0.001	427.0 (257.0, 597.0)
Time to ICU liaison	1413.7	(249.1)	1026.0	(76.5)	0.130	387.7 (-113.7, 889.1)
[a]Estimated marginal means: adjusted for ISS and trauma call						
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, ICU = intensive care unit, PCA = Patient controlled analgesia						

Discussion

This study evaluated the implementation of a blunt chest injury care bundle (ChIP) by assessing the fidelity of delivery (fidelity, dose, reach). The implementation strategy based on the BCW resulted in a high and sustained reach (97.1%) and dose of the ChIP care bundle over the 19-month post-implementation evaluation period. Discharges after a ChIP activation decreased over the post-implementation period; this suggests an improvement in the identification of patients that were eligible for ChIP activation by staff.

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 [38]; however, this study has demonstrated it can be successful with strategic theory-based planning [39].

Implementation was considered to be successful in that changes to care delivery were 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.

To assess the need for a ChIP activation, ED staff were required to do a respiratory assessment 30 minutes after analgesia. There were fewer patients in the post-group who got 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].

Implementation strategy scalability

The ChIP intervention and implementation strategy are 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 [41]. The implementation plan included multi-modal 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 based implementation studies include 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 [42]. The ChIP implementation included a combination of all of these strategies.

The implementation strategies were associated with high fidelity for care bundle implementation [43]. Minimal costs were incurred for implementation. The funding for clinical champions was not used while still maintaining high fidelity. Clinical champions were hired for the role from the existing nursing workforce; however, of the eight initial positions, only two clinical champions continued in the role due to secondments and other extenuating circumstances. The two staff that continued as clinical champions were in positions where they could provide support with one being a clinical educator and the other the ICU liaison role and were able to fulfil the role sufficiently. Demonstrating that sites without funding may be able to implement without the extra resources.

Strengths and Limitations

A limitation is that there may have been some records missed in the screening. The eMR screening identified patients who were not picked up by the ICD-10 and DRG codes screening. 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 in the medical record coding screen. The ICD-10 codes were retrospectively checked for the records that were missed. Some examples of the ICD-10 codes given to the missed patients were “chest pain, unspecified” and “injury, unspecified”. These codes were not included in the ICD-10-AM request as they were considered medical-related or vague.

Another limitation is that the ChIP missed group is relatively small, a strength of the intervention reach, but this did lead to limiting power of statistical analysis in comparison to ChIP.

There were fewer patients in the pre-group; this may have been due to poor documentation of chest injury symptoms in the pre-group medical records.

A limitation is that results were based on the effectiveness of documentation of the healthcare professionals, for example, if staff provided education but did not document that they did. Using documentation for implementation evaluation can sometimes lead to low implementation fidelity [40]; however, implementation fidelity was high in this study, suggesting it has been an adequate method of evaluation in this case. It was important for this study to evaluate implementation in the real-world without researcher interference. Further, other methods have their problems. For example, direct observation can lead to changes in behaviour due to being observed and may not be feasible due to high cost and ethical considerations around observing patients in direct care [44]. Self-report is also problematic, with a risk of self-report bias overestimating fidelity [44, 45].

This evaluation did not evaluate 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.

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 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 [49-51], perhaps needing greater use of behaviour change theories to improve implementation design [52]. This implementation evaluation can inform future spread and scale of ChIP, including for research or clinical implications [53]. Further, it can improve the validity of the ChIP patient outcome studies [54].

Conclusion

Following a robust theoretical-based implementation plan is associated with high implementation delivery. Implementation evaluation of complex health interventions in the ED context requiring a multidisciplinary response may require multi-modal implementation strategies to be successful. The results from this study can inform future implementation efforts in the acute care environment, such as the ED.

