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ORIGINAL RESEARCH

Preliminary Psychometric Evaluation of the Brachial Assessment Tool Part 2: Construct Validity and Responsiveness

Bridget Hill, PhD,[a,b,c] Gavin Williams, PhD,[b] John Olver, MBBS,[b] Scott Ferris, MBBS,[c] Andrea Bialocerkowski, PhD[a]

From the [a]Menzies Health Institute, Brisbane, Queensland; [b]Epworth Monash Rehabilitation Medicine Unit, Epworth HealthCare, Melbourne, Victoria; and [c]The Alfred, Melbourne, Victoria, Australia.

Abstract

Objectives: To evaluate construct validity and responsiveness of the Brachial Assessment Tool (BrAT), a new patient-reported outcome measure for people with traumatic brachial plexus injury (BPI), and to compare it to the Disabilities of the Arm, Shoulder and Hand (DASH) and the Upper Extremity Functional Index (UEFI).

Design: Cross-sectional study.

Setting: Outpatient clinics.

Participants: Adults (N=29; age range, 20−69y) with confirmed traumatic BPI.

Interventions: Participants completed the BrAT 3 times over an 18-month period together with 16 DASH activity items and the UEFI. Evaluations were undertaken of construct validity, known-groups validity, 1-way repeated analysis of variance, and effect size.

Main Outcome Measures: BrAT, DASH, and UEFI.

Results: The BrAT demonstrated a moderate to low correlation with the DASH activity items (<0.7) and a large correlation with the UEFI (>0.7). According to known-groups validity, only the BrAT was able to discriminate between people who stated they could use their hand versus those who were unable to use their hand to perform activities. All measures indicated a significant effect for time with the exception of BrAT subscale 1. The effect size was highest for the BrAT but lower than expected (BrAT, .52−.40; DASH, .15; UEFI, .36).

Conclusions: These preliminary findings support the BrAT as a valid and responsive patient-reported outcome measure for adults with traumatic BPI. The BrAT activity items appear to be more targeted than the DASH or UEFI particularly for people with more severe BPI. The BrAT also appears to be measuring a different activity construct than the DASH and the UEFI. Further work is required to confirm these results with larger sample sizes.

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People with brachial plexus injuries (BPIs) demonstrate a wide spectrum of ability to use their arm to perform day-to-day activities. In recent years, microsurgical options have improved the outcome for people with this serious injury. For example, those with complete BPI should be able to stabilize or carry light objects with the affected arm, freeing the unaffected limb to perform more complex activities. Persons with a C5-6 injury may be expected to regain near-normal use of their affected limb.[1-3] However, the degree of heterogeneity seen in this population means that assessment of outcome is complex. Outcome measures must contain a wide range of items that truly reflect the abilities of all adults with a BPI, including for those who may regain only a limited but important ability to use their arm.[4]

Patient-reported outcome measures are increasingly being recognized as pivotal to understanding the impact of an injury on the individual and are having a direct influence on the clinical decision-making process.[5,6] While a few patient-reported outcome measures have been used to evaluate function after BPI, most do not contain items that assess the full range of ability of adults with a BPI.[7,8] Further, none have been psychometrically evaluated for this population.[7,9,10]

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The Brachial Assessment Tool (BrAT) is a new unidimensional, targeted, 31-item patient-reported outcome measure, with each item quantified on a 4-point scale. Experts, including people with BPI, generated items for inclusion in the BrAT based on the following *International Classification of Functioning, Disability and Health* (ICF) definition of activity: "execution of a task or action by an individual."[11(p.5)] The BrAT items are important to people with BPI, regularly performed and appear to represent the spectrum of ability of this population.[8,12] The BrAT is composed of 3 subscales: (1) 8 "dressing and grooming" items, (2) 17 "whole arm and hand" items, and (3) 6 "no hand" items; or alternatively, all 31 items may be added to produce a summed score. Content validity and unidimensionality of the BrAT have been established using Rasch analysis.[12] Reliability has been evaluated and a minimal detectable change score calculated for each subscale and the summed score. Further evaluation of construct validity and responsiveness is required to complete the initial psychometric testing.

