

Early Mobilization of Older Adults in the Cardiovascular Intensive Care Unit

I. RESEARCH QUESTION

Is an early progressive mobilization program safe, feasible, and effective in older adults in the Cardiovascular Intensive Care Unit (CICU)?

II. HYPOTHESES

1. An early mobilization (EM) program is safe, feasible, and effective in older adults in a Canadian tertiary care academic CICU.
2. Level of function on CICU discharge and time spent lying in bed during hospitalization is associated with health-related quality of life scores and functional status at longer-term follow-up.

III. SPECIFIC AIMS

Aim #1: To determine functional status and longer-term patient-centered outcomes of older adults admitted to the CICU prior to the implementation of the EM program (“pre-intervention” cohort)

Aim #2: To assess the safety and feasibility of an EM program in a Canadian academic tertiary care CICU

Aim #3: To determine the effectiveness of EM at improving the functional status of older adults during CICU admission and improving longer term patient-centered outcomes (“intervention” cohort)

Aim #4: To evaluate the association of daily time spent lying in bed with functional status at CICU discharge and following hospital discharge

Aim #5: To assess the amount of skeletal muscle mass loss during admission for acute cardiovascular disease

IV. BACKGROUND

A. Physical Function and Impairment in Older Adults in the Critical Care Unit

Older adults (age $60 \geq$ years old) comprise the majority of patients admitted to the CICU.¹ Older adults have a higher burden of prehospital functional impairment, which is an important predictor of morbidity and mortality during and following critical care unit hospitalization.^{2,3} During hospitalization, older adults are at risk for rapid loss of muscle mass and strength from critical illness, immobility, and prolonged bedrest.⁴ As a result, survivors of critical illness frequently develop physical impairments, such as a reduced ability to ambulate and difficulty performing activities of daily living (ADLs), which can endure well-beyond index hospitalization.⁵⁻⁷ Up to 70% of older adults in the critical care unit are unable to return to prehospital levels of activity at discharge and have significant physical impairments that persist months later.⁵ The enduring physical impairments following critical care unit hospitalization can have devastating effects on the ability of older adults to maintain independence and quality of life and also results in increased morbidity and mortality.⁸

B. Early Mobilization in the Intensive Care Unit: Opportunities and Challenges

EM describes progressive mobilization activities that start immediately upon hemodynamic and respiratory stabilization, typically within 24-48 hours of intensive care unit admission.⁵ The objectives of EM is to prevent loss of muscle function, promote rapidity in

mobility recovery, and to maintain or help patients regain prehospital functional capabilities. There is evidence that EM is associated with improvements in muscle strength, physical function, and quality of life in patients admitted to critical care units.^{9, 10} In addition, EM has also been shown to decrease critical care delirium, improve long-term cognitive outcomes, decrease critical care and hospital length of stay, reduce hospital readmissions, decrease long-term mortality, and result in considerable cost savings.^{5, 11-14} The safety of EM programs in critically ill patients has also been established with only rare reports of serious adverse events and catheter dislodgement. The most commonly reported complications are transient physiologic changes.^{15, 16}

Yet despite the demonstrated effectiveness and safety in the peer-reviewed literature for EM practices in critical care units, there is evidence that actual practice is lacking.¹⁷ A recent survey of Canadian physicians working in critical care units reported that, while more than half of physicians believed that mobilization should begin as early as possible after unit admission, almost three-quarters felt that they lacked adequate knowledge or training to mobilize patients.¹⁸ In addition, the physicians noted a number of barriers to early mobilization, such as a lack of a standardized protocol and concern over patient safety. Addressing these barriers is essential to the successful implementation of an EM program.

C. Frailty in Older Adults with Cardiovascular Disease

Older adults are at increased risk of developing frailty, a syndrome characterized by sarcopenia, subclinical multi-organ dysfunction, and reduced capability of handling physiological stress.¹⁹ Sarcopenia is the age-related alteration in protein metabolism, decline in muscle mass, strength, and functional capacity. The prevalence of frailty in the critical care unit ranges from 10-40%, depending on the population and setting.^{20, 21} Frail older adults are more likely to have increased muscle loss during periods of acute illness and immobilization, functional decline during hospitalization, and long-term disability following discharge. Frailty in cardiovascular patients is also a strong predictor beyond the chronological age of increased morbidity, hospital and critical care unit stays, mortality, discharge to rehabilitation facilities and institutionalization, and higher rates of readmission. Early progressive mobilization activities may have an even greater impact on frail older adults than on their non-frail counterparts.

