

**School of Nursing and Midwifery
Curtin Health Innovative Research Institute**

**Predicting risk: developing and testing of a nomogram to predict
hospitalisation in chronic heart failure (CHF-Risk Study).**

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**This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University**

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Declaration

“To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.”

A handwritten signature in black ink, consisting of a stylized 'V' and 'B'.

Vasiliki Betihavas

Date: 17th November 2013

ABSTRACT

Chronic heart failure (CHF) is the leading cause for hospital admission for adults over the age of 65 years. In spite of extensive research, no model exists that provides a prediction of absolute risk of rehospitalisation. The absolute risk reflects a person's individual overall risk. Current models provide information pertaining to the relative risk of individual's risk of rehospitalisation. Relative risk is a proportional measure of an individual's risk within a given group. Furthermore, current risk prediction models are limited in their scope with an emphasis on biomedical factors. The research reported in this thesis has been labeled the "**CHF-Risk Study**" and examines the limitations within current risk models; the identification of risk prediction factors from the perspective of patient, provider and system; and the development of a risk nomogram using a derivation cohort of a contemporaneous Australian CHF population. The CHF-Risk Study was conducted in 3 phases with the aim of generating factors for the risk nomogram from a literature review, factors within current risk models, key stake holder consultation and testing within a prospective cohort of individuals with CHF.

The CHF-Risk Study received ethics approval from Curtin University Human Research Ethics Committee, approval code SON&M16-2010. The CHF-Risk Study was a sub study of a randomised control trial (RCT) funded by the National Health and Medical Research Council, Which Heart failure Intervention is most Cost-effective and consumer friendly in reducing Hospital care (WHICH?) Trial. The WHICH? Trial was undertaken in three teaching hospitals in Australia where recruited adult patients with CHF were randomised to either clinic based or home based CHF management.

The 3 phases of the CHF-Risk Study were:

1. Phase 1:

A literature review was undertaken to determine factors predicting hospitalisation risk from the perspective of patient, provider and system. Studies reviewed were prospective in design and were conducted post beta-blocker boom of the late 1990's which saw the management of CHF alter. However, the studies involved predominantly North American cohorts.

2. Phase 2:

Factors from current risk prediction models were identified. Furthermore, using an online survey, 119 CHF experts ranked (0-10) each identified factor as a predictor for

rehospitalisation. The experts also had the opportunity to add any additional factors that they thought predicted rehospitalisation.

3. Phase 3:

Phase 3 was the development of the risk prediction model for rehospitalisation within the prospective cohort of the WHICH? Trial.

Phase 1

Phase 1 identified 1963 articles for factors predicting the risk of hospitalisation for adults with CHF. Factors that predicted all cause or CHF specific hospitalisations were identified and classified into patient, provider or system categories. The majority of factors identified were patient focussed, and were obtained from N=159 studies. This was followed by provider factors identified from N=27 studies. The least amount of factors identified were system factors and these were obtained from N=25 studies.

Phase 2

Consultation was undertaken via an online survey using the Survey Monkey platform, a secure online system, with key informants from multidisciplinary backgrounds providing input, critique and feedback regarding the CHF-Risk model items. Key informants were health professionals involved in heart failure disease management and/or research. The survey was distributed through Listserves of the National Heart Foundation, Australasian Cardiovascular Nurses College and the Cardiac Society of Australia and New Zealand. This was particularly important to derive health professional's drivers for admission to hospital particularly within the context of the Australian health care system. However, no further risk factors for rehospitalisation were identified by the experts. Factors were rated from 1 for low risk to 10 for high risk. Factors which scored high in predicting rehospitalisation with a mean score were poor adherence to medications (9.04) and prior hospitalisation for heart failure (8.33). Having private health insurance (4.8) and females (4.9) scored low for predicting rehospitalisation for adults with heart failure.

Phase 3

The development of a risk prediction model for rehospitalisation within the prospective cohort of the WHICH? Trial was undertaken as part of phase 3. Briefly the WHICH trial (ACTRN12607000069459) was a multi-centre, randomised controlled study of two forms of CHF-MP (home based and clinic based) to determine which was most cost-effective and if there was a difference in the mortality and morbidity rates between the two methods of program delivery. Participants were recruited from three sites in Australia (Sydney, Adelaide and Brisbane). The study cohort consisted of patient's with confirmed

CHF (systolic or heart failure with preserved systolic function) on echocardiography, with related, persistent, moderate to severe symptoms with at least one previous acute HF admission that were to be discharged home. In the WHICH? Trial, participants were followed up for 18 months and details of all the hospitalisations were documented. All hospitalisations were adjudicated by a blinded endpoint committee. The WHICH? Trial recruited 280 men and women between the ages of 23 and 98 years. From the cohort 37 (13%) were rehospitalised for a cardiovascular event (including CHF) within 28 days, and a further 149 (53%) were rehospitalised during the follow-up period for a cardiovascular event. Phase 3 found, factors associated with an increased risk of cardiovascular rehospitalisation were: age (HR 1.07, 95% CI 0.90-1.26) for each 10-year increase in age; living alone (HR 1.09, 95% CI 0.74-1.59); those with a sedentary lifestyle (HR 1.44, 95% CI, 0.92-2.25) and the presence of multiple co-morbid conditions (HR 1.69, 95% CI 0.38-7.58) for 5 or more co-morbid conditions compared to individuals with one documented co-morbidity). The C-statistic of the final model was 0.80.

Conclusion

This thesis has identified an absolute risk model for individualising the risk of rehospitalisation for adults with CHF. Phase 1 and 2 revealed limitations with current risk prediction models for rehospitalisation for adults with CHF. These were: no current model provides an absolute risk for rehospitalisation; models were all developed using cohorts from the United States of America and may therefore not be applicable to universal healthcare systems; risk factors identified for rehospitalisation were predominantly related to clinical factors. Phase 3 found factors associated with an increased risk of cardiovascular rehospitalisation were: age; living alone; a sedentary lifestyle and the presence of multiple co-morbid conditions. The C-statistic in prior models were no higher than 0.75. Therefore, it would appear that both in our model (C-statistic 0.80) and prior models, important risk factors for rehospitalisation have not been identified. The need for an accurate model, inclusive of patient, provider and patient factors incorporated into model design was identified. Developing an absolute risk model that identifies an individual's risk of rehospitalisation may have the potential to target at risk individuals in the community more effectively than current risk prediction models do. Furthermore, streamlining disease management for at risk individuals for rehospitalisation has the potential to decrease hospitalisations, improve health status of individuals with CHF and decrease the financial, social and psychological burden associated with hospitalisation(s) for the individual and the community. These data suggest that an initial hospitalisation for CHF signals a period of

high risk and the importance of implementing integrated and coordinated disease management strategies.

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- To my **Friends** in alphabetical order (as I value each of you equally in my heart): **Carla** and your girls **Alosi** and **Malia**, **Damiano**, **Jen**, **Justin**, **Louise**, **Naomi**, **Nicole**, **Olivia**, **Patsy**, **Pauline**, **Rebecca**, **Sheila**, **Simone** and **Sue**, – thank you for your unyielding support.

Dedication:

This Thesis is dedicated to, **The Unreasonable Man.**

“The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man.”

George Bernard Shaw

List of Publications included in the Thesis

Published work with full bibliographic citations

Publication 1.

BETIHAVAS, V., NEWTON, P. J., DU, H. Y., MACDONALD, P. S., FROST, S. A., STEWART, S. & DAVIDSON, P. M. 2011. Australia's health care reform agenda: Implications for the nurses' role in chronic heart failure management. *Australian Critical Care*, 24, 189-197.

Australian Critical Care is a peer reviewed journal published by Elsevier for the Australian College of Critical Care Nurses.

Publication 2.

BETIHAVAS, V., NEWTON, P. J., FROST, S. A., MACDONALD, P. S. & DAVIDSON, P. M. 2013. Patient, provider and system factors influencing rehospitalisation in adults with heart failure. *Contemporary Nurse*, 43, 244-256.

Contemporary Nurse is a peer reviewed journal published by econtent Management focusing on Asia-Pacific nurse educators, researchers and practitioners.

Publication 3.

BETIHAVAS, V., DAVIDSON, P. M., NEWTON, P. J., FROST, S. A., MACDONALD, P. S. & STEWART, S. 2012. What are the factors in risk prediction models for rehospitalisation for adults with chronic heart failure? *Australian Critical Care*, 25, 31-40.

Australian Critical Care is a peer reviewed journal published by Elsevier for the Australian College of Critical Care Nurses.

Publication 4.

BETIHAVAS, V., NEWTON, P. J. & DAVIDSON, P. M. 2012. An overview of risk prediction models and the implications for nursing practice. *British Journal of Cardiac Nursing*, 7, 259-265.

British Journal of Cardiac Nursing is a peer reviewed journal published by MA Healthcare Ltd focusing on clinical and professional issues regarding cardiovascular nursing.

Publication 5.

BETIHAVAS, V., NEWTON, P. J., FROST, S. A., ALEXANDROU, E., MACDONALD, P. S. & DAVIDSON, P. M. 2012. Importance of Predictors of Rehospitalisation in Heart Failure: A Survey of Heart Failure Experts. *Heart, Lung and Circulation*, 2013. 22: 179 – 187.

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Accepted for Publication 6.

BETIHAVAS, V., FROST, S., NEWTON, P. J., MACDONALD, P. S., Stewart, S., Carrington, M.J., Chan, Y.K., & DAVIDSON, P. M. 2014 An absolute risk prediction model to determine unplanned cardiovascular readmission for chronic heart failure.

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Statement of Contribution by Others

This is a Thesis by publication. A number of researchers contributed in part to the publications included within this thesis. However, the actual research undertaken and the preparation of the manuscripts was solely my own work (except where duly acknowledged). The co-authors statements are provided in the appendix. It is acknowledged that all co-author jointly published manuscripts included in this thesis provided their consent for the inclusion of each manuscript in this thesis. All other work included in this thesis, not part of published papers or those accepted for publication is entirely my own work, except where duly acknowledged. The contribution of every author to each of the publications included in this thesis is outlined below:

Publication 1

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Publication 4

Title: An overview of risk prediction models and the implications for nursing practice.

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Publication 5

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Journal: Heart, Lung and Circulation, In Press.

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List of additional publications by the candidate relevant to the thesis but not forming part of it

Additional Publication

NEWTON, P. J., BETIHAVAS, V. & MACDONALD, P. 2009. The role of b-type natriuretic peptide in heart failure management. *Australian Critical Care*, 22, 117-123.

The literature review by Newton and colleagues[1] explored the use of b-type natriuretic peptide (and nt-proBNP) as markers for heart failure. In response to pressure and volume overload, the left ventricle releases BNP. BNP levels may therefore be used to identify individuals with heart failure who present to the emergency department with symptoms of breathlessness.

Additional Conference Presentation

BETIHAVAS, V., DAVIDSON, P. M., NEWTON, P. J., FROST, S. A., MACDONALD, P. S. & STEWART, S. 2010. Elements of Risk Prediction Models to Predict Readmission to Hospital in Older Patients with Chronic Heart Failure. *Heart, Lung and Circulation*, 19, S69.

The objective of the conference presentation by Betihavas and colleagues[2] was to identify absolute risk scores for rehospitalisation for individuals with chronic heart failure (CHF). However, the presentation identified 5 validated model[3-7] for predicting the relative risk for rehospitalisation. The only cross over in predictors that was distinguished within the models was a history of Diabetes Mellitus (DM); an elevated BUN; and a history of prior admission to hospital within 1 year. Currently, there is no model that predicts absolute risk for rehospitalisation for adults with CHF.

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Introduction and Overview

This exegesis and the supporting documents are submitted as a **“Thesis by Publication.”** This thesis is titled **“Predicting risk: developing and testing of a nomogram to predict hospitalisation in chronic heart failure (CHF- Risk Study).”** The CHF-Risk Study was a three phase sub-study of a randomised controlled trial (RCT) titled, Which Heart failure Intervention is most Cost-effective and consumer friendly in reducing Hospital care (WHICH?) Trial.

The WHICH? Trial (ACTRN12607000069459) was a prospective multicentre, RCT conducted at 3 tertiary referral hospitals in Australia. The WHICH? trial’s aim was to ascertain if multidisciplinary disease management of individuals within their homes was superior to care delivered within a specialist outpatient clinic[6]. Adults who were discharged home and had a diagnosis of CHF, with persistent moderate to severe symptoms were approached for inclusion into the trial. Following blinded randomisation, participants were categorised into the specialist CHF outpatient clinic or the nurse-led home-based intervention arm of the trial. A total of 280 patients, 73% male with a mean age of 71 ± 14 years were enrolled in the WHICH? trial[6]. Primary endpoints included: unplanned readmissions or all-cause death. The primary endpoint occurred in 102 of 143 (71%) HBI versus 104 of 137 (76%) CBI patients (adjusted hazard ratio [HR]: 0.97 [95% confidence interval (CI): 0.73 to 1.30], $p = 0.861$): 96 (67.1%) HBI versus 95 (69.3%) CBI patients had an unplanned hospitalisation ($p = 0.887$), and 31 (21.7%) versus 38 (27.7%) died ($p = 0.252$)[7]. Data from the WHICH? trial was used for analysis within the CHF-Risk Study. Findings of the WHICH? trial found that home based intervention (HBI) was not superior to CBI in reducing all-cause death or hospitalisation. However, CBI was associated with significantly higher healthcare costs, attributable to additional days of hospitalisation.

Five publications and one manuscript accepted for publication have been submitted as part of the CHF-Risk Study thesis.

The first publication[5] is titled *“Australia’s health care reform agenda: Implications for the nurses’ role in chronic heart failure management.”* The manuscript details the implications of Australia’s health care reforms on the management of individuals with chronic heart failure (CHF). The Chronic Care Model[8] (CCM) **see figure 1**, has been used to illustrate the complex and multifaceted approach required to improve disease management within an Australian context. Additionally, a solution is offered regarding chronic disease management of CHF in Australia with reference to the elements of the CCM.

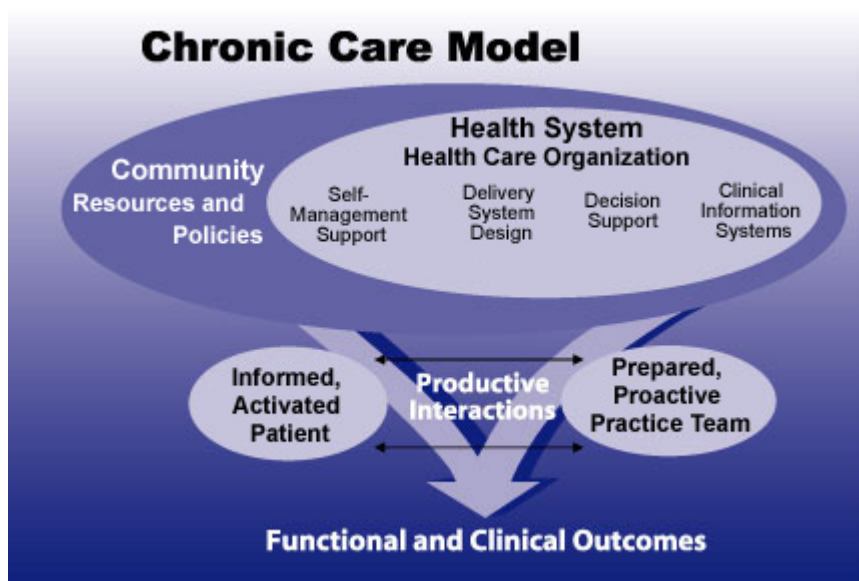


Figure 1.

The Chronic Care Model

*[8] (permission has been granted to reproduce the diagram above, evidence has been provided in the Appendices)

The CCM views the health care system as an extension of the broader community. Within this system, a productive interaction occurs between system factors, providers and an active informed individual collaborating together in the disease management of an individual with a complex and chronic disease. To offer a holistic approach to disease management, the terms patient, provider and system have been used.

The second publication[2] is titled *"Patient, provider and system factors influencing rehospitalisation in chronic heart failure: a literature review."* The literature review itemises factors from studies that have been identified as risk predictors for rehospitalisation for individuals with CHF. The primary finding from this review was that current literature focuses on predominately clinical patient factors to predict the risk of rehospitalisation. Such factors include: multiple co-morbidities such as diabetes and chronic obstructive pulmonary disorder; ejection fraction and renal function. A limitation with the literature suggests that a wider scope of study needs to be undertaken to identify provider and system factors that contribute to the risk of rehospitalisation for individuals with CHF.

The third publication[4] is titled *“What are the factors in risk prediction models for rehospitalisation for adults with chronic heart failure?”* The rationale for this paper was to examine current risk prediction models for rehospitalisation and identify what factors had been incorporated into risk model design. What was evident from this review was that the majority of factors integrated into these current risk models were primarily biomedical patient specific factors. This therefore, possibly limits the accuracy of risk prediction due to the absence or insufficient number of provider and system factors that were incorporated in the risk model design.

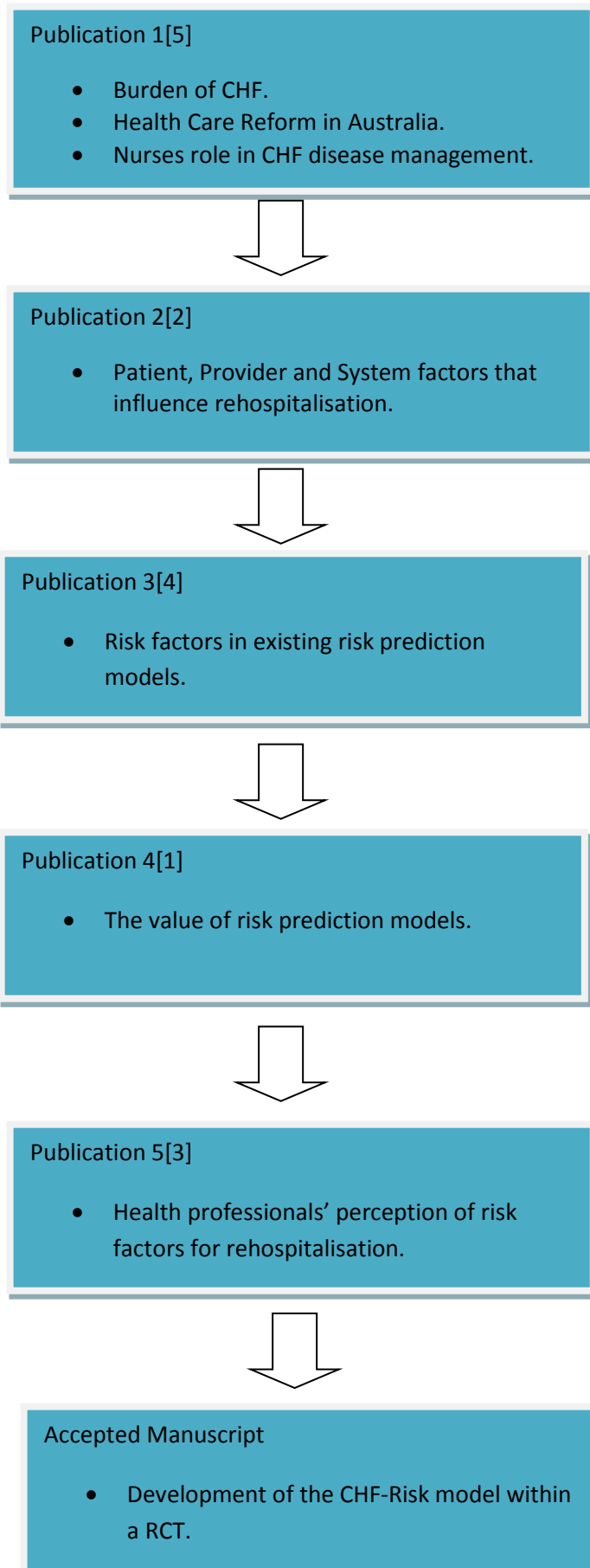
The fourth publication[1] is titled *“An overview of risk prediction models and the implications for nursing practice.”* The manuscript describes the value of incorporating patient, provider and system factors into risk model design. Also, the ramifications of nurses utilising risk prediction models in clinical practice to target individuals at risk is discussed.

The fifth publication[3] is titled *“Importance of predictors of rehospitalisation in heart failure: a survey of heart failure experts”*. The purpose of the online survey was to obtain the opinion of experts within CHF disease management and/or research as to what they perceived to be factors that predicted the risk of rehospitalisation in individuals with CHF. Experts used were employed within Australia or New Zealand. Having been employed within Australian and New Zealand facilities, the accuracy of risk factors identified would be more applicable and appropriate for a risk prediction model that was being designed to be tested within an Australian cohort. Furthermore, previous risk models had not undertaken broad expert consultation when being designed. This was a unique component of the CHF-Risk Study.

The manuscript accepted for publication, 6 is titled *“An absolute risk prediction model to determine unplanned cardiovascular readmissions for chronic heart failure.”* The accepted manuscript, describes the development of an absolute risk model for the prediction of rehospitalisation for adults with CHF. The model was developed using the integration of findings from the literature review, expert consultation and risk factors from current models. These were then tested using the cohort of the WHICH? Trial.

Flow diagram of the CHF- Risk Study

- Main points within each study is provided below



Literature Review

History

Heart failure (HF) is a progressive complex syndrome. In 1872 Georg Ebers, an Egyptologist, purchased a 20 meter papyrus scroll found in Thebes (known today as Luxor), written in hieratic Egyptian inscription dating 1550BC[9]. The papyrus scroll contained medical information, including how to detect heart failure[10]. The papyrus scroll known as the Ebers papyrus, is the most primitive form of medical information relating to the diagnosis and management of heart failure. Due to improvements in management of many heart conditions, chronic heart failure has emerged as a pressing health issue in contemporary society.

Chronic Heart Failure definition

Many definitions for chronic heart failure exist[11-13]. As this study focused on an Australian cohort the CHF definition as outlined by The National Heart Foundation (NHF) in conjunction with The Cardiac Society of Australia and New Zealand (CSANZ) was chosen.

CHF is defined as:

“CHF is a complex clinical syndrome with typical symptoms (e.g. dyspnoea, fatigue) that can occur at rest or on effort, and is characterised by objective evidence of an underlying structural abnormality or cardiac dysfunction that impairs the ability of the ventricle to fill with or eject blood (particularly during physical activity). A diagnosis of CHF may be further strengthened by improvement in symptoms in response to treatment, p6”[14].

Classifications of chronic heart failure

Although descriptions of heart failure have varied over the years, commonly heart failure is now categorised on the basis of left ventricular systolic function. There are two types of classifications for heart failure. The two types are referred to as systolic heart failure and diastolic heart failure. Systolic heart failure is predominantly referred to as heart failure with a reduced ejection fraction (EF). Whereas diastolic heart failure is now commonly being referred to as heart failure with a preserved EF (HFPEF). This classification is also referred to as heart failure with preserved systolic function (HFPSF). However, there is no consensus regarding the parameter for what constitutes a preserved EF[11]. Furthermore, the EF value is not included in the ACC/AHA[12] or the ESC[11] guidelines for systolic or HFPEF. Whereas the NHF and CSANZ guidelines[14] define HFPSF as a left ventricular ejection fraction (LVEF) $\geq 45\%$ on echocardiogram. The lack of consensus with EF

can be problematic. Within some RCTs, cohorts may be categorised according to HFPEF or heart failure with reduced ejection fraction (systolic heart failure). However, values for preserved and reserved EF differ amongst RCT studies. Owan and colleagues[15] categorised their cohort by using the value of > 50% for HFPEF and <50% for systolic heart failure. Whereas, Yusuf and colleagues[16] used a EF >40% for HFPEF. This lack in consistency in EF cut offs alters interpretation of data.

Systolic Heart Failure

Systolic heart failure is the most common form of heart failure. Coronary artery disease (CAD) and hypertension are the main contributors to systolic heart failure. Systolic heart failure is a weak ability for the heart to contract in systole[14].

Diastolic Heart Failure - Heart Failure with Preserved Systolic Function (HFPSF)

HFPSF or diastolic heart failure can occur with or without systolic heart failure. The main contributors to HFPSF include: age; hypertrophy and ischemia. HFPSF is characterised by impairment of the left ventricle (LV) to fill during diastole as a result of slow or early relaxation of the LV, or as a result of increased stiffening of the myocardium which leads to higher filling pressures[14].

Physical examination with abnormal clinical symptoms (identified below) is used for a provisional diagnosis of heart failure. For a definitive diagnosis of heart failure, diagnostic tools such as an electrocardiogram (ECG); echocardiogram; chest x-ray (CXR), full blood count (FBC) and urea, electrolytes and creatinine (UEC) levels are measured[14]. Individuals diagnosed with heart failure have the following clinical features:

Symptoms

- Breathlessness at rest or on exercise, fatigue, tiredness, ankle swelling[11].

AND

Signs

- Tachycardia, tachypnoea, pulmonary rales, pleural effusion, raised jugular venous pressure, peripheral oedema, hepatomegaly[11].

