Heart, Lung and Circulation (2020) **29**, 1054–1062
1443-9506/04/$36.00
https://doi.org/10.1016/j.hlc.2019.08.010

ORIGINAL ARTICLE

Validation of the ''Doorbell Test'': A Novel Functional Test of Frailty and Clinical Status After Acute Decompensated Heart Failure

James E. Gunton, BMBS, PhD [a,b*], Savvy Nandal, BMBS [a,b], Julieanne Jones, RN [a,b], Derek P. Chew, MBBS, MPH [a,b], Thomas H. Marwick, MBBS, PhD, MPH [c], Carmine G. De Pasquale, BMBS, PhD [a,b]

[a]Department of Cardiovascular Medicine, Flinders Medical Centre, Adelaide, SA, Australia
[b]School of Medicine, Faculty of Medicine, Nursing and Health Sciences, Flinders University, Adelaide, SA, Australia
[c]Baker Heart and Diabetes Institute, Melbourne, Vic, Australia

Received 6 January 2019; received in revised form 24 July 2019; accepted 17 August 2019; online published-ahead-of-print 3 September 2019

Background Acute decompensated heart failure (ADHF) carries a high event rate following discharge. The complex interplay between age, frailty and decongestion may lend itself to a functional test.

Methods In the doorbell test the patient simulates answering the doorbell. They are timed rising from a recumbent position, bending over twice and walking 10 metres, this time is added to the change in respiratory rate. We aimed to determine if the doorbell test was associated with post ADHF events (death or readmission). The test was performed at hospital discharge, with follow up at 30-days and 1-year.

Results In 74 patients at 30-days there was a 14% event rate. At 1-year there were 40 (54%) events (9 deaths and 31 readmissions, 28 were cardiovascular of which 14 were [heart failure] HF). Amongst those who had an event at 30-days only doorbell test scores were different (58 [36,72] vs 32 [26,53] $p < 0.05$). One-year (1-year) events were associated with doorbell test scores (47 [29,62] vs 30 [26,42] $p < 0.05$), body weight (78 kg [68,94] vs 95 [76,105] ($p < 0.05$), creatinine (134 mmol/L [114, 173] vs 99 [82, 133] $p < 0.01$) and age (76 years [61,86] vs 67 [53, 73] $p < 0.01$). Heart failure readmissions were associated with doorbell test scores (56 [46,68] vs 30 [26,47] $p < 0.001$). Death was associated with body weight (74 kg [69,81] vs 88 [72,101] $p < 0.05$) and age (83 years [78,86] vs 69 [55,77] $p < 0.01$).
After age stratification, the hazard ratio for heart failure readmission associated with a high doorbell test score was 11.08 (95%C.I. 2.01–61.17 $p = 0.006$), while the hazard ratio for 1-year cardiovascular readmission was 4.62 (95%C.I. 1.71–12.51 $p = 0.003$). There was no association with 1-year mortality.

Conclusion The doorbell test represents a novel test of multiple domains of the ADHF pre-discharge state and demonstrates an association with 30-day and 1-year rehospitalisation.

Keywords Acute Decompensated Heart Failure • Chronic Heart Failure • Functional test

*Corresponding author at: Department of Cardiovascular Medicine, Flinders Medical Centre, Flinders Drive, Bedford Park SA 5042, Australia.
Tel.: (08) 8404 2001; Fax: (08) 8404 2150., Email: james.gunton@sa.gov.au

Introduction

Chronic heart failure (CHF) is notorious for the burden of morbidity and mortality it carries. Despite striking improvements in the array of evidence-based therapies over the last 25 years, rehospitalisation rates for acute decompensated heart failure (ADHF) remain disconcertingly high [1,2]. Indeed, 30-day readmission rates are in the realms of 20–25% [3] with 1-year death/readmission rates over 50% [1,3]. Consistent with the complexity of patients with the heart failure syndrome, only approximately 50% of readmissions are due to heart failure or related cardiovascular conditions [4].

The complex interplay between age and frailty, the necessary and aggressive decongestion associated with ADHF hospitalisation, and the impact on blood pressure and heart failure cardiorespiratory function may lend itself to a discharge functional test.

We devised a simple functional test aimed at challenging the domains of frailty (core strength and mobility), congestion and respiratory distress (orthopnoea, bendopnoea [5] and exertional dyspnoea), intravascular volume status and orthostatic blood pressure in ADHF patients on the day of discharge. The ''doorbell test'' was conceived from elements of the 6-minute walk test and the timed ''Up and Go'' test. The latter is a basic test of functional strength and mobility in the frail/elderly where the patient is timed rising from a chair, walking three metres, turning and returning to be seated [6]. The 6-minute walk test is a well-validated test of submaximal exercise performance that is predictive of outcomes in many cardiac and respiratory diseases including heart failure [7,8]. Although these tests clearly provide useful information, they are not tailored to the particular haemodynamic and cardiorespiratory stresses of the immediate post ADHF state and are limited as they focus on specific features of the heart failure syndrome which might impact event rates differently depending on the stage of the heart failure illness. Moreover, the 6-minute walk test is relatively demanding on time, thereby limiting its broad applicability in the post discharge setting [9]. Therefore, we explored the association of the doorbell test at ADHF hospital discharge with major cardiac events at 30 days and 1 year.