D. Knowledge gaps targeted in this proposal

Recent reviews of EM programs in the peer-reviewed literature have identified a number of evidence gaps to be directly addressed by this study.²²

1. Safety and feasibility of EM in the CICU: The majority of EM intervention studies were performed in the medical intensive care unit or in populations with low rates of primary acute cardiovascular disease and it is unknown whether the findings can be generalized to the CICU. The CICU contains a unique population of patients with primary cardiovascular disease, high illness acuity, and a considerable burden of non-cardiovascular disease.²³ Barriers to mobility for cardiac patients may also differ from those of the general critical care population. To date, minimal data exist in the literature on the use of EM in acute cardiovascular populations.^{5, 24} An expert panel from Health Quality Ontario reviewed the literature for articles assessing EM interventions in hospitalized acute heart failure patients and could not identify any relevant studies.²⁵ A retrospective Canadian study of post-TAVR patients demonstrated a reduction in median hospital length of stay with an early discharge protocol including EM as part of a multimodal intervention strategy.²⁶

2. EM in older adults: Whether older adults, particularly frail older adults, benefit more from EM than younger or nonfrail older adults is uncertain. Prior EM intervention studies were composed of younger patient cohorts and there have been no studies that specifically focus on EM in older adults.²⁴

3. EM and patient-centered outcomes: Prior studies on the impact of EM on outcomes have focused mainly on healthcare resource outcomes (i.e., length of stay, readmission rates) and there are limited data on the effect of EM on patient-centered outcomes. The Canadian Institute for Health Research has identified patient-centered research as a priority for the healthcare system.²⁷ Health-related quality of life and functional status are patient-centered measures that are recommended as key metrics when studying older adults with cardiovascular disease.²⁸

4. Lack of published nurse-driven EM protocols

Prior published EM protocols typically include intensive involvement in daily EM by physiotherapists.^{22, 29} However, given the limited availability of physiotherapists for 24/7 care in the critical care setting and the need for protocol generalizability, it is essential to establish a protocol that can be easily implemented by nursing staff and will provide enough details for replication.

5. Knowledge translation

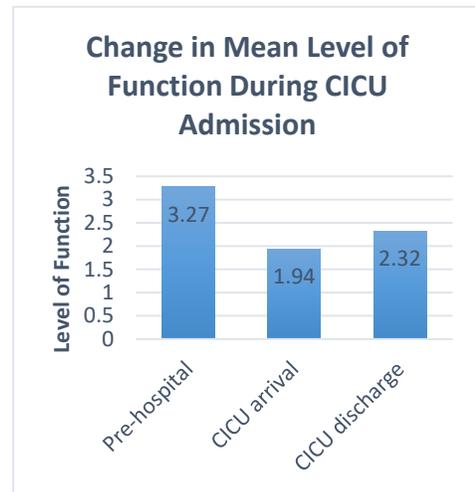
There are few available tools on how to implement an EM program, particularly in an acute cardiovascular unit. A lack of written protocols or guidelines, as well as insufficient clinician knowledge, has been identified as a barrier to implementing EM in critical care units.¹⁸

6. Patient positioning and activity in patients with acute cardiovascular disease: Precise identification of patient position (lying, sitting, and standing) and physical activity using body-worn sensors is now possible due to improvement in accelerometer technology. Accelerometry has been validated in numerous populations, including in the ICU, mainly in the context of mechanically ventilated patients.³⁰ However, previous studies in the ICU were limited by small sample sizes and short duration of patient monitoring, ranging from 60 minutes to 48 hours, and monitoring did not extend beyond ICU unit stay.³⁰ *There are also no studies in the literature specifically looking at positioning and activity in patients with acute CV disease.* It is important to understand the time spent in the different mobility positions and the relationship with functional outcomes in older adults with acute CV disease. Decreasing the duration of time spent in a lying position is a potentially modifiable factor.

V. PRELIMINARY STUDIES

During my Cardiac Intensive Care fellowship at Cedars-Sinai Medical Center in Los Angeles, CA, I participated in the EM program and instituted frailty screening in the CICU. We used a level of function (LOF) assessment tool in the EM program that ranged from 1 to 5, where 1 was bedbound and 5 was ability to walk > 50 feet (see sidebar). Preliminary analysis of the retrospective cohort of 264 patients with acute cardiovascular disease undergoing EM showed that 90 (34.1%) patients were frail, 65 (24.6%) were vulnerable, and 109 (41.3%) were not frail. We found a moderate correlation between prehospital LOF and frailty ($r = -0.580, P=0.01$). Prehospital LOF was higher in nonfrail elderly than in frail elderly (mean score of 3.71 ± 0.61 vs. 2.59 ± 1.03 ; $P < 0.001$). LOF improved in both nonfrail and frail elderly during CICU stay, however, there was greater improvement in LOF in the frail group (mean increase of 0.53 vs 0.70; $P < 0.01$). The initial data analysis suggests that frailty status is a potential predictor of responsiveness to EM. Further analysis of this dataset is needed to identify other predictors of responsiveness to EM in the CICU.