AND

Structural or functional heart abnormalities

- Cardiomegaly, third heart sound, cardiac murmurs, abnormality on the echocardiogram, a raised natriuretic peptide concentration[11].

Heart failure classifications for severity

Two classifications exist for grading heart failure severity. The first is a classification system based on symptom severity. This is known as the New York Heart Association (NYHA) functional classification[17]. Individuals are classified from Class I through to Class IV.

- Class I – no limitation on physical activity.
- Class II – Slight limitation of physical activity.
- Class III – Marked limitation of physical activity
- Class IV – Symptoms at rest.

The second, classification system was formulated by the American College of Cardiology Foundation/American Heart Association (ACC/AHA)[12]. This system classifies individuals according to the structural abnormality of their heart. There are 4 stages A – D.

- Stage A – No identified structural or functional abnormality. However, individuals are at high risk for developing heart failure.
- Stage B – Developed structural heart disease that is strongly associated with the development of heart failure.
- Stage C – Symptomatic heart failure associated with underlying structural heart disease.
- Stage D – Advanced structural heart disease and marked symptoms of heart failure at rest despite maximal medical therapy.

Incidence and prevalence

The incidence and prevalence for heart failure is high. Approximately 5 million adults in the United States[18] and 15 million in Europe[11] have a diagnosis of heart failure. The exact figures for Australia remain unknown due to the absence of reliable data systems. It has been estimated that within the Australian population of 21 million, 2.5% of Australians aged 55-64 years have CHF, with this figure rising to 8.2% for adults over the age of 75 years[19]. The prevalence of heart failure in European populations has been estimated at 2%[11]. However, this figure rises to 20% for adults aged between 70-80 years[11]. In the United States approximately 10 per 1000 people over the age of 65 years have heart failure[20]. These figures reflect the Australian trend of an ageing population being diagnosed with heart failure. Furthermore, the older an individual becomes the greater their risk of developing heart failure. Heart failure is also associated with high

hospital admissions. Concerns are therefore raised for individuals who are at risk of being hospitalised.

Metrics of assessing hospitalisation

There are inconsistencies in data being reported on the incidence of heart failure. As a result of these studies[21-24], it is difficult to identify if the incidence of heart failure is increasing, decreasing or has resulted in a plateau. Most incidence data for heart failure is obtained from the episodes of hospitalisation of participants within RCTs. However, many individuals are nowadays reviewed and possibly diagnosed in primary care settings, or as outpatients within clinics. As such, these individuals are not included in the incidence data for heart failure (collected from hospitalisation with RCTs) as they may have yet to be hospitalised. Furthermore, due to the advancement in technology, diagnostic tools such as echocardiograms and guidelines provided by The European Society of Cardiology (ESC)[11] and The American College of Cardiology/American Heart Association (ACC/AHA)[12] and more recently the National Heart Foundation(NHF) and The Cardiac Society of Australia and New Zealand (CSANZ) have assisted with the diagnosis of heart failure now being made in community settings and not primarily in hospital. Ezekowitz and colleagues[25] identified the incidence and prevalence of heart failure diagnosis of patients made in the emergency department (ED) and in outpatient clinics. These investigators have identified an increase in the volume of individuals being diagnosed with HF in outpatient clinics (45.7%) compared to in hospital (36.6%)[25]. Furthermore, though the incidence of HF (per 100 000) was shown to have decreased from 1999-2007, the prevalence of heart failure increased over the study period. This coincides with previous literature of an increase in the prevalence of heart failure due to individuals living longer with CHF[15, 26]. A principle finding of the study by Ezekowitz and colleagues[25], was the identification that the highest proportion of all-cause hospitalisation occurred in individuals with previous ED presentations. The relevance of this for future research is the importance of identifying individuals in the community at risk of hospitalisation. Also, an ED presentation, should be viewed as a risk marker for hospitalisation and individuals targeted to prevent subsequent hospitalisations[27].

Absolute and relative risk prediction

There are generally two ways of expressing *risk*. One is absolute risk, and the second is relative risk. *Absolute risk* is an individual's risk of developing a given event (such as rehospitalisation) over a time period[28]. The figure for absolute risk is generally expressed as a percentage. The absolute risk is not compared to any other risk. Whereas

relative risk is comparing the risk in two different groups of people, (individuals with heart failure and those without heart failure). An important element of the relative risk is that it does not inform you of an individual's actual risk. Relative risk (RR) is the probability that a member of an exposed group (individuals with heart failure) will experience an event (rehospitalisation) relative to the probability that a member of an unexposed group (individual with no HF) will experience that event (rehospitalisation)[28]. However, in CHF, the absolute risk of rehospitalisation may also vary depending on the individual's clinical health status at the time of risk assessment. In other words, an absolute risk score for rehospitalisation for individuals with heart failure may fluctuate rather than be a constant value. This may be problematic for clinicians when treatment decisions are required. Furthermore, if an individual was only using an absolute risk score taken at a previous moment in time to determine their need to seek treatment at present, that absolute risk score may not be an accurate predictor and therefore, unsuitable to guide decisions. As a result, an absolute risk score for rehospitalisation should firstly be conducted at that given moment in time and not be used in isolation when deciding treatment options and HF disease management decisions but rather, as a tool to guide in management in conjunction with a holistic view of the individual considering patient, provider and system factors.

Hospitalisation for heart failure

CHF hospitalisation is common in the developed world. The most universal chronic disease hospital diagnosis for adults is heart failure[13, 29]. In the United States of America (USA), approximately 80% of individuals with heart failure who are hospitalised are over 65 years of age[30]. This figure is reflected in Europe and Australia. In the USA, heart failure is responsible for 12 to 15 million clinic visits and 6.5 million hospital stays annually[31]. Hospital discharges with the diagnosis of heart failure have increased by 174% from 1979-2003[20]. In a recent Western Australian (WA) study examining the trends in heart failure hospitalisations, it was revealed that the diagnosis for heart failure was higher in males than in females, with an overall rate of 111.3 per 100, 000[21]. Furthermore, over the 16 year period of the study, heart failure hospitalisations increased by 4.2%[21]. The rise in hospitalisations occurred despite the advancement in pharmacological regimes that include ACE inhibitors and beta-blockers. Pharmacological interventions, therapies and individual self management strategies post myocardial infarct have contributed to individuals with CHF living longer[32]. However, hospital admissions are occurring despite diverse interventions. Hospitalisation may occur as a result of heart failure disease progression; an exacerbation of an acute episode due to inadequate symptom management and control.

However, hospitalisation is a preventable event[33]. Furthermore, an emergency department (ED) presentation as a result of an exacerbation in heart failure symptoms that result in hospitalisation are possibly avoidable if an individual within the community at risk of deteriorating was identified early and interventions were targeted accordingly. An individual's risk of hospitalisation can be determined from a risk prediction model. Currently, there are several models[34-42] that make predictions regarding an individual with heart failure at risk of hospitalisation. Unfortunately, current risk prediction models for hospitalisation do not accurately target individuals at risk of hospitalisation. This is because current risk models do not provide an absolute risk for individuals at risk of hospitalisation. Therefore, creating risk prediction models that accurately target individuals at risk is paramount. Risk models need to reflect realistic current practices and systems of delivery. Additionally, risk models need to expand their scope to include non medical factors other than patient specific characteristics[43]. With the ageing of the baby boomer generation, it is expected that the number of people diagnosed with heart failure will increase. Teng and colleagues[21] in the WA study, identified a 55.2 fold increase in the age specific rate of hospitalisation for adults over 75 years of age compared to the age group less than 65 years. The rise in the risk of hospitalisation for adults as they age is alarming considering the ageing of the baby boomer generation has yet to peak. An ageing population and subsequent diagnosis of heart failure will intensify the burden to health care services and disease management programs for HF.

Burden of hospitalisation

The burden for hospitalisation is great. Financial, social and physical burdens influence, not only the individual who is hospitalised, but also their family as well as the community[44]. Loss of income from not being able to undertake employment occurs[45]. Physical burdens including depression, decrease mobility and fatigue result. Individuals with HF become reliant on family members and the community for assistance. Within the larger community, hospitalisation is the primary area for health care costs and resource allocation. This is followed by expenses for pharmacological regimes. The direct and indirect expenditure of heart failure in the USA has been estimated at \$30 billion[46]. Compared to the UK where direct expenditure has been estimated at £716 million, 69% of which is directed to hospitalisation and pharmacological regimes[47]. In Australia, the direct and indirect cost for heart failure is over \$1 billion[48]. With an ageing population and the risk of heart failure hospitalisation increasing with age, the projected volume of expenditure and resource allocation for heart failure disease management will rise.

Currently, the primary expenditure is for hospitalisation. If hospitalisation could be prevented, not only could funding then be reallocated elsewhere, such as primary health care, adverse events, such as falls or rehospitalisation that accompany hospitalisation may also be prevented. Hospitalisation is a risk factor for increased mortality[49]. In Australia, individuals who are not hospitalised have a 25% lower case fatality[50]. Furthermore, hospitalisation increases the risk of hospital readmission[18]. Once hospitalised, individuals have a 50% risk of being rehospitalised within 6 months[51]. At present, admissions for heart failure patients in the USA result in a length of 4-5 day stay in hospital[18]. However, premature discharge of patients, without follow-up into the community result in rehospitalisation[52]. Aims to reduce the risk of hospitalisation may also indirectly decrease the burden associated with hospitalisation.

Hospital avoidance

CHF hospitalisations exert a considerable burden on the health care system. An avoidable hospital admission is defined as an admission that may perhaps have been controlled or avoided[53]. Most CHF hospitalisations occur as a result of an exacerbation in symptoms, such as pulmonary oedema[54]. This deterioration in health status occurs as deteriorating signs and symptoms have not been detected by providers or services within the community (or even the patient). For example, patients will present to ED with pulmonary oedema, however, they may have been short of breath or may have increased their weight several days prior to presentation. Monitoring weight, fluid restriction, lowering their sodium intake and adjusting diuretics may have prevented the presentation to ED[55].

Within the Cochrane Consumer Network, (an arm within the Cochrane Collaboration which produces systematic reviews based on healthcare interventions), level 1 evidence is derived from systematic reviews of RCTs[56]. However, this can be problematic. RCT cohorts tend to be different to the majority of individuals who present to ED departments[46]. Additionally, the reluctance of individuals to participate in RCTs results in smaller participation rates[57, 58] and difficulty in replicating real world situations. Clark and colleagues[59] discuss in relation to heart failure-management programs, the often oversimplification in reporting of complex interventions, smaller sample sizes in RCTs that may lead to random error and short term follow up that may not identify mortality and morbidity as accurately as longer term follow ups. Furthermore, there may be limitations with generalizability of outcomes from RCTs to the wider community. One innovative method to perhaps overcome this limitation with generalizability was described recently in studies by Voss and colleagues[57] and Stauffer and colleagues[58]. Voss and

colleagues[57] replicated the Care Transitions Intervention[60]. The Care Transitions Intervention empowers individuals to contribute to the management of their health and inform their care provider of any concerns or alteration in signs and symptoms. Individuals who undertook the Care Transitions Intervention, reduced their risk of rehospitalisation. An absolute readmission rate of 12.8% was identified for the intervention group compared to 20% for the control group[57]. Stauffer and colleagues[58] replicated a transitional care program led by an advance practice nurse. Outcomes of the study included a decrease by 48% in 30-day readmission. Repeating outcomes from RCTs within real world settings has previously been encountered with obstacles. The studies by Voss and colleagues[57] and Stauffer and colleagues[58] have been identified as two studies that show positive effects of interventions derived from RCTs being replicated in real world settings and shown to be effective in reducing hospitalisations.

Risk prediction for hospitalisation

At present, risk prediction for hospitalisation is challenging. The primary cause for hospitalisation in adults with existing CHF is an exacerbation[61]. Bonow[33] argued that currently, it is difficult to identify who is at risk of hospitalisation and emphasised that provider and system factors contribute to hospitalisation. Giamoutzis and colleagues[43] also stated the importance of non patient factors contributing to hospitalisation. However, the incorporation of non patient factors is not reflected in current risk models. Current models[34-38, 40-42] predominantly focus on patient characteristics such as age[39] and co-morbidities[37]. Furthermore, the numerous risk models that exist are evidence of the inability of one model to accurately predict hospitalisation. Complications do exist. Considering the complex and diverse heart failure population a risk prediction model for one individual may not be accurate for another. Furthermore, a model that identifies risk in one cohort may not accurately identify risk in another. Such an example of inaccurate risk prediction can be seen with the Framingham risk score for cardiovascular disease.

The Framingham study was undertaken in North America[62]. When the Framingham risk score was tested within a German cohort, the Framingham risk score overestimated German male and female risk of developing cardiovascular disease[63]. This complication of accurate targeting of high risk individuals is also evident within the risk prediction of breast cancer[64]. Therefore, designing a risk prediction model with a scope extending to provider and systems may possibly more accurately identify those individuals at risk than current patient focused risk models. Furthermore, developing an absolute model that targets an individual's risk for rehospitalisation rather than providing a relative

risk score for an individual may assist with improved disease management. Within heart failure management, identification of high risk individuals for hospitalisation is crucial. Targeting individuals at risk may prevent deterioration and hospitalisation, improve outcomes and decrease the direct expenditure allocated to heart failure.

Fundamentally, it has been identified that the current literature is lacking in providing risk models that accurately target individuals with CHF at risk of rehospitalisation. Though several risk prediction models for hospitalisation of adults with CHF exist, their emphasis remains on patient specific characteristics, with a biomedical focus, and do not provide an absolute risk score for rehospitalisation. This limitation with scope and risk prediction may contribute to the challenges of targeting people with CHF at the greatest risk of hospitalisation. Developing an absolute risk prediction model for adults with heart failure may potentially target those at risk more accurately.

Research Design

The above review and consideration of the literature reveal a number of important questions that remains unanswered.

These questions are:

- What is the current state of heart failure disease management in Australia?
- What patient, provider and system factors have been previously identified within studies that predict the risk of hospitalisation for adults with CHF but have not been included in existing risk models?
- What risk factors for rehospitalisation have been incorporated into previous models and which of these factors are replicated when comparing the risk models?
- What is the value of having risk models in clinical practice?
- What is the perception of experts within CHF disease management and/or research as to the patient, provider and system factors that predict rehospitalisation for adults with CHF?

- How accurate is an absolute risk prediction model that is developed and tested using an RCT cohort compared to existing models?

This thesis aimed to answer the above gaps in the literature by combining the findings from a literature review, factors from existing models, expert opinion and testing of the risk model within a prospective cohort.

Aims of the study

This study aimed to test an absolute risk model for predicting the risk of hospitalisation for individuals with CHF. The testing of the model was undertaken using the Which Heart failure Intervention is most Cost-effective and consumer friendly in reducing Hospital care, (WHICH?) Trial database as a derivation cohort. Briefly, the WHICH? Trial is a randomised controlled trial of home based compared with clinic based management of individuals with CHF that was conducted in Australia[6].

Objectives

The specific objectives of the CHF-Risk study were to:

1. Describe the current state of heart failure management in Australia. See publication 1 for a discussion of a literature review. The nursing role in heart failure disease management and the implications of the National Health and Hospital Reforms Commission report on CHF management in Australia is discussed.
2. Determine factors predicting hospitalisation risk from the perspective of patient, provider and system factors based upon the findings of a literature review. See publication 2 for a discussion of a literature review. Risk factors have been categorised into factors that increase the risk of rehospitalisation and factors that decrease the risk of rehospitalisation.
3. Generate items for the risk prediction model through identifying independent predictors of the risk of hospitalisation from existing models. See publication 3 where a breakdown of current risk factors within existing models has been identified and discussed.
4. Describe the value of risk prediction models within the clinical area. See publication 4 where a discussion is made related to risk models and their use by clinicians in clinical areas to target individuals at risk of adverse events.
5. Generate items for the risk prediction model through expert consultation. See publication 5 where a discussion on how the items were generated for the online survey and the findings identified from the expert consultation.

6. Develop and test an absolute risk prediction model and assess for reliability and validity in a prospective RCT. See the accepted manuscript for a discussion of the CHF-Risk model development and testing using data obtained from the WHICH? Trial.

Ethics Approval

Ethics approval for the CHF-Risk study was obtained from the Curtin University Human Research and Ethics Committee, approval code SON&M 16-2010.

Data Analysis

Data analysis was undertaken using the STATA 11 software package [65].

The analysis was a three step process using two models, one that confirmed and one that explored prediction factors.

- A Cox Proportional Hazard model was used to develop a prediction model based upon Phases 1 and 2.
- The accuracy of the final predictive model (calibration and discrimination) was assessed using the methods suggested by Harrell and colleagues [66].

Step 1: In the first instance, predictor items were identified in previously published series using prospective methods using a standardised data collection tool, (Current Risk Models + Review).

Step 2: Validity of these items and the clinician's perception and ranking of relevance were determined in an online questionnaire (Survey).

Step 3: The second exploratory model used bootstrap methods to retain the factors that predict rehospitalisation, (testing using WHICH? data).

Format of the Thesis

The publications produced as part of this thesis are presented as the full text papers. A discussion chapter is provided to summarise, discuss the limitations and implications for future directions of the thesis findings. The appendices provide statements from the co-authors, permission letters regarding copyright, evidence supporting the refereed status of the publications, ethics approval and the online survey questionnaire.

Abbreviations and Glossary of Terms

Chronic Heart Failure (CHF): A complex clinical syndrome that is frequently, but not exclusively, characterised by an underlying structural abnormality or cardiac dysfunction that impairs the ability of the left ventricle (LV) to fill with or eject blood, particularly during physical activity.

Nomogram: a chart representing numerical relationships.

Risk factor: is any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury.

Randomised Control Trial (RCT): a trial that identifies if a cause-effect relation exists between treatment and outcome and for assessing the cost effectiveness of a treatment.

Which Heart failure Intervention is most Cost-effective and consumer friendly in reducing Hospital care (WHICH?): the title of an Australian multicentre, randomised trial of home-based versus clinic-based, nurse-led, multidisciplinary management of chronic heart failure.

ACTRN12607000069459: Australian and New Zealand Clinical Trial registry identification number for the WHICH? Trial.

Hazard: the rate at which events happen.

Hazard Ratio (HR): the hazard in one group is a constant proportion of the hazard in the other group. This proportion is the hazard ratio.

Confidence Interval (CI): is an interval estimate of a population parameter and is used to indicate the reliability of an estimate and can be interpreted as the range of values that would contain the true population value 95% of the time if the survey were repeated on multiple samples.

Receiver Operating Characteristic (ROC): a plot of (true positives) sensitivity versus (false positives) 1-specificity.

C-index: the value for the measurement of discrimination.

Absolute risk: probability that an outcome/event will occur as contrasted with the relative risk.

Relative risk: is the risk of the endpoint, such as disease, death, readmission, among those exposed versus the risk of the endpoint among the unexposed.

Patient: relates to the multidimensional facets of individuals including physical, social, psychological, economic, cultural, and existential characteristics.

Provider: denote health professionals providing formal care giving.

System: pertains to factors relating to the organisation, funding and policy milieu of health care system delivery.

B-type natriuretic peptide (BNP): A 32-amino-acid polypeptide secreted by the ventricles of the heart in response to excessive stretching of cardiomyocytes.

N-terminal prohormone of brain natriuretic peptide (Nt-proBNP): 76 amino acid N-terminus fragment of brain natriuretic peptide.

Diabetes Mellitus (DM): metabolic disease caused by the body's failure to produce insulin or failure of cells to use insulin appropriately.

Blood urea nitrogen (BUN): blood test that determines renal function measuring urea nitrogen, products which are formed when protein is broken down.

Chronic Care Model (CCM): an organisational framework for chronic care management and practice improvement consisting of 6 concepts identified as: organisational support, clinical information systems, delivery system design, decision support, self-management support, and community resources.

National Heart Foundation (NHF): a federated charity that funds cardiovascular research, promotes guidelines for health professionals, informs the public and assists people with cardiovascular disease management.

Cardiac Society of Australia and New Zealand (CSANZ): is the professional society for cardiologists and those working in the area of cardiology including researchers, scientists, cardiovascular nurses, allied health professionals and other healthcare workers.

Ejection Fraction (EF): volume of blood that is ejected from the left ventricle at the end of diastole that is then expelled during contraction.

Heart Failure with a Preserved Ejection Fraction (HFPEF): (values vary) a left ventricular ejection fraction >40%, >45%, or >50%.

Heart Failure with a Preserved Systolic Function (HFPSF): HFPSF is characterised by impairment of the left ventricle (LV) to fill during diastole as a result of slow or early

relaxation of the LV, or as a result of increased stiffening of the myocardium which leads to higher filling pressures.

American College of Cardiology (ACC): non profit medical society dedicated to formulation of health policy, standards and guidelines, and cardiovascular research.

American Heart Association (AHA): national voluntary health agency to help reduce disability and death from cardiovascular diseases and stroke.

Coronary Artery Disease (CAD): hardening and narrowing of arteries due to atherosclerosis.

Left Ventricle (LV): one of the four chambers of the heart. It receives blood from the left atrium.

Electrocardiograph (ECG): graphic recording of electric potentials generated by the heart.

Chest X-ray (CXR): radiograph of the chest.

Full Blood Count (FBC): blood test that determines red blood cells, white blood cells and platelets.

Urea, Electrolytes and Creatinine (UEC): blood test that determines renal function (urea and creatinine) and minerals that carry an electric charge Sodium(Na^+), Potassium (K^+), Chloride (Cl^-).

New York Heart Association (NYHA): a member of the American National Heart Association. The New York Heart Association developed a scale for classifying the severity of heart failures known as the New York Heart Association functional classification.

Incidence: the rate at which new cases occur in a population during a specified period.

Prevalence: the proportion of a population that is affected by the disease at a specific time.

European Society of Cardiology (ESC): a society representing European and Mediterranean cardiology professionals promoting scientific and educational activities.

Emergency Department (ED): ward within a hospital specialising in acute care of individuals who present unplanned.

Rehospitalisation: an acute care admission within a specified time interval following discharge from hospital. Policymakers and researchers differ on the specified time and it varies between 48 hours, 28 days, 30 days, 60 days or 90 days.

Western Australia (WA): a state located on the West coast of Australia.

STATA: a statistical software package.

National Health and Hospitals Reform Commission (NHHRC): Commission established in 2008 by the Australian Government with the aim of developing a long term health plan for Australia.

Cumulative Index to Nursing and Allied Health Literature (CINAHL): a research database providing journals in the areas of nursing and allied health.

Cardiovascular disease (CVD): a class of disease that involves the cardiovascular system (heart and blood vessels). In Australia the main types of CVD are heart failure, coronary heart disease and stroke.

Chronic Heart Failure Management Programs (CHF-MPs): a disease management program involving specialty care and a multidisciplinary team that identifies and manages patients' co-morbidities, optimises drug therapy, promotes patient education, and follow-ups with early identification of problems.

Council of Australian Governments (COAG): the peak intergovernmental forum in Australia. The members of COAG are the Prime Minister, State and Territory Premiers and Chief Ministers and the President of the Australian Local Government Association.

Registered Nurse (RN): professional nursing health care worker with a Bachelor degree and registered with a national regulatory body or agency.

General Practitioner (GP): medical practitioner specialising in primary health care registered with a national regulatory body or agency.

New South Wales (NSW): a state located on the East coast of Australia.

United Kingdom (UK): is a sovereign state located off the North-Western coast of continental Europe.

Nursing and Midwifery Council (NMC): the former governing body for nursing registration in Australia. Currently referred to as the Australian Health Practitioner Regulation Agency (AHPRA).

Beck Depression Inventory (BDI): is a 21-question multiple choice self report inventory for measuring the severity of depression.

National Health and Medical Research Council (NHMRC): is Australia's peak funding body for medical research. NHMRC was established to develop and maintain health standards and is responsible for implementing the National Health and Medical Research Council Act of 1992.

Statewide Planning and Research Cooperative System (SPARCS): is a comprehensive data reporting system that was established in 1979 in New York (USA) as a result of cooperation between the health care industry and government.

International Classification of Diseases (ICD): is the standard diagnostic tool for epidemiology, health management and clinical purposes and is used by World Health Organisation member states.

Outcomes of a Prospective Trial of Intravenous Milrinone for Exacerbation of Chronic Heart Failure (OPTIME-HF): is a randomised placebo controlled trial to assess the utility and safety of short-term intravenous milrinone in patients admitted with worsening chronic heart failure.

Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE): is a randomised control trial designed to test the long-term safety and efficacy of treatment guided by hemodynamic monitoring and clinical assessment versus that guided by clinical assessment alone in patients hospitalised with New York Heart Association class IV CHF.

Centre for Medicaid and Medicare Services (CMS): is a federal agency within the United States Department of Health and Human Services (DHHS) that administers the Medicare program. The CMS works in partnership with state governments to administer Medicaid, the State Children's Health Insurance Program (SCHIP) and health insurance.

Acute Decompensated Heart Failure Registry (ADHERE): was designed to bridge the gap in knowledge and care by prospectively studying characteristics, management, and outcomes in a broad sample of patients hospitalised with acute decompensated heart failure.

