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Before-after evaluation of patient length of stay in a rehabilitation context following implementation of an electronic patient journey board

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ABSTRACT

Purpose: To investigate whether the installation of electronic patient journey boards in an inpatient adult rehabilitation centre in Victoria, Australia, is associated with shorter lengths of stay for admitted adult rehabilitation patients.
Methods: A retrospective before-after analysis of 3 259 adult inpatient rehabilitation episodes from 2013 to 2018 was performed, analysing case-mix adjusted lengths of stay.
Results: A reduction in case-mix adjusted length of stay of 4.1 days per episode (95 % confidence interval: 2.0–6.4 days) was found. The corresponding reduction in hospital costs was estimated to be $3 738 per episode (95 % confidence interval $2 398–$4 983).
Conclusions: Installation of electronic patient journey boards was associated with shorter lengths of stay in an inpatient adult rehabilitation centre. Additional research is needed to 1) provide further evidence of the causal effect of the boards on length of stay, and 2) investigate the mechanisms by which they reduce lengths of stay (e.g., increased currency of information, changes to procedures, remote viewing) in rehabilitation settings.

1. Introduction

Rehabilitation care involves health professionals working with individuals to overcome injury or disability that limits that person's ability to function within their environment. In order to facilitate a patient's safe discharge from inpatient rehabilitation care, the individual goals and needs of the patient and family are required to be addressed. In attending to these needs, a variety of tasks are identified and must be coordinated and completed by health professionals from a range of disciplines before a discharge is deemed appropriate. This also includes planning for future care needs and long-term goal achievement outside the inpatient setting. This coordination requires a high degree of team engagement, communication and accountability.

Patient journey boards are tools for coordinating patient care and flow, whereby relevant information about patients is displayed on a board in a central location such as a nurse's station. An electronic patient journey (EPJB) board is similar, but can offer advantages associated with digitisation, such as real-time updating of information from central data sources and remote viewing.

1.1. Scientific background

Visual management tools are tools of continuous performance improvement typically used in manufacturing [1]. More recently, they have been used in the healthcare setting where they have the potential to enhance staff communication and patient flow management [2–5]. Non-electronic journey boards have been studied in the context of patient flow and discharge processes [6,7].

There has been limited research into the effect of electronic versions of patient journey boards on inpatient patient flow, with previous research focussing on acute settings. Wong et al. [8] conducted surveys and a usage audit to evaluate adoption of a new electronic whiteboard in a general internal medicine inpatient unit of an acute care hospital in Toronto, Canada. Gururajan et al. [9] used surveys to study staff opinions before and after installation of EPJBs in hospitals in Queensland, Australia. Clark et al. [10] reported a reduction in average length of stay following installation of 50 EPJBs in hospitals in Queensland, Australia, although no tests of statistical significance or confidence intervals were reported. Tariq et al. [11] examined barriers to adoption of

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a hospital-wide EPJB based on experiences in acute wards at two large public hospitals in metropolitan Sydney, Australia. There appears to be no published work on the effect of EPJBs on patient flow for rehabilitation inpatients.

1.2. Rationale

The change to using an EPJB connected to a hospital's Information Technology (IT) system, as part of business-as-usual care, may be associated with shorter lengths of stay. This study was conceived to develop an evidence base on the effect of an EPJB solution on hospital length of stay and associated hospital costs for adult inpatient rehabilitation care.

1.3. Organisational setting

The McKellar Centre of Barwon Health is a publicly-funded, 100-bed inpatient rehabilitation centre in Victoria, Australia which operates as a separate campus of a regional acute-care hospital. The rehabilitation centre utilises the same key IT systems (e.g., inpatient health record, patient flow system) as the hospital. The centre provides services in the areas of rehabilitation, geriatric evaluation and management (GEM) and palliative care. It is physically divided into 3 wings: North, Central and South.

A 2014 internal review of the rehabilitation centre identified that a reconfiguration of specialities and bed counts within the three wards might better reflect "streams of care" and patient demand for services. In October 2015 a reconfiguration redistributed the three services across the three wings. A key change was consolidation of GEM to the Central Wing. In the rehabilitation context, South Wing maintained 34 rehabilitation beds, although the mix of impairments changed. Prior to the changes, rehabilitation patients were split between South Wing (34 beds; Orthopaedics, General rehabilitation and Amputee) and Central Wing (20 beds; Stroke, Neurological and Trauma). Following the changes, rehabilitation patients were split between South Wing (34 beds; 26 Orthopaedics, 4 Amputee, and 4 Trauma) and North Wing (16 beds; Stroke and Neurological). There was no change to the medical or support staffing FTE numbers.