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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Figures

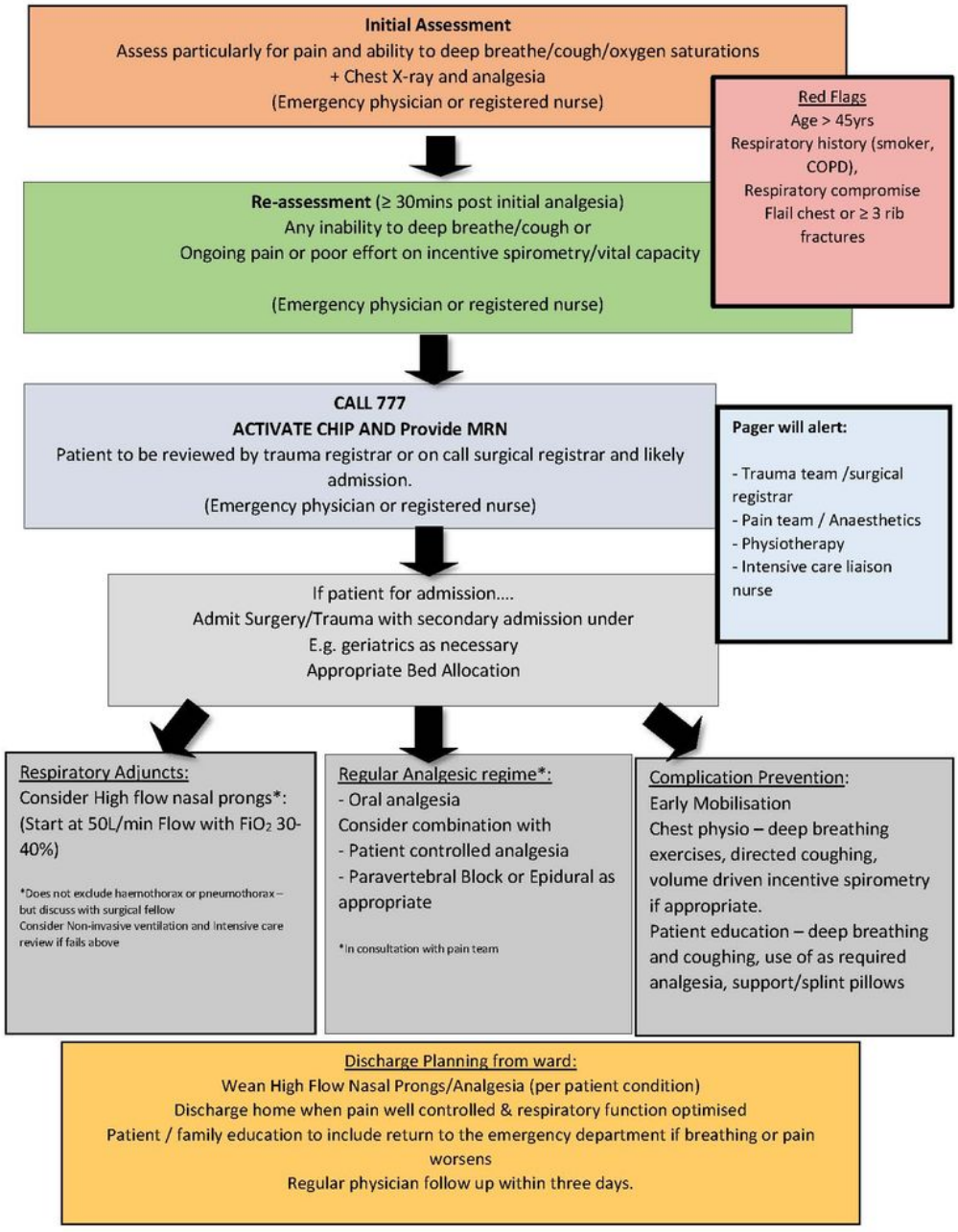