Materials and Methods

Study Design

This study was performed in a subgroup of the Multicentre Australian Risk Algorithm To predict Heart Failure readmission (MARATHON) study, an Australia wide longitudinal study of heart failure which recruited 2014 through 2015 [10]. Patients were identified by the primary diagnosis of ADHF by their treating doctor. Exclusion criteria have been previously published [10] but included moderate or worse left sided stenotic cardiac valvular dysfunction, unstable myocardial ischaemia, device malfunction, endocarditis, left ventricular assist devices, potentially reversible myocardial dysfunction or a concomitant terminal non-cardiac illness expected to impact on 12-month mortality. The only extra exclusion criteria for study involvement from the MARATHON trial was being wheelchair bound or residing in institutionalised care. Baseline data were collected at hospital discharge including socio-demographic, clinical, echocardiographic, admission biochemical, cognitive function and mental health and 30 day and 1-year readmission or death data were collected by telephone contact with dates and details obtained from medical records [10].

This sub-study was performed on consecutive patients from one MARATHON site; the Flinders Medical Centre, a tertiary, university teaching hospital in Adelaide, Australia. The study was approved by the Southern Adelaide Clinical Human Research Ethics Committee.

The doorbell test was performed on the day of discharge from ADHF hospitalisation on subjects enrolled in the MARATHON study.

The Doorbell Test

Doorbell test protocol is as follows:

- patient begins in a horizontal recumbent position
- the respiratory rate is taken (RR1)
- remains horizontal for 3 minutes (to precipitate orthopnoea)
- the patient is asked to ''*imagine they are alone at home, lying in bed, and their doorbell rings*'' (the imagined purpose puts a time pressure on the task), they are to ''*rise from their bed*'' (recumbent position), ''*put on slippers*'' (a pair of backless slip-on shoes), ''*walk to the door*'' (a defined 10 m distance), ''*pick up a dropped door key*'' (and hand it to the tester who is standing at the 10 m mark).
- the timer is started
- the patient rises off the bed (testing core strength)
- puts on a pair of backless slip-on shoes which are under the foot of the bed lined up with the edge of the bed such that the patient will have to bend over to put them on (testing bendopnoea, postural hypotension, balance and core strength).
- walk 10 m (testing mobility and submaximal exercise capacity)
- bend down to pick up a small object on the floor at the 10 m mark (imagining picking up a dropped door key)(testing bendopnoea, postural hypotension)
- hand the object it to the tester who at that point stops the timer
- respiratory rate is then measured (RR2).

The doorbell test score is calculated from the time taken in seconds (doorbell time) added to the difference in the respiratory rates (RR2–RR1). Test supervision was performed by a medical officer trained in the methodology thereby limiting inter-observer variability. Each patient was instructed from a scripted protocol and given one opportunity to complete the test.

Outcome Events

Clinical events were collected at 30 days and 1 year post discharge from the ADHF admission. Events were coded as all-cause death or all-cause recurrent hospitalisation (minimum of one overnight stay). The latter composed cardiovascular (CV) rehospitalisation (i.e. cardiac ischaemia, heart failure, arrhythmia, cardiac syncope/presyncope, peripheral/cerebrovascular disease), which was further sub-classified into hospitalisation for heart failure (defined as admission for symptoms and signs of heart failure requiring intravenous loop diuretic/inotrope or fortification of regular oral loop diuretic dosage). The primary outcome measure was all events at 1 year. The secondary outcomes of interest were events at 30 days, death, cardiovascular readmission and heart failure readmission.

Statistical Analysis

Baseline categorical variables are presented as counts (%), while continuous data were not normally distributed and are presented as median (25th, 75th percentile). Between group differences were assessed using Mann Whitney U test for continuous variables and Chi-square test for categorical variables. Correlations were performed using Spearman's Rho.

The values of the doorbell test at baseline among those with events were compared with patients without events at 30 days and 1 year. The discriminatory capacity of the test for 30-day and 1-year outcomes was assessed using logistic regression models with the doorbell test result entered as the continuous explanatory variable. The discriminatory capacity is expressed as the area under the curve [c-statistic] and the receiving operating characteristic was plotted.

Due to the small sample size, the doorbell test results were then dichotomised at the median value for the population and defined as either high-doorbell or low-doorbell. The discriminatory capacity of the dichotomised test was then explored in the same manner. Baseline characteristics associated with a high-doorbell test are presented. Kaplan-Meier survival and freedom from death or CV rehospitalisation by 12 months are plotted. To explore the overall hazard ratio associated with a high-doorbell test result and 30-day and 1-year outcomes, Cox proportional hazards models for the time to death within 1 year and the combined endpoint of death or cardiovascular readmission was undertaken. While no adjustment for other co-variates was undertaken, the potential influence of age on overall survival was recognised. This was accounted for by stratifying these models by age at the median (dichotomised as age<70years and age≥70years), thereby allowing the underlying baseline hazards to vary between these age groups, and the overall averaged hazard ratios are reported. The proportional hazards assumption was assessed and found to be valid.

All analyses were conducted with STATA 15 (College Station, TX, USA) and a p value <0.05 was regarded as statistically significant.