Construct validity is an ongoing iterative process that assesses how well a measure provides expected scores based on knowledge of the underlying construct.[13] The underlying construct of a new outcome measure may be evaluated by comparing how closely items are related to existing measures that assess similar (convergent validity) or dissimilar (divergent validity) constructs. There is no known criterion standard to assess upper limb activity. The Upper Extremity Functional Index (UEFI) is a generic, 20-item patient-reported outcome measure designed to assess upper extremity function in people with musculoskeletal disorders. It is thus appropriate for use in conditions that involve the whole upper limb, and similar to the BrAT, assesses primarily activity of the upper limb.[14] The Disabilities of the Arm, Shoulder and Hand (DASH)[15] is the most frequently used patient-reported outcome measure after BPI. Comparison of the UEFI and the DASH to the BrAT is warranted.[7,9,10]

In addition to ensuring an outcome measure is assessing what is intended (construct validity), outcome measures also need to be responsive[13,16]—that is, able to detect change over time in the construct measured.[17] Construct validity and responsiveness are related and considered by some to be the same measurement property.[13] For this project, construct validity refers to the validity of a single score, and responsiveness refers to the validity of a change score.[17] The purpose of this study was to investigate the preliminary construct validity and responsiveness of the BrAT.

Methods

This project used a multicenter, prospective repeated-measure design. Ethical approval was gained from 3 human research and ethics committees (Griffith University, Alfred Health, Melbourne Health), and all participants provided signed informed consent before commencement of the project. The construct validity and responsiveness analyses were informed by the COSMIN (*CO*nsensus-based *S*tandards for the selection of health *M*easurement *IN*struments) checklist recommendations.[17]

List of abbreviations:

BPI	**brachial plexus injury**
BrAT	**Brachial Assessment Tool**
DASH	**Disabilities of the Arm, Shoulder and Hand**
GPUS	**Global Perceived Use Scale**
ICF	***International Classification of Functioning, Disability and Health***
UEFI	**Upper Extremity Functional Index**

Participants

Participants comprised a convenience sample recruited from the 106 people with BPI who participated in the Rasch analysis arm of a previously reported project. Data were collected concurrently for the Rasch analysis, a reliability project, and this project.[12] The primary inclusion criteria for all 3 projects were (1) a diagnosis of traumatic BPI confirmed by magnetic resonance imaging, nerve conduction studies, clinical assessment, or intraoperative findings; and (2) age >18 years. In contrast to the reliability arm, participants were only recruited if they had undergone microsurgery to reanimate the upper limb within the previous 2 years. Thus, it was biologically plausible that their ability to use their arm could improve over the course of this project. Exclusion criteria for all 3 projects included (1) a diagnosis of brachial plexus birth injury; (2) pre-existing upper limb conditions; (3) an inability to provide informed consent; or (4) evidence of spinal cord injury confirmed by magnetic resonance imaging.[12]

Data collection

Once participants consented, they were mailed a copy of the BrAT together with the DASH[15] and the UEFI[14] at recruitment, and again at 9 and 18 months with a reply-paid envelope. A global perceived use scale (GPUS) was completed at 9 and 18 months. Outcome measures were reordered at each time point to decrease possible survey bias.[18]

Measures

Two outcome measures were compared with the BrAT. The DASH contains 30 items and is known to be multidimensional,[19,20] with only 16 items specific to activity as defined by the ICF.[7,8,21] These 16 items have been shown to contain 2 further dimensions, variously reported as "gross motor activities" and "fine motor activities"[20] or "shoulder range of motion" and "manual functioning."[19] Moreover, unlike the BrAT the DASH is not limb specific, with respondents able to answer irrespective of the strategy they use to complete the activities, including compensatory mechanisms or altering hand dominance.[22,23] It is likely that the DASH may measure a different aspect of day-to-day arm use than the BrAT and demonstrate divergent validity. UEFI responses are attributed to the affected limb, and as with the BrAT, all but 2 of the 20 items (items 1 and 2) are specific to activity as defined by the ICF. The UEFI may assess a similar construct to the BrAT, demonstrating convergent validity.[14,24] A priori hypotheses were formulated based on the expected relationship between the measures (table 1).[13,25]

The 5-point GPUS was used as a reference criterion to anchor arm use as perceived by people with BPI during the evaluation period.[25,26] Responses were attributed specifically to use of the affected limb. Options were as follows: 1, "much less than last time"; 2, "a little less than last time"; 3, "no change to last time"; 4, "a little better than last time"; and 5, "much better than last time." Table 2 outlines the key measurement properties of the 4 measures.