Percutaneous Coronary Intervention (PCI): is one of the two revascularisation techniques currently used in the treatment of ischaemic heart disease by dilating the coronary artery involved.

World Health Organization Commission on Social Determinants of Health (CSDH): a Commission established in 2005 by the World Health Organisation to provide advice on how to reduce the social determinants of health. The social determinants of health are the conditions in which people are born, grow, live, work and age, this also included the health system.

Intensive Care Unit (ICU): specialised unit within a hospital providing critical care or intensive care medicine.

Intensive Care National Audit and Research Centre (ICNARC): an organisation in the UK that aims to improve organisation and practice of care within critical care areas through audits and research.

Acute Psychology and Chronic Health Evaluation (APACHE): severity-of-disease classification system applied within 24 hours of a patient being admitted to an intensive care unit.

Simplified Acute Physiological Score (SAPS): is a severity of disease classification system for patients admitted to an intensive care unit the 24 hours following admission.

Mortality Probability Model (MPM): system to estimate the probability of hospital mortality for admitted patients.

The Predicted Risk, Existing Diseases and Intensive Care Therapy model (PREDICT): long term survival of critically ill patients using clinical variables collected within the first 5 days of hospital admission.

Angiotensin Converting Enzyme (ACE): conversion of angiotensin I to angiotensin II resulting in blood vessel constriction.

Australian Cardiovascular Nurses College (ACNC): professional organisation that supports any nurse within Australia, New Zealand and the wider region of Asia who have a major interest or role in caring for patients with cardiovascular disease.

World Health Organisation (WHO): is a specialised agency of the United Nations (UN) concerned with international public health.

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Published Papers

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The chapter following this provides the actual journal article published in Australian Critical Care by Elsevier. The publication explores Australia’s health care reform strategies and the importance of the nursing role within chronic heart failure (CHF) disease management.

Background

- Australia has a health care system that offers universal health coverage for all citizens[1].
- Hospital funding by the Commonwealth government has been in a state of decline[2].
- An ageing population living longer with chronic diseases are currently a burden to the health sector due to hospitalisation[3].
- The highest expenditure for hospitalisation is related to cardiovascular diseases[3].

What this publication adds

- This review delineates the Australian government’s plan for health care reform and refers to the reform goals of tackling access and equity, redesigning the health system and creating a system that is sustainable.
- This review demonstrates the diversity of nursing roles in chronic heart failure management that can assist in identifying at risk individuals for hospitalisation and proposes that cross collaboration of a sundry of nursing roles can improve services offered within CHF disease management.
- Elements of the Chronic Care Model have been applied to demonstrate the complex and distinct interventions required within chronic disease management in an Australian context.

Where to from here?

- As part of the reforms the Commonwealth government will become directly responsible for funding basic community care for adults over the age of 65 years (in most States and Territories).
- The identification of risk factors and targeting of individuals with CHF at risk of hospitalisation is paramount.
- The identification of risk factors will enable the range of nursing roles particularly within primary care settings to target at risk individuals and implement or alter disease management strategies and prevent adverse outcomes.

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ELSEVIER

REVIEW PAPER

Australia's health care reform agenda: Implications for the nurses' role in chronic heart failure management

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Summary

Introduction: The importance of the nursing role in chronic heart failure (CHF) management is increasingly recognised. With the recent release of the National Health and Hospitals Reform Commission (NHHRC) report in Australia, a review of nursing roles in CHF management is timely and appropriate.

Aim: This paper aims to discuss the implications of the NHHRC report and nursing roles in the context of CHF management in Australia.

Method: The electronic databases, Thomson Reuters Web of Knowledge, Scopus and the Cumulative Index to Nursing and Allied Health Literature (CINAHL), were searched using keywords including; "heart failure", "management", "Australia" and "nursing". In addition policy documents were reviewed including statements

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and reports from key professional organisations and Government Departments to identify issues impacting on nursing roles in CHF management.

Results: There is a growing need for the prevention and control of chronic conditions, such as CHF. This involves an increasing emphasis on specialist cardiovascular nurses in community based settings, both in outreach and inreach health service models. This review has highlighted the need to base nursing roles on evidence based principles and identify the importance of the nursing role in coordinating and managing CHF care in both independent and collaborative practice settings.

Conclusion: The importance of the nursing role in early chronic disease symptom recognition and implementing strategies to prevent further deterioration of individuals is crucial to improving health outcomes. Consideration should be given to ensure that evidence based principles are adopted in models of nursing care.

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Health reform in Australia

The Australian health care system is in need of reform to respond to increasing pressures of costs and demand. The National Health and Hospitals Reform Commission (NHHRC) released the National Plan for Health Reform in July 2009.¹ Initially, the cost involved for implementing the NHHRC strategies was estimated to be between \$2.8 billion and \$5.7 billion.¹ However, if key reforms are executed, the government is projected to save \$4 billion a year by 2032.¹ The report acknowledged three reform goals that would assist with the transformation of the Australian health care system. These reform goals are:

1. tackling major access and equity issues that affect health outcomes for people now;¹
2. redesigning our health system so that it is better positioned to respond to emerging challenges;¹ and
3. creating an agile and self-improving health system for long-term sustainability.¹

With an ageing population living longer with chronic diseases such as chronic heart failure (CHF), implementation of the NHHRC goals will directly impact on management of individuals with CHF in the acute and community settings.

Chronic heart failure in Australia

Chronic heart failure is burdensome not only on the individual but also the community. The prevalence of CHF rises from 2.5% for people aged 55–64 years to 8.2% for those aged over 75 years.² Within the Australian population, many individuals with CHF are living longer due to advancement in ther-

apies, diagnostic techniques, and chronic disease management.³

Burden of cost

Australia is supported by a system of universal health care coverage and the burden of health costs increases in older people and those with multiple chronic conditions. In 2005–2006, \$86.9 billion or 9% of the gross domestic product was spent on healthcare.² Cardiovascular disease (CVD) accounted for the highest expenditure. Eleven percent of the total healthcare budget is related to CVD.⁴ Expenditure can be divided into cost for treatment and the cost for prevention. With an ageing population spending on health treatment is expected to soar up to 111% by 2032.² Currently, the total health care expenditure for CHF is over 1 billion Australian dollars.⁵ The majority of this expenditure is for individuals aged 85 years and over. Eight times the amount was spent on this age group compared to expenditure for individuals aged 45–54 years with CVD.⁵ Therefore, the burden of cost is reflective of an ageing population with multiple chronic illnesses requiring care.

Many patients who are admitted to hospital with CHF have complex co-morbidities. The interaction of health, social and psychological issues require specialist care with input from multiple specialties. Identifying patients' needs and employing strategies through collaborative interventions from multiple specialties may decrease length of hospital stay in acute areas. The cost of hospitalised patients in acute beds is \$1100/day, whereas stay in subacute areas costs the Australian government \$550/day.⁶

McAlister et al. identified in a systematic review, cost savings, predominately through decreasing hospitalisations, were apparent when CHF disease management programs incorporated multidisciplinary teams and patient education.⁷ Through identifying early signs of clinical deterioration strategies can be implemented to reduce the risk of hospitalisation. The majority of health related expenses are allocated to hospitalisation particularly for persons over 85 years.⁵ This means that there is an increased need for planning, discharge and support in chronic care. Phillips et al.⁸ have identified that improved discharge planning and post discharge support in the community can decrease rehospitalisation for individuals with CHF. Similarly, Chronic Heart Failure Management Programs (CHF-MPs) are an evidence based strategy for community based care based upon Level 1 evidence.⁹ Due to complex disease management of individuals with chronic conditions, the National Health and Hospital Reforms Commission (NHHRC) have prioritised better delivery of care as a reform goal.¹ CHF-MPs are an excellent demonstration of incorporating evidence based principles in health care reform.

This paper aims to first, discuss the Australian plan for health reform. Secondly, it will explore Australian nursing roles and the implications these roles have on future chronic heart failure management. Elements of the Chronic Care Model (CCM)¹⁰ will be used throughout this analysis to identify areas for reform. The CCM has empirically derived items of interventions to improve chronic care. There is an increasing recognition of the need for prevention and control of chronic conditions such as CHF and an emphasis on community care. This emphasises the importance of the nursing role in coordinating and managing CHF care in both independent and collaborative practice settings.

Early symptom recognition

Early identification of chronic disease symptoms and disease awareness through health education is paramount in chronic disease management. An educated, empowered population, making informed decisions promotes wellness and places less of a financial burden on the government and the community. With an ageing population living longer with CHF, the importance of individuals understanding their disease and disease progression will permit patients to monitor their symptoms in conjunction with health care teams.¹¹ Health literacy, is the ability of individuals to access, understand, and

use information for health.¹² Through health literacy, support is advocated for greater empowerment in health decision making. Collaboration, particularly between CHF-MPs and the individual with CHF, promotes communication of complex medical information. Early detection of CHF deterioration and disease management delivery systems will provide chronic illness care for individuals with CHF and will potentially decrease financial expenditure in the long term.

The CCM developed by Wagner¹³ provides elements of a systematic approach, with responsive interventions and cross-sector interactions with the patient as the focus to promote high quality chronic disease management. There are six essential elements of the CCM that contribute to improving patient outcomes. All six components of the CCM can be implemented in conjunction with the NHHRC recommendations to better manage individuals with CHF in Australia. Elements of the CCM are discussed below in relation to the Australian health reform agenda.

Resources and policies

The NHHRC acknowledges that creating resources and policies that foster partnerships within the community to meet the needs and engage community involvement of its individuals is paramount. Engaging the community is dependent on increasing access to information, fostering awareness and access to appropriate health care personnel. Vitry et al.¹⁴ identified a lack of dissemination of resource information for individuals with CHF, recommending a national move towards the distribution of resources and the access and availability of material. Providing sufficient funds for community based care and mechanisms of access is an important focus of the health care reform agenda.¹

Organisational health care

Organisational health care involves endorsing models of intervention that promote safety and quality. The NHHRC report emphasises that promoting communication between health and aged care services is imperative in achieving care coordination.¹ Central to achieving this is increasing sub-acute facilities and investment in support services for people at home and communication with primary care. Evidence based discharge planning and endorsing affordable health care are also strategies in promoting an effective and accessible health care system.

Significant initiatives are being undertaken in Australia to promote primary care. The Australian government increased expenditure for cardiovascular diseases in Australia by 18% in the period 2000–2005, with the majority of expenses being allocated to community based services.⁵ However, future distribution of funds may need to be increased at the local level to promote suitable chronic disease management for the growing ageing population.

Furthermore, a competency-based framework is to be the foundation for health curricula, fostering productive partnerships between industry and education. Curricula that are competency based promote safe work practices, critical thinking, reflection and allow the application of theory into clinical practice.¹⁵

Self-management support

Self-management is a naturalistic decision-making process.¹⁶ The American Heart Association (AHA) has identified several behaviours required for self-management by individuals with CHF. These behaviours include: adherence to prescribed medications, diet and exercise; symptom and weight monitoring; fluid and alcohol restrictions; the cessation of smoking; informing their physician of any non prescribed medication they may be administering including complimentary therapies; and incorporating preventative behaviours in their lifestyle such as regular dental care.¹⁶ However, Riegel and Carlson¹⁷ identified in an North American study that individuals with CHF encountered barriers to self-management. Barriers included a lack of understanding of CHF symptoms, complex treatment regimes, being limited in undertaking activities of daily living and emotional wellbeing.¹⁷ Many participants acknowledged an inadequate understanding of CHF. However, Carlson et al.¹⁸ identified that experience aided self-management for participants with CHF. Participants' ability and confidence to manage their care improved with time and familiarity of events. Nevertheless, strategies to educate individuals regarding self care including symptom recognition and interventions were identified as areas in need of improvement.

Decision support

Decision support is evidence based quality care with input and feedback from patients involved in management of their disease. It involves the use

of practical evidence based guidelines to govern chronic disease management of individuals. Clark et al.¹⁹ identified the lack of adherence to guidelines, diagnostic tests and implementation of interventions in rural communities compared to urban areas for the care of individuals with CHF. Furthermore, the NHHRC has acknowledged the discrepancy between the right to health care and the limitation to access encountered by individuals in remote communities. Strategies proposed by the NHHRC include an increase in workforce supply, funding for services, providing for patient travel and accommodation as well as training opportunities for health professionals at the undergraduate and graduate level in rural and remote communities.¹

Delivery system support

Delivery system support strengthens effective, efficient care and support. The creation of a National Health Promotion and Prevention Agency, aimed at primary prevention and early interventions will promote education, informed health choices, and early detection of individuals' deterioration. Funding will be shifted from the state to the federal government, and will result with the Commonwealth paying 100% of all public hospital outpatient services.¹ Currently, 93% of chronic heart failure management programs (CHF-MP) exist in high accessible areas.²⁰ Clark and Driscoll²⁰ exposed the discrepancy in primary health care programs for individuals with CHF living in remote areas. The Australian Institute of Health and Welfare (AIHW)² have also reported that life expectancy decreases with increasing remoteness. Therefore, the NHHRC¹ have recommended that increased funding and training for clinicians in remote areas be a priority. Furthermore, as Australia is a country rich in diverse cultures and customs, streamlining care should be structured to meet the needs of individuals with CHF. Davidson et al.²¹ justified the inclusion of family members of individuals with CHF in the care and decision making process. Other factors that need to be considered include cultural norms, individuals' definition of illness, and health care expectations when planning CHF management programs to enable appropriate interventions to then be implemented.

Clinical information systems

Provision of clinical information systems permits access to key data to efficiently facilitate resource-

ful and high-quality care. Setting national access targets to identify if members of the community are accessing services they require will pinpoint individuals in need. Introduction of an electronic health record as part of the National Health and Hospitals Network, has the potential to increase efficiency and safety in the delivery of health care and decrease reproductions and surplus of information.²² These discrete, yet linked elements of the CCM need to be considered in developing and adapting sustainable models that are responsive to the Australian health care system. Workforce is a critical issue in improving chronic care and nurses play a crucial role. Below, the implications of CHF in the future are considered within nursing roles and associated scopes of practice.²³

Implications for Australian nurses

The World Health Organisation has identified a global crisis regarding the health workforce. Education and training with concentration on nurses and midwives has been identified as a priority.²⁴ Positive outcomes for individuals in primary care or acute care settings require a strong foundation in the provision of nursing services. A review of Australia's health workforce was described in The Productivity Commission report. The report identified the shortages of workforce supply, and the increase in workforce demand primarily in remote and rural areas.²⁵ In December 2009, the Australian government established Health Workforce Australia (HWA)²⁶ which has signalled a process of workforce reform. Managing the demand and increasing the supply of Australian health care providers is both a multifaceted and challenging process. One such focus is the recruitment of individuals to the health workforce and retaining the individuals currently employed in the health industry. Furthermore, The Council of Australian Governments (COAG) have affirmed the increase in funding placements to undergraduate health discipline training including nursing as well as funding for supervision of such placements.²⁷ This is beneficial as training at the undergraduate level will expose health students to real world settings and improve safe practice and efficiency through exposure in the clinical setting.^{28,29}

Knowledge gained through research has contributed to the shaping of the role of registered nurses in chronic disease management. However, the scope of practice of the CHF nurse's role including education and training is varied.³⁰ The CHF nursing role of an advanced autonomous clinician, guided by assessment, decision making based on

evidence and planning, contributes to the chronic disease management within a healthcare team for individuals with CHF. The spectrum of CHF disease management ranges from prevention through to palliation. In Australia, nursing practice is guided by the guidelines set out by The Australian Nursing and Midwifery Council.³¹ However, the span is generic aimed at all Registered Nurses (RNs) and not specific to CHF nurses.

The scope of practice for the CHF nurse may also differ. Practice may be dependent on the policies of an institution, understanding of the CHF role within a multidisciplinary team, demographics of employment and the supply or number of CHF nurses available.³⁰ In the acute setting the nursing role is predominantly assessment and acute symptom management. Individuals generally present with an increase in shortness of breath and fatigue.³² Whereas, in community based care the focus is on trying to prevent an individual's presentation to hospital. The following discusses the different roles registered nurses have in community based management of individuals with CHF.

Heart failure nurse specialists

Heart failure nurse specialists work within a multidisciplinary team to deliver evidence based care to improve patient outcomes and address the needs of patients and their families. CHF nurse specialists require advanced training whose aim is to identify appropriate post discharge management to prevent readmissions of hospitalised individuals. The economic benefit of the CHF nurse specialist has been shown, as well as the impact of their role has in reducing mortality and length of hospital stay.^{33,9}

Nurse practitioners

Nurse practitioners are expert leaders with advanced knowledge and skill providing autonomous care to individuals. Commissioner Garling recommended an increase in the funding for nurse practitioner roles as a strategy to workforce shortages in his Special Commission of Inquiry into Acute Care in New South Wales (NSW) Public Hospitals.³⁴

One example of nurse practitioners working within a multidisciplinary team is the NSW severe chronic disease management program. This program targets >65 year old and >45 year old Indigenous population.³⁵ The service attempts to increase the quality of life through streamlining appropriate care for individuals with chronic dis-

eases. Stromberg et al.³⁶ identified that nurse led community CHF programs empowered individuals and promoted self-care behaviour in their disease management and improved survival of CHF patients.

Practice nurses

The practice nurse is a nurse employed within a general practice whose tasks often includes screening and assessment of clients.³⁷ As the practice nurse role is in its infancy in Australia, lack of clarity and role blurring of the position exist. Tertiary level accreditation requires formulation and implementation to enhance professionalism of the role.³⁸ Nonetheless, Halcomb et al.³⁹ showed the benefits of practice nurses, located within general practitioner (GP) clinics made access to members of the community easier. Practice nurses contribution to individuals with chronic diseases facilitated a decrease in burden of disease; decrease readmission rates to hospital and decreased hospital lengths of stay.³⁹ Political imperatives, community needs and financial outgoings impact on the attention primary nursing receives.⁴⁰ Therefore, practice nurses need to be strategic in making their role/position clear in formulating a niche in the community. This will facilitate awareness of practice nurses' role amongst community members and health care professionals.

The practice nurse role should be differentiated from the community health nurse role where the latter will predominantly review and assess the individual, providing complex care in the individual's home. The practice nurse works within the general practice setting.⁴¹ Similarly, to the practice nurse, role blurring and multiple titles of the community health nurse exist. These terms include district nurse or primary health nurse and have led to an unclear understanding of the community health nurse position.⁴² The review by Brookes et al.⁴² also identified an increase in the position of specialist nurses within community health nursing services. A shift from general community health nursing towards specialised roles has been influenced by evidence based research and a chronic ageing population with multiple co morbidities requiring specialised interventions in the community.

Specialist versus generalist approaches

Competency standards for registered general nurses (RN) in Australia are overseen by the Aus-

tralian Nursing and Midwifery Council. Competency standards are the basic skills, knowledge and conduct that an RN must adhere by to retain their license to practice. The standards relate to the appropriateness of care and are divided into domains of practice.¹⁵ These criteria enable safe, effective and proficient care to be delivered by general RNs to individuals within the community and clinical areas. Though these are domains for which general nurses must practice under, no such national domains are current for specialist nursing roles (apart for midwives) in Australia. However, in the United Kingdom (UK), the Nursing and Midwifery Council (NMC) which oversees the registration of RNs and midwives, have introduced standards of practice for specialist community public health nurses.⁴³ The NMC stated the standards were created due to the role of community public health nurses being distinctive from other nursing disciplines. It was stressed that community public health nurses worked within a given population and at times were required to make clinical decisions that impacted on a given individual or population without having consulted every member of that community.⁴³ Furthermore, in a UK study⁴⁴ it was identified that home visits post hospitalisation of individuals with CHF by specialist nurses decreased the risk of rehospitalisation through early detection of deteriorating symptoms. This is also reflected in Australian studies.^{45,46} Therefore, specialist nurses in chronic care such as CHF have developed knowledge and skills through education and training to practice under minimal or no supervision to deliver safe, proactive care and thereby decreasing adverse health outcomes. In order to promote the safety and quality of patient care, domains of practice for specialist nursing roles should be considered and specific competencies be addressed. Furthermore, support must be provided for consultation to occur with relevant authorities and professional organisations to develop and monitor standards. Specialist and generalist approaches should not be viewed as antagonistic but synergistic. Developing policies and care pathways based upon patient's acuity and needs are likely to generate efficiencies. Models of nursing care include home-based, clinic and hybrid approaches. The applicability of these approaches is likely to be dependent on available resources and patient characteristics.²³

Increasing access and equity

In Australia, the highest prevalence of CHF occurred in areas with high concentrations of people over

65 years of age and in areas with higher proportions of Indigenous people. At this time, there are no CHF management programs in The Northern Territory or Tasmania.⁴⁷ Clark and Driscoll²⁰ showed that no CHF-MPs had been established outside of cities to service the estimated 72,000 individuals with CHF living in rural and remote areas. Furthermore, in community settings, the majority of CHF-MPs are located in urban areas where transport and access issues are not as problematic as in rural and remote areas. Therefore, one response should be for the government to recognise and utilise resources that are already available to individuals in rural and remote communities. Unlike some health professions, there is more equitable distribution of nurses across urban and remote regions. In 2005, the supply was highest in very remote areas compared to urban areas.² Therefore, implementing health care management and assessment with primary nurses leading these interventions may be of benefit to individuals in rural and remote areas. However, equity issues surrounding CHF-MPs exist. Streamlining care should be based on practical, evidence based research that favours optimal endpoints for individuals with CHF. Driscoll et al.⁴⁸ demonstrated the variability in Australia's CHF-MPs. Of note, was 30% of CHF programs had no discharge criteria.⁴⁸ Inconsistencies when providing health care management to individuals with CHF has the potential to result in poorer outcomes. One method of overcoming the obstacle of access and failure to recognise early signs and symptoms of deterioration is telemonitoring programs. Clarke et al.⁴⁹ identified in their review that telemonitoring in individuals with CHF reduced admissions to hospital and all cause mortality. Nevertheless, the follow up period for the studies in this review were less than six months and may require longer follow up periods to determine if the findings can be sustained over a greater period.

Cross sector collaboration

Cross sector collaboration facilitates early recognition of symptoms and implementation of strategies to prevent deterioration for the individual with CHF. This pooling of resources to streamline disease management increases access of the individual to health care and is a benefit of multidisciplinary collaboration.⁵⁰ The National Heart Foundation's (NHF) components of multidisciplinary care include elements targeting biomedical; self-care education and support; psychosocial care and palliative care.⁵¹ The diversity of needs for individuals with

CHF means that management should be tailored to each individual's situation and unmet needs. Multidisciplinary disease management programs, underpinned by evidence based guidelines, focusing on the identification of early signs and symptoms of health deterioration and self-care promotion are fundamental components for individuals being included in management of their disease. Including individuals in the decision making process is also central to the CCM model and effective chronic disease management.¹³ Furthermore, exploring patient, provider and system barriers to collaboration and care coordination is critical within the context of health system reform.

Conclusion

This paper describes considerations for CHF nursing models in the NHHRC agenda for overhauling Australia's health care system. The nursing role in CHF management has the potential to increase efficiencies and improve health outcomes. In order to carve a niche in the newly configured health care system, CHF nurses have to be proactive in clearly articulating models of care and their scope and range of practice.

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The chapter following this provides the actual journal article published in *Contemporary Nurse* by econtent Management. The publication explores the literature and identifies risk factors for rehospitalisation for adults with chronic heart failure (CHF). These risk factors have been categorised into patient, provider and system.

Background

- CHF is the leading cause for rehospitalisation for adults over the age of 65 years in developed countries[1].
- One in four patients who are discharged with the diagnosis of CHF will be rehospitalised within 30 days[2].
- The older an individual is, the higher the probability of them being rehospitalised[3].

What this publication adds

- This review identifies patient, provider and system factors that influence disease management and contribute to rehospitalisation of individuals with CHF.
- This review categorises patient, provider and system factors that lead to an increase in the risk for rehospitalisation.
- This review categorises patient, provider and system factors that lead to a decrease in the risk for rehospitalisation.

Where to from here?

- Studies need to be undertaken to identify further provider and system factors that contribute to rehospitalisation of individuals with CHF.
- Investigate the influence of patient, provider and system on health outcomes.

- Examine current models to identify predictors that have been incorporated into model design.

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Patient, provider and system factors influencing rehospitalisation in adults with heart failure

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ABSTRACT: *Objectives:* To identify patient, provider and system factors predicting rehospitalisation in adults with heart failure (HF). *Method:* The electronic data bases MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase and PsychInfo were searched from 1996–2008 to identify studies identifying predictors of rehospitalisation from which the factors of patient, provider and systems were extracted. *Results:* A total of 62 elements were identified. These elements were then sorted into patient, provider and system categories. Risk factors identified for rehospitalisation were predominantly related to clinical factors. There were less factors identifying risk from the perspective of provider and health care systems. *Conclusions:* In people with HF it is likely that non-clinical factors including provider and system play an important role in rehospitalisation. There is a need to identify individuals at risk of rehospitalisation and tailor disease management programmes accordingly.