Figure 1

ChIP flowchart

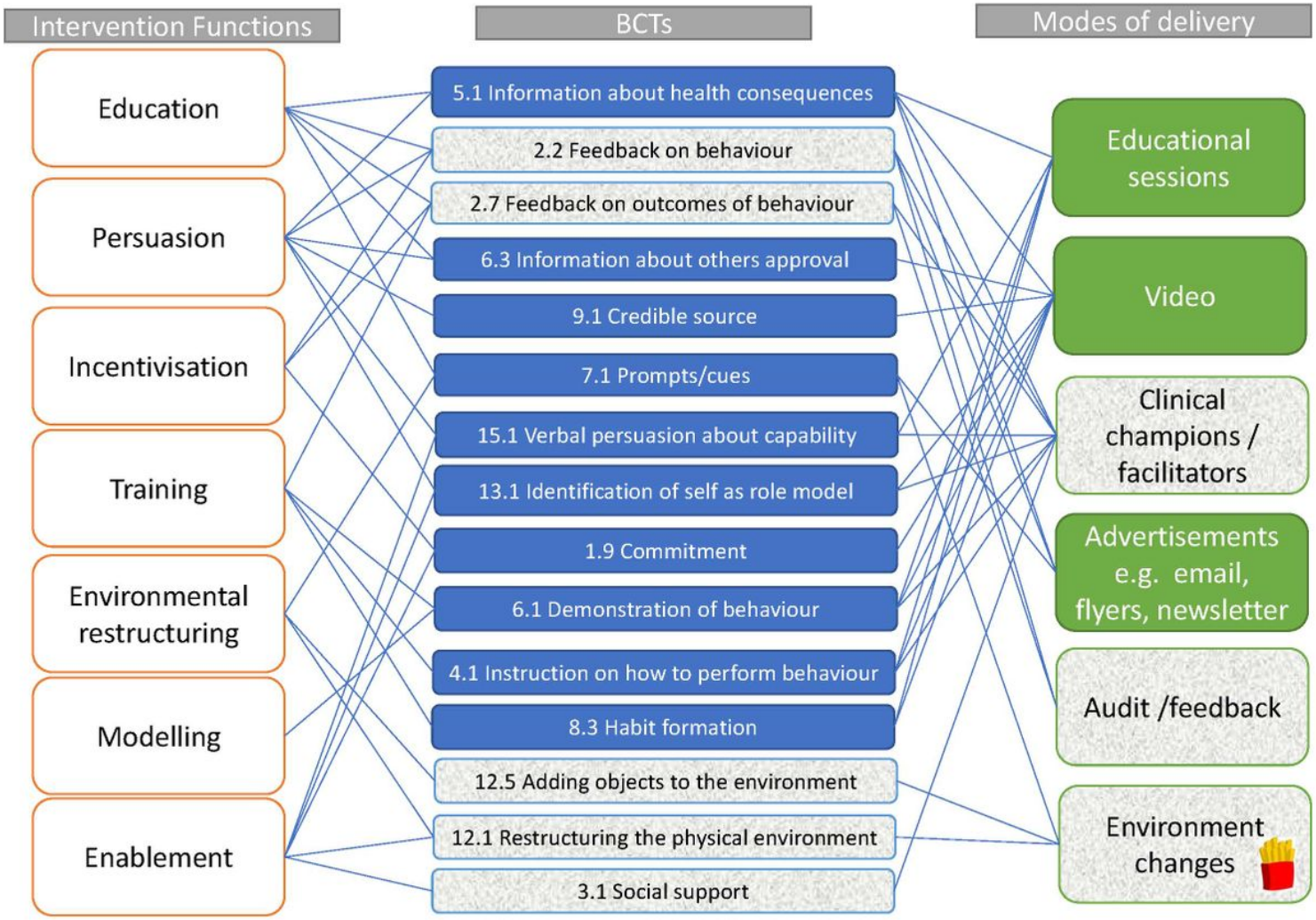

Figure 2

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) [25]