Results

Patient Population

Clinical and demographic characteristics of the entire patient cohort are presented in Tables 1 and 2. There were 74 subjects with a median age of 70 (58, 79) years. Fifty-one (51) (69%) were male, 20% had a clinical history of ischaemic heart disease and the median left ventricular ejection fraction was 31%. Among these patients, angiotensin converting enzyme-inhibitors (ACEi) or angiotensin receptor blockers, beta blockers, loop diuretics and mineralocorticoid receptor antagonists were prescribed in 74%, 93%, 96% and 63% at the time of hospital discharge, respectively. At 30 days post ADHF discharge there were nine hospitalisation events and one death (total 14% event rate). At 1 year there were 40 events (54%) of which nine were deaths (12%) and 31 readmissions comprising 28 cardiovascular (38%) and three non cardiovascular. There were 14 H F readmissions at 1 year (19%).

The Doorbell Test

As expected, time taken to complete the doorbell test (without the addition of the change in respiratory rate), hereafter referred to as the doorbell time (seconds), and the doorbell test score (no unit) were intimately correlated, $r = 0.96$, $p < 0.0001$. The doorbell test score correlated strongly with age ($r = 0.59$, $p < 0.0001$), moderately with ejection fraction (EF) ($r = 0.44$, $p < 0.0001$) and weakly with systolic blood pressure (BP) ($r = 0.34$, $p = 0.003$), body weight ($r = -0.25$, $p = 0.032$), heart rate ($r = -0.26$, $p = 0.027$) and plasma sodium ($r = -0.23$, $p = 0.046$). The median doorbell test score was 34 (26, 56). When dichotomised at the median for the population, patients with a higher doorbell test were older, had higher systolic blood pressure and left ventricular EF, higher use of post discharge home services with lower body weight, heart rate and use of mineralocorticoid receptor antagonists. Levels of creatinine and NT-proBNP were similar among those patients with a high and low doorbell test score (Tables 1 and 2).

Associations of Events

Differences in the baseline characteristics and clinical parameters between patients that had clinical events and those who did not were assessed. Higher doorbell test scores were associated with 30-day events, 1-year events, cardiovascular readmissions and heart failure readmissions. Death, however, was only associated with lower body weight and older age (Table 3).

As a continuous variable, plotting of the receiver-operating characteristic suggests that the doorbell test has a c-statistic of 0.72 (95%C.I. 0.55–0.89) and 0.85 (95%C.I. 0.76–0.93) for death or cardiovascular readmission within 30 days though these were not significant due to the small sample size. By 12 months, the doorbell test had a c-statistic of 0.68 (95% C.I. 0.56–0.80) and 0.75 (95%C.I. 0.63–0.878) for cardiovascular readmission and heart failure readmission, respectively, with a c-statistic of 0.61 (95%C.I. 0.37–0.86) for death. (Figure 1) Dichotomising the doorbell test at the median value suggested that ability to discriminate 12-month death or cardiovascular readmission remained at a moderate degree (c-statistic 0.65 (95%C.I. 0.54–0.76).

Survival Analysis

Figure 2 describes the survival and event free survival for patients in this cohort dichotomised at the median doorbell

Table 1 Baseline characteristics of acute decompensated heart failure patients dichotomised at the median doorbell test score.

Demographics	Total	<Median DB*	≥Median DB*	P-value
Age (years)†	70 (58, 79)	60 (48, 68)	78 (71, 86)	0.000
Gender (% male)	69	74	63	0.31
Non English first language (%)	21	30	10	0.032
Lives alone (%)	41	35	40	0.67
Married (%)	50	56	53	0.77
Services post DC (%)	25	6	40	0.001
Co-morbidities	%	%	%	
Coronary artery disease	20	24	18	0.52
Hypertension	53	50	55	0.67
Valvular disease (≥moderate regurgitant)	32	36	29	0.49
Atrial flutter /fibrillation	40	29	48	0.11
CKD	24	24	25	0.94
CVD	14	15	13	0.78
COPD	17	12	18	0.49
OSA	9	12	5	0.29
Depression	20	15	23	0.39
Obesity	30	38	20	0.08
Diabetes mellitus	41	38	45	0.27
Cognitive impairment	3	6	0	0.12
Medications/Intervention	%	%	%	
ACEi/ARB	74	74	68	0.57
Beta blockers	93	97	87	0.13
MRA	63	71	48	0.045
Loop diuretic	96	97	95	0.65
Digoxin	15	12	18	0.49
Ivabradine	4	9	0	0.06
Aspirin	31	32	35	0.81
Antidepressant	12	12	13	0.92
CCB	4	3	3	0.91
Antiarrhythmic	15	9	23	0.11
Statin	57	47	68	0.08
Device	24	24	28	0.28
Discharge characteristics				
NYHA classification	-	-	-	0.79
- II (%)	13	15	13	
- III (%)	43	38	46	
- IV (%)	43	47	41	
Weight loss (kg)†	2 (0.8, 4)	2 (1, 4)	1 (0.7, 3)	0.34
LOS (days)†	7 (4, 10)	7 (4, 9)	7 (4, 11)	0.84

Abbreviations: DB, doorbell test score; DC, hospital discharge; CKD, chronic kidney disease; CVD, cerebrovascular disease; COPD, chronic obstructive pulmonary disease; OSA, obstructive sleep apnoea; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; MRA, mineralocorticoid receptor antagonist; CCB, calcium channel blocker; LOS: length of stay

†Median values with 25th and 75th percentile.