The adoption of an EPJB to replace whiteboard-based patient journey boards was a natural progression for the centre. Five years of workflow development and optimisation using whiteboards had resulted in an accurate and coordinated approach to discharge planning.

1.4. System details and system in use

In 2016 a commercial EPJB system was installed in the rehabilitation centre. Prior to the EPJB, large whiteboards on each ward were used to display each patient's journey and progress towards discharge. Limitations of this method included the requirement of staff to be in a single physical location to view and update information, and the risk of accidental loss of data when information was altered. Rehabilitation staff were engaged in designing features of the new EPJB system. Engagement began early in April 2015 with an initial roundtable discussion followed by a workshop to determine workflows and key requirements of the new EPJB. Installation of the EPJB was phased with an implementation date of 3 March 2016 for North Wing and 27 June 2016 for Central and South Wings.

The commercial system uses large computer monitors to replace the whiteboards at nurse's stations. Regular computer monitors are also used where team collaboration occurs. In addition, a customised board was installed in the admissions office to provide a consolidated view of all wards and further support for patient access and flow in the centre. Functionality and automation were the most significant changes. The system integrates with the centre's IT systems, so it displays key clinical and discharge planning details, including estimated discharge date and destination, length of stay, and staffing allocations. It also includes "traffic lights", i.e. coloured indicators for completion of tasks by individual disciplines; and plans for services and transport on discharge. A ward "handover report" can also be printed. The system is also accessible from any password-protected, networked computer. This is expected to result in more timely and accurate data, as staff can easily update the required information simultaneously from multiple locations. During multidisciplinary team meetings, for example, staff can update the EPJB in real-time as decisions are made. Moving the whiteboard into an electronic format also aimed to offer an improved user experience. Anecdotally, the electronic boards are not as messy and colours are more pronounced, thereby achieving greater visual impact.

1.5. Objectives of study

This study seeks to answer questions about the effect of EPJBs on patient flow in the adult inpatient rehabilitation context. The primary study question is: what is the size of the change (if any) in case-mix adjusted lengths of stay following the change to using an EPJB in business-as-usual care? A secondary aim is to estimate the magnitude of the change in hospital cost arising from shorter lengths of stay (if any). Exemption from ethics review to study de-identified data was granted by the hospital's Human Research Ethics Committee (project 18/57).

2. Methods

2.1. Study design

We conducted a retrospective before-after comparison of adult rehabilitation inpatient lengths of stay following implementation of an EPJB in 2016. The study used de-identified, routinely collected hospital data for patients discharged between July 1, 2013 and March 31, 2018.

2.2. Selection of participants

Episode level data for all rehabilitation patients discharged from the rehabilitation centre during the study period was used. This data was provided by the hospital which operates the rehabilitation centre as a table of episode-level data collected for all hospital patients (e.g., demographic data, episode start and end dates) and a separate table of supplementary data relevant to rehabilitation patients. Fig. 1 summarises the data filtering and merging steps to prepare the final cohort for analysis. Data linkage between the two tables failed for six episodes and one episode had missing relevant values. As these episodes are a very small fraction of the data, they were omitted from analysis.

2.3. Outcomes

The primary outcome in this study is the "case-mix adjusted length of stay". The "length of stay" for a hospital episode is defined as the number of days between admission and discharge. For inpatient admissions with an overnight stay this must be at least one. Rehabilitation cases may include leave from hospital, defined as a temporary absence from hospital for 7 days or less with medical approval. The "leave adjusted length of stay" subtracts the number of leave days. "Case-mix adjusted length of stay" attempts to control for heterogeneity in rehabilitation cases by finding the difference between the leave-adjusted length of stay and the benchmark duration for episodes of a similar type. Rehabilitation episodes can be classified using the Australian National Subacute and Non-Acute Patient (AN-SNAP) system [12,13]. Benchmarks are published by the Australasian Rehabilitation Outcomes Centre (AROC) [14]. For this study, public sector AN-SNAP class (version 3) benchmarks for financial years 2013–2014 to 2017–2018 were used. Case-mix adjusted lengths of stay can take fractional values, arising from fractional values in the benchmarks.