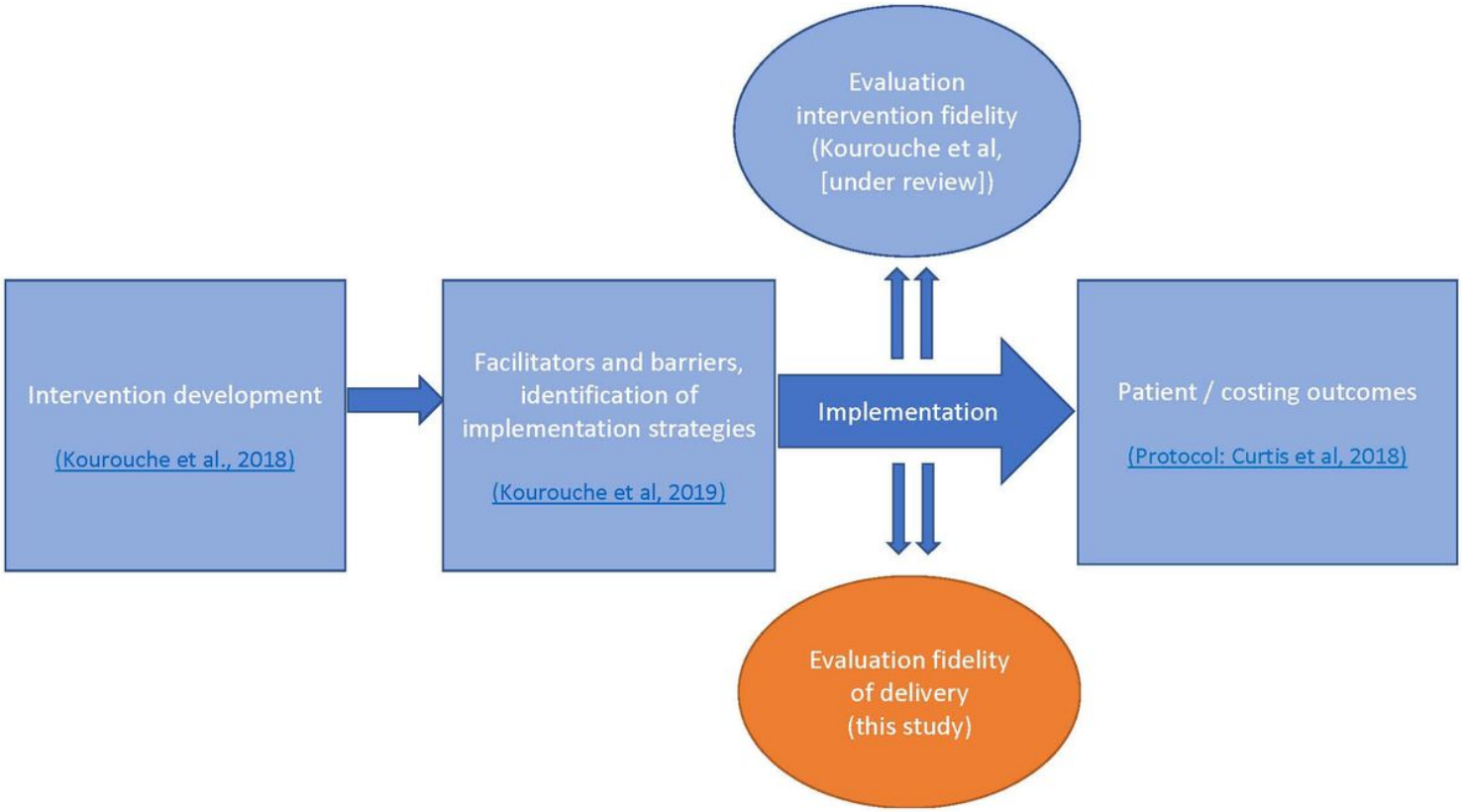

Figure 3

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

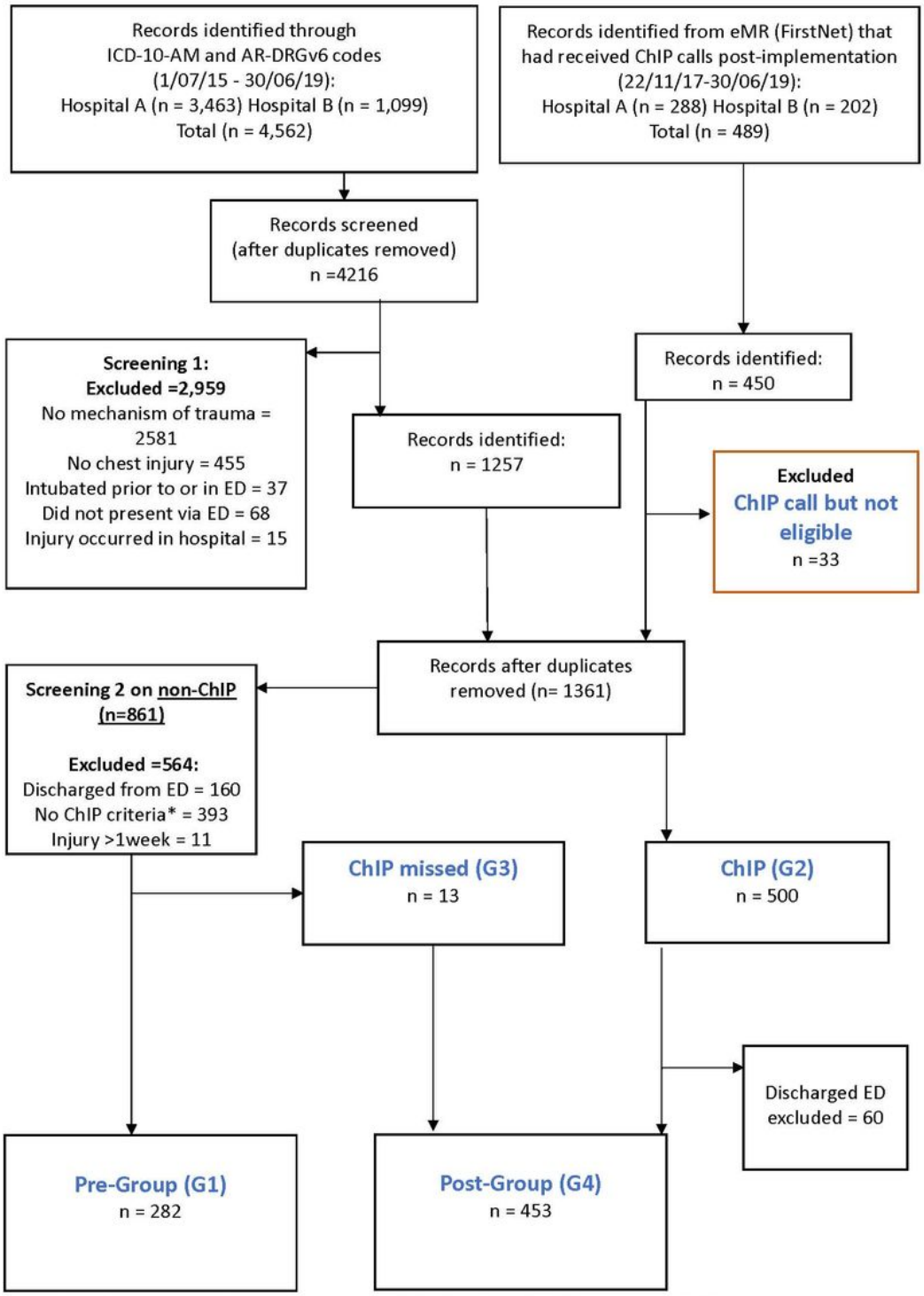

Figure 4

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