*The median doorbell test score was 34 (26, 56).

test score. Due to the known power of age as a risk factor for events and the limited numbers in the study and doorbell test effect would be overwhelmed by age as a continuous variable. Age was therefore dichotomised around the median age of 70 years to determine if the doorbell test still held up as an independent association. After adjusting for age dichotomised at the median of 70 years, the hazard ratio for recurrent heart failure readmission associated with a high doorbell test

Table 2 Clinical parameters of acute decompensated heart failure patients on hospital admission dichotomised at the median doorbell test score.

Clinical parameters	Total	<Median DB*	≥Median DB*	P-value
SBP (mmHg)	120 (108, 134)	112 (104, 129)	123 (115, 143)	0.01
DBP (mmHg)	70 (62, 76)	68 (64, 74)	70 (60, 78)	0.81
HR (/min)	76 (70, 86)	82 (72, 92)	74 (70, 84)	0.04
RR (/min)	20 (16, 22)	19 (15, 20)	20 (16, 22)	0.20
Weight (kg)	84 (71, 99)	92 (83, 103)	74 (65, 96)	0.002
Echo parameters				
EF (%)	31 (24, 40)	29 (23, 35)	40 (31, 53)	0.000
LA size (cm^2)	29 (26, 39)	29 (26, 34)	33 (26, 39)	0.80
TR gradient (mmHg)	36 (28, 43)	33 (25, 41)	38 (32, 43)	0.08
E:e′	22 (16, 23)	21 (18, 23)	18 (15, 28)	0.5
Biochemical parameters				
Hb	127 (114, 140)	128 (118, 144)	123 (112, 139)	0.33
Na	139 (137, 140)	139 (138, 141)	138 (136, 140)	0.04
Urea	11 (8, 15)	9 (7,12)	11 (8, 17)	0.14
Creatinine	123 (93, 163)	120 (93, 156)	130 (91, 173)	0.60
Albumin	35 (32, 38)	36 (33, 39)	34 (31, 38)	0.21
Troponin T	49 (36, 96)	43 (37, 113)	53 (34, 75)	0.50
NT proBNP	3,511 (2109, 6105)	3,406 (2338, 5761)	3,511 (1789, 9078)	0.98
CRP	10 (3, 17)	10 (4, 17)	10 (3, 19)	0.90
Cholesterol	3.8 (3, 4.9)	4.3 (3.3, 5.6)	3.5 (2.9, 4.5)	0.08

Abbreviations: DB, doorbell test score; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; RR, respiratory rate; EF, left ventricular ejection fraction; LA, left atrial size; TR, tricuspid regurgitation; E, mitral inflow early wave velocity; e′ mitral annular early wave displacement; Hb, haemoglobin; Na, sodium; NT proBNP, N-terminal fragment of pro brain natriuretic peptide; CRP, C reactive protein.

All data is presented as median (25^{th}, 75^{th} percentile).

*The median doorbell test score was 34 (26, 56).

was 11.08 (95%C.I. 2.01–61.17 p = 0.006), while the hazard ratio of cardiovascular readmission within 12 months was 4.62 (95%C.I. 1.71–12.51 p = 0.003). A doorbell test above the median was not associated with an increase in the hazard ratio for mortality alone by 12 months.

Discussion

The premise of the doorbell test was to stress multiple domains of the typical complex heart failure patient particular to the dynamic pathophysiologic setting of ADHF discharge. It was hypothesised that this test of core strength, mobility, dyspnoea patterns particular to heart failure and orthostatic symptoms would be associated with major events, particularly rehospitalisation. Our results strongly support this broad concept, although more work is needed to validate this novel test and explore its potential clinical utility.

There has been much focus on predictors of poor outcome following ADHF hospitalisation. Many and varied independent associations have been identified, reflecting the complexity of the syndrome and host. Broadly, predictors of events can be grouped as age [11], cardiovascular/pathophysiologic [12,13] /haemodynamic (in particular congestion [14–16]), usage of evidence based therapy [17], comorbidities [18] (particularly renal [19]) and social/supportive issues [12]. Less well recognised but seemingly of significant importance are indices of function and frailty [20,21], cognition [10] and psychiatric disease/distress [10,22]. The myriad of characteristics associated with poor outcome if taken in isolation cannot provide meaningful and actionable clinical guidance [23,24]. Moreover, the picture is further complicated by the stage of the HF journey. Chun and co-workers have demonstrated that 30% of all cardiovascular readmissions occur within the first 2 months post diagnosis while 50% occur within the first 2 months before death [25].

The 6-minute walk test has served as a reliable test of submaximal exercise capacity in chronic disease (including CHF) for more than 30 years [26], however, its application is limited due to factors such as required time and space, and limited patient mobility [9]. Recently, Harris and co-workers reported a 60-foot walk test as a viable replacement for the 6-minute walk test, which overcomes many of the aforementioned limitations [27]. The doorbell test is less in distance (essentially 30 feet) and demonstrates a similar association with future hospitalisation thereby supporting the concept of a shorter (in time and distance) test giving similar

Table 3 Differences in baseline characteristics and clinical parameters of acute decompensated heart failure patients who had clinical events compared with those who did not.