For analysis that spans several years, there are several choices for

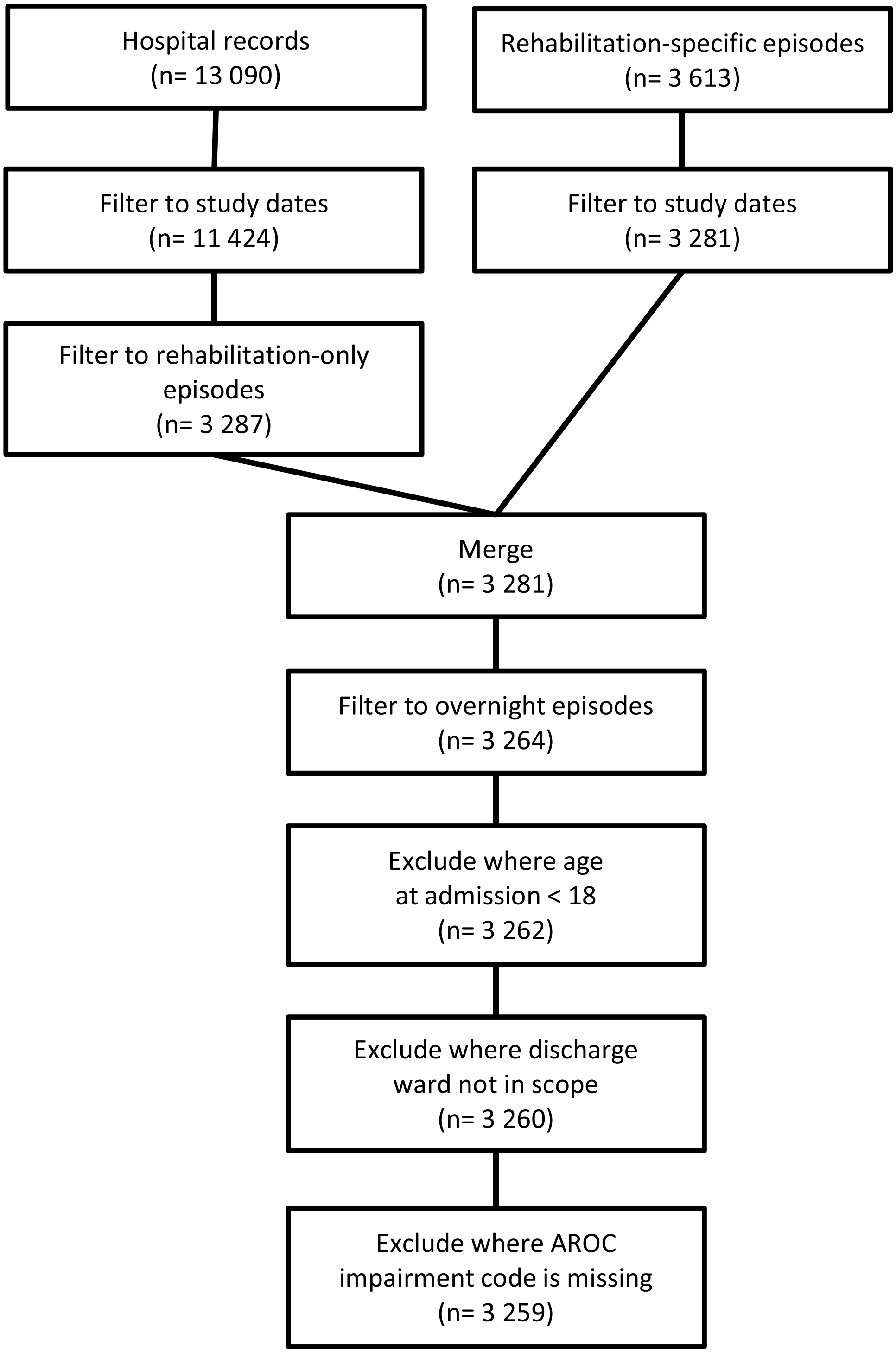

Fig. 1. Participant data flow. Data was provided as a table of hospital episode-level data and a separate table of supplementary data relevant to rehabilitation patients. Australasian Rehabilitation Outcomes Centre (AROC) impairment codes provide a system to classify rehabilitation episodes according to impairment groups.