Progressive Mobility	
Level of Function 1	Bed Activity
Level of Function 2	Able to Sit
Level of Function 3	Able to Stand
Level of Function 4	Walks < 20 feet
Level of Function 5	Walks > 50 feet



The current mobility practices and LOF assessment for patients admitted to the CICU of the Jewish General Hospital were reviewed by a nurse educator on two separate dates as part of continuous quality improvement requested by the quality of care committee of the division of cardiology. We looked at a convenience sample of patients in the CICU on two separate dates. There were 26 patients in the analysis (mean age 71.7 years old, standard deviation (SD) ± 10.9 , female 38.4% (n=10)). There were 10 patients (38.5%) who would not be initially eligible for entry into the study (see eligibility criteria below; four due to age, two on noninvasive or invasive ventilation, two with a transvenous pacemakers, and two who were not hemodynamically stable). For patients who were initially eligible for the study, the mean prehospital LOF was 4.7 (SD ± 0.6) and the mean LOF on CICU admission was 2.3 (SD ± 1.2). Of the eligible patients, 14 patients (87.5%) said they would agree to participate in an EM study and 12 patients (75%) were followed prior to hospitalization by a hospital-affiliated cardiologist.

VI. METHODS

Design, participants and setting

An EM program is being developed as a quality improvement project in conjunction with the Quality and Safety Committee of the Division of Cardiology at the Jewish General Hospital (JGH). For our study, we will perform a prospective, pre/post-EM intervention study in adults aged ≥ 60 years old admitted to the CICU at the JGH. During a 3-month period, we will prospectively enrol patients to the pre-intervention cohort. The EM intervention will then be implemented. During a 12-month period, we will prospectively enrol patients to the intervention cohort. 1 and 12 months following hospital discharge, patients in the pre-intervention and post-intervention cohorts will be contacted by phone by a member of the research team to assess for functional status and quality of life measures.

A multidisciplinary EM implementation team developed a LOF assessment tool targeted for the CICU patient population. The assessment tool was created to be easy to use, quantitative, nurse-driven, and potentially generalizable to other CICUs. The creation of the EM team and EM program was an initiative of the Quality of Care Committee in the Division of Cardiology at the Jewish General Hospital.

All patients admitted to the CICU are eligible for the EM program, except for patients meeting pre-defined hemodynamic, respiratory, neurologic, or in-dwelling device criteria. The exclusion criteria were chosen based on expert guidelines for EM safety³¹ and adapted for the acute cardiovascular patient population through collaboration with the multidisciplinary EM team.

For entry into our study, the inclusion criterion is age ≥ 60 years and exclusion criteria are CICU stays less than 24 hours and patients with prehospital LOF 0 (immobile), LOF 1 (bedbound) or 2 (can sit in chair only). Cardiac surgery patients will also be excluded. Patients with a pacemaker or defibrillator will not be included in the bioimpedance substudy (contraindication for use of bioimpedance scale). For the pre-intervention cohort, patients will be prospectively enrolled over a 3-month period by a member of the research team during CICU admission. Following the 3-month pre-intervention period, the intervention (EM program) will be implemented and patients will be prospectively enrolled during CICU admission over a 12-month period by a member of the research team. Informed consent will be obtained for all participants during enrolment by a member of the research team.

Pre-intervention

Prior to the implementation of the EM intervention, nurses will ascertain and record the prehospital LOF, admission LOF, and LOF on the day of CICU transfer (Appendix A), but will continue usual mobilization practices. Patients who meet eligibility criteria for the EM intervention will be prospectively enrolled over a 3-month period (“pre-intervention cohort”) by a member of the research team during CICU admission. Informed consent will be obtained by a member of the research team. Following discharge, a member of the research team will review the medical record to extract demographic data (age, sex), comorbid illnesses, primary admission diagnosis, frailty status, adverse events during mobilization (falls, dislodgements, and injuries), mobilization activities, length of critical care unit stay, length of hospital stay, mortality, and discharge location.

Intervention

On admission to the CICU, the patient’s treating nurse will assess the patient for the EM program. Patients participating in the EM program will be assessed for enrolment in our study by a member of the research team and will obtain informed consent during CICU admission (“intervention cohort”). The potential participants are likely to be competent and medically fit to be approached for informed consent as patients who are not medically fit will be excluded from the early mobilization program based on clinical factors, which include hemodynamic criteria.

The EM program consists of a progression of functional activities from LOF 0 (lowest mobility) to 5 (highest mobility). Each LOF has 3 primary activities designed to promote the patient to the next level. The nurse will begin with mobility activities based on the LOF that matches the patient’s current status. The nurse and clinical partner will attempt and/or complete each LOF activity once per shift. Physiotherapy assistance is available if required, although not obligatory. Nurses will also provide documentation and education to patients and families on

how to perform and assist with certain activities. LOF, activity attempts/completion, and adverse safety events will be recorded on an EM flowsheet. The intervention will start while the patient is in the CICU and will continue until discharge from the CICU.