	Event	No Event	P-value
30-days			
Doorbell test score	58 (36, 79)	32 (26, 53)	0.02
Doorbell time (sec)	50 (36,76)	31 (24, 47)	0.03
One-year			
Doorbell test score	47 (29,62)	30 (26,42)	0.02
Doorbell time (sec)	41 (27,57)	29 (23, 39)	0.004
Body weight (kg)	78 (68,94)	95 (76,105)	0.02
Creatinine (mmol/L)	134 (114, 173)	99 (82, 133)	0.003
Age (years)	76 (61,86)	67 (53, 73)	0.01
Cardiovascular readmissions			
Doorbell test score	47 (30,60)	30 (16, 51)	0.02
Doorbell time (sec)	43 (29,55)	29 (23,40)	0.01
Body weight (kg)	77 (64,95)	91 (76, 103)	0.03
Heart rate (bpm)	74 (70, 76)	84 (70, 90)	0.04
Heart failure readmissions			
Doorbell test score	56 (46, 68)	30 (26,47)	0.001
Doorbell time (sec)	51 (42, 60)	30 (24, 41)	0.002
Death			
Body weight (kg)	74 (69,81)	88 (72, 101)	0.05
Age (years)	83 (78,86)	69 (55, 77)	0.002

All data is presented as median (25th, 75th percentile).

information. In comparison to the population studied by Harris and co-workers the doorbell test population was more representative of the typical ADHF patient being older (70 versus 57 years), more gender balanced (31% female versus 22%) and allowing preserved ejection fraction heart failure.

The test gave a purpose to the task (answering the doorbell) thereby mimicking a common activity of daily living that the patient discharged to independent living would face; it was expected that this assigned task would limit effort bias. Finally, the doorbell test aims to tailor the task to the particular peculiarities of the immediate pre-discharge ADHF clinical state. Here the balance between ongoing congestion and consequent cardiac dyspnoea, and over-diuresis and consequent postural unsteadiness, are coupled with both a short walk and core strength manoeuvres tailored to stress central haemodynamics.

Our results highlight the multifactorial nature of physical limitation in the discharged ADHF patient and support the concept of a pre-discharge functional test tailored to assess multiple pathophysiological domains. The most striking finding was an association of the doorbell test score with both 30-day events and HF rehospitalisation. Thirty-day (30-day) events would be expected to result from inadequate decongestion (with resultant dyspnoea) or over-diuresis leading to orthostatic symptoms, both of which may be reflected in higher doorbell scores. Heart failure events would similarly be expected to reflect dyspnoea (orthostatic, exertional and bendopnoea), fatigue, muscle weakness and frailty, hence the strong association with the doorbell test score supports the concept of the doorbell test concurrently testing several important components of the HF state.

While 30-day events and HF rehospitalisation were most strongly associated with the doorbell test score, 1-year event rates were less so, and death was not associated at all. Indeed, mortality was only associated with the well-recognised poor prognostic characteristics of increasing age and low body weight [28]. One-year (1-year) total event associations demonstrate the complexity and competing risks in the ADHF population. The well-known mortality associations of age and low body weight were represented along with renal impairment and the doorbell time as well as the doorbell test score itself. It is of interest that at 1 year the addition of the change in respiratory rate to the time component of the doorbell test did not add to the association with events. This would suggest that, unlike in the first 30 days post discharge and for HF readmission, by 12 months it is the mobility, strength and frailty components that dominate events rather than the degree of dyspnoea (as reflected in the increase in respiratory rate with the doorbell test). The time taken to complete the task will be extended by a number of factors