the appropriate benchmark to perform case-mix adjustment. The benchmarks by AN-SNAP class for any particular year would serve as representative. Using the benchmark specific to the discharge year of each episode is another possibility, but variability in the benchmarks across years may confound changes in the length of stay. Another possibility explored here is to form a multi-year benchmark. Recognising that the yearly benchmarks for each AN-SNAP class are the mean of leave-adjusted lengths of stay for episodes reported to AROC, we formed the weighted average across the years of the study by using the number of episodes reported in each year as a weight. See Supplementary Information 1 for details.

A secondary outcome for the study is the average episode cost. See Supplementary Information 2 for details.

2.4. Methods for data analysis

2.4.1. Key covariates

Several covariates were used in the statistical analysis. These have been included to answer the research questions, address confounding and avoid omitted-variable bias. Addressing both the role of age in treatment outcomes and patient/case heterogeneity, in particular, necessarily leads to some model complexity. Our approach to addressing heterogeneity by impairment has been informed by the AN-SNAP classification system. Data for our analysis was either provided in the data extract or defined as part of the study analysis. In all cases, the covariates are defined for each episode.

2.4.1.1. Before/after implementation variable. A before/after indicator variable was defined to indicate whether the patient was discharged before or after the implementation date of the EPJB (11/3/2016 for North Wing, 27/6/2016 for Central and South Wings) based on the patient's ward of discharge. For patient episodes that spanned the implementation date, episodes were assigned to the "before" period if at least half of their episode days were in the "before" period.

2.4.1.2. Grouped impairments. Impairment plays a key role in episode heterogeneity. In Australia, rehabilitation episodes are assigned an impairment such as orthopaedic conditions, brain dysfunction, amputation of limb, or major multiple trauma. A taxonomy [15] classifies impairments with codes 1–16, and then subdivides for further detail.

To address small episode counts in the data for some impairments, those with fewer than 50 episodes were grouped into a larger "All other impairments" group for the purpose of statistical modelling, as shown in Table 1.

2.4.1.3. Functional Independence Measure (FIM) scores. The Functional Independence Measure (FIM) is a scoring method to measure cognition and motor skills. There are 5 items for cognition (e.g., comprehension, expression, memory) and 13 items for motor skills (e.g., eating, grooming, bathing). Each item is scored as an integer from 1 to 7. Thus, the total score for cognition is integer-valued in the range 5–35, and the total score for motor skills is integer-valued in the range 13–91. The total FIM score is the sum of the cognition and motor scores, so integer-valued in the range 18–126. Scores are measured at admission and at discharge. For AN-SNAP class version 4 only, the FIM motor score is calculated as a weighted sum using publicly available weights.

2.4.1.4. AN-SNAP classes. The AN-SNAP classification system classifies episodes with more detail than using AROC impairment codes alone. Version 3 of the system was released for use in 2012 [12]. Version 4 of the classification system was released for use in 2015 [13]. For this analysis AN-SNAP classes (both versions 3 and 4) were calculated for each episode. Since the study period includes episodes from before the release of AN-SNAP version 4, version 3 is used unless otherwise mentioned. This provides complete benchmark coverage across the study period.

Table 1
Impairment labels after grouping to address small episode counts.

Impairment	Grouped impairment label
Amputation of Limb	Amputation of Limb
Arthritis	All other impairments
Brain Dysfunction	Brain Dysfunction
Burns	All other impairments
Cardiac	All other impairments
Congenital Deformation	All other impairments
Major Multiple Trauma (MMT)	All other impairments
Neurological	Neurological
Orthopaedics-all other	Orthopaedics-all other
Orthopaedics-fractures	Orthopaedics-fractures
Orthopaedics-replacement	Orthopaedics-replacement
Other Disabling Impairments	All other impairments
Pain Syndromes	All other impairments
Pulmonary	All other impairments
Reconditioning	Reconditioning
Spinal Cord Dysfunction	Spinal Cord Dysfunction
Stroke	Stroke

2.4.2. Other covariates

Additional control variables regarding an episode (e.g., existence of complications or comorbidities) or timing (e.g., episode is before/after the ward reconfiguration or episode spans the implementation date) were used in the statistical modelling. These are described below and summarised in Section 2 of Supplementary Information 1.