KEYWORDS: nursing, risk factors, rehospitalisation and heart failure

Heart failure (HF) is a heterogeneous syndrome and a common cause of rehospitalisation. Not only is rehospitalisation costly for the community, it is also a marker of high risk for the individual declaring a new phase in the HF syndrome (Jaarsma et al., 2009). In Australia, HF is identified in 8.2% of the population over the age of 75 years (Australian Institute of Health and Welfare, 2008). Furthermore, it is the most commonly diagnosed chronic disease in adults. Keenan and colleagues identified that one in four patients with HF are rehospitalised within 30 days post discharge and many of these admissions are preventable (Keenan et al., 2008; Sochalski et al., 2009). Hospitalisation, particularly among the elderly increases the risk of not only adverse cardiac events but also non-cardiac events such as falls, infections and delirium (Oliver et al., 2007; Shah, Tsai, Klein, & Heidenreich, 2011).

Increasingly, rehospitalisations are identified as a marker of quality of care (Foraker et al., 2011). As a consequence, there is an increased scrutiny of processes and strategies to identify individuals at high risk. Seminal work in improving outcomes for chronic conditions has resulted

in the need to consider *patient, provider* and *systems* issues in implementing disease management strategies (Bodenheimer, Wagner, & Grumbach, 2002; McEntee, Cuomo, & Dennison, 2009). The chronic care model (CCM) developed by Wagner (1998) provides a framework for highlighting the interaction between the individual, health care providers and the health care system. There is also a recognition that health and well-being is influenced by social determinants of health and that access to health care services and health care disparities can influence health outcomes (van der Wal & Jaarsma, 2008; WHO, 2010).

Giamouzis et al. (2011) note that current risk prediction models provide limited information to clinicians as they lack sensitivity and acknowledge the complexity of clinical management. Several factors contribute to this lack of utility, including the heterogeneity of the HF population (Giamouzis et al., 2011) and the emphasis on clinical factors identified from derivation cohorts (Ross et al., 2008). To date, risk prediction models for rehospitalisation for individuals with HF (Chin & Goldman, 1997a; Felker et al., 2004;

Krumholz et al., 2000; Philbin & DiSalvo, 1999; Yamokoski et al., 2007) primarily include clinical factors (Giamouzis et al., 2011). Therefore, these models do not always reflect the complex relationship between physical, social, economic and psychological factors that impact on health outcomes (McDonagh et al., 2011; Schweitzer, Head, & Dwyer, 2007).

This paper seeks to summarise patient, provider and system factors predicting rehospitalisation in adults with HF. For the purposes of this paper, patient, provider and system will be defined as follows: *patient* relates to the multidimensional facets of individuals including physical, social, psychological, economic, cultural, and existential characteristics. *Providers* denote health professionals providing formal care giving; and *system* pertains to factors relating to the organisation, funding and policy milieu of health care system delivery. Furthermore, the terms acute and chronic have been used to label or categorise HF within some of the literature. However, there are discrepancies with their uses within the literature and by clinicians in clinical settings (Dickstein et al., 2008). Acute HF has been used to refer to new onset HF. However, it has also been used to describe an exacerbation in symptoms of HF, such as pulmonary oedema that results in rehospitalisation. The individual is then labelled by some clinicians as having an acute exacerbation of a chronic condition. Therefore, the literature used for this review, did not distinguish between risk predictors for acute or chronic HF. We endeavoured to identify risk predictors for rehospitalisation for individual's with HF.

METHODS

Research question

The research question for the review was: 'What are the patient, provider and system factors influencing rehospitalisation in adults with HF?'

Search strategy

The MeSH terms that were used for the literature search included: 'heart failure'; 'hospitalisation'; and 'heart failure congestive'. The databases, MEDLINE; Cumulative Index to Nursing and

Allied Health Literature (CINAHL); Embase and PsychInfo were searched for the period 1996–2008. Due to the advancement in therapies and the resulting alteration in the disease management of chronic HF (CHF), literature following the late 1990s was selected. Bibliographic details and abstracts of the papers identified through the search strategy were exported directly from the electronic databases into a bibliographic software package (Endnote XI). After duplicate items were removed, inclusion and exclusion criteria dictated which articles remained for the review. Three researchers independently completed the review by categorising the items into patient, provider and system factors.

Inclusion criteria

Types of studies

This review focussed on studies obtained from electronic databases; identifying factors that predict all cause or HF specific hospitalisation; and adults with HF.

Types of participants

The types of participants within the literature were adults (over the age of 18 years) with HF.

Exclusion criteria

The following were excluded: studies not written in the English language, reviews and papers published prior to the year of 1996 and paediatric studies (populations < 18 years).

Quality appraisal

The process of evaluating the quality of the papers was a three stage process. Firstly, the papers were rated by the primary author (Vasiliki Betihavas) and identified for inclusion or exclusion using the preset criteria. Manual searching of the literature occurred for the factors included in the final model. Secondly, 20% of the papers were reviewed by a second reviewer (Phillip J Newton) and verified to the accuracy of the analysis. Finally, a third reviewer (Patricia M Davidson) evaluated the overall scrutiny of the final factors that were identified. Discrepancies between any of the reviews were discussed and resolved between the three reviewers.

RESULTS

A total of 2355 articles were identified from the initial search. The majority of the studies identified from the review were conducted in North America. Follow up periods ranged from 21 days–5.5 years. Most of the studies included mortality, HF specific hospitalisation, or the combined endpoint of all cause hospitalisation and mortality as primary outcomes. Data were categorised as patient, provider or system factors. Following review and data extraction 229 factors were identified as predictors of rehospitalisation for adults with HF. Following consolidation of items, these were then collapsed into 62 categories. Item reduction was undertaken by combining items, such as the grouping of biochemical data. Risk factors for rehospitalisation are summarised in Table 1 and key points are summarised below as patient, provider and system factors. Further categorisation is made by identifying from the literature factors that increase or decrease the risk of rehospitalisation. These lists are not meant to be exhaustive but illustrative of factors contributing to increasing or decreasing the risk of rehospitalisation.

Patient factors

Factors that increase the risk of readmission

The majority of factors identified predicting the risk of rehospitalisation for individuals with HF were patient factors. The patient factors are further categorised into biological, psychological and social and these are listed below. Some factors such as race can be debated regarding whether they should be classified as biological or social. The categorisation is meant to aid with identifying the literature, rather than defining it.

Biological: Age, the risk of rehospitalisation increases with advancing age (Cowie et al., 2002; Kossovsky et al., 2000; Pocock et al., 2006). With the ageing of the baby boomer generation and the projected increase in individuals who will be diagnosed with HF, rehospitalisation for the elderly may further increase.

Anaemia (Anand et al., 2004; Felker et al., 2004; Komajda et al., 2006; Silverberg et al., 2002); low haemoglobin levels are indicative

of individuals at risk of rehospitalisation. This decrease in oxygen carrying capacity will further compromise the individual and may result in further deterioration in other areas. An example of this is, confusion secondary to hypoxia which may affect an individual's ability to titrate medications appropriately potentially increasing the risk of rehospitalisation.

Arrhythmia (Benza et al., 2004); dilation of the left ventricle and a reduced ejection fraction increase the likelihood of ventricular tachyarrhythmias, and death (Dickstein et al., 2008). However, recent implantable cardioverter-defibrillator (ICD) implantation has been used as a secondary measure to prevent or terminate tachyarrhythmias, without the need for rehospitalisation.

An increase in the number of co-morbidities (e.g., diabetes, chronic obstructive pulmonary disease, osteoarthritis; Doughty et al., 2002; van der Wel et al., 2007) an individual has, the greater their risk of rehospitalisation.

Fluid overload (Bart et al., 2005); increases in weight are predictors of rehospitalisation. Individuals have been shown to have an increase in weight several days prior to their rehospitalisation (Chaudhry, Wang, Concato, Gill, & Krumholz, 2007).

Worsening renal function (Hillege et al., 2006) elevated blood urea nitrogen (BUN) levels, elevated urea and creatinine and low glomerular filtration rate (GFR) are signs of worsening renal function and are associated with adverse events for individuals with HF. Factors contributing to worsening renal function have been identified as male sex, a history of hypertension, a high creatinine level on admission, elevated systolic blood pressure, presence of rales and a basilar pulse rate > 100 bpm (Krumholz et al., 2000).

Left ventricular function less than 45% is a risk factor for rehospitalisation (Smith, Masoudi, Vaccarino, Radford, & Krumholz, 2003; Sweitzer, Lopatin, Yancy, Mills, & Stevenson, 2008).

Disease progression New York Heart Association (NYHA) IV class (Glick, Michowitz, Keren, & George, 2006; McKee, Leslie, LeMaitre, Webb, & Denvir, 2003); the NYHA classifies HF according to functional ability; the classifications

TABLE 1: EXAMPLES OF PATIENT, PROVIDER AND SYSTEM FACTORS PREDICTIVE OF HOSPITAL READMISSION

Patient factors: Multidimensional facets of individuals- including physical, social, psychological, cultural, and existential characteristics N = 159 studies	Provider factors: Health professionals providing formal care giving N = 27 studies	System factors: Relating to the organization, funding and policy milieu of health care system delivery N = 25 studies
Individual factors	Multidisciplinary* teams (Stewart, Pearson, & Horowitz, 1998)	Social service and insurance (Philbin & DiSalvo, 1999)
Psychological: Depression (Jiang et al., 2001)	Heart failure expertise knowledge (Jong et al., 2003)	Performance indicators (Luthi, Burnand, McClellan, Pitts, & Flanders, 2004)
Cognitive impairment (Trojano et al., 2003)	Qualifications and credentialing (Reis et al., 1997)	Health service coordination (Cleland et al., 2003)
Social behavioural: Treatment adherence (Komajda et al., 2005)**		Setting and mode of care delivery (Riegel et al., 2002)
Level of education (Sui, Gheorghade, Zannad, Young, & Ahmed, 2008)		
Income (Philbin et al., 2001)		
Health literacy (Murray et al., 2009)		Rurality (Clark et al., 2007)
Living alone (Luttik, Jaarsma, Veeger, & van Veldhuisen, 2006)		
Race (Fang, Mensah, Croft, & Keenan, 2008)		
Biological: Co-morbidities (Braunstein et al., 2003)		
Low haemoglobin (Go et al., 2006), sodium (Gheorghade et al., 2007), albumin (Gerstein et al., 2001), renal dysfunction (Hillege et al., 2006)		
Ejection fraction (Yusuf et al., 2003)		
Sex (Adams et al., 1999)		

*Multidisciplinary teams are comprised of a diversity of health specialties that are engaged in the delivery of comprehensive care to meet the widespread needs of individuals (Mitchell, Tieman, & Shelby-James, 2008); **Adherence: The World Health organisation has defined adherence as '... the extent to which a persons' behaviour (taking medication, following diet, and/or executing lifestyle changes) coincides with agreed recommendations from a health care provider' (Sabate, 2003).

can be transient dependant on the individual's symptoms at time of assessment.

History of HF (Jarnert, Edner, & Persson, 2007) with prior hospitalisation; previous admissions to hospital further increase the probability of rehospitalisation. This may be due to the individual's progression in HF severity or adverse events that occur whilst hospitalised increasing the risk of rehospitalisation.

Elevated B-type natriuretic peptide (BNP); levels > 400 pg/ml and NT-pro BNP levels > 450 pg/ml (Newton, Betihavas, & Macdonald, 2009) on discharge have been shown to be predictive of an individual at risk of rehospitalisation

(Cournot, Leprince, Destrac, & Ferrieres, 2007; Logeart et al., 2004; Verdiani et al., 2005).

Hypertension (Filippatos et al., 2008; Levy, Larson, Vasan, Kannel, & Ho, 1996); a history of hypertension and unmanaged hypertension increase the likelihood of rehospitalisation.

Hyponatremia (Gheorghade et al., 2007) is a sign of disease progression and is associated with poorer outcomes.

Race (Afzal et al., 1999; Deswal, Petersen, Urbauer, Wright, & Beyth, 2006); African Americans have higher rates of HF diagnosis compared to Caucasians (Franciosa et al., 2002).

Psychological: Individuals who have depression and HF have an increased risk of being rehospitalised (Braunstein et al., 2003; Jiang et al., 2001; Rumsfeld et al., 2005). Individuals with high Beck Depression Inventory (BDI) scores (Sharp & Lipsky, 2002) have also been shown to have higher NYHA class (Ferketich, Ferguson, & Binkley, 2005). This may be due to inflammatory mediators that contribute to disease progression (Pasic, Levy, & Sullivan, 2003). Furthermore, Sherwood et al. (2007) identified those who live alone have an increase risk of hospitalisation (Harris, Aboueissa, & Hartley, 2008; Stewart et al., 2006). Having a partner may prevent an individual from further deterioration as early symptom recognition may occur and management strategies are implemented.

Education (Koelling, Johnson, Cody, & Aaronson, 2005; Krumholz et al., 2002) and literacy levels (Baker et al., 2002) have an impact on self-management by individuals with CHF. Non adherence with medication administration (Chin & Goldman, 1997b) and current smoking (Suskin, Sheth, Negassa, & Yusuf, 2001) are risk factors for rehospitalisation. Smoking cessation programmes incorporated into patient education sessions have been shown to decrease the risk of hospitalisation (Chouinard & Robichaud-Ekstrand, 2005). Furthermore, a multifaceted approach of affordable health care, particularly for pharmaceutical products, patient education and multidisciplinary care has the potential to increase adherence to medication regimes for the elderly with HF (van der Wal & Jaarsma, 2008).

Social: Socioeconomic status (Blustein, Hanson, & Shea, 1998; Philbin, Dec, Jenkins, & DiSalvo, 2001) and insurance status (Philbin & DiSalvo, 1999) is associated with an increased risk of rehospitalisation. Low health related quality of life can also influence rehospitalisation (Konstam et al., 1996). Culture and ethnicity may influence the individual's risk of rehospitalisation. African American individuals have a higher risk than Caucasians for being rehospitalised for HF (Deswal et al., 2006). Biological factors

as well as health disparities contribute to this increased risk. Language, health literacy levels, and understanding of HF disease management (DeWalt et al., 2006) affect how an individual manages themselves in conjunction with their health care provider.

Factors that decrease the risk of readmission

Biological: Few studies have identified a lower risk for women, although this is not consistent across studies (O'Meara et al., 2007).

Psychological: Major elements in preventing rehospitalisation within the psychological domain are social support from the community and patient education. Patient support regarding HF management pre discharge decreases the risk of rehospitalisation (Koelling et al., 2005). Furthermore, ongoing patient education in the community has been shown to decrease inappropriate resource utilisation (Heidenreich, Ruggiero, & Massie, 1999). However, due to multi co-morbidities and cognitive dysfunction of the elderly population with HF, education of individuals regarding HF disease management needs to be targetted to meet the needs of this population (Stromberg, 2005). The overall aim of education sessions should be to provide individuals with options regarding disease management so that they may make informed choices regarding their health and adhere to management strategies thus decreasing their risk of rehospitalisation.

Social/behavioural: Adhering to treatment is an important consideration in HF management. Medication adherence decreases the risk of rehospitalisation for individuals with HF. However, it has been identified that only 10% of individuals with HF adhere to their medication regimes (Leventhal, Riegel, Carlson, & De Geest, 2005).

Provider

Factors that increase the risk of readmission

The quality of care, measured by guideline adherence, provided by clinicians influences the

individual's risk of rehospitalisation (Keenan et al., 2008; Polanczyk, Newton, Dec, & Di Salvo, 2001). In addition, being managed by a carer provider who is not a HF specialist increases the likelihood of an individual being rehospitalised. The quality of inpatient care increases the risk of rehospitalisation (Keenan et al., 2008). Those individuals who do not receive evidence based recommendations for care (Komajda et al., 2005), are discharged prematurely, discharged without follow up care, and the failure to provide support services in the community increases the risk of rehospitalisation for those individuals.

Factors that decrease the risk of readmission

Multidisciplinary health care providers including registered nurses (de la Porte et al., 2007; Naylor et al., 2004; Sisk et al., 2006; Thompson, Roebuck, & Stewart, 2005) cardiologists (Ahmed et al., 2003; Philbin, Weil, Erb, & Jenkins, 1999) and pharmacists (Lopez Cabezas et al., 2006) providing collaborative input into care, can improve outcomes. Management of individuals with CHF by advanced practice clinicians and specialist providers (Blue et al., 2001; Fonarow et al., 1997; McDonald et al., 2001) have been shown to decrease the risk of being rehospitalised. HF management programs (HF-MP; Kimmelstiel et al., 2004; Piepoli et al., 2006) and multidisciplinary teams (Martineau, Frenette, Blais, & Sauve, 2004; O'Connell, Crawford, & Abrams, 2001) have been shown to decrease the risk of rehospitalisation. Managing individuals with chronic diseases holistically within a health care team has the potential to capture individuals who have social and psychological risk factors and not only biological risk factors.

System factors

Factors that increase the risk of readmission

The drivers for funding of health care services can alter not only the individual's risk of rehospitalisation but also the threshold of providers to recommend hospitalisation. The distance of residence of an individual from a hospital, impacts on rehospitalisation. Harris et al. (2008) identified that the closer an individual was to a hospital

the higher the probability of rehospitalisation. As such, distance from a hospital will dictate how often an individual seeks treatment (Clark et al., 2007). Furthermore, some individuals from rural areas are reluctant or unable to travel the distance required to access care. Individuals who wait until they have deteriorated before seeking treatment increase the risk of longer hospital stays, as they are admitted to high acuity areas due to the severity of their clinical condition.

Factors that decrease the risk of readmission

Discharge planning (Naylor et al., 2004) and quality of care by the provider particularly adherence with guideline recommendations (Fonarow et al., 2008) decreases the risk of rehospitalisation. Discharge planning that begins immediately upon the hospitalisation phase and continues with follow up care post hospitalisation has the potential to capture patients at risk of deterioration and intervene accordingly prior to deterioration (Capomolla et al., 2002). The use of evidence based guidelines to guide and manage individuals with HF whilst in hospital also increases the likelihood of appropriate management being implemented and preventing early rehospitalisation post discharge (Peterson et al., 2006). CHF-disease management programmes with follow up care in the community post discharge have also shown to decrease the risk of rehospitalisation (Stewart, Marley, & Horowitz, 1999).

DISCUSSION

This review has illustrated that despite the increased emphasis on provider and system factors impacting outcomes for HF, current risk prediction models do not address these factors and individual clinical studies contributing to these derivation models do not collect or report these data (Giamouzis et al., 2011). It is also highly likely that patients, providers, funding and regulatory bodies may have varying priorities and perceptions of risk and adverse outcomes which may influence the validity and utility of risk prediction models. As HF is increasingly recognised as a cardiogeriatric syndrome, provider and system factors will increase

in prominence not only in increasing the risk of hospitalisation but also influencing the clinician's threshold to admit an individual to hospital (McDonagh et al., 2011).

The heterogeneity of the HF syndrome influences the applicability of current risk reduction models (Giamouzis et al., 2011). In addition, treatment changes such as the introduction of implantable cardiac defibrillators can contribute to changing the illness trajectory for HF. What has emerged from this review and others (Giamouzis et al., 2011; Ross et al., 2008) is the need to increase the scope of current risk prediction models to address non-clinical factors. Deriving consensus from the perspective of patient, provider and systems issues may contribute to this increased understanding and the development and validation of risk prediction models that incorporate this broad perspective. As measures such as 30 days readmission increasingly become the metric of organisational performance, accurately measuring baseline risk and intervening with individuals at highest risk is an important focus for future health services research (Bisognano & Boutwell, 2009). Providing greater consideration to socioeconomic and cultural factors in appraising risk may assist in targeting those at highest risk. Ghali et al. (2003) have identified the importance of considering sex differences, culture and ethnicity in contributing to the burden of HF. Many of the non-clinical reasons associated with increased hospitalisation relate to poor adherence and failure to implement self-management programmes. The importance of considering self-care in management plans is increasingly underscored (Riegel et al., 2009). The reasons why individuals choose not to adhere to recommended guidelines for HF management are multi-factorial and often relate to patient, provider and system factors (Hauptman, 2008; McEntee et al., 2009). This complexity should not result in the failure to include these factors in empirically derived models that are tested in a range of contexts, both hospital and community. Further research should focus on identifying the relative and absolute predictive value of these factors.

Limitations

This review has several limitations. Firstly, a meta-analysis was not performed so it is not possible to discuss effect size of individual factors due to heterogeneity in study design, endpoints, interventions and methods of outcome assessment. Furthermore, participants within HF RCTs may not always be representative of real world populations. The use of RCTs could possibly have also inferred a bias as many registries may identify predictors of rehospitalisation in the usual care environment (Gluud, 2006). Potentially, registry data may shed light on factors such as insurance status and models of care delivery that may impact on clinical outcomes. Also, this literature review was conducted in 2008. As such, a limitation of this study is that no literature appears following 2008.

CONCLUSION

Heart failure is a complex and heterogeneous syndrome requiring comprehensive management to prevent hospitalisation. Based on this review and the increasing recognition of risk factors being important in identifying individuals at risk, there is a need for strategies to be implemented within the community to target individuals at risk. In spite of the increasing recognition of the social determinants of health and the acknowledgement that HF is a complex and commonly cardiogeriatric syndrome, limited data is available to describe the influences of these factors on health outcomes and should be considered in the development of future risk prediction models.

AUTHORS' CONTRIBUTIONS

Vasiliki Betihavas, Phillip J Newton, Steven A Frost, Peter S Macdonald and Patricia M Davidson all participated in the design of the study. Vasiliki Betihavas, Phillip J Newton and Patricia M Davidson conducted the literature search. Vasiliki Betihavas, Phillip J Newton and Patricia M Davidson made the initial analysis of the data and drafted the manuscript. All authors (Vasiliki Betihavas, Phillip J Newton, Steven A Frost, Peter S Macdonald and Patricia M Davidson) had discussions about the analysis and reporting as well as in finalising the manuscript. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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The chapter following this provides the actual journal published in Australian Critical Care by Elsevier. The publication explores existing risk prediction models and identifies risk factors that have been incorporated into those models.

Background

- Risk prediction models are used to identify at risk individuals[1].
- Risk prediction models or scores are classified as either absolute or relative[1].
- Current risk prediction models for rehospitalisation have been developed with North American cohorts[2].

What this publication adds

- This review identifies factors within current risk prediction models.
- This review discovered the discrepancy with risk factors incorporated into risk model design.
- This review pinpoints the limited amount of factors that are replicated in the risk models that were reviewed.
- Currently, there is no absolute risk score for rehospitalisation.

Where to from here?

- Studies in the exploration of risk factors need to expand the lens of focus to include provider and system factors.
- Administrative data sets and randomised control trials (RCTs) dominate as the sources for factors that are included in risk prediction models. Using innovative sources such as clinical expertise may expose risk factors for rehospitalisation that have yet to be identified from administrative data sets and RCTs.

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What are the factors in risk prediction models for rehospitalisation for adults with chronic heart failure?☆

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Summary

Background: Risk prediction models can assist in identifying individuals at risk of adverse events and also the judicious allocation of scarce resources. Our objective was to describe risk prediction models for the rehospitalisation of individuals with chronic heart failure (CHF) and identify the elements contributing to these models. **Methods:** The electronic data bases MEDLINE, PsychINFO, Ovid Evidence-Based Medicine Reviews and Scopus (1950–2010), were searched for studies that describe models to predict all-cause hospital readmission for individuals with CHF. Search terms included: patient readmission; risk; chronic heart failure, congestive heart failure and heart failure. We excluded non-English studies, pediatric studies, and publications without original data.

Results: Only 1 additional model was identified since the review undertaken by Ross and colleagues in 2008. All models were derived from data sets collected in the

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United States and patients were followed from 60 days to 18 months. The only common predictors of re-hospitalisation in the models identified by Ross and colleagues were a history of diabetes mellitus and a history of prior hospitalisation. The additional model extends its scope to include the non clinical factors of social instability and socioeconomic status as predictors of rehospitalisation.

Conclusions: In spite of the burden of hospitalisation in CHF, there are limited tools to assist clinicians in assessing risk. Developing risk prediction models, based on patient, provider and system characteristics may assist in identifying individuals in the community at greatest risk and in need of targeted interventions to improve outcomes.

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Introduction

Hospitalisation is common in individuals with chronic heart failure (CHF). In people over the age of 65 years CHF is the leading cause of admission to the hospital.^{1–3} In Europe, where the prevalence of CHF is estimated to be 15 million,⁴ hospitalised individuals with CHF accounts for 5% of hospital admissions and 2% of the total health care expenditure.⁴ Though the incidence of CHF in Australia is unknown, the prevalence is estimated to be 263 000 within a population of 21 million.⁵ Within the Australian population, 2.5% of Australians aged between 55 and 64 years have CHF, this figure rises to 8.2% for individuals over the age 75.⁵ Therefore, the prevalence of CHF increases with age as individuals are living longer with CHF. These factors impact the individual, health care and community sectors. The potential exists for an escalation in the number of individuals who will be at an increased risk of hospitalisation.