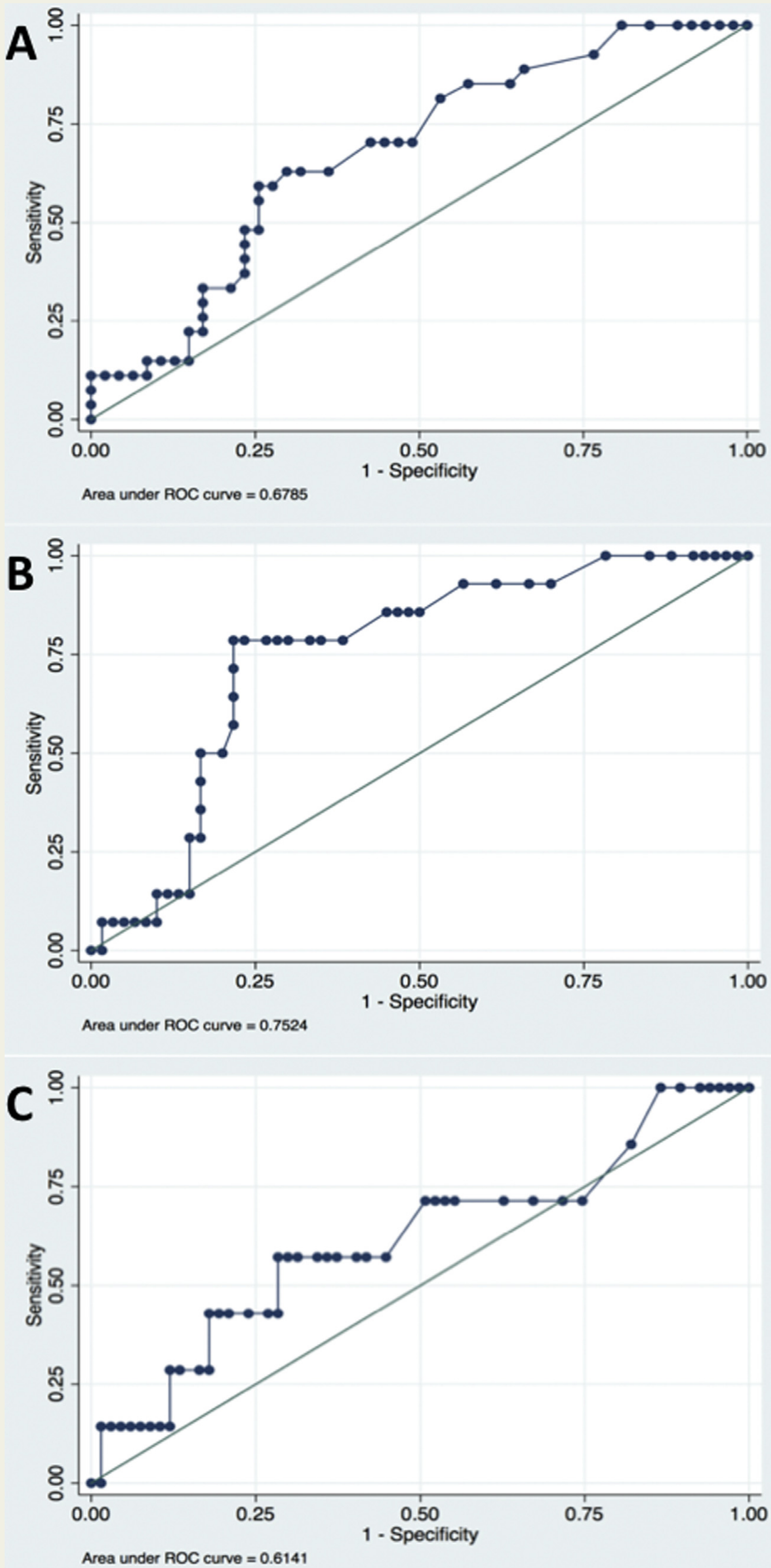

Figure 1 Receiver operating characteristic curves for 12 month a) CV events b) HF events or c) Death events. Abbreviations: CV, cardiovascular; HF, heart failure

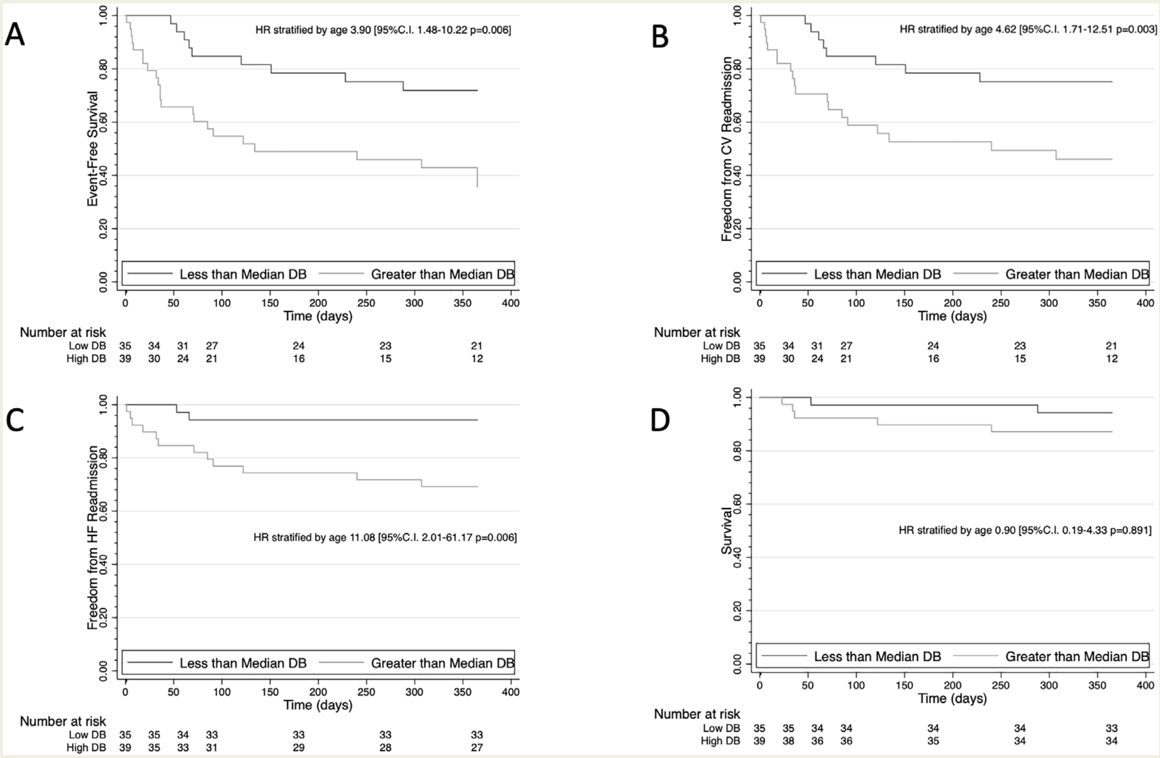

Figure 2 Kaplan-Meier estimates of freedom from event(s) dichotomised based on the doorbell test (above and below the medium doorbell test score of 34 s).
Panel A shows result of event-free survival (freedom from all-cause readmission, and death). Panel B (freedom from cardiovascular readmission). Panel C (freedom from heart failure readmission). Panel D (overall survival).