2.4.2.1. Reconfiguration indicator. As evident from the extract data, October 22, 2015 was set as the first date for discharges following the ward reconfiguration. A new variable was defined to indicate an episode discharge was before or after the ward reconfiguration.

2.4.2.2. Discharge ward-reconfiguration Indicator. A new variable combining the discharge ward with the before-after reconfiguration data was defined to capture the changing roles of each wing. In particular, South Wing had rehabilitation discharges from both periods, although their case-mix may have changed. For this reason, we distinguish between South Wing before and after the reconfiguration. Rehabilitation discharges were largely non-existent from North Wing prior to the reconfiguration date (n = 1) and from Central Wing after the reconfiguration (n = 2) so these were not split.

2.4.2.3. Total suspension days. Suspension days are the days a patient is unable to participate in their rehabilitation program for medical reasons leading to a suspension of their treatment before a return to the same rehabilitation program. As these can lead to a delay in discharge, the total number of suspension days in the episode is included as a covariate.

2.4.2.4. Additional indicators. Three additional indicator variables related to complications, comorbidities, and first rehabilitation experience were provided in the extract for rehabilitation patients, deemed to be important for capturing heterogeneity in patient episodes, and used in the analysis.

2.4.3. Statistical models

Statistical models to investigate case-mix adjusted length of stay and length of stay were used in this study. In addition, a statistical model was used to check whether there was a change in discharge practice, as captured by total FIM score at discharge. Additional details for each model are described below and in Supplementary Information 1. The variables used in each model are shown in Table 2. For each model, the coefficient of the before/after variable provides a measure of the change between the "before" and "after" period, after accounting for all other factors in the model. Interaction terms are included in the model specifications, primarily to address heterogeneity by impairment. These interactions are informed by the subdivisions used in the AN-SNAP classification system [12,13] (e.g., impairment-patient age, impairment-FIM cognition score, impairment-FIM motor score, impairment-FIM total score). An interaction term between impairment and the before-after ward-reconfiguration variable was also included. This controls for possible differences in outcomes due to the ward reconfiguration that might differ by impairment.

Linear Mixed Effects Models [16] were used to analyse case-mix adjusted lengths of stay, which are not integer-valued. To address possible non-linear effects from non-categorical variables, natural cubic splines were used for age at admission, total suspension days, and FIM total score at admission. To address dependence arising from multiple observations per patient, and multiple observations per ward, random effect terms for patient ID and the discharge ward-reconfiguration indicator were included in the model.

For the economic analysis, the change in average episode cost was

Table 2
Summary of variables used in each statistical model. See Section 3 of Supplementary Information 1 for complete model specifications, including use of variable interactions and cubic splines.

Variable	Description	Case-mix adjusted length of stay	Total FIM score at discharge	Length of stay
Before/after implementation	key research variable	x	x	x
Patient sex	male/female	x	x	x
Patient age at admission (recentered)	age - mean of age	x	x	x
Patient impairment (grouped)	One of ten impairment groups	x	x	x
Total FIM score on admission	integer; 18–126	x		
Total FIM motor score on admission	integer; 13–91			x
Total FIM cognition score on admission	integer; 5–35			x
Complication indicator	control variable	x	x	x
Comorbidity indicator	control variable	x	x	x
First rehabilitation indicator	control variable	x	x	x
Indicator that episode spans before and after periods	control variable	x	x	x
Indicator that episode was after the ward reconfiguration	control variable	x	x	x
Total suspension days		x	x	x
De-identified patient identifier	Patient ID (de-identified)	random effect		
Combined discharge ward-reconfiguration indicator		random effect	x	x

determined using the change in length of stay. Length of stay is integer-valued. Compared to case-mix adjusted length of stay, length of stay has additional heterogeneity as it does not include any attempt to account for variation by AN-SNAP class. For this analysis, over-dispersed Poisson regression models, which are variants of Generalised Linear Models [17], were used as a Poisson generalised linear mixed model did not converge. To address clustering (i.e., multiple observations per patient, multiple observations per discharge ward), the robust ("sandwich") estimator of variance-covariance [18] was used. This provided consistent confidence intervals and p-values in the presence of departures from modelling assumptions including clustering and heteroscedasticity. Natural cubic splines were used for age at admission, total suspension days, FIM motor score at admission and FIM cognition score at admission. Average cost of a rehabilitation episode was calculated using the average cost per episode for sub-acute and non-acute episodes by AN-SNAP class (version 4) as reported by the Independent Hospital Pricing Authority [19, Appendix 25] in Australia.