Many of these hospitalisations are rehospitalisations which are likely to be predictable and therefore possibly preventable. Chronic care management programs utilising multidisciplinary teams have demonstrated decreased rehospitalisation rates in individuals with CHF.⁶ Begg and colleagues⁷ identified that individuals with CHF who had never been hospitalised had a 25% lower case fatality than those who had a history of hospitalisation. Although all patients with a history of hospitalisation for CHF are at a high risk, there are some individuals with greater vulnerability and some of these factors are shown in [Table 1](#).

Risk prediction models

Risk prediction models use factors to calculate or predict an outcome. Alternate names for predictive models include: nomograms; clinical prediction

rules and prognostic models.⁸ These models are usually developed from large data sets using logistic regression modelling⁹ encompassing a combination of categorical and continuous variables.¹⁰ Unlike diagnostic models which are often cross-sectional in design and use patient factors to predict an underlying diagnosis,¹¹ predictive models incorporate the measurement of time, are generally longitudinal, and aim to determine the likelihood of the future event occurring within a given population. Risk can be assessed in either relative or absolute conditions. The term relative risk is synonymous with risk ratio, rate ratio or forces of morbidity. Relative risk is the risk of the endpoint, such as disease, death, readmission, among those exposed versus the risk of the endpoint among the unexposed.¹¹ Conversely absolute risk, is the probability of an event in a population under study, as contrasted with the relative risk.¹¹ As a result, these scores or values allow a prediction to be made to assist in clinical decision making.

Risk prediction models identify individuals and characteristics which are considered at greater risk. Currently, prediction models are used to pinpoint a given population's risk and direct initiatives to those individuals. The identification of at risk individuals, allows for the implementation of strategies to reduce the risk of the endpoint. The benefit of using risk prediction models is that interventions and treatment can be targeted to those at greater risk, resulting in greater efficiency in resource utilisation.¹² Absolute risk models incorporating variables including: organizational system; health care providers and patient factors may enhance the identification of at risk individuals and hence assist in implementing early interventions. The benefits of risk prediction models are: to identify individuals at varying levels of risk; inform individuals about their options for management and potential outcomes; and guide management and

Table 1 Factors influencing rehospitalisation in heart failure.

Decreases the risk of rehospitalisation	Increases the risk of rehospitalisation
Disease management delivery systems ^{28,29}	Poor adherence by cardiologists and primary care physicians ⁴⁰ with treatment recommendations ⁴¹
Appropriate use and adherence to evidence-based pharmacotherapy ^{30–33}	New onset anemia ⁴²
Beta-blocker use ³³	Persistent hyponatremia ⁴³
ACE inhibitor use ³⁴	Co morbidities ⁴⁴
Home follow up by a nurse practitioner ³⁵	Age ⁴⁵
Multidisciplinary teams involved in managed care ^{36,37}	Social and economic factors related to poverty influencing adherence to treatment ⁴⁶
Post discharge care ³⁸	The cost of pharmaceutical therapies ⁴⁷
Patient education ³⁹	A history of hospitalisation ²⁰

assessment. This article seeks to identify risk reduction models and identify common data elements.

Method

A systematic review was published by Ross and colleagues¹³ to identify risk prediction models and we replicated this method to search for risk prediction models with the assistance of a medical librarian. The electronic databases Medline, PubMed, Scopus, PsychINFO, and the Evidence-Based Medicine Reviews on Ovid were searched using MeSH terms patient readmission, risk and heart failure. We used the medical subject heading (MeSH) term patient readmission (exploded) and the key words readmi\$ and rehospi\$ (using '\$' for truncation). In every data base except for Medline * was used as a truncation instead of \$. Then linked the terms with 'or'. Secondly, we searched using the MeSH term risk (exploded) and the key words, model\$, predict\$, use\$, util\$, and risk\$. Following the second search we linked the terms with 'or'. Our third search included the MeSH term heart failure, congestive (exploded). The fourth search combined the term results from the patient readmission, risk and HF searches. Inclusion criteria for the search were: publications from 1950 to 2010, readmission among individual patients hospitalised for CHF as primary, secondary or composite outcome. We excluded: data without quantitative endpoints, publications without original data, abstracts, pediatric studies, non-English studies, and any experimental studies.

Results

Following removal of duplications, our search yielded 1002 results. Our search strategy identified

only 1 additional model¹⁴ since the review of Ross and colleagues.¹³ Table 2 summarizes these models and the derivation is discussed below.

Chin and Goldman¹⁵ developed an 11 point scoring system from 25 candidate variables in their risk score for death or all cause readmission to any hospital within 60 days. The variables were obtained prospectively between 1993 and 1994 from 257 patient medical records and questionnaires from patients who had an unplanned admission with CHF from a single hospital.

Philbin and DiSalvo¹⁶ developed a 15 point scoring system from 60 candidate variables (looking at patient characteristics, hospital features, process of care and clinical outcomes) in their risk score for CHF specific readmission within 1 year. The variables were obtained retrospectively from the Statewide Planning and Research Cooperative System (SPARCS) using administrative data on 42,731 patients with International Classification of Diseases 9-Clinical Modification Codes (ICD-9) collected in 1995 by the New York State Department of Health from 236 New York State hospitals.

Krumholz and colleagues¹⁷ developed a multivariate model with 32 variables that identified factors that would predict readmission within 6 months following hospital discharge. During the derivation phase of the study the variables were obtained from 9 acute care Connecticut hospitals from patients $n=1129$ with ICD-9-CM codes for heart failure. All patients were Medicare fee-for-service patients, in the year 1994. For the validation phase, 12 Connecticut hospitals $n=1047$ in the year 1995 were used. Endpoints were 6 month all-cause readmission, heart failure-related readmission, and readmission and death combined.

Felker and colleagues¹⁸ developed a statistical score from 41 candidate variables derived from 949 patients admission data from 78 centers within the United States who were participants in the

Table 2 Risk scores.

Source	Study type	Data source	Study location	No. of hospitals/no. of patients	Study outcome	Follow-up period
^a Chin and Goldman ¹⁵	Prospective cohort	Medical record review	Boston, U.S.A.	1/257	All-cause readmission or death	60 days
^a Philbin and DiSalvo ¹⁶	Retrospective cohort	SPARCS, from the New York State Department of health (1995)	New York State, U.S.A.	236/42713	HF-specific readmission	1 year
^a Krumholz et al. ¹⁷	Retrospective cohort	MEDPAR file from HCFA and medical record review	Connecticut, U.S.A.	18/1129 in derivation cohort and 1047 in validation cohort	All-cause readmission	6 months
^a Felker et al. ¹⁸	RCT cohort	Collected during RCT	U.S.A.	78/949	All-cause readmission or death	60 days
^a Yamokoski ¹⁹	RCT cohort	Collected during RCT	U.S.A. and Canada	26/373	All-cause readmission	6 months
Amarasingham et al. ¹⁴	Prospective cohort	Electronic medical record review	Texas, U.S.A.	1(136)/1372	All-cause readmission or death	18 months

Existing scores adapted from Ross and colleagues with permission¹³.

SPARCS – Statewide Planning and Research Cooperative System.

HF – heart failure.

MEDPAR – Medicare provider analysis and review.

HCFA – health care financing administration (now the Centers for Medicare and Medicaid services).

RCT – randomised controlled trial.

^a Table adapted with kind permission of the Journals of the American Medical Association from Archives of Internal Medicine.

Outcomes of a Prospective Trial of Intravenous Milrinone for Exacerbations of Chronic Heart Failure (OPTIME-CHF). This risk stratification aimed to predict 60 day mortality or the composite of death and rehospitalisation at 60 days.

Yamokoski and colleagues¹⁹ developed a statistical model from 18 candidate variables derived from 373 patients with class IV CHF enrolled in the Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE) trial that was conducted in 26 CHF and transplant centers in the United States and Canada. This sub-study compared the model against the nurses and physicians estimation of readmission using their own clinical judgment following review of patient case reports. The endpoints being predicted were all cause readmission at 6 months. Rehospitalisation was not predicted well by the model, nurses or physicians.

Amarasingham and colleagues¹⁴ developed and validated a model using non clinical and clinical data extracted from electronic medical records of 1372 index admissions in a major urban hospital during the period of January 2007–August 2008. A data linkage service enabled subjects readmitted to 1 of 136 hospitals within the study region to be identified and included in the analysis. The risk stratification model was designed to predict death or all-cause readmission within 30 days of discharge. In-hospital deaths were not included in the final model nor were subjects that died within 30 days of hospitalisation without readmission to hospital. The final model was developed using a conceptual framework based on experience and findings from a literature review. The model utilised clinical and non clinical variables and was validated against The Centre for Medicaid and Medicare Services model (CMS) and the Acute Decompensated Heart Failure Registry (ADHERE). Non clinical factors identified as predictors of rehospitalisation included increasing age, the number of home address changes, a history of depression or anxiety and cocaine use.

Final risk predictors were diverse within each model. Chin and Goldman¹⁵ listed the risk predictors as reasons for acute clinical deterioration prior to hospitalisation and only used data obtained from the index hospitalisation. No data was reviewed for patients who had subsequent admissions. Amarasingham and colleagues¹⁴ were the only other study to use index admission at a single hospital to recruit subjects. However, through data linkage software, they were able to use subsequent rehospitalisations of subjects at other facilities within the area. The use of successive rehospitalisations included in the model design is important as a history of

hospitalisation has been shown to be a predictor of rehospitalisation.²⁰ Felker and colleagues¹⁸ identified independent predictors for all cause readmission or death. However, unlike Krumholz and colleagues¹⁷ variables added that the researchers theorized would be associated with outcomes were age and ejection fraction (EF). Independent predictors of death or rehospitalisation at 60 days were prior congestive heart failure hospitalisations within 12 months $p=0.0002$, lower systolic BP $p=0.0001$, elevated blood urea nitrogen $p=0.0001$, lower hemoglobin $p=0.006$, and a history of percutaneous coronary intervention (PCI) $p=0.05$.¹⁸

Krumholz and colleagues¹⁷ was the only study that used a validation cohort following the finding of 4 factors in their derivation study that had strong bivariate association for increased risk for all cause rehospitalisations. Four of the 32 variables were found to be significant risk predictors of readmission 6 months after discharge. These were prior admission within 1 year $p=0.012$, history of diabetes mellitus (DM) $p=0.07$, prior heart failure $p=0.03$, and creatinine >2.5 mg/dL at discharge $p=0.0001$.¹⁷ Amarasingham and colleagues¹⁴ validated their model, however unlike Krumholz and colleagues who used an entirely different cohort for the validation phase, Amarasingham and colleagues¹⁴ used prior validated models, the CMS risk adjustment models and ADHERE mortality model to test the validity of their electronic readmissions model.

Yamokoski and colleagues¹⁹ stated blood urea and nitrogen (BUN) and high dose diuretics at discharge were independent predictors for rehospitalisations. Though these factors have been identified as predictors in previous studies^{21,22} they were not replicated in any other model within this review. Amarasingham and colleagues¹⁴ as well as Chin and Goldman¹⁵ identified that single status was a predictor of rehospitalisation. Furthermore, the category of race was identified by both Amarasingham and colleagues¹⁴ and Philbin and colleagues¹⁶ as a predictor of rehospitalisation. The mappings of predictors of readmission across the 6 published models are summarized in Table 3.

Discussion

It is important for clinicians to identify individuals at risk of readmission. Currently, there is no individual absolute risk prediction model for adults with CHF predicting hospital readmission.

The use of administrative data sets for model development have been used by Philbin and

Table 3 Factors within models that were predictive of rehospitalisation.

Risk prediction factors within models	Single marital status	Charlson comorbidity index score	Initial systolic BP \leq 100 mm hg	No ST-T wave changes on initial ECG	Black race	Hispanic race	Medicare insurance	Medicaid insurance	Commercial payment method	Self-pay	Home health care services after discharge	CHD					
Chin and Goldman ¹⁵ Philbin and DiSalvo ¹⁶ Krumholz and colleagues ¹⁷ Felker and colleagues ¹⁸ Yamokoski and colleagues ¹⁹ Amarasingham and colleagues ¹⁴	■	■	■	■	■		■	■			■	■					
Risk prediction factors within models	Valvular heart disease	Diabetes mellitus	Renal disease	Chronic lung disease	Idiopathic cardiomyopathy	Prior cardiac surgery	Use of telemetry during index hospitalization	Creatinine > 2.5 mg/dl at discharge	Prdr admission within 1 year	No. of prior inpatient admissions	No. of prior emergency room visits	No. of prior outpatient visits					
Chin and Goldman ¹⁵ Philbin and DiSalvo ¹⁶ Krumholz and colleagues ¹⁷ Felker and colleagues ¹⁸ Yamokoski and colleagues ¹⁹ Amarasingham and colleagues ¹⁴	■	■	■	■	■	■	■	■	■	■	■	■					
Risk prediction factors within models	Presented to emergency department 6 a.m.–6 p.m. for index admission	Low systolic BP	Prior HF	Elevated BUN	Low Hb	History of PCI	High dose diuretic at discharge	^a Tabak ⁴⁸ mortality score (per 10 point increase)	History of depression or anxiety	Male sex	Residence census tract in lowest socioeconomic quintile	History of cocaine use	No. of home address changes	History of leaving against medical advice	Used a health system pharmacy	Age (per 10 year)	History of missed clinic visit
Chin and Goldman ¹⁵ Philbin and DiSalvo ¹⁶ Krumholz and colleagues ¹⁷ Felker and colleagues ¹⁸ Yamokoski and colleagues ¹⁹ Amarasingham and colleagues ¹⁴	■		■	■	■	■	■		■	■	■	■	■	■	■	■	■

BP – blood pressure; ECG – electrocardiogram; CHD – coronary heart disease; HF – heart failure; BUN – blood urea nitrogen; Hb – haemoglobin; PCI – percutaneous coronary intervention.

^a Tabak Mortality Model⁴⁸ is specific to heart failure individuals and scores their severity of illness.

DiSalvo¹⁶ as well as Krumholz and colleagues.¹⁷ Using real world data such as administrative and registry data may assist in developing models that can assist in clinical decision making. Results or scores produced from these models would potentially not have been possible to replicate nor be as applicable to the wider community if the data had come from a cohort in a randomised control trial (RCT).²³ However, Philbin and DiSalvo¹⁶ observed CHF specific readmission as their endpoint whereas the remaining four studies did not. Length of follow up also varied between studies. The minimum duration for follow up was in the studies conducted by Chin and Goldman¹⁵ and Felker and colleagues¹⁸ with 60 days. This was followed by Yamokoski and colleagues¹⁹ and Krumholz and colleagues¹⁷ with 6 months. Philbin and DiSalvo¹⁶ had a follow up period of 1 year but this was retrospective in design. Amarasingham and colleagues¹⁴ study was conducted over an 18 month period. No model has extended beyond 18 months in follow up. A longer longitudinal study may identify the power of individual factors contributing to risk. At present, models are limited in their prediction, in that they provide scores or only identify factors that precede readmission. Three^{15–17} of the 6 existing scores or prediction factors were created prior to the beta-blocker era and may therefore be outdated requiring further replication in today's clinical setting to verify their accuracy. Furthermore, Yamokoski and colleagues¹⁹ whose study was conducted after the introduction of beta blockers for CHF acknowledged that "rehospitalisations was not predicted well by... the prognostic model" p. 11. As such, accuracy of the models prediction of rehospitalisation for adults with CHF was poor and unfortunately may be unsuitable to be used in contemporary clinical practice. Additionally, the data was derived from the Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE) trial (which was prematurely stopped in 2003) where the majority of participants were end stage CHF. Though Felker and colleagues¹⁸ developed a risk model for all cause readmission, they have not individualised the risk score. As such, the model is only stratifying risk predictions and may not be as accurate in observed individual outcomes. Their model was developed during a derivation study and therefore has not been tested to show that it is suitable for the purpose for which it was developed (all cause readmission).

A striking feature of this review, was the minimal agreement in the variables that were predictive

of readmission across the 6 models. Only a history of diabetes mellitus; an elevated BUN; and a history of prior admission to hospital within 1 year, single marital status and race were predictive in more than one model. However, the replication of risk predictors did not occur in more than 2 models for any given predictor. The reasons for this lack of consistency may include differences in the baseline population and data sources.

Though Krumholz and colleagues¹⁷ identified a history of prior hospital admission as a predictor, it was Felker and colleagues¹⁸ who identified a prior CHF specific admission as being significant. However, Krumholz and colleagues¹⁷ predictor of prior hospital admission was only identified within the derivation study. The finding was not replicated in the validation study. Felker and colleagues¹⁸ and Chin and Goldman's¹⁵ risk prediction models comprised two composite endpoints, death and rehospitalisation within 60 days. Amarasingham and colleagues¹⁴ electronic readmission model also estimated the composite endpoints of death or readmission, however, their model predicted the endpoints within 30 days of hospital discharge. Consequently, these models may have limited predictive variables for rehospitalisation alone. To date, none of these approaches are absolute risk scores or absolute risk models.

The lack of individual absolute risk prediction models for readmission is problematic. If predictors or absolute risk of hospital readmission for individuals with CHF was identified and made known to clinicians and patients, then tailoring care according to risk may occur. At present, risk models or scores to predict risk of readmission are limited in the range of factors incorporated in model development. Factors are predominantly focused on patient characteristics and predominantly biomedical. Psychosocial factors including a history of depression²⁴ or marital status,²⁵ which have been shown to influence health status and therefore hospitalisation, were only included in 1 of the final models. Although care settings were identified in the method of each research paper, no model incorporated this factor into model design. Study location is relevant as the clinical area²⁶ will influence what resources are available including health care personnel, diagnostic tools and access to diagnostic and management strategies. Study location will also influence length of hospital stay and hospital readmission.²⁷ In Australia, hospitals use the 30 day readmission rate as a quality indicator of hospital performance. Hospitals that prematurely discharge individuals as a consequence of inadequate resources with limited community discharge

follow-up may result in rehospitalisation of individuals. As a result, availability of resources influences assessment and management of individuals within each facility and hence outcomes. Therefore, a model or score that integrates characteristics of patient factors, services, including the organization and health care system(s) as well as providers of health care to determine absolute risk for individuals readmitted to hospital, has the potential of accurately identifying individuals at high risk.

Through incorporating an absolute risk predictive model in the delivery of care, individuals as well as health care providers and policy makers can revise their approaches to health care and detect patients at risk of deterioration or rehospitalisation and implement interventions accordingly. To date, there is no validated model to predicting the absolute risk of rehospitalisation in CHF and this is an important area for future investigation to improve health outcomes, particularly within the context of the Australian health care system.

Limitations

The limitations of this literature review are, that though this is not a systematic review, and as such, may not explore the literature with as much rigor, this literature review was undertaken using search terms from a previous systematic review exploring risk prediction models. Since the publication of that systematic review by Ross and colleagues,¹³ only 1 additional paper was identified that discussed the development and validation of a new model that aimed to predict the risk of rehospitalisation. All studies that were identified in this literature review are North American in focus. Replicating risk predictions using these current risk models in populations outside of North America may not result in similar outcomes. All the studies had short follow up periods. No study went further than 18 months. Longer longitudinal studies may uncover risk factors that are relevant to patient, provider and system elements. No risk factors were replicated in more than 2 models. As such, the varied number of risk factors made comparison of individual risk factors difficult. Therefore, further study is required examining larger cohorts within longitudinal studies that are not predominated by North American populations with longer follow up periods. Widening the extent of factors being integrated into risk model design to include patient and also provider and system elements has the potential to identify and accurately predict individuals with CHF at risk of rehospitalisation.

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Background

- CHF is characterised by high symptom burden that often leads to hospitalisation[1].
- Nurse-led interventions have been effective in decreasing adverse events[2].

What this publication adds

- The application of valid and reliable CHF risk prediction models to be used by nurses within health care settings to target at risk individuals for rehospitalisation is required.
- This review argues for the integration of patient, provider and system factors into risk model design which will potentially increase the accuracy of targeting at risk individuals.

Where to from here?

- The development of an absolute risk model that targets individuals at risk of rehospitalisation.
- Undertaking an original route to CHF risk model development by identifying the opinion of experts as to the risk factors for rehospitalisation for individuals with CHF.

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An overview of risk prediction models and the implications for nursing practice

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Chronic heart failure (CHF) is a costly (Stewart et al, 2002), debilitating and deadly (Stewart et al, 2001) clinical syndrome and is a major public health issue. The syndrome of CHF is characterised by a high symptom burden, such as breathlessness and fatigue and functional impairment (Dickstein et al, 2008). Of particular relevance to nursing, CHF is the leading cause of hospitalisation for individuals over the age of 65 years within the developed world (Rodriguez-Artalejo et al, 1997; Adams et al, 2005). Due to an ageing population, the number of adults that will be affected by CHF is projected to rise. This entails that emergency department presentations for individuals with shortness of breath, weakness or confusion will increase. This projected rise in hospitalisation rates of adults with CHF will have an impact on nursing practice.

Hospitalisation is not only a marker of adverse outcome but of importance to health-care planning and it has been shown that many of these admissions are preventable (Braunstein et al, 2003). In addition to costs and pressures on scarce resources, hospitalisation can have poor outcomes, particularly in the elderly because of the high risk of adverse events, such as falls (Vincent et al, 2001; Brennan et al, 2004). Increasingly there is a focus on rates of hospitalisation and lengths of stay as markers of organisational performance. In spite of fiscal considerations and demands for efficiencies, targeting and monitoring at-risk patients through early interventions with the aim of decreasing hospital admissions and emergency room presentations will lessen the financial and social burden on the individual and the community (McMurray and Stewart, 2002). Therefore, developing valid and reliable risk models is of importance to allow identification of individuals at highest risk and assist in developing and implementing appropriate models of care.

Appropriate models of care should consider not only clinical characteristics but also available resources. The overall aim of risk models should be to target those at risk and by doing so, reduce adverse events that include rehospitalisation or emergency department presentation(s).

There are limited empirical means to allow clinicians to identify those with heart failure at highest risk of rehospitalisation. Furthermore, no current risk model provides an individual with an absolute risk score for rehospitalisation. This limits the application of current models to individuals to assess their risk for rehospitalisation. The following is a description of risk models and the implications for nursing.

Current risk prediction models for chronic heart failure

Currently, methods are not widely available in clinical practice to discriminate between levels of risk in many conditions, but particularly CHF. Absolute risk is the calculation of an individual's risk of the event occurring over a given time (Sedgwick, 2001), whereas relative risk, also referred to as the risk ratio, is the comparison between two groups, one with the risk factor, and one without, in estimating the risk of the event occurring (Sedgwick, 2001). While relative risk models provide a method of comparison,

ABSTRACT

Chronic heart failure is a common and costly condition and is one of the most common causes of hospitalisation and emergency department presentations in the elderly. This paper discusses risk prediction models in chronic heart failure, their utility in clinical practice and describes the implications for nursing practice. Based on a review of the literature, a description is presented of current risk models for chronic heart failure; the use of risk models in other conditions and the benefits of applying valid and reliable measurement tools in clinical practice. Consideration is given for clinical as well as non-clinical factors being incorporated into risk prediction models.

KEY WORDS

- ◆ Clinical practice
- ◆ Heart failure
- ◆ Risk assessment
- ◆ Screening tools
- ◆ Hospital readmission

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absolute risk models provide an individual risk score of the end outcome (Gail and Pfeiffer, 2005).

A risk prediction model is a tool that describes the association between factors, to calculate the probability of an outcome or event (Steyerberg, 2009). Predictive models also include a temporal element and aim to predict future risk in a given population. Identifying the level of risk would allow for the implementation of interventions to reduce adverse outcomes. An emerging literature suggests that patient (Keenan et al, 2008), provider (Jaarsma, 2005) and system (Adams et al, 2005) factors influence the risk

of hospitalisation. Although risk prediction models have been developed, there has been minimal consideration of the political, financial and social determinants in ascertaining risk.