Table 1 A priori hypotheses to assess construct validity and responsiveness of the BrAT

No.	Hypothesis and Rational for Hypothesis	Hypothesis Accepted
1	A low to moderate association ($r \leq 0.7$) between the BrAT and the DASH as they measure dissimilar activity constructs	Yes
2	A moderate association ($r \geq 0.7$) between the BrAT and the UEFI as they measure similar activity constructs	Yes
3	Based on known-groups validity, participants who indicated they are able to use their affected hand will have higher scores for all outcome measures than those who indicate they are unable to use their affected hand.	For the BrAT only
4	All measures will demonstrate a significant effect for time as measured by a 1-way repeated ANOVA; ie, use of the affected limb will improve over time.	Yes
5	The BRAT will have a moderate to large effect size of >0.5 for those participants who self-report improved hand use in activity.	Yes
6	The BrAT will have a greater effect size than the DASH or UEFI.	Yes

Abbreviation: ANOVA, analysis of variance.

Data analyses

All statistical analyses were undertaken using SPSS version 22.[a] Descriptive statistics were generated to describe the sample. Data were analyzed separately for each of the 3 BrAT subscales and the summed score.[12] Normality of the data was evaluated using visual inspection together with skewness and kurtosis statistics and the Shapiro-Wilk test. Construct validity was evaluated using Pearson correlations to test the association between the BrAT scores with the DASH activity items and the UEFI at 3 time points (recruitment, 9 and 18mo). Correlation coefficients were categorized as high if >.70, moderate between .51 and .70, and low if ≤.50.[27] Floor and ceiling effects were considered

Table 2 Outcome measure properties

Measure	No. of Items	Score Range	Response Option	Attributed to Affected Limb	Interpretation	Reliable for BPI	Valid for BPI
BrAT summed score	31	0–93	5-point Likert scale (0, "Cannot do now" to 5, "Easy to do now")	Y	Higher score = more ability	ICC = .97, α = .98 SEM = 4.5, MDC_{90} = 10.3 PSI = .86[7]	Local independence No DIF for age, TPI, or hand dominance
BrAT subscale 1	8	0–24	5-point Likert scale (0, "Cannot do now" to 5, "Easy to do now")	Y	Higher score = more ability	ICC = .91, α = .92 SEM = 1.8, MDC_{90} = 4.1 PSI = .88[7]	Local independence No DIF for age, TPI, or hand dominance
BrAT subscale 2	17	0–51	5-point Likert scale (0, "Cannot do now" to 5, "Easy to do now")	Y	Higher score = more ability	ICC = .97, α = .97 SEM = 2.8, MDC_{90} = 6.5 PSI = .94[7]	Local independence No DIF for age, TPI, or hand dominance
BrAT subscale 3	6	0–18	5-point Likert scale (0, "Cannot do now" to 5, "Easy to do now")	Y	Higher score = more ability	ICC = .90, α = .90 SEM = 1.6, MDC_{90} = 3.7 PSI = .80[7]	Local independence No DIF for age, TPI, or hand dominance
DASH activity	16	16–80	5-point Likert scale (1 "No difficulty" to 5, "Unable")	N	Higher score = more disability	Not reported	Not reported
UEFI	20	0–80	5-point Likert scale (0, "Extreme difficulty or unable to perform activity" to 4, "No difficulty")	Y	Higher score = more ability	Not reported	Not reported
GPUS	5	1–5	5-point Likert scale (1, "Much less use than last time to 3", " No change in use" to 5, "Much better use than last time")	Y	NA	NA	NA

Abbreviations: α, Cronbach alpha; DIF, differential item functioning; ICC, intraclass correlation coefficient; MDC, minimal detectable change; N, no; NA, not applicable; PSI, person separation index; TPI, time post injury; Y, yes.