Although not a primary research outcome, the possibility of a before-after change in total FIM score at discharge was investigated. Since these scores are bounded integer values in the range 18–126, the use of linear or Poisson regression models is not appropriate. Beta regression is a statistical approach for outcome variables in the range 0–1, exclusive of endpoints. To satisfy this requirement on the outcome variable, the total FIM score at discharge was transformed as shown in Eq. (1)

Table 3
Summary of the rehabilitation cohort.

	Level	Before	After
Number of Episodes		1980	1279
Age at Admission (mean (std. dev.))		72.40 (14.39)	70.48 (14.72)
Sex (%)	male	793 (40.1)	544 (42.5)
	female	1187 (59.9)	735 (57.5)
Indigenous (%)	no/unknown	1966 (99.3)	1266 (99.0)
	yes	14 (0.7)	13 (1.0)
Impairment (%)	Amputation of Limb	72 (3.6)	50 (3.9)
	Arthritis	20 (1.0)	2 (0.2)
	Brain Dysfunction	58 (2.9)	45 (3.5)
	Burns	1 (0.1)	0 (0.0)
	Cardiac	13 (0.7)	6 (0.5)
	Congenital Deformation	1 (0.1)	1 (0.1)
	Major Multiple Trauma (MMT)	17 (0.9)	9 (0.7)
	Neurological	97 (4.9)	75 (5.9)
	Orthopaedics-all other	71 (3.6)	48 (3.8)
	Orthopaedics-fractures	728 (36.8)	385 (30.1)
	Orthopaedics-replacement	375 (18.9)	236 (18.5)
	Other Disabling Impairments	2 (0.1)	4 (0.3)
	Pain Syndromes	25 (1.3)	6 (0.5)
	Pulmonary	8 (0.4)	2 (0.2)
	Reconditioning	157 (7.9)	121 (9.5)
	Spinal Cord Dysfunction	25 (1.3)	37 (2.9)
	Stroke	310 (15.7)	252 (19.7)
Discharge ward (%)	Central Wing	456 (23.0)	2 (0.2)
	North Wing	81 (4.1)	368 (28.8)
	South Wing	1443 (72.9)	909 (71.1)
Discharge Financial Year (%)	FY1314	686 (34.6)	0 (0.0)
	FY1415	670 (33.8)	0 (0.0)
	FY1516	609 (30.8)	43 (3.4)
	FY1617	15 (0.8)	735 (57.5)
	FY1718	0 (0.0)	501 (39.2)
Admission FIM motor score (median [IQR])		54 [41, 62]	51 [35, 61]
Admission FIM cognition (median [IQR])		31 [26, 34]	30 [25, 34]
Discharge FIM total score (median [IQR])		107 [93, 113]	105 [89,111]

Table 4
Summary descriptive statistics for the primary outcome variable.

		Before	After
Number of episodes		1980	1279
Case-mix adjusted length of stay (weighted average benchmark)	mean (std. dev.)	4.35 (21.62)	−2.12 (18.03)
	median [IQR]	1.94 [−4.72, 10.15]	−2.45 [−8.46, 3.28]

$$\text{score}_{\text{new}} = \frac{\text{score}_{\text{old}} - 17}{110} \quad (1)$$

To address possible non-linear effects from age at admission and total suspension days, higher power terms were included (up to the fourth power for age and third power for total suspension days). Cubic splines were not used due to technical difficulties in combining them with beta regression.