Current models that classify the risk of hospitalisation have been derived from either randomised controlled trials (RCTs) or administrative data sets (Table 1). Predictors identified in these models are primarily biomedical, clinical factors such as age and a history of diabetes. Furthermore, the predictors incorporated into each of the models are diverse on comparison. The accuracy of a

Table 1.
Current risk models in chronic heart failure

Study authors	Study type	Study region	Study independent predictors
Amarasingham et al, 2010	Prospective	USA	Age (per 10 years) History of cocaine use History of depression History of leaving against medical advice History of missed clinic visit Male sex Number of home address changes Presented to emergency department 6 am–6 pm for index admission Residence census tract in lowest socioeconomic quintile Tabak* mortality score (per 10-point increase) Used a health system pharmacy
Chin and Goldman, 1997	Prospective	USA	Charlson** comorbidity index score Initial SBP <100 mmHg No ST-T wave ECG changes Single marital status
Felker et al, 2004	RCT	USA	BUN (per 5 mg/dl) Heart failure hospitalisation <1 year SBP (per 10 mmHg)
Keenan et al, 2008	Retrospective	USA	Acute coronary syndrome Arrhythmias Asthma Atherosclerosis Cardiorespiratory failure Chronic obstructive pulmonary disease Diabetes Electrolyte/fluid/acid–base disorders History of CABGs Hemi/paraplegia/paralysis/functional disability Other/unspecified heart disease Renal failure Stroke Urinary tract disorders Vascular disease Valvular and rheumatic disease

model to predict is measured by the area under the curve (AUC) also referred to as the c-index. The c-index ranges from 0.5 which shows no predictive ability of the model to 1, which shows perfect discrimination (Cook, 2008). The highest c-index in these risk models (Pocock et al, 2006). This implies that there are possibly risk prediction factors that may yet be undiscovered, or currently not included in existing risk models. Therefore, undertaking further research to identify and incorporate predictors that extend to providers and systems may further accurately predict the risk of hospitalisation and mortality for individuals with CHF, particularly in community settings (Giamouzis et al, 2011). Identifying individuals in the community at risk of hospitalisation and then implementing strategies through multidisciplinary interventions has the potential to prevent adverse events that include readmission to hospital or presentation to the emergency department.

To date, risk prediction models for CHF have limited uptake. This may be explained by the heterogeneity in data

elements across studies (Ross et al, 2008) and failure to see the relevance and applicability of items to specific care contexts (Ghali et al, 2010). Furthermore, the generalisability of study cohorts may not be replicable in clinical settings. All the CHF risk prediction models were derived from studies conducted within the USA. Unlike Australia, New Zealand, the UK and many European countries, the USA does not offer universal health coverage. As a result, risk models created from cohorts within the USA may not be applicable within the clinical areas of these countries as the systems of health-care delivery differ.

Therefore in order to meet the needs of an ageing population with increasing chronic conditions, prediction models considering the perspective of patient, provider and system factors are likely justified. For the purposes of this paper, patient factors relate to the multidimensional facets of individuals including physical, social, psychological, cultural, and existential characteristics; provider factors include those relating to health professionals pro-

Table 1 continued.
Current risk models in chronic heart failure

Study authors	Study type	Study region	Study independent predictors
Krumholz et al, 2000	Retrospective	USA	Prior admission within 1 year Prior heart failure
O'Connor et al, 2005	RCT/registry	USA	Age (per 10 years) Heart failure hospitalisation <1 year Nitrates
Philbin and DiSalvo, 1999	Retrospective	USA	Black race Diabetes mellitus Ischemic heart disease Medicaid insurance Medicare insurance Renal disease Requiring home health services Valvular disease
Pocock et al, 2006	RCT	USA	Bundle branch block Cardiomegaly Diabetes Oedema Ejection fraction Heart failure hospitalisation HF diagnosis > 2 years NYHA class III NYHA class IV DBP (per 10 mmHg)

* Tabak et al, 2007

** Charlson et al, 1987

RCT = randomised controlled trial; BUN = blood urea nitrogen; SBP = systolic blood pressure; CABGs = coronary artery bypass graft surgeries; NYHA class = New York Heart Association functional classification of heart failure; DBP = diastolic blood pressure

viding formal care-giving for example skill mix, professional groups such as nurses or doctors, and system factors will pertain to factors relating to the organization, funding and policy milieu of the health-care system delivery (Betihavas et al, 2011). Risk models considering patient, provider and system issues have the potential to improve outcomes at all levels; at the micro (hospitalisation increases the risk of mortality and adverse outcomes for patients (Brennan et al, 2004)), the meso (CHF is the leading cause of hospitalisation in those over the age of 65 years (Adams et al, 2005)), and the macro (where the hospitalisation is the biggest cost for society (Bundkirchen and Schwinger, 2004)).

Phases in risk model development

In the context of developing risk prediction models it is important to consider the strengths and weaknesses of various approaches. There is generally two phases when designing a risk model: the derivation and the validation phase. The development or derivation phase involves a cohort of individuals to generate items, whereas the validation phase is the process of assessing that the developed model tests what it is intended to test or predict. However, there can be problems when comparisons are made between development and validation cohorts. Of interest is the difference in heterogeneity between development and validation cohorts, which may account for the poor generalisability, over-fitting or over-optimism in prediction model development (Moons et al, 2004).

Limitations with current risk models in chronic heart failure

There exists a gap in the literature between risk predictive models in hospitalisation for patients with CHF. Presently, there is no model that incorporates the diverse perspective of patient, provider and system factors to predict an individual with CHF at risk of hospitalisation. Existing predictive models do not include political, financial and social determinants in conjunction when ascertaining risk. A report from the World Health Organization Commission on Social Determinants of Health (CSDH) identified 12 social factors that impact on individuals and communities and contribute to wellbeing in determining health outcomes (CSDH, 2008). These social determinants of health do have a bearing on individuals with CHF and may be used to identify the risk of hospitalisation.

Furthermore, the recognition of the need for health care reform has led to the uptake of the Chronic Care Model (Bodenheimer et al, 2002; Coleman et al, 2009). Aims of the Chronic Care Model are maintaining health and quality of life for individuals with chronic conditions. This approach is a proactive multidimensional approach with input at a community, organisational, clinical and patient level. A review by Tsai et al (2005) reported on 112 studies, (21 of which focused on CHF) that incorporated at least one element of the Chronic Care Model in practice. The incorporation of at least one element led to better outcomes for patients within the 21 CHF studies that were

reviewed. Therefore, incorporating elements of the Chronic Care Model in a risk prediction model may be efficacious.

Favoured models predominantly classify risk of hospitalisation as determined by patient factors that include clinical variables (Philbin and DiSalvo, 1999; Krumholz et al, 2000). These predictors are primarily patient factors. The reasons for this are the reliance on RCTs for derivation cohorts. Incorporating predictors that extend to providers and services may further accurately predict the risk of hospitalisation for individuals with CHF (Ross et al, 2008; Giamouzis et al, 2011). As such, there are discrepancies in current estimates of risk prediction for hospitalisation, possibly due to the limited determinant factors researchers have at present integrated in their predictive models.

Risk prediction models for other conditions

Often it is useful to look to other clinical areas that have used similar conceptual approaches. In the intensive care unit (ICU) predictors for readmission occur predominantly with patients who already have an increase in the severity of their illness and have responded poorly to treatment. In the study by Cooper et al (1999) CHF was the most common reason for non-surgical patients being readmitted to the ICU. Furthermore, a systematic review by Rosenberg et al (2001) identified patients readmitted to ICUs to be associated with increased mortality rates, longer length of hospital stay and a poorer quality of life following their discharge. In a prospective UK study (Harrison et al, 2007) a prediction model, the Intensive Care National Audit & Research Centre (ICNARC) model that would predict admission to the ICU was developed from pre existing risk models. These models include the Acute Physiology and Chronic Health Evaluation 11 (APACHE 11), APACHE 111, Simplified Acute Physiology Score 11 (SAPS 11) and the Mortality Probability Model 11 (MPM 11). Combining patient factors from the existing models, the ICNARC prediction model was found to perform better in prediction and had a lower c index (0.003) when compared to the models from which it was developed.

In a retrospective Australian study (Ho et al, 2008) a nomogram was formed from pre-selected predictors that enabled the estimation of median survival time for patients with acute illnesses and long-term survival probabilities. The Predicted Risk, Existing Diseases, and Intensive Care Therapy (PREDICT) model was developed from APACHE 11 scores and patient factors. The cohort was derived from patients within an ICU setting where patients with CHF accounted for 7.4% ($n=11\ 930$) of the sample size. Within this study, age and comorbidities were found to be the two variables that determined long-term prognosis.

At present, models that predict patient's risk of readmission to the ICU have been developed from prior models with additional patient variables added and then tested within the clinical area of ICU. With the advancement in technology and knowledge gained from research, which

has then been implemented into health care, these current models have been upgraded from existing models to ensure their predictability in today's clinical area of ICU. (No current heart failure risk prediction model has been updated or modified from previous heart failure risk models.) As such, the benefit associated with the improvement in risk predictive models is the awareness of factors that contribute to patient deterioration and endeavours made to prevent this breakdown in health status.

Problems have also arisen when attempts have been made to generalise a risk score. One such example has been the adaptation of the Framingham risk score. The Framingham risk score aims to estimate the 10-year risk of developing cardiovascular disease (Wilson et al, 1998). However, limitations of the Framingham model include the cohort from which the model was developed as the majority of study participants are predominantly white middle-class Anglo-Saxons. The Framingham score also fails to identify any biomarkers that acknowledge genetic predisposition to cardiovascular disease. Furthermore, the Framingham risk score was identified as having overestimated the mortality risk of men when comparisons were made during the National Health and Nutrition Examination Survey (Liao et al, 1999). Another model predicting cardiovascular risk is the Reynolds risk score model (Ridker et al, 2007). Yet, a limitation of the Reynolds model is its derivation from a cohort of only women with a history of diabetes (Ridker et al, 2007). These examples underscore the importance of deriving data from valid, contemporaneous and appropriate derivation cohorts.

Summary of what makes a good risk prediction model

Risk models should aim to target at risk individuals and provide justification for management and treatment. However, in clinical practice, risk models that were created from RCTs may not be replicable or as accurate outside of RCT cohorts. One such example is found within the area of breast cancer. There currently exist two streams to assist clinicians when risk-assessing women for breast cancer. The first is the risk prediction model known as the Gail and Claus model (Gail et al, 1989), which aims to predict a woman's risk of developing breast cancer. The second are four risk models (Couch et al, 1997; Shattuck-Eidens et al, 1997; Frank et al, 1998; Parmigiani et al, 1998) that estimate the probability of a woman carrying the BRCA1 or BRCA2 gene. However, when all four models were applied to risk-predict one family, incongruent results occurred (Domchek et al, 2003). Disparate results have occurred in other areas of nursing when numerous clinical models have been used to predict adverse outcomes.

Myers and Nikoletti (2003) tested the reliability and validity of two falls risk models. The models were inaccurate in their predictions within the clinical area and were not able to predict the individuals at risk of falling and those who were not. Clark et al (2009) argued (in relation to CHF-MP) that types of programmes, populations and

care settings were not incorporated into analyses. To successfully predict risk, particularly in community-based settings, models should integrate patient, provider and system factors. This amalgamation of patient, provider and system factors into risk models has the potential to target at-risk individuals more accurately and enable nurses to streamline disease management of individuals.

Suggestions for how a risk prediction model for CHF may be developed

Nurses are increasingly compelled to identify individuals at risk and implement appropriate strategies. Currently, methods are ad hoc and variable and lack sensitivity. This is reflected in the high burden of hospitalisation for CHF. At present, risk models for individuals with CHF at risk of hospitalisation are based on RCTs and administrative data sets and include predominately clinical factors, (Chin and Goldman, 1997; Philbin and DiSalvo, 1999; Krumholz et al, 2000; Felker et al, 2004; Yamokoski et al, 2007; Amarasingham et al, 2010) one such clinical factor being age. A comprehensive nursing assessment takes into consideration both clinical and non-clinical factors and particularly in the elderly social situations and caregiver access (Naylor et al, 2004). In addition to assessing these factors, it is also important to assess an individual's level of need (Davidson et al, 2004). For example, an individual may have a high symptom burden and experience frailty but have a low level of need of accessibility and availability of clinical services. Further, the absence of a designated general practitioner is a major barrier to effective community-based care and is an important consideration. Therefore, these factors need to be considered in health-care planning at the micro, meso and macro levels.

The challenge remains to develop reliable and valid assessment tools with clinical utility and predictive validity. As the burden of chronic and complex conditions continue to increase, the metric of assessment of risk and models of assessing and managing risk need to be refined. Nurses play a critical role in planning and coordinating care and are cognisant of the need to address both clinical and non-clinical factors. Currently, multiple risk assess-

KEY POINTS

- ◆ The incidence of chronic heart failure (CHF) is likely to rise due to an ageing population
- ◆ CHF is the leading cause of hospitalisation for the elderly
- ◆ Current risk models for hospitalisation are predominantly biomedical in focus
- ◆ In other areas of health care, risk models have been updated from existing risk prediction models
- ◆ Incorporating patient, provider and system factors into risk model design may identify individuals at risk for rehospitalisation

ment tools exist for a plethora of reasons, such as falls and delirium (Oliver et al, 2006) and these are focused on events in the acute care setting. Broadening the focus of this assessment is important in empirically managing patients at risk.

Nurse-led interventions have shown to be beneficial in improving health outcomes in CHF (Stromberg et al, 2003) but there are challenges in treatment allocation (Lim et al, 2005) and variability in implementation has been recognised (Dietz, 2004). Assessing the risk of individuals may assist in the allocation of sparse specialist resources. The use of risk prediction models in clinical practice is to aid in clinical decision making; targeting of at-risk populations and streamlining and rationalising management of at-risk individuals. Accurate risk prediction models that enable accurate prediction need to reflect real-life populations. At present, risk prediction models are limited in their prediction of those at risk of rehospitalisation. This limitation has implications for clinicians making decisions that have consequences for at risk individuals. This review has identified the need to further refine and develop models for risk assessment that are reliable, valid and demonstrate utility for clinicians.

Conclusions

As the burden of heart failure considers being a major concern globally, developing methods to tailor and target interventions are crucial. A risk prediction model integrating patient, provider and system factors into model design has the potential to accurately target individuals at risk. Current risk reduction models have demonstrated limited utility as they focus on predominately clinical factors. Developing an absolute risk reduction model has the potential to improve health outcomes by identifying individuals at the highest risk of adverse outcomes such as hospitalisation.

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Publication 5 Title: “Importance of predictors of rehospitalisation in heart failure: a survey of heart failure experts.”

Reference

BETIHAVAS, V., NEWTON, P. J., FROST, S. A., ALEXANDROU, E., MACDONALD, P. S. & DAVIDSON, P. M. 2012. Importance of Predictors of Rehospitalisation in Heart Failure: A Survey of Heart Failure Experts. *Heart, Lung and Circulation*, 2013. 22: 179 – 187.

The chapter following this provides the actual journal published in Heart, Lung and Circulation by Elsevier. The publication identifies risk factors for rehospitalisation for adults with chronic heart failure (CHF) as perceived by heart failure experts.

Background

- The development of a questionnaire requires the generation of items relevant to the question[1].
- Current CHF risk models for rehospitalisation are developed primarily from administrative data sets and RCTs[2].
- The high rate of rehospitalisation of individuals with CHF is not being addressed by current risk models[3].

What this publication adds

- This study confirmed that no further risk factors were identified from experts in CHF research/management.
- This is the first study to utilise expert opinion to rank patient, provider and system risk factors for rehospitalisation in adults with CHF.
- Experts ranked poor adherence to medications as a high risk predictor for rehospitalisation.
- Experts ranked having private health insurance as a low risk predictor for rehospitalisation.

Where to from here?

- Integrating the findings from the Predictors of Readmission in Heart Failure Survey, the literature review and factors identified from current models, a risk model for the prediction of rehospitalisation for adults with CHF will be developed using the W.H.I.C.H cohort.

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Importance of Predictors of Rehospitalisation in Heart Failure: A Survey of Heart Failure Experts

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Aims: We investigated the opinion of clinical experts and researchers involved in chronic heart failure disease management regarding the ranking of patient, provider and system factors that predict the risk of rehospitalisation.

Methods: Item generation for the online survey was informed by a literature review and current risk prediction models. Consultation with experts was undertaken via a secure online survey platform. Invitations to participate in the 10 question online survey were sent through Listserves of professional nursing and medical associations within Australia and New Zealand.

Results: Data were collected in August 2011. A total of 119 respondents completed the survey. Respondents ranged from researchers, registered nurses, cardiologists and allied health personnel. A mean importance score was used to rank risk factors for rehospitalisation. Risk factors that scored high for predicting the risk for rehospitalisation included poor adherence to medications (9.04) and prior hospitalisation for heart failure (8.33). Having private health insurance (4.8) and being female (4.9) scored lower in influencing rehospitalisation for adults with heart failure.

Conclusions: No new risk factors were identified from the experts in predicting the risk of rehospitalisation. The survey results will contribute to the development of a nomogram to convey prognostic information related to adults with heart failure that will guide clinicians in management decisions.

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Keywords. Expert opinion; Heart failure; Hospital readmission; Risk factor

Introduction

Chronic heart failure (CHF) is a complex syndrome that predominantly affects the elderly [1]. Advances in treatments, particularly the use of beta-blockers [2,3] and angiotensin converting enzyme (ACE) inhibitors [4] mean that individuals are surviving longer. The burden of hospitalisation for CHF increases with age and is responsible for a significant burden on both individuals and society [5,6]. As a consequence, targeting those at the greatest risk of adverse events and rehospitalisation is important. A range of patient, provider and system factors contribute to this risk [7]. To date, existing risk prediction models predominantly have focussed on patient factors [8] including:

previous co-morbidities [9], previous hospitalisations [10] and age [11]. A risk prediction model for rehospitalisation incorporating patient, provider and system factors has the potential to target individuals at the highest risk. In addition to describing factors in existing risk prediction models, it is also important to consider the views of individuals involved in the care of individuals with CHF. We therefore sought expert consultation as it is important to acknowledge expertise as a strength when determining factors for rehospitalisation of individuals with CHF.

The aim of our study was to examine the opinion of experts in the care, management and/or research of individuals with CHF. We sought consultation to validate risk factors from the perspective of patient, provider and system that predicted the risk of rehospitalisation of individuals with CHF.

Ethics Approval

Ethics approval for the CHF-Risk study was granted from a university ethics committee. Participants were emailed a

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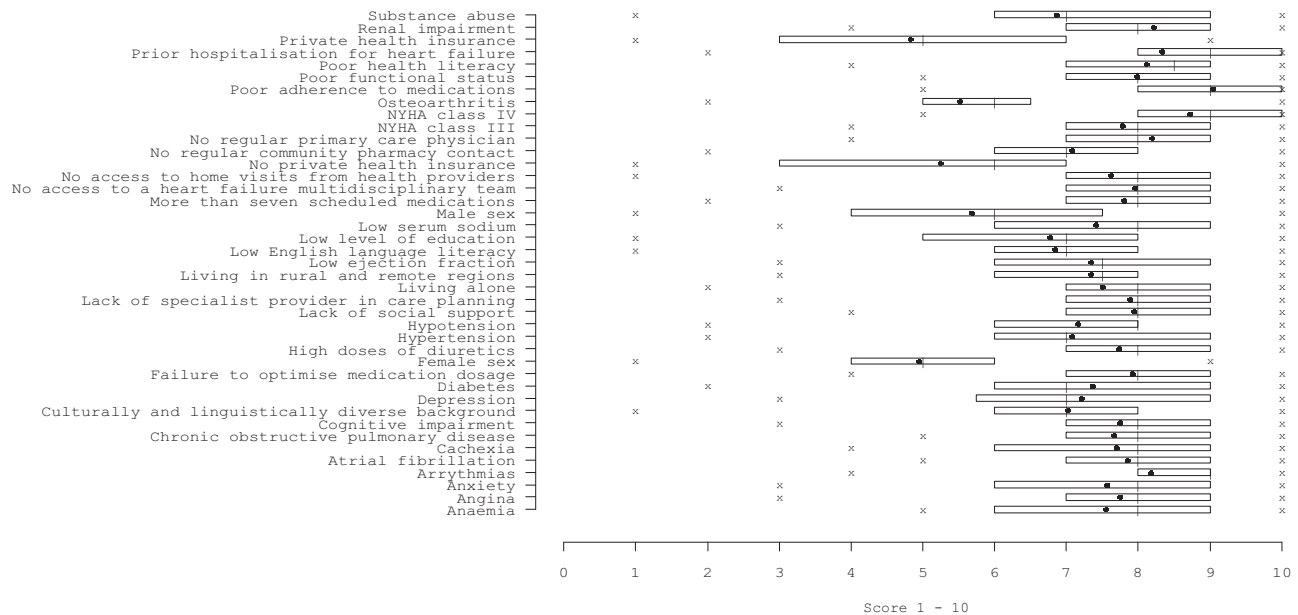


Figure 1. Box plots of score of importance given to predictors of rehospitalisation in heart failure. Boxes represent distance between 25th and 75th percentile, with median “|”. Solid points are mean and lowest and highest values given by “x”.

cover letter explaining the purpose of the survey. Consent was implied by the participants who chose to undertake the survey. This study conformed to the guidelines as set out by the National Health and Medical Research Council of Australia [12].

Methods

Sample

Consultation with experts in heart failure was undertaken via a secure online survey platform. Experts in heart failure were professionals with extensive skills and knowledge developed through practice and/or research over time. The sampling frame of participants was sought through Listserves of the National Heart Foundation (of Australia) (NHF), The Australasian Cardiovascular Nurses College (ACNC) and the Cardiac Society of Australia and New Zealand (CSANZ). The total number of potential participants emailed could not be confirmed. However, a total of 131 participants attempted the survey with 119 having completed the survey. The respondents varied from researchers, registered nurses, cardiologists and allied health personnel who disclosed within the questionnaire that they were involved in either research or disease management of individuals with heart failure (Fig. 1).

Design

The survey was derived from risk factors identified from a literature review (currently under review), and risk factors from existing prediction models [9–11,13–18]. Questions related to the demographics of the responders was also featured in the survey. The aim of this was to verify the clinical and/or research expertise of the responders in relation to heart failure disease management.

Item Generation

Item generation was a two-step process. The first step of the *Predictors of Readmission in Heart Failure Survey* included the literature review (currently under review) and the identification of risk factors from current risk prediction models [19].

The second step required items to be categorised into themes and then reduced to single items or questions. This was done to create a manageable survey without removing imperative domains or themes. Item generation within the survey was created by the researchers (VB, PJN, and PMD). The items were specific to risk classification and risk predictors. The final items were relevant to assist in the identification of patient, provider and system factors for the risk of rehospitalisation in adults with chronic heart failure.

Piloting and Validation by An Expert Panel

Experts have previously been used to validate instrument development [20,21]. The piloting and testing of the survey was conducted with the assistance of clinically current clinicians and researchers who were actively involved in CHF disease management. The use of current experts was sought with the aim of creating a relevant survey that would accurately identify risk factors for rehospitalisation. Study conceptualisation and content measurement was addressed by informing the panel of the focus of the instrument and the intended use of the survey and by whom. Piloting of the survey was conducted to increase the likelihood of appropriate items being placed in the survey, identify errors and to increase the likelihood of accurate risk factors for rehospitalisation being identified when the survey was released to a larger panel.

Table 1. Responders to the Predictors in Heart Failure Survey.

Responders	N
Registered Nurses	49
Doctors	8
Allied Health Personnel	34
Researchers	28

The final survey consisted of 10 questions administered online. Responses were either ordinal or used Likert scales. The questions related to: commenting on the high risk classification developed by the NHF and CSANZ; the presence of a heart failure service program; postcode of employment; identification of occupation; years engaged in CHF care; time allocated to the care of individuals with CHF; setting of employment; and the strength of factors predicting the risk of rehospitalisation. Using a secure password protected online platform, Survey Monkey®, participants were emailed the link to the survey. Participation was voluntary and the surveys were anonymous. Three email reminders were sent following the initial email.

Data Analysis

Quantitative data were analysed using descriptive statistics that included, frequencies and means.

Results

In August 2011, the *Predictors of Readmission in Heart Failure Survey* was emailed to members from the Australian and New Zealand professional bodies of the NHF, ACNC, and CSANZ. The survey was closed in September 2011 following no responses after nine days. The survey yielded 119 responses. Responders varied from registered nurses, doctors, allied health personnel and researchers and are shown in Table 1.

Descriptive statistics were used to rank the experts opinion of the predictors for rehospitalisation in adults with heart failure. There were 41 predictors for rehospitalisation that survey respondents were asked to rank from high risk to low risk and these are presented in Table 1. The predictor that was ranked by the experts as being the highest risk predictor for rehospitalisation was, having a poor adherence to medications (9.04). The experts ranked having no private health insurance (4.82) as the least predictive factor for rehospitalisation.

Discussion

Identifying factors that predict rehospitalisation of adults with CHF is important, because rehospitalisation is associated with increased mortality and further rehospitalisation. In this survey which used experts to provide their opinion on the strength of risk factors for rehospitalisation, we have found no further factors that identify an adult's risk of rehospitalisation compared to previously published series [8]. Experts used their own personal experience and knowledge to validate the risk factors predictive

of rehospitalisation. Poor adherence to medication was ranked as the highest predictor for rehospitalisation.

Poor adherence to medication has been discussed in the literature [22]. Adverse events such as mortality [23] and rehospitalisation [24,25] are outcomes from poor adherence to medication. This predictor may have been ranked the highest due to the emphasis being placed on guideline adherence by professional bodies [26–28] and concurrence with current literature. Whereas having no private health insurance was ranked the least predictive. This may be due to Australia and New Zealand having universal health coverage. This risk factor may have been ranked higher if the study had been completed by experts who work in health care systems that do not offer universal health coverage. Literature conducted in the United States, a country which offers no universal health coverage, has identified that insurance status to be a predictor of rehospitalisation [29].