Table 3 Participant demographics (N=29)

Demographic	n (%)
Sex	
Male	29 (100)
Female	0 (0)
Injury level	
C5-6	6 (21)
C5-7	4 (13)
C5-8	11 (38)
C8–T1	2 (7)
Complete avulsion	6 (21)
Mechanism of injury	
Motor car	3 (10.3)
Motor bike	15 (51.7)
Bicycle	5 (17.2)
Pedestrian	0 (0)
Work injury	1 (3.4)
Fall from height	2 (7.9)
Sporting injury	2 (7.9)
Gunshot	1 (3.4)
Preinjury dominance	
Right	23 (79)
Left	6 (21)
Injured limb	
Right	13 (45)
Left	16 (55)

present if ≥15% of participants scored the lowest or highest scores.[28]

Known-groups or discriminant validity was assessed using independent *t* tests to establish whether score differences were similar for those who self-reported they could use their affected hand versus those who self-reported they could not use their affected hand to do any activity at the time of assessment.[13] Responsiveness was assessed using 1-way, repeated-measures analyses of variance for all measures to compare the scores on each outcome measure at recruitment, 9 and 18 months later for participants who stated their arm use had improved or deteriorated on the GPUS. In addition, the effect sizes or the magnitude of change was calculated by dividing the mean of change in the score during the period by the SD of the baseline score.[29] The effect size was considered small if <.20, moderate if >.50, and large if >.80.[29]

Results

Twenty-nine participants, recruited from 3 outpatient clinics in Melbourne, Australia, commenced this study. Twenty-five completed all assessments at 9 months and 28 at 18 months. There were no missing data for the BrAT or the UEFI. Seven DASH questionnaires were returned with up to 3 missing items. Results were inputted based on the DASH scoring manual. Table 3 outlines the participants' demographics. Skewness statistics confirmed a normal distribution (range, .811 for the BrAT subscale 1 at recruitment to .67 for the UEFI at 18mo). The Shapiro-Wilk test was nonsignificant for all but BrAT subscale 2.

Validity

There were no floor effects or ceiling effects for the total scores or subscales (table 4). The DASH activity scores showed greater disability at 9 months than at recruitment or 18 months (see table 4). The correlations between the BrAT scores and DASH activity items at recruitment and 18 months were moderate (range,−.48−.69), indicating they were assessing a different construct, supporting

Table 4 Mean ± SD, floor and ceiling effects, and Pearson correlations between measures

		Floor Effect		Ceiling Effect		Correlations	
	Mean ± SD	n	%	n	%	DASH	UEFI
Recruitment							
BrAT summed score	41.76±25.82	0	0	0	0	−.55	.78
BrAT subscale 1	14.62±5.70	0	0	2	7	−.58	.67
BrAT subscale 2	18.17±15.85	0	0	1	3	−.48	.76
BrAT subscale 3	8.97±5.85	3	10	1	3	−.57	.76
DASH activity items	44.83±23.63	0	0	1	3		−.76
UEFI	34.9±21.41	0	0	1	3		
9mo							
BrAT summed score	46.20±24.92	0	0	1	3	−.73	.78
BrAT subscale 1	14.84±5.81	0	0	2	7	−.79	.64
BrAT subscale 2	21.08±15.43	0	0	1	4	−.62	.76
BrAT subscale 3	10.28±5.58	2	8	4	14	−.70	.60
DASH activity items	45.40±23.31	0	0	0	0		−.62
UEFI	37.48±20.23	0	0	1	3		
18mo							
BrAT summed score	51.93±24.99	0	0	0	0	−.62	.81
BrAT subscale 1	16.68±5.55	0	0	3	10	−.69	.63
BrAT subscale 2	23.89±16.08	0	0	1	4	−.52	.78
BrAT subscale 3	11.36±5.50	1	4	2	7	−.61	.73
DASH activity items	41.07±21.71	0	0	0	0		−.85
UEFI	43.29±20.26	0	0	1	3		