2.4.4. Software

All analysis was performed in R version 3.4.2 [20]. Linear Mixed Effects Models were fit using the lmer() command of the lme4 package. Over-dispersed Poisson models were fit using the glm() command with the "quasipoisson" option. Beta regression models were fit using the betareg() command of the betareg package. Bootstrap confidence intervals for Linear Mixed Effects Models used the confint() command, with 1000 iterations. Robust confidence intervals of over-dispersed Poisson and beta regression models used the coefci() command of the lmtest package with the robust (sandwich) option (i.e., "hc0″). To capture non-linear effects from non-categorical variables, natural cubic splines were included using the ns() command of the splines package. See Supplementary Information 1 for a complete list of modelling formulae used to fit the models.

3. Results

3.1. Demographic and other study coverage data

Table 3 summarises episodes of the rehabilitation cohort for a variety of demographic and episode variables.

3.2. Study findings and outcome data

3.2.1. Summary statistics for case-mix adjusted length of stay

Table 4 shows summaries of the primary outcome variable, case-mix adjusted length of stay, in the before and after periods of the study. The summaries include the mean (with standard deviation), the median (i.e., the 50-th percentile) and interquartile range (25-th and 75-th percentiles). Both the mean and median for the after period suggest a reduction.

3.2.2. Estimate of the change in case-mix adjusted length of stay

Table 5 summarises before-after results for analysis of case-mix adjusted length of stay using the weighted average benchmark, reported in days. (See Section 4.1 of Supplementary Information 1 for more information on the model, including model coefficients.) The estimate is the size of the change in the outcome between the before and after periods, according to the statistical model, after accounting for all other factors in the model. The change in the "after" period is −4.1 days (95 % bootstrap confidence interval: −6.4 to −2.0), or a reduction of 4.1 days, after accounting for all other factors in the model. A sensitivity analysis was also conducted, replacing the weighted average benchmark with alternatives. Using benchmarks from any particular financial year yields nearly identical results. See Supplementary Information 1 for additional details.

Table 5
Summary of before-after analysis results.

Outcome	Estimate of "after" effect	95 % confidence interval
Change in case-mix-adjusted length of stay (weighted average benchmark) in days, vs. before	−4.1	(−6.4, −2.0)

With shorter lengths of stay, there is the possibility that patients were simply discharged earlier from their care. To help rule out this possibility, a before-after analysis of total FIM scores at discharge was completed. Lower FIM scores at discharge would be an indicator of an unfavourable change in patients' functional independence at discharge between the "before" and "after" period. This analysis showed no statistically significant change in total FIM scores in either the transformed scale (−0.03; 95 % robust confidence interval −0.1 to 0.1) or the original scale (−2.92; 95 % robust confidence interval: −14.1 to 8.3). (See Section 4.2 of Supplementary Information 1 for more information on the model, including model coefficients.) This suggests patients were not discharged earlier at the expense of motor or cognition rehabilitation, as measured by the total FIM score.

3.2.3. Economic analysis results for length of stay

In the statistical model for length of stay, the "after" coefficient is -0.19 (95 % robust confidence interval −0.3 to −0.1). (See Section 4.3 of Supplementary Information 1 for more information on the model, including model coefficients.) After transforming from the log-linear to the original scale, this says episode lengths of stay in the "after" period are 82.4 % of "before" episodes (95 % robust confidence interval 76.6 %–88.7 %), after controlling for all other factors in the model. In other words, the *reduction* in length of stay in the "after" period is 17.6 % (95 % robust confidence interval 11.3 %–23.4 %).

The average cost of an overnight adult rehabilitation episode was estimated as $20 353 (in financial year 2015–2016 dollars), or $21 271.17 (inflation adjusted [21], as at September 2018). (For additional details see Supplementary Information 2.) For the estimated reduction in the length of stay, the corresponding reduction in episode cost is $3 738 (95 % robust confidence interval: $2 398–$4 983) in September 2018 dollars. On an annual basis, for an estimated 686.0 episodes per year in the rehabilitation centre, the corresponding reduction in cost is $2.6 m (95 % robust confidence interval: $1.6 m–$3.4 m).

4. Discussion

The results presented here provide evidence that implementation of an EPJB is associated with shorter lengths of stay. We have demonstrated that the use of the EPJB system is associated with a reduction in case-mix adjusted length of stay of 4.1 days per episode (95 % confidence interval: 2.0–6.4 days). Case-mix adjusted lengths of stay are used in the rehabilitation context as a measure of episode lengths of stay relative to case-specific benchmarks. For an economic analysis, we have used the episode length of stay (a different measure of episode duration which does not include benchmarks) and demonstrated that use of the EPJB is associated with a reduction of 17.6 % (95 % robust confidence interval 11.3 %–23.4 %) in episode durations, which corresponds to an estimated reduction in hospital costs of $3 738 per episode (95 % confidence interval $2 398–$4 983).