This study is important as it has asked experts to rank risk factors for rehospitalisation for adults with heart failure. However, in other areas of health, experts have been consulted on identifying risk factors. One such example is The World Health Organisation (WHO) seeking expert consultation in identifying risk factors for metabolic syndrome [30]. Furthermore, an online Delphi technique was used to identify intensivists' opinion in the ordering of chest X-rays in intensive care units [31]. The use of expert consultation within this study was two-fold. Firstly, for experts to validate current risk prediction factors and secondly, to identify any factors not previously mentioned within the literature.

The present study's findings must be interpreted within the context of its strengths and limitations. The strength of this survey is that item generation followed a comprehensive review of the literature and an online survey was used to access a wide range of participants. Strengths of the survey included that the objective of our survey was clear and well defined. Expert opinion was obtained. Individuals who were clinically current within the delivery of disease management and research of CHF were sought. Terms used within the survey were terminology specific to health care providers. The survey was initially piloted and following feedback, adjustments were then made. Terms were clear, concise and unambiguous. The time required to complete the survey was short (<10 min), this may have contributed to an increase in the response rate.

The methods of survey administration preclude reporting participation rates and therefore the external validity of the questionnaire. Further, this review only seeks the perspective of health professionals. Through the questioning of individuals with CHF, insight may have been gained to further determine risk factors that predict rehospitalisation. The Chronic Care Model recognises the importance of input from individuals with chronic diseases into disease management [32]. Furthermore, the disparity between individuals' needs and the system designed to implement care and the providers who do so may be clearer to individuals with CHF.

Experts used within the survey were located in Australia and New Zealand. The factors identified from these

experts may be specific and relevant to an Australian and New Zealand context only. Undertaking the survey in areas such as Europe and North America may have yielded other factors currently unidentified. In addition, as the survey was conducted online, experts without access to the internet may have been excluded.

Conclusion

In summary, the results of the survey suggest that expert consultation between Australian and New Zealand researchers and clinicians identified a poor adherence to medications and a history of prior hospitalisation as high predictors for the risk of rehospitalisation. The implications for policy, practice and future research suggests the importance of addressing and monitoring medication adherence and preventing rehospitalisation for individuals within the community through targeting those at highest risk.

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Accepted for Publication Manuscript 6 title: “An absolute risk prediction model to determine unplanned cardiovascular readmissions for chronic heart failure”

Manuscript

BETIHAVAS, V., Frost, S.A., Newton, P.J., Macdonald, P., Stewart, S., Carrington, M.J., Chan, Y.K., and Davidson, P.M. 2014. An absolute risk prediction model to determine unplanned cardiovascular readmissions for chronic heart failure.

The chapter following this provides the accepted manuscript for publication. The accepted manuscript presents an absolute risk model for predicting rehospitalisation for adults with CHF.

Background

- There is a growing burden (financial, physical, and social) associated with CHF rehospitalisation[1].
- RCT participants often do not reflect “the real world” of individuals with CHF[2].
- Current risk models are derived from RCTs and administrative data sets[3].
- The W.H.I.C.H trial was a RCT seeking to determine the two most common forms of face-to-face CHF disease management strategies: multidisciplinary disease management delivered in a person’s home versus management delivered in a specialist CHF outpatient clinic[4].

What this manuscript adds

- This study was the first to incorporate a novel approach to risk model design to predict rehospitalisation in adults with CHF.
- This study was the first to develop an individual absolute risk prediction model for rehospitalisation in adults with CHF using factors identified from a literature review, previous risk models, expert opinion and testing within a RCT.
- The absolute risk model was tested using the cohort of the W.H.I.C.H trial.
- The C-statistic for the absolute risk model was 0.80. Previous models have been no higher than 0.75[5]. Therefore, there are still factors that are unidentified regarding risk prediction for rehospitalisation.

Where to from here?

- Emphasis of the Chronic Care Model is placed on the empowerment of individuals to contribute to the management of the chronic disease. Therefore, future study examining the perceptions of individuals with CHF to identify factors which they

believe predict rehospitalisation may be beneficial to disease management and timely.

- Undertaking testing of the absolute risk model in larger cohorts within Europe and the United States, to identify the accuracy in populations outside of Australia.

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Title: An absolute risk prediction model to determine unplanned cardiovascular readmissions for adults with chronic heart failure

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Abstract

Background: Frequent readmissions are a hallmark of chronic heart failure (CHF). We sought to develop an absolute risk prediction model for unplanned cardiovascular readmissions following hospitalization for CHF.

Methods: An inception cohort was obtained from the WHICH? Trial, a prospective, multi-centre randomized controlled trial which was a head-to-head comparison of the efficacy of a home based intervention versus clinic-based intervention for adults with CHF. A Cox's proportional hazards model (taking into account the competing risk of death) was used to develop a prediction model. Bootstrap methods were used to identify factors for the final model. Based on these data a nomogram was developed.

Results: Of the 280 participants in the WHICH? Trial 37 (13%) were readmitted for a cardiovascular event (including CHF) within 28 days, and a further 149 (53%) were readmitted within 18 months for a cardiovascular event. In the proposed competing risk model, factors associated with an increased risk of hospitalization for CHF were: age (HR 1.07, 95% CI 0.90-1.26) for each 10-year increase in age; living alone (HR 1.09, 95% CI 0.74-1.59); those with a sedentary lifestyle (HR 1.44, 95% CI, 0.92-2.25) and the presence of multiple co-morbid conditions (HR 1.69, 95% CI 0.38-7.58) for 5 or more co-morbid conditions compared to individuals with one documented co-morbidity). The C-statistic of the final model was 0.80.

Conclusion: We have developed a practical model for individualizing the risk of short-term readmission for CHF. This model may provide additional information for targeting and tailoring interventions and requires future prospective evaluation.

Key words: heart failure; hospitalization; risk assessment; risk factors; risk model

Background

Chronic heart failure (CHF) is a major cause of morbidity and mortality and is a frequent cause of hospitalization [1]. High rates of hospitalization place a burden not only on the individual and their family but also society [2]. Increasingly readmission to the hospital is identified as an important marker of the quality of care, and highlights many of the vulnerabilities for patients in their transition from the hospital to the community. Reducing readmissions holds the potential of not only improving patient outcomes but also decreasing costs [3]. As many hospitalizations have been noted to be preventable, identifying those patients at most risk and developing interventions to prevent readmission have been a focus of clinicians and policy makers [3].

Risk prediction models identify individuals and characteristics which are considered at greater risk for a particular event [4]. Identifying individuals with CHF at higher risk of readmission has the potential to decrease adverse events and costs [5]. A number of models have been developed [6-16] predicting the risk of adverse events including hospital readmission and death, yet these models have demonstrated only modest discriminative ability [3, 15]. The challenge of identifying individuals at the highest risk, particularly from administrative databases, has been noted and the need to identify factors, such as length of stay, which increase the sensitivity of these models considered [7]. In order to more accurately target individuals at risk of readmission to hospital after an admission with CHF, we sought to develop an absolute risk prediction model using data from a contemporary CHF trial.

The Which Heart failure Intervention is most Cost-effective & consumer friendly in reducing Hospital care (WHICH?) Trial tested the hypothesis that compared to an equivalent clinic-based program [CBI] of management, a home-based, nurse-led, post-discharge, multidisciplinary management program [HBI] for CHF patients would be more effective in

optimizing health outcomes due to a better overall understanding of the patient and their environment [17]. As part of the WHICH? Program, we wanted to identify those patients who were most at risk for readmission in the early (28 days) and medium (12 months) term.

METHODS

Subjects and setting

The design and primary results for the WHICH? Trial have been published previously. [18, 19]. Briefly, all patients admitted to participating centres were screened for study eligibility according to the following criteria: i) aged ≥ 18 years, ii) discharged to home with a diagnosis of CHF as confirmed by a cardiologist, iii) persistent moderate to severe symptoms (NYHA II-III) and iv) a recent history of ≥ 1 admission for acute heart failure. Individuals living outside a 30km radius of the hospital, those who had a terminal condition, were non-English speaking and/or were unable to provide informed consent were ineligible to participate. All events in the WHICH? Trial were reviewed by a blinded endpoint committee and adjudicated on the type (elective versus unplanned) and cause of all readmissions. The WHICH? Trial was undertaken according to the principles outlined in the Declaration of Helsinki and CONSORT guidelines for pragmatic trials [20, 21] (Trial no. 418967). All WHICH trial participants provided written informed consent and ethics approval for the study was obtained from Curtin University Human Research Ethics Committee. All participants in the WHICH? Trial (n =280) were included in this analysis.

Steps in model development

Following a comprehensive review of current risk models [22] variables predicting readmission were identified. To ensure relevance and appropriateness these variables were subsequently verified in an online survey of heart failure experts [23]. For the purposes of this analysis only unplanned cardiovascular readmissions were included in the model development.

Statistical methods

A modified Cox's proportional hazards model that included death as a competing risk was used to develop the multivariate prediction model, using the methods suggested by Therneau [24]. Data items, such as age and comorbidities, identified from previous literature and surveys of experts in CHF were forced into all models [11, 13]. Potential effect modification was assessed using interaction terms (none were significant at a 0.10 level). Bootstrap methods were used to identify factors for our final model and presented in a nomogram. In this process, variables were selected using a backward-deletion-method, with a generous p -value for retention (0.2). This procedure was repeated 200-times, and predictors appearing in at least 60% of Bootstrap models were included in the final model [25] Verification of the proportional hazards assumption was based on a visual inspection of smoothed Schoenfeld residual plots [26].

Model validation

The ability of the final model to discriminate between individuals who had been readmitted and those without a readmission, was assessed by the C-statistic [27]. Internal validation of the final predictive model included Bootstrap methods. This was done to assess how accurately the model would predict readmission in a similar population of individuals with CHF. In this method, a sub-sample of 50 patients was used to create a training model which was then applied to the whole data set to estimate biases between the observed and predicted rates of readmission. This was repeated 200 times to create a distribution of bias between predicted and observed rates, and to estimate the maximum calibration error [28]. The design package developed by Harrell was used to create the nomogram [28]. Using the final model a nomogram for predicting the probability of readmission for a

cardiovascular event within 28-days or 1-year, for an individual was developed. All analyses were undertaken using the R statistical language [29].

RESULTS

The WHICH? Trial participants were typically older (mean age 71 ± 14 years), male (73%) and 73% with a left ventricular ejection fraction $\leq 45\%$. Nearly all participants (254; 91%) were prescribed an ACE inhibitor/angiotensin receptor blocker or a beta blocker, 154 (61%) of whom were prescribed the combination of both. The majority of patients were also prescribed a loop diuretic. There was a high degree of comorbidity (mean Charlson Index 6.1 ± 2.4) (**Table 1**).

Cardiovascular readmission and death

37 individuals (13%) experienced a cardiovascular readmission within 28 days of index hospital discharge. A further 149 (53%) were readmitted due to CHF during the 18 months follow-up. Compared to those individuals who were not readmitted, those who were readmitted were older ($p \leq 0.001$); had more comorbidity (as measured by the Charlson Index) ($p \leq 0.001$); and reported a sedentary lifestyle at baseline ($p \leq 0.001$). During the 18-months of follow-up 69 (25%) of study participants had died.

Model fit and clinical application

The risk of readmission (as hazard ratios, with 95% confidence intervals) using the predictors of: age, sex, living alone, sedentary lifestyle, co-morbidities and years since diagnosis of CHF are shown in **Table 2**. Internal validation of the model using Bootstrap methods resulted in an estimated maximum calibration error of approximately 3% and 2% between predicted probabilities and observed frequencies of readmission at 28-days and 1-year respectively.

A nomogram to individualize the risk of readmission is presented in **Figure 1**. The C-statistic of the final model was 0.80. An example of the model application can be made with the following scenario: a 70 year-old female, who lives alone, has a sedentary lifestyle, has two co-morbidities, a history of diabetes mellitus and has had CHF for 10-years, has an approximate 12% risk of readmission at 28-days and 60% risk of readmission at 1-year for heart failure.

This nomogram can be used by clinicians within the hospital or community settings to target at risk individuals and prevent unnecessary admissions to the hospital.

DISCUSSION

Identifying individuals with CHF at risk of readmission has become an important area of research [30]. Presently, there is no agreed model for risk-prediction that can be used to individualize the risk for readmission for people with CHF [22]. Prior prediction models have been limited and not necessarily applicable to ‘real world’ individuals with CHF. There has been little consistency of variables used to derive these models. This may be a consequence of the heterogeneity between populations and models of care delivery used to derive the models [22]. The C-statistic in prior models were no higher than 0.75 [14]. Therefore, it would appear that both in our model (C-statistic 0.80) and prior models, important risk factors for readmission have not been identified, thus warranting further investigation to understand what these unidentified factors are that may predict hospital readmission. It is likely, as CHF is a complex cardiogeriatric syndrome, that issues such as socioeconomic status, depression and geographical isolation contribute to the burden and the risk of readmission [31]. Our model included not only traditional risk factors but also individual and health system factors. We found that older age, living alone, a sedentary lifestyle and the presence of multiple comorbid conditions were risk factors for readmission for a cardiovascular event. Despite this, our model still had limited discrimination. Like previous

models, we were limited by the items that were measured in the WHICH? Trial and factors which may be important to include in future model development might include factors such as the inability to undertake activities of daily living and frailty [32]. Further development of our model through the inclusion and testing of these factors may help to improve its discrimination.

Ideally, the predicted risk of readmission would be used to stratify to allow for better targeting of resources to avoid readmission to hospital. The nomogram has the potential to be used both within the hospital and community setting. Due to the individualization of risk, clinicians could use such a tool to assess the risk of readmission in patients and adjust treatment accordingly, such as organizing a home visit in a timely manner. Importantly, the actual level of risk for readmission at which clinicians would decide to intervene and modify treatment in patients with CHF need to be identified. The nomogram derived from the WHICH? derivation cohort, is likely a useful instrument for clinicians to individualize risk for readmission for individuals with CHF but requires validation in prospective studies.

There are some important limitations that need to be considered. Like previous models, the model and nomogram we have developed are limited by the characteristics and variables measured in the parent study. The WHICH? Trial was conducted at three metropolitan hospitals and individuals living beyond a 30 kilometre radius from the study centres and those living in assisted living facilities were excluded which limits the external validity of the model. Notwithstanding this, the WHICH? Trial was a pragmatic trial which recruited an elderly cohort, with multiple comorbidities who were receiving high rates of gold-standard pharmacotherapy. The use of unplanned cardiovascular readmissions in the model likely increases the utility of the nomogram for tailoring and targeting interventions for those at the highest risk. However, the failure to address all cause readmission may limit the capacity to identify risks that are not related to their cardiovascular burden. Also relatively

small number of participants had been readmitted at 28-days (n=37), therefore our prediction for readmission within this period needs to be validated by larger studies.

A strength of this study is that the presentation of risk factors in a nomogram allows the individualization of risk for readmission in adults with CHF. Although these may appear apparent to the experienced clinician, data suggests that health professionals frequently fail to address these issues [33, 34] emphasizing the potential utility of a nomogram to calculate risk. Our method of identifying model variables, through multiple sources to develop the model including previously developed models [22] and expert opinion [23] increases the relevance to contemporary CHF care. However, the majority, if not all of the factors included in our nomogram are not modifiable. Therefore, future research to identify risk factors for readmission should include those with cognitive impairment and other limitations of functional activity that may preclude participation in a clinical study. And, a longitudinal study using an inception cohort of people with CHF who have been admitted to hospital could potentially identify more risk factors for readmission, particularly those that could be modified to reduce readmission rates.

CONCLUSION

This study has shown that older age, living alone, a sedentary lifestyle and the presence of multiple co-morbid conditions were risk factors for cardiovascular readmission. This model may provide additional information for targeting and tailoring interventions and requires future prospective evaluation.

Authors' Contribution

VB, SAF, PJN, and PMD, conceived the study and participated in its design and drafting of the manuscript. VB, SAF, PJN, SS, MJC, YKC, and PMD assisted with the acquisition of data. Analysis of data was conducted by VB and SAF. Critical revision and approval of final manuscript was conducted by all authors

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Table 1. Characteristics of study participants at baseline and readmission status.

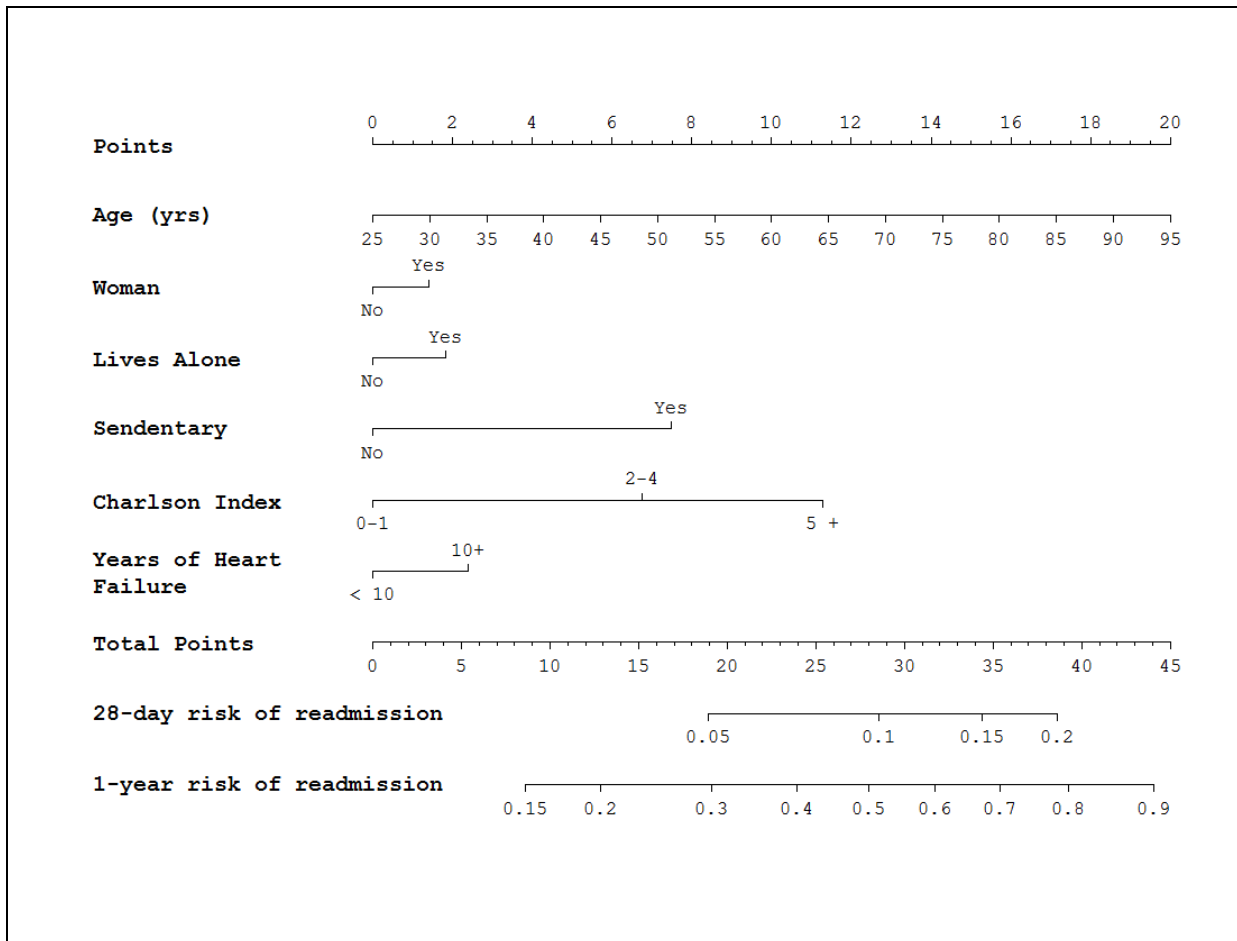
Characteristic	Readmission status			Combined (N=280)	P-value
	No readmission (N=94)	Readmitted within 28 days (N=37)	Readmitted After 28 days (N=149)		
Age (years), median (IQR)	69 (57-77)	79 (71-82)	75 (66-83)	74 (64-81)	< 0.001
Female, % (n)	77% (72)	70% (26)	70% (105)	72% (203)	0.60
Weight (kg), median (IQR)	78 (70-95)	77 (62-89)	77 (64-91)	77 (66-92)	0.40
Height(cm), median(IQR)	172(165-178)	167 (158-172)	170 (160-177)	170 (162-178)	0.09
Lives alone, % (n)	66% (62)	57% (21)	64% (96)	64% (179)	0.20
Depression score, median (IQR)	6 (0-23)	0 (0-17)	12 (0-22)	8 (0-22)	0.60
Cognitive Impairment, % (n)	39% (37)	49% (18)	50% (74)	46% (129)	0.30
Sedentary, % (n)	62% (58)	86% (32)	82% (122)	76% (212)	< 0.001
Dizziness, % (n)	16% (15)	19% (7)	14% (21)	15% (43)	0.80
Ascites, % (n)	18% (17)	11% (4)	9% (13)	12% (34)	0.09
Na (mmol\L) , median (IQR)	138 (136-141)	138 (136-139)	139 (137-141)	139 (136-141)	0.20
K (mmol\L), mean (SD)	4.3 (4.0-4.6)	4.2 (4.0-4.3)	4.3 (4.0-4.6)	4.2 (4.0-4.5)	0.20
Pulmonary Oedema, % (n)	57% (54)	62% (23)	38% (57)	48% (134)	0.002
NYHA class II, % (n)	22% (21)	8% (3)	32% (48)	26% (72)	0.02
NYHA class III, % (n)	59% (55)	68% (25)	58% (86)	59% (166)	
NYHA class IV, % (n)	19% (18)	24% (9)	10% (15)	15% (42)	
Hospital length of stay (days), median (IQR)	6 (3-10)	7 (4-11)	6 (4-12)	7 (4-11)	0.50
Current smoker, % (n)	12% (11)	3% (1)	8% (7)	9% (24)	0.50
Caucasian/European decent, % (n)	96% (90)	92% (34)	94% (140)	94% (264)	0.20
Completed secondary education, % (n)	17% (16)	22% (8)	20% (30)	19% (54)	0.70
Creatinine (mmol/L), median (IQR)	105 (90-139)	133 (109-149)	112 (88-146)	111 (90-146)	0.10
Haemoglobin (g/L), median (IQR)	129 (112-145)	120(110-132)	128 (114-141)	128 (113-142)	0.20
Charlson Index, median (IQR)	6 (4-7)	7 (6-8)	6 (5-8)	6 (5-8)	<0.001
Years of heart failure, median (IQR)	1 (0-3)	3 (1-5)	2 (0-3)	2 (0-3)	0.40
SBP, median (IQR)	110 (100-130)	115 (96-131)	112 (100-130)	110 (100-130)	0.50
DBP, median (IQR)	64 (60-72)	60 (52-70)	65 (60-75)	65 (60-74)	0.20
Claudication, % (n)	6% (6)	14% (5)	9% (14)	9% (25)	0.30

Table 2. Final model for risk of readmission for a cardiovascular event

Predictors	Hazard Ratios (95% Confidence Interval)	
	Crude	Adjusted
Age (each 10-year increase)	1.18 (1.05, 1.33)	1.07 (0.90, 1.26)
Women versus men	1.12 (0.79, 1.60)	0.99 (0.67, 1.48)
Lives alone		
No	1.0 (ref)	1.0 (ref)
Yes	1.07 (0.76, 1.51)	1.09 (0.74, 1.59)
Sedentary		
No	1.0 (ref)	1.0 (ref)
Yes	1.72 (1.12, 2.62)	1.44 (0.92, 2.25)
No. of comorbid conditions		
0-1	1.0 (ref)	1.0 (ref)
2-4	1.32 (0.31, 5.62)	1.25 (0.29, 5.37)
5+	2.31 (0.57, 9.34)	1.69 (0.38, 7.58)
Number of years with CHF		
< 10	1.0 (ref)	1.0 (ref)
10+	1.56 (0.93, 2.63)	1.40 (0.83, 2.38)

CHF=chronic heart failure

Figure 1. Nomogram for predicting the probability of readmission for a cardiovascular event in CHF patients at 28-days and 1-year.



Instructions: For each characteristic, locate the individual’s profile on the appropriate axis. Using a pencil and a ruler, draw a line vertically up to the top “points” axis. Sum the points for the individual characteristics to create a total score. Using the total score, draw a line vertically down the “total points” axis through the “28-day risk of readmission” or “1-year risk of readmission” axis to obtain risk. For example, a 70 –year-old female (14 points), who lives alone (2 points), has a sedentary lifestyle (7 points); has two co-morbidities - a history of diabetes mellitus and heart failure (7 points); has a 10 year history of heart failure, (2 points); has a total point score of 29, corresponding to a 17% risk of readmission at 28-days and 69% risk of readmission at 1-year.