such as respiratory distress, fatigue, weakness, and light headedness on standing from a recumbent or bent-over position. We cannot answer whether the doorbell test score adds to the timed Up and Go test with regards to 1-year outcomes without a head to head comparison. Indeed, to our knowledge, the timed Up and Go test has not been systematically studied in the ADHF population. Moreover, when respiratory rate change is added to the doorbell test time (to give the doorbell test score) the association with HF events and 30-day events are stronger. The differing associations with different times post discharge and different endpoints, supports the concept of a discharge test tailored to the peculiarities of the ADHF discharge state rather than a simple test of mobility.

The population studied was not quite typical of ADHF in Australia, as our cohort was younger (median age 70) with over representation of male gender (69%) and heart failure with reduced ejection fraction (HFrEF) (median EF 31%) and perhaps an under representation of associated coronary artery disease (20%). Although subjects were enrolled consecutively, we believe the exclusion of moderate or greater stenotic left-sided valvular disease, institutionalised patients and recruitment from the cardiology rather than general medical wards accounts for much of this imbalance. The doorbell test only excluded wheelchair bound subjects such that any patient returning to independent living (where they might be required to answer the doorbell) was included with their walking aid to be used i.e. walking stick, frame or wheeler. We would not expect the older, female, heart failure with preserved ejection fraction (HFpEF) and degenerative aortic stenosis patients to be significantly different in their limitations. Indeed, we would propose that these subgroups would be even more disabled by exertional dyspnoea and frailty, thereby potentially strengthening the results; however this remains to be tested.

Limitations

Our study and conclusions are limited by small numbers and the single site nature of our cohort, such that it should be interpreted as a pilot study. Indeed, our analysis has only adjusted for age as a co-variable; this pilot study has not shown the doorbell test score to be an independent predictor of outcome events. The test itself, despite needing little time to complete does require a bed, backless slip-on shoes and the presence of the latter ''prop'' may reduce its broad applicability. However, given the magnitude of the problem, the comorbid complexity of the cohort and the profound degree of disability HF patients suffer, a simple and functionally relevant prognostic test to help guide and focus post-discharge supports is a worthy aim. Indeed in an era of ever-increasing health care cost concern, if the doorbell test could prove itself to be a reliable marker of patients warranting intensified early follow-up/support (be that medical, nursing and/or allied health) to prevent readmissions, it would be expected to have an extremely favourable cost effectiveness. A further limitation is the lack of data on inter-observer and test retest reliability of the doorbell test. The carefully standardised and strictly scripted test instructions (as is the case with the 6-minute walk test) and training of medical officers who implemented the test was aimed at minimising test variability. Finally, the doorbell test was conceived for this population (ADHF) and this study represents its first application, we have no control group data in other populations.

Conclusion

The doorbell test represents a novel test of multiple fragile domains of the ADHF pre-discharge state and demonstrates an association with 30-day and 1-year rehospitalisation and in particular HF rehospitalisation, but not mortality. The discriminatory associations with major post discharge events of this bespoke HF functional test documented in this pilot study warrants further exploration in larger and broader HF cohorts.

Supported in part by a Grant from the National Health and Medical Research Council, Canberra, Australia (GRT1059738).

Acknowledgements

This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation

Conflict of Interest

There are no relationships to industry in this study.