Our findings in the rehabilitation context are consistent with findings elsewhere in the acute context [10]. They also quantitatively demonstrate the general sense that visual case management can improve patient flow [7]. Our analysis has gone further by estimating the size of the reduction and associated cost savings in a rehabilitation context. The information displayed on the EPJB is not dramatically different to the previous manually-updated whiteboard. However, the EPJB facilitates more timely access for updating the information. This is due to the ability of staff to access and update the information from any networked hospital computer, eliminating the need to return to the central nursing station for updates. Access and flow staff (including referral sources) are able to view this information and can plan admissions according to predictions based on EPJB data. Anecdotally, the EPJB display may achieve additional visual impact through increased clarity and more pronounced colours.

The nature of inpatient rehabilitation care did not change with the implementation of the EPJB. The requirement to meet patients' needs and goals prior to safe discharge remained the same. These, combined with our finding that discharge FIM scores did not significantly change, mean the reduction of length of stay found in this study was unlikely to have arisen from a change in clinical practice.

Shorter lengths of stay benefit hospitals by freeing up beds to treat additional patients without the need to increase bed numbers. As we have shown, reduced hospital costs for each episode have the potential to generate hospital savings. In addition, where hospitals are funded per episode, rather than per day or activity, an increase in the number of patients per year translates into increased hospital revenue for the same level of resourcing.

It is important to note that these findings do not establish that the EPJB was the sole *cause* of the reduction in length of stay. Independent, simultaneous changes (e.g., changes to processes and procedures) not included in the modelling may have also impacted the results. We are not aware of any such changes, and assume these have not occurred. Similarly, these results cannot distinguish between an effect from the installation and use of the EPJB *per se* and any changes to processes or procedures that are part of its integration into hospital systems.

4.1. Limitations

As with other studies that use routinely collected administrative hospital data, its use here comes with some caveats. We assume the data extract is a complete and representative snapshot of hospital activity. Missing episodes or incorrectly recorded data has the potential to change the results, although we have no reason to believe that has influenced findings in this study. The economic analysis uses the average cost of SNAP class episodes as reported by IHPA as representative of costs in Australian public hospitals. Costs at any individual public hospital will vary. Average cost per episode is based on the case-mixes reported by the rehabilitation centre and reported collectively to IHPA. Different case-mixes will lead to different average cost per episode. Savings from rehabilitation episodes is assumed to be proportional to episode length of stay. If costs are more clustered within episodes, savings may differ.

5. Conclusion

Overall, this analysis has found that there has been an 18 % (95 % robust confidence interval: 11 %–23 %) reduction in length of stay for rehabilitation episodes in this inpatient rehabilitation centre. Whilst it can't be determined the EPJB is the sole reason for this, the reduction does coincide with the installation. The reduction has led to estimated savings of approximately $3 738 (95 % robust confidence interval: $2 398–$4 983) per episode without negatively impacting on patient outcomes, considering there was no significant change in the discharge FIM score between the "before" and "after" periods. This economic benefit corresponds to an estimated annual savings of $2.6 m (95 % robust confidence interval: $1.6 m–$3.4 m) for the rehabilitation centre.

Author contributions

Study concept and design: DAR, RJ, CM, SH.
Data preparation and analysis: DAR, SK, AR, NL.
Initial manuscript preparation: DAR.
Manuscript review and editing: DAR, SK, AR, NL, RJ, CM, SH.

Summary table

What was already known before this study:

- Computerisation provides an opportunity for electronic versions of patient journey boards, which can provide real-time updating from central data sources and remote view and update via networked systems/devices.
- Studies of electronic patient journey boards have focussed on acute care. Limited analysis on patient length of stay suggest episode duration may be shorter.

What this study has added to our knowledge:

- Implementation of electronic patient journey boards is associated with a reduction in length of stay for adult rehabilitation inpatients. The reduction was found to be about 4.1 days (95 % confidence interval: 2.0–6.4 days) after controlling for confounding factors.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijmedinf.2019.104042.

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