Table 5 Known-group validity based on perceived hand use

Hand Use	n	BrAT Summed		BrAT Subscale 1		BrAT Subscale 2		BrAT Subscale 3		DASH Activity		UEFI	
		Diff ±SD	*P*	Diff ±SD	*P*	Diff ±SD	*P*	Diff ±SD	*P*	Diff ±SD	*P*	Diff ±SD	*P*
Initial													
Able use hand	19	51.21±26.15	.01	16.26±5.46	.03	24.06±15.99	.01	10.37±6.06	.05	38.32±14.28	.17	40.68±20.40	.04
Unable use hand	10	23.8±12.63		11.50±4.99		6.00±4.32		6.30±4.59		47.10±18.59		23.90±19.73	
9mo													
Able use hand	19	51.95±24.84	.04	15.26±5.85	.53	25.05±15.60	.01	11.63±4.98	.03	41.79±17.13	.54	40.37±19.93	.21
Unable use hand	6	28.00±15.27		13.50±6.03		8.50±4.04		6.00±6.03		46.83±18.51		28.33±20.09	
18mo													
Able use hand	23	56.26±24.85	.05	17.30±5.56	.21	26.61±16.33	.01	12.35±5.30	.04	37.04±15.16	.45	44.61±22.00	.20
Unable use hand	5	32.00±14.62		13.80±4.97		11.40±6.43		6.80±4.32		42.60±11.04		37.20±7.26	

Abbreviations: Diff, difference; Sig, significant ($P<.05$) independent *t* tests.

Table 6 Repeated-measure ANOVA over time (18mo)

Effect	Wilks Lambda	F	(df, Error)	*P*	PTA
Time vs BrAT summed	.35	5.96	2, 22	.01	.35
Time vs BrAT subscale 1	.83	2.34	2, 22	.12	.18
Time vs BrAT subscale 2	.61	6.98	2, 22	.01	.39
Time vs BrAT subscale 3	.71	4.53	2, 22	.02	.29
Time vs DASH activity	.77	3.21	2, 22	.06	.23
Time vs UEFI	.75	3.71	2, 22	.04	.25

Abbreviations: ANOVA, analysis of variance; df, degrees of freedom; PTA, partial eta squared; Sig, significance.

hypothesis 1 (see table 1). In contrast, correlations between the BrAT and UEFI were large (range, 0.6–0.8), indicating they were measuring similar constructs and lending support to, but not confirming hypothesis 2. Based on known-groups validity, all BrAT scores discriminated between people who self-reported hand use (with the exception of subscale 1 at 9 and 18mo), indicating that the BrAT activities are targeted to this population. The DASH did not discriminate between the 2 groups at any time point. The UEFI only discriminated between the groups at recruitment (table 5), indicating the items contained in these outcome measures may not be targeted to people with BPI. Hypothesis 3 was confirmed for the BrAT total score and subscales 2 and 3 only (see table 5).

Responsiveness

Change, as measured by 1-way, repeated-measures analyses of variance (table 6), indicated a significant effect for time for all outcome measures with the exception of BrAT subscale 1 (dressing and grooming items). This supported hypothesis 4. Only subscale 3 (no hand items) achieved an effect size >.50, indicating the magnitude of change over time was small for all the outcome measures. Hypothesis 5 that effect sizes would be >.50 was not supported (table 7). The magnitude of change as measured by the effect size was larger for the BrAT than the DASH and the UEFI, indicating the BrAT is more responsive to change, supporting hypothesis 6.

Discussion

This project presents preliminary psychometric evaluation of the construct validity and responsiveness of the BrAT, a new patient-reported outcome measure for the assessment of activity after adult traumatic BPI. As hypothesized, divergent validity was confirmed between the BrAT and DASH, with only a moderate correlation (<0.7) with the DASH activity items at recruitment and the 18-month time point. This indicates that the BrAT is measuring a different aspect of upper limb use compared with the

Table 7 Effect size

Outcome Measure	Effect Size
BrAT summed score	.43
BrAT subscale 1	.40
BrAT subscale 2	.40
BrAT subscale 3	.52
DASH activity	.15
UEFI	.36

DASH.[21] One reason for the higher correlation found between the BrAT and the UEFI compared with the BrAT and the DASH may be the way people respond to the 3 outcome measures. The BrAT and the UEFI are limb specific, with responses attributed directly to the affected limb. In contrast, the DASH does not differentiate between the 2 limbs, with responses based on the ability to perform the activity regardless of which hand, arm, or part of the body is used; that is, people can use a variety of compensatory techniques. Mancuso et al[22] (2016) investigated the influence of compensation on outcome as measured by the DASH for people with BPI. Participants were requested to respond to the DASH in 1 of 2 ways—unqualified responses (usual instructions) and qualified instructions (using the affected limb as they would have before their injury with no compensatory techniques). A difference was found between the 2 scores, with people reporting they would be unable to do 46% of the tasks when not using compensatory techniques, compared with only 18% when using compensatory techniques. It is clear from Mancuso's study that people can differentiate between compensatory techniques and use of the affected limb after BPI. Compensatory techniques are very important to people with BPI. However, we would argue that to fully assess day-to-day use of the affected limb, it is important that responses are related directly to the affected limb if we are to measure the actual impact of expensive surgery and ongoing rehabilitation. The results of this study, in particular the inability of the DASH to discriminate between those who could use their affected hand and those who could not, lend further support to this argument.