Discussion

This thesis consisted of a series of five published manuscripts and 1 accepted for publication manuscript. These manuscripts have addressed the aims of the CHF-Risk Study. The following review/discussion chapter provides a summary of the six manuscripts. Limitations of the thesis are also noted. Consideration is also made for future directions for further research to be undertaken. A conclusion highlighting the thesis findings is made with direct application of the risk model into practice.

Summary

Rehospitalisation of individuals with CHF is a result of deterioration in symptoms and disease progression. This is either as a direct result from CHF such as fluid overload leading to impaired oxygen exchange or inadvertent and therefore unforeseen such as an individual who presents to hospital following a motor vehicle accident. Komajda and colleagues[1] identified that adherence of physicians to the European guidelines for the treatment of CHF was a strong predictor of fewer cardiovascular hospitalisations. Furthermore, Fitzgerald and colleagues[2] identified that medication non adherence by adults with CHF was associated with an increased risk of cardiovascular hospitalisations and all-cause mortality. Therefore, adherence to guidelines has shown to reduce the risk of hospitalisation. Additionally, targeting individuals at risk of hospitalisation is crucial due to the adverse events that occur from a hospitalisation. In this thesis, some important means of identifying foreseeable risk factors related to cardiovascular problems for rehospitalisation in adults with CHF have been addressed.

Some important findings of this thesis are:

What is the current state of heart failure disease management in Australia?

This thesis has shown the multifaceted role of nurses in disease management of individuals with CHF in Australia. Australia has a health care system that is supported by universal health coverage. However, it is a system in need of reform. The NHHRC reform goals if executed are projected to save the government \$4 billion by 2032[3]. Within the health care budget, the primary cause for expenditure is directed at hospitalisation[4]. Hospitalisation costs are also the leading expenditures within the health care budgets of Europe and North America[5]. With an ageing population and an anticipated rise in diagnosis for CHF and subsequent hospitalisations, the need for identifying risk factors for rehospitalisation are paramount. Implementing the CCM[6] in CHF disease management strategies has the potential to monitor those individuals within the community at risk of

rehospitalisation. However, current practices are inconsistent with discharge criteria and follow-up and therefore individuals are at further risk of rehospitalisation[7]. Furthermore, CHF disease management programs are predominantly located within urban areas[8]. Utilising a best practice approach to develop policies that directly state what discharge criteria and follow-up is required within the community, is necessary to the disease management of individuals with CHF. Additionally, unlike other health professions such as medicine, there is a more even distribution of nurses across urban and remote areas[4]. Therefore, implementing policies to support and skill nurses within their practice to disease manage individuals within remote areas thereby operating CHF disease management programs that are evidence based, practical and appropriate to prevent rehospitalisation should be viewed by the health care authorities as an asset.

What patient, provider and system factors have been previously identified within studies that predict the risk of hospitalisation for adults with CHF but have not been included in existing risk models?

This thesis has shown that previous literature has predominantly focussed on patient specific characteristics that increase the risk of rehospitalisation. Some of these include: age[9], fluid overload[10] and co morbidities[11]. Currently, risk models are developed using primarily patient characteristics. However, factors that influence health are dynamic and do not occur in a vacuum. Identifying factors for rehospitalisation by expanding the lens to include provider(s) and system(s) factors may be beneficial to the CHF population and clinicians. Furthermore, to include factors that may perhaps decrease the risk of rehospitalisation may also prove to be beneficial in preventing rehospitalisation. Some examples of provider and system risk factors that decrease the risk of rehospitalisation include: collaborative input in disease management from multidisciplinary health care providers[12], and discharge planning[13].

What risk factors for rehospitalisation have been incorporated into previous models and which of these factors are replicated when comparing the risk models?

This thesis has shown that prior to this study, there was no individual absolute risk model that predicted the risk of rehospitalisation for adults with CHF. Prior models[14-19] were all created in North America and tended to use patient focussed risk factors obtained from either administrative, registry data sets or through RCTs. Furthermore, there was a minimal consensus on the factors used in the risk models. Diabetes, elevated blood urea nitrogen (BUN), a previous hospitalisation within 1 year, single status and race were

replicated within the models. However, the replication of risk predictors did not occur in more than 2 models for any given predictor[20].

What is the value of having risk models in clinical practice?

This thesis has shown that risk models are tools which aid clinicians in disease management decisions. The use of risk prediction models in clinical practice is to aid in clinical decision making; targeting of at risk populations and streamlining and rationalising management of at risk individuals. Clinicians are able to target individuals at risk and rationalise interventions accordingly. However, current risk prediction models for CHF have been developed from factors identified purely within administrative data sets and RCTs and therefore, may not be replicable or as accurate outside the cohort from which the model was developed. Furthermore, it has been highlighted that risk predictors should never be viewed in isolation[21]. Therefore, it is a combination of risk factors that contribute to rehospitalisation rather than a single factor.

What is the perception of experts within CHF disease management and/or research as to the patient, provider and system factors that predict rehospitalisation for adults with CHF?

This thesis has shown that experts within CHF disease management or/and research located in Australia or New Zealand did not identify any further risk factors for rehospitalisation for adults with CHF other than those derived from existing guidelines and the literature review[22]. Experts ranked risk predictors for rehospitalisation from highest (score of 10) to lowest (score of 1). The risk factor that respondents ascribed the highest risk was a poor adherence to medications. Poor adherence to medications is recognised throughout the literature as being a predictor for rehospitalisation[23]. However, having private health insurance scored the least. As Australia and New Zealand offer a system of universal health coverage, an emergency department presentation requiring interventions will not be influenced by the individual's insurance status. Therefore, having private health insurance in Australia and New Zealand is a moot point for an emergency presentation. However, Philbin and DiSalvo[16] as well as Amarsingham and colleagues[14] incorporated insurance status within their risk models for rehospitalisation. As these risk models were developed using North American cohorts from a country that offers no universal health coverage, replicating these two models within an Australian and New Zealand context would be inappropriate. In addition, having the CHF-Risk model used by North American clinicians may be a limitation in its prediction as it was developed from a country offering universal health coverage.

How accurate is an absolute risk prediction model that is developed and tested using an RCT cohort compared to existing models?

This thesis has shown that an individual absolute risk prediction model was developed from amalgamated factors identified from a literature review, expert opinion and data obtained from an RCT. Risk factors identified as being predictive of rehospitalisation included: age; individuals living alone; those with a sedentary lifestyle; and multiple co-morbidities. The area under the receiver operating characteristic curve (AUC) or *c statistic* of the final model was 0.80. In prior risk models, the AUC was no higher than 0.75[24]. This may imply that there are factors yet to be unmasked that in combination may better predict rehospitalisation. Hence the need for future investigation is paramount. It has been argued by Cook[25] that the *c statistic* may not be an appropriate guide to use when assessing models that predict future risk. However, Cook[25] also argues that eliminating a model on the basis of a low *c statistic* may be inappropriate. Therefore, though the risk model had a *c statistic* of 0.80, this value is consistent with prior risk models and as such should not be eliminated but further explored for clinical importance.

Limitations

The results of this thesis must be considered in the context of some potential limitations. These limitations are:

No systematic review or meta-analysis was undertaken to identify risk factors for rehospitalisation from the literature. Benefits of systematic reviews and/or meta-analysis include assessment of consistencies across studies; an increase in the power and precision in estimating effect size and risks; and generalizability of individual studies across participants and settings[26].

No input from individuals with CHF was made to identify their perception of risk factors that contribute to rehospitalisation. Prior studies[27-28] have acknowledged the benefits of incorporating patient perceptions in formulating disease management programs to predict outcomes.

The cohort used to test the nomogram was 280 individuals from an RCT with an 18 month follow-up. A longer longitudinal study with a larger cohort may have yielded additional association and/or causal findings[29]. It is therefore possible that the results may not be representative of the entire spectrum of individuals with CHF.

In spite of these limitations, this thesis has drawn from evidence in the literature, expert knowledge and developed a nomogram which individualises the risk of rehospitalisation for adults with CHF.

Future Directions

As the proportion of the elderly population increases, chronic diseases which include CHF has been identified as a major public health challenge for the future[30]. The incidence of elderly diagnosed with CHF is projected to rise with the ageing of the baby boomer generation[31]. Goals for future research should be directed at decreasing the risk of individuals developing CHF[32]; identifying appropriate and practical disease management strategies for individuals that do develop CHF[33-34] and identifying at risk populations for adverse events[35]. Furthermore, implementing schemes that will accommodate individuals and communities when adverse events do occur.

The following are some topics for future directions for further research in CHF, risk identification and CHF disease management that would be of value and useful to the individual with CHF and the community.

Decreasing the risk of individuals developing CHF

Primary health care campaigns aimed at increasing community awareness through diverse mediums including electronic and hard copy, regarding identifying risk factors for developing heart failure is paramount and timely. Heart failure is the leading cause for hospitalisation in the developed world for adults over the age of 65 years. However, community awareness of this is lacking. Furthermore, management of hypertension by individuals and reducing health disparities has the potential to decrease individuals developing CHF. In addition, Vitry and colleagues[36] have also reasoned for the dissemination of material and resources for individuals with CHF. Therefore, increasing access and equity to information and resources has the potential for individuals within the community to make informed decisions regarding their lifestyle/health that are positive and decrease potential adverse events.

Identifying appropriate and practical disease management strategies for individuals that do develop CHF

Utilising the CCM and incorporating individuals with CHF into heart failure disease management programs in conjunction with multidisciplinary teams within the community. The development of policies that is mandatory for clinicians to follow once an individual has been diagnosed with heart failure and/or discharge from hospital.

Identifying at risk populations for adverse events

It is important for primary health care physicians and clinicians to identify at risk populations with CHF for adverse events such as rehospitalisation. However, populations and health care systems differ globally as such, a model developed in Australia may not be accurate in risk prediction when used on a population from a country which does not support universal health coverage. By altering the CHF-Risk Study's design, CHF expert opinion would be obtained from clinicians/researchers globally (rather than just nationally as was done with the CHF-Risk study). Furthermore, acquiring the opinion from individuals with CHF as to what they perceive to be risk factors that predict rehospitalisation may uncover potential risk factors not previously identified in the literature. This would then be followed by the amalgamation of risk factors that have been identified to create a risk nomogram.

Implementing schemes that will assist individuals and communities when adverse events do occur

To prevent adverse events and identify the potential for rehospitalisation, it is imperative that individuals discharged into the community be reviewed as soon as possible. Using the nomogram developed within the CHF-Risk Study, clinicians and primary care physicians may implement strategies post discharge, such as telemonitoring with multidisciplinary interventions to observe individuals at risk of rehospitalisation at 28 days.

Conclusion

This thesis has sequentially developed a nomogram that provides an absolute risk score for rehospitalisation for adults with CHF at 28 days and 1 year post discharge. The results of this study indicate that important factors that were identified to be associated with an increased risk of rehospitalisation for adults with CHF were: age (for each 10-year increase in age); individuals living alone; those with a sedentary lifestyle and the presence of multiple co-morbid conditions. The nomogram may be used as a tool by clinicians and individuals to guide in disease management of adults with CHF and possibly prevent adverse events.

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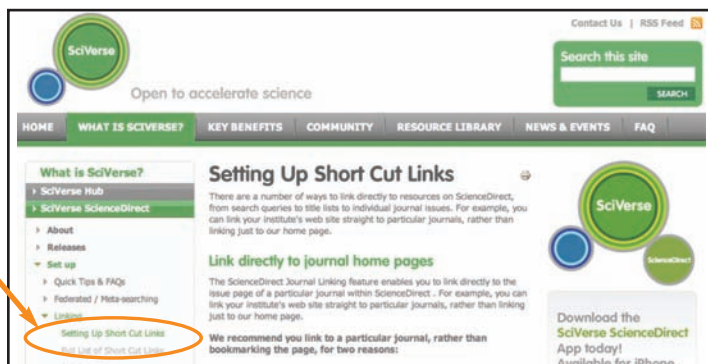
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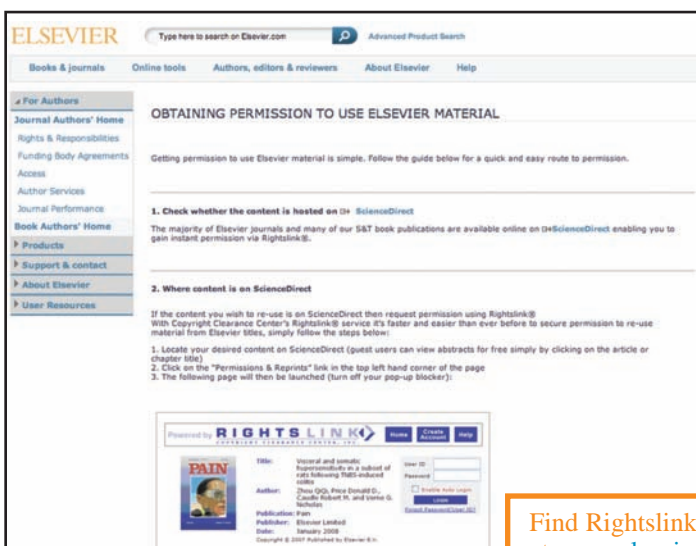
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This is a Thesis by publication. A number of researchers contributed in part to the publications included within this thesis. However, the actual research undertaken and the preparation of the manuscripts was solely my own work (except where duly acknowledged). The co-authors statements are provided in the appendix. It is acknowledged that all co-author jointly published manuscripts included in this thesis provided their consent for the inclusion of each manuscript in this thesis. All other work included in this thesis, not part of published papers or those accepted for publication is entirely my own work, except where duly acknowledged. The contribution of every author to each of the publications included in this thesis is outlined below:

Publication 1

Title: Australia's health care reform agenda: Implications for the nurses' role in chronic heart failure management.

Authors: Betihavas, V., Newton, P., Du, H.Y., Macdonald, P.S., Frost, S.A., Stewart, S., and Davidson, P.M.

Journal: Australian Critical Care. 2011; 24, 189-197.

Study concept design: Betihavas, V., Davidson, P.M.


Acquisition of Data: Betihavas, V.


Analysis of Data: Betihavas, V., Newton, P. J., Davidson, P.M.

Critical Revision of Manuscript: Betihavas, V., Newton, P., Du, H.Y., Macdonald, P.S., Frost, S.A., Stewart, S., and Davidson, P.M.

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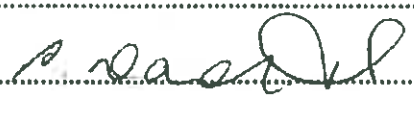
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Signatures:

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Steven A Frost

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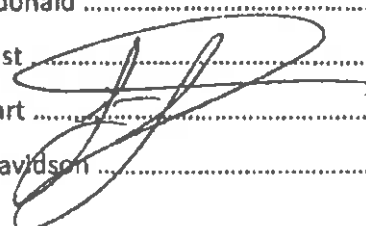
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Publication 2

Title: Patient, provider and system factors influencing rehospitalisation in adults with heart failure.

Authors: Betihavas, V., Newton, P.J., Frost, S.A., Macdonald, P.S., and Davidson, P.M.

Journal: Contemporary Nurse, 2013; 43, 244-256.

Study concept design: Betihavas, V., Newton, P.J., and Davidson, P.M.

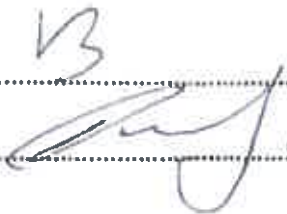
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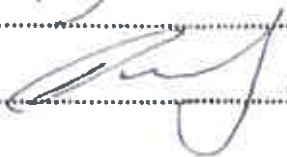
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Steven A Frost

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Phillip J Newton

Steven A Frost

Peter S Macdonald 

Patricia M Davidson

Publication 3

Title: What are the factors in risk prediction models for rehospitalisation for adults with chronic heart failure?

Authors: Betihavas, V., Davidson, P.M., Newton, P. J., Frost, S. A., Macdonald, P.S. and Stewart, S.

Journal: Australian Critical Care; 2012, 25, 31-40.

Study concept design: Betihavas, V., Davidson, P.M., Newton, P. J., and Frost, S. A.

Acquisition of Data: Betihavas, V., Davidson, P.M., Newton, P. J., and Frost, S. A.

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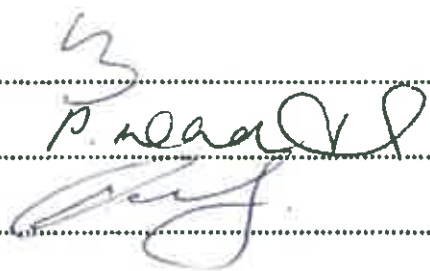
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Steven A Frost

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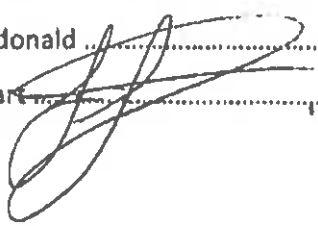
Patricia M Davidson

Phillip J Newton

Steven A Frost

Peter S Macdonald

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Publication 4

Title: An overview of risk prediction models and the implications for nursing practice.

Authors: Betihavas, V., Newton, P.J., and Davidson, P.M.

Journal: British Journal of Cardiac Nursing; 2012, 7, 259-265.

Study concept design: Betihavas, V.




Acquisition of Data: Betihavas, V.

Analysis of Data: Betihavas, V., Newton, P.J., and Davidson, P.M.

Critical Revision of Manuscript: Betihavas, V., Newton, P.J., and Davidson, P.M.

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Patricia M Davidson 

Publication 5

Title: Importance of Predictors of Rehospitalisation in Heart Failure: A Survey of Heart Failure Experts.

Authors: Betihavas, V., Newton, P.J., Frost, S.A., Alexandrou, E., Macdonald, P.S. and Davidson, P.M.

Journal: Heart, Lung and Circulation, In press.

Study concept design: Betihavas, V., Newton, P.J., and Davidson, P.M.

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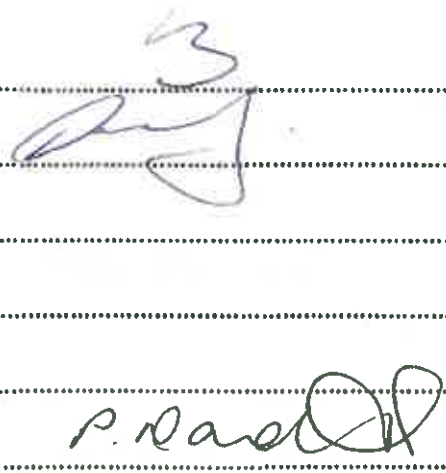
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Steven A Frost

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Phillip J Newton

Steven A Frost

Evan Alexandrou

Peter S Macdonald 

Patricia M Davidson

Manuscript 6

Title: An absolute risk prediction model to determine unplanned cardiovascular readmissions for chronic heart failure.

Authors: Betihavas, V., Frost, S.A., Newton, P.J., Macdonald, P., Stewart, S., Carrington, M.J., Chan Y.K., and Davidson, P.M.

Journal: BMC Emergency Medicine (under review)

Study concept design: Betihavas, V., Frost, S.A., Newton, P.J., and Davidson, P.M.

Acquisition of Data: Betihavas, V., Frost, S.A., Newton, P.J., Stewart, S., Carrington, M.J., Chan Y.K., and Davidson, P.M.

Analysis of Data: Betihavas, V., Frost, S.A.,

Critical Revision of Manuscript: Betihavas, V., Frost, S.A., Newton, P.J., Macdonald, P., Stewart, S., Carrington, M.J., Chan Y.K., and Davidson, P.M.

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February 18, 2013

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Parramatta Campus
Locked Bag 1797
Penrith South DC NSW 1797

Dear Ms. Betihavas:

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Figure 1: Edward H. Wagner, MD, MPH, Chronic Disease Management: What Will It Take To Improve Care for Chronic Illness? *Effective Clinical Practice*, Aug/Sept 1998, Vol 1

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Vasiliki Betihavas
Curtin University of Technology
Centre for Cardiovascular and Chronic Care
39 Regent Street
Chippendale, 2008 NSW Australia

In response to your request to use:

Journal	Citation	Year	Specific Item
Archives of Internal Medicine	168:1371-1386	2008	Table 1 (Adapted)

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Online Survey Questionnaire for Publication 5

See next page for online survey questionnaire for publication 5

Welcome!

Dear colleague,

Thank you for taking the time to complete this survey. This study will have been explained to you in the email providing the link to this survey.

Currently, risk models predominantly classify risk of hospitalisation from factors that have been derived from both randomised controlled trials and administrative data sets. Predictors identified in these risk models are primarily biomedical, patient factors.

We have undertaken a review to determine factors predicting the risk of hospitalisation for adults with chronic heart failure from the perspective of patient, provider and system factors. Also, we have identified risk factors for hospitalisation from current risk prediction models.

This brief online survey will collect information about your expert opinion regarding patient, provider and system factors that you believe are risk predictors for hospitalisation for adults with chronic heart failure.

We would very much appreciate your time in completing the survey, which should take about 5 minutes.

Information from this survey will assist us in developing and testing a model that considers the complex interface between patient, provider and system factors.

This survey is being undertaken as part of the Doctoral work of Vasiliki Betihavas who is supported by an NHMRC scholarship.

For more information please contact the research supervisor Patricia Davidson on p.davidson@curtin.ed.au

1. Currently the NHF/CSANZ guidelines identify the presence of two or more of the following characteristics as denoting HIGH RISK:

- **Age ≥ 65 years**
- **NYHA Class III or IV symptoms**
- **Charlson Index of Comorbidity Score of 2 or more**
- **Left ventricular ejection fraction (LVEF) $\leq 30\%$**
- **Living alone or remote from specialist cardiac services**
- **Depression**
- **Language barrier (e.g. non-English speaking)**
- **Lower socio-economic status**
- **Significant renal dysfunction**

Do you agree with this classification. If NO please provide clarification of your response

Yes

No

If NO please provide explanation

Patient population

2. Are you currently involved in the planning, delivery or administration of a heart failure service/program for community-based individuals with CHF in Australia?

Yes

No

3. What is the postcode of your place of employment?

4. Does your workplace provide a multidisciplinary heart failure service or program?

Yes

No

Health professional information

5. What is your profession/job title ?

- Aboriginal Health Worker
- Multicultural Community Health Care Worker
- Dietitian
- Cardiologist
- Physician
- General Practitioner
- Registered Nurse
- Clinical Nurse Specialist
- Clinical Nurse Consultant
- Enrolled Nurse
- Nurse Practitioner
- Practice Nurse
- Physiotherapist
- Occupational Therapist
- Exercise Physiologist
- Podiatrist
- Social Worker
- Community Pharmacist
- Hospital Based Pharmacist
- Community Based Psychologist
- Hospital Based Psychologist
- Researcher
- Advanced trainee
- Resident medical officer
- Other (please specify)

6. How many years have you been involved in CHF care?

Years

7. What is the percentage of your time devoted to direct clinical care of people with CHF?

% of time

Setting of CHF care

8. What is the primary setting focus in which you are involved in CHF care?

- Home based program
- Hospital based clinic (physician led)
- Hospital based clinic (nurse led)
- Private practice (specialist)
- General Practice
- Cardiac Rehabilitation
- Generalist community nursing program
- Telemedicine
- Policy, planning, administration
- Other (please specify)

No regular primary care physician	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
No regular community pharmacy contact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
No access to home visits from health providers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
More than seven scheduled medications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
No access to a heart failure multidisciplinary team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Private health insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
No private health insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cachexia	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Osteoarthritis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hypotension	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Angina	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Substance abuse	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Arrhythmias	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

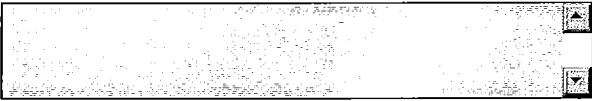
Other (please specify)

Conclusion and thankyou

This is the end of the survey!

Thank you for taking your valuable time to undertake this survey.

10. Please feel free to add any comments or risk factors yet unidentified that you believe will help assist in identifying patient, provider or system risk factors in individuals with heart failure at risk of readmission.



Ethics approval

See next page for Ethics approval by Curtin University Human Research Ethics Committee

memorandum

To	Ms Vasiliki Betihavas
From	Professor Dianne Wynaden
Subject	Approval: SON&M16-2010
Date	28 th May 2010
Copy	Professor Patricia Davidson

Thank you for your "Form C application for your Research with Minimal Risk (Ethical Requirements)" project titled "**PREDICTING RISK: DEVELOPING AND TESTING OF A NOMOGRAM TO PREDICT HOSPITALISATION IN CHRONIC HEART FAILURE**". On behalf of the Human Research Ethics Committee I am authorised to inform you that the ethics for the project is approved.

Approval of this project is for a period of twelve months from **28th May 2010** to **28th May 2011**. If at any time during the twelve months you have any amendments or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **SON&M 16-2010**. *Please quote this number in any future correspondence.*



Professor Dianne Wynaden
Low Risk Coordinator
School of Nursing and Midwifery

Please Note: The following standard statement must be included in the information sheet to participants: *This study has been approved by the Curtin University Human Research Ethics Committee. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.*

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