References

[1] Maggioni AP, Dahlstrom U, Filippatos G, Chioncel O, Crespo Leiro M, Drozdz J, et al. EURObservational Research Programme: regional differences and 1-year follow-up results of the Heart Failure Pilot Survey (ESC-HF Pilot). Eur J Heart Fail 2013;15:808–17.
[2] Ross JS, Chen J, Lin Z, Bueno H, Curtis JP, Keenan PS, et al. Recent national trends in readmission rates after heart failure hospitalization. Circ Heart Fail 2010;3:97–103.
[3] Krumholz HM, Merrill AR, Schone EM, Schreiner GC, Chen J, Bradley EH, et al. Patterns of hospital performance in acute myocardial infarction and heart failure 30-day mortality and readmission. Circ Cardiovasc Qual Outcomes 2009;2:407–13.
[4] Setoguchi S, Stevenson LW. Hospitalizations in patients with heart failure: who and why. J Am Coll 2009;54:1703–5.
[5] Thibodeau JT, Turer AT, Gualano SK, Ayers CR, Velez-Martinez M, Mishkin JD, et al. Characterization of a novel symptom of advanced heart failure: bendopnea. JACC Heart Fail 2014;2:24–31.
[6] Podsiadlo D, Richardson S. The timed ''Up & Go'': a test of basic functional mobility for frail elderly persons. J Am Geriatrics Soc 1991;39:142–8.
[7] Guyatt GH, Sullivan MJ, Thompson PJ, Fallen EL, Pugsley SO, Taylor DW, et al. The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. Can Med Assoc J 1985;132:919–23.
[8] Peeters P, Mets T. The 6-minute walk as an appropriate exercise test in elderly patients with chronic heart failure. J Gerontol A, Biol Sci Med Sci 1996;51:M147–51.
[9] Brawner CA, Keteyian SJ. Do we need another walking test? JACC Heart Fail 2017;5:421–2.
[10] Huynh QL, Negishi K, Blizzard L, Saito M, De Pasquale CG, Hare JL, et al. Mild cognitive impairment predicts death and readmission within 30 days of discharge for heart failure. Int J Cardiol 2016;221:212–7.
[11] Fonarow GC, Abraham WT, Albert NM, Stough WG, Gheorghiade M, Greenberg BH, et al. Age- and gender-related differences in quality of care and outcomes of patients hospitalized with heart failure (from OPTIMIZE-HF). Am J Cardiol 2009;104:107–15.
[12] Foraker RE, Rose KM, Suchindran CM, Chang PP, McNeill AM, Rosamond WD. Socioeconomic status, Medicaid coverage, clinical comorbidity, and rehospitalization or death after an incident heart failure hospitalization: Atherosclerosis Risk in Communities cohort (1987 to 2004). Circ Heart Fail 2011;4:308–16.
[13] Mountantonakis SE, Grau-Sepulveda MV, Bhatt DL, Hernandez AF, Peterson ED, Fonarow GC. Presence of atrial fibrillation is independently associated with adverse outcomes in patients hospitalized with heart failure: an analysis of get with the guidelines-heart failure. Circ Heart Fail 2012;5:191–201.
[14] Stevenson LW, Tillisch JH, Hamilton M, Luu M, Chelimsky-Fallick C, Moriguchi J, et al. Importance of hemodynamic response to therapy in predicting survival with ejection fraction less than or equal to 20% secondary to ischemic or nonischemic dilated cardiomyopathy. Am J Cardiol 1990;66:1348–54.
[15] Testani JM, Chen J, McCauley BD, Kimmel SE, Shannon RP. Potential effects of aggressive decongestion during the treatment of decompensated heart failure on renal function and survival. Circulation 2010;122:265–72.
[16] Bettencourt P, Azevedo A, Pimenta J, Frioes F, Ferreira S, Ferreira A. N-terminal-pro-brain natriuretic peptide predicts outcome after hospital discharge in heart failure patients. Circulation 2004;110:2168–74.
[17] Fonarow GC, Abraham WT, Albert NM, Stough WG, Gheorghiade M, Greenberg BH, et al. Influence of beta-blocker continuation or withdrawal on outcomes in patients hospitalized with heart failure: findings from the OPTIMIZE-HF program. J Am Coll Cardiol 2008;52:190–9.
[18] Abraham WT, Fonarow GC, Albert NM, Stough WG, Gheorghiade M, Greenberg BH, et al. Predictors of in-hospital mortality in patients hospitalized for heart failure: insights from the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF). J Am Coll Cardiol 2008;52:347–56.
[19] Heywood JT, Fonarow GC, Costanzo MR, Mathur VS, Wigneswaran JR, Wynne J. High prevalence of renal dysfunction and its impact on outcome in 118,465 patients hospitalized with acute decompensated heart failure: a report from the ADHERE database. J Cardiac Fail 2007;13:422–30.
[20] Flint KM, Matlock DD, Lindenfeld J, Allen LA. Frailty and the selection of patients for destination therapy left ventricular assist device. Circ Heart Fail 2012;5:286–93.
[21] Cacciatore F, Abete P, Mazzella F, Viati L, Della Morte D, D'Ambrosio D, et al. Frailty predicts long-term mortality in elderly subjects with chronic heart failure. Eur J Clin Invest 2005;35:723–30.
[22] Rutledge T, Reis VA, Linke SE, Greenberg BH, Mills PJ. Depression in heart failure a meta-analytic review of prevalence, intervention effects, and associations with clinical outcomes. J Am Coll Cardiol 2006;48:1527–37.
[23] Kansagara D, Englander H, Salanitro A, Kagen D, Theobald C, Freeman M, et al. Risk prediction models for hospital readmission: a systematic review. JAMA 2011;306:1688–98.
[24] Desai AS, Stevenson LW. Rehospitalization for heart failure: predict or prevent? Circulation 2012;126:501–6.
[25] Chun S, Tu JV, Wijeysundera HC, Austin PC, Wang X, Levy D, et al. Lifetime analysis of hospitalizations and survival of patients newly admitted with heart failure. Circ Heart Fail 2012;5:414–21.
[26] Butland RJ, Pang J, Gross ER, Woodcock AA, Geddes DM. Two-, six-, and 12-minute walking tests in respiratory disease. Br Med J 1982;284:1607–8.
[27] Harris KM, Krantz DS, Kop WJ, Marshall J, Robinson SW, Marshall JM, et al. A new clinically applicable measure of functional status in patients with heart failure: the 60-foot walk test. JACC Heart Fail 2017;5:411–20.
[28] Pocock SJ, McMurray JJ, Dobson J, Yusuf S, Granger CB, Michelson EL, et al. Weight loss and mortality risk in patients with chronic heart failure in the candesartan in heart failure: assessment of reduction in mortality and morbidity (CHARM) programme. Eur Heart J 2008;29:2641–50.