It is unclear why the DASH score increased at the 9-month time point—that is, participants described themselves as more disabled than at recruitment. One possibility is that at 9 months, participants may not be showing much improvement postinjury, and they view themselves as less able to use their affected limb. It is clear from the literature that people with BPI experience a wide range of emotional states including depression and anxiety linked to their arm use.[4,30-34] More work in this area is required to explain what may be occurring, particularly in the extended period before people can begin to expect some recovery postsurgery.

With the use of a known-groups comparison, only the BrAT was able to differentiate between those participants who stated they could use their affected hand to perform any activities and those who could not. Further, the BrAT demonstrated the greatest magnitude of change and the greatest effect size of the 3 measures. These results may reflect the inclusion of activities specifically targeted toward people with less ability to use their affected limb.[12] For example, the 6 activities that make up subscale 3 include controlling the arm without using a sling, stabilizing objects, and carrying objects against the chest wall or over the forearm, none of which require any hand use. For people with complete plexus injury, these may be the only activities that improve over time; however, none are assessed by the DASH or UEFI. It is vital that outcome measures contain a range of activities that cover the spectrum of ability of the target group in order to assess change over time. By establishing the psychometric properties of each of the 3 subscales and the total summed score, clinicians may tailor the BrAT for individual patients—for example, using only subscale 3 for people with more severe injury and less use of their limb. The BrAT has been shown to be well targeted to people with BPI, with a range of activities for all ability levels.[12] To our knowledge, this is 1 of only 2 patient-reported outcome measures that specifically address this type of arm and hand use.[35]

The 8 items that comprise subscale 1 ("dressing and grooming") demonstrated the greatest disparity with the a priori hypotheses. These activities are performed daily, usually from the day of injury, and are some of the most important for people with BPI.[8] As a consequence, people with BPI may use compensatory skills that are not used to perform other items. Ongoing evaluation is required to determine the relationship of these activities to the others.

Study limitations

To our knowledge, this is 1 of only 2 studies that have used only the DASH activity items to evaluate construct validity.[36] We acknowledge that the DASH is not designed to be used in this way. However, the retained DASH activity items allowed a closer comparison between the 2 outcome measures and eliminated the difficulties related to summing and interpreting the score of a multidimensional measure. Further, as the most commonly used patient-reported outcome measure for BPI, the direct comparison has highlighted the differences between the 2 measures.

The sample size used in this project, while within accepted boundaries, was small. However, while BPI injury is a devastating injury, it is relatively uncommon, recovery is slow, and recruitment is challenging, particularly for a project that spanned an 18-month commitment. To our knowledge, this is the largest BPI cohort that has been used to investigate the psychometric properties of outcome measures at multiple time points. Ongoing research is required to confirm the results of this study in larger cohorts from multiple centers. Further investigation of the minimal important change scores for the 4 BrAT scores is still required.

Conclusions

This preliminary study appears to indicate that the BrAT is a valid and responsive patient-reported outcome measure for people with BPI. The BrAT appears to measure different activities than the DASH activity items and the UEFI, and better represents the BPI population, particularly those with limited use of their arm. These results support the use of the BrAT for people with BPI; however, ongoing investigation is required to confirm these findings with larger sample sizes. As a unidimensional measure solely of activity, we recommend that the BrAT be used as part of a suit of outcome measures that evaluate BPI from multiple perspectives.

Supplier

a. SPSS version 22; IBM Corp.

Keywords

Brachial plexus; Outcome assessment; health care; Rehabilitation; Upper extremity; Validation studies

Corresponding author

Bridget Hill, PhD, Epworth Monash Rehabilitation Medicine Unit, Epworth HealthCare, 89 Bridge Rd, Richmond, Vic, 3122 Australia. *E-mail address:* bridget.hill@epworth.org.au.

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