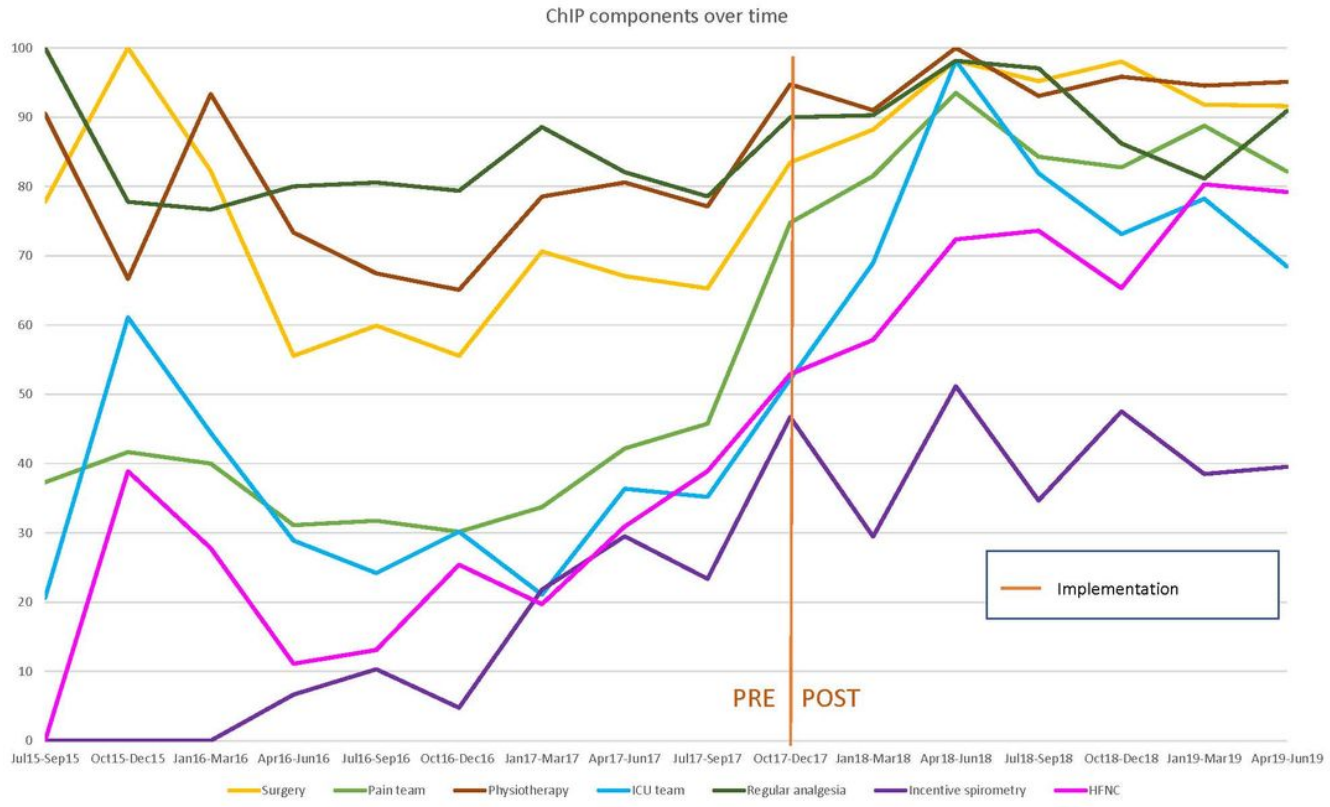

Figure 5

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

Supplementary Files

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

- Additionalfile1.ChIPImplementationplanredacted.pdf
- Additionalfile5.Supplemantaryresults.pdf
- Additionalfile4.ICD10DRG.pdf
- Additionalfile3.StaRI.pdf
- Additionalfile2.Implementationresources.pdf