To introduce the EM protocol to the nursing staff, the nurse and physician champion will provide a series of in-service training sessions. Physicians routinely caring for older adults in the CICU and rotating trainees will receive education in the CICU through “Lunch and Learn” conferences. Weekly audits will be performed by the nurse champion to assess for adherence to the EM protocol. Reminders and further education will be provided if necessary. Monthly status reports will be created and disseminated to the nurses and the CICU team.

Frailty will be assessed on admission using the Clinical Frailty Scale (CFS) by the patient’s nurse or a member of the research team (Appendix B).³² The CFS is a simple bedside assessment tool that uses a single global judgement-based measure to assign a score from 1 (very fit) to 9 (terminally ill) with increasing scores from 5 to 8 indicating more advanced frailty.²⁰ The CFS correlates with more comprehensive frailty tools, has been shown to accurately diagnose frailty in critically ill and acute cardiac populations, and provides short and long-term prognostic information.^{20, 21, 33}

Enrolled participants will be approached to participate in this prospective substudy. Patients accepting participation will be asked to wear an accelerometer monitor during CICU stay until the end of hospitalization to capture the time spent in each mobility position. Body composition parameters including skeletal muscle mass and fat mass will be measured daily with a segmental multi-frequency bioimpedance scale.

Instruments

The ActiGraph GT9X Link Bluetooth Activity Monitor (ActiGraph, Pensacola, Florida) is an activity monitoring device worn on the thigh that uses a 3-axis accelerometer and inclinometer to provide information on position (lying, sitting, and standing), and physical activity (time spent walking and exercise intensity). The ActiGraph GT9X Link has been shown to accurately and reliably identify lying, sitting, standing and activity in hospitalized inpatients recovering from acute or critical illness.³⁴ It is superior in position identification compared to other commonly used accelerometers that use a dual-axis approach.³⁵ The device uses Bluetooth to communicate with the ActiLife software, which uses validated algorithms to differentiate between the various mobility positions.³⁵ Tabular and graphic displays of position data are automatically reported by the software. The average battery life of the device is 14 days, ensuring that it will not require recharging in the vast majority of participants. The monitors are to be removed temporarily if participants will be exposed to water (i.e., shower). The device is reusable and will be cleaned using standard isopropyl alcohol-based solutions as clinically required for disinfection and by the research coordinator between participants. The device includes a wear time sensor that detects if the device has been removed in order to measure compliance. Five Actigraph monitors will be purchased, so that up to five patients can be enrolled in the accelerometer substudy at a given time. The cost for five Actigraph monitors, software, and necessary support is \$4,280. An application for Investigational Testing Authorization will be submitted to Health Canada for the use of the Actigraph monitoring system. The Actigraph monitor has already been approved for investigational use in another Canadian-based research study.³⁶

The InBody 770 segmental multi-frequency bioimpedance (BIA) scale has been validated for the determination of skeletal muscle mass (Appendix A). The BIA scales are currently

housed in the Frailty Assessment Unit of the JGH's cardiovascular ward and can be used at the point of care. The BIA scales provide a full analysis of body composition in less than 1 minute, including determination of skeletal muscle mass. There are no risks associated with the bioimpedance scale, except for patients with a permanent pacemaker or defibrillator, who will be excluded from this trial (the reason being that bioimpedance scale currents may disrupt the functioning of pacemakers or defibrillators).

Post-discharge follow-up

One month and 12-months post-discharge a member of the research team will call participants by phone to assess for health-related quality of life and functional status. The member of the research team will determine the current LOF and administer the Short-Form 36-Item Health Survey (SF-36) and Barthel index.

Outcome Measures

The primary outcome will be the LOF at CICU discharge and at 1 and 12 months post-hospitalization. Secondary outcomes are (1) Short Form (SF)-36 physical component summary score at 1 and 12 months, (2) SF-36 mental component summary score at 1 and 12 months, (3) Barthel index score at 1 and 12 months, (4) length of hospital stay, and (5) discharge to healthcare facility (including rehabilitation facility, convalescence, transfer to another acute care facility, and long-term care placement).

The SF-36 is a patient-reported survey of health and is the most widely used health-related quality of life instrument.⁵³ The physical and mental component scores are subsets of the SF-36 with score ranges from 0-100 and are calibrated for an average score of 50, using Canadian normative data, with higher scores indicating less disability.⁵⁴ The Barthel index is a disability measure validated in elderly cardiac patients that incorporates ten activities of daily living (i.e., feeding, dressing, incontinence).^{55, 56} Only two components of the Barthel index address mobility issues (transfer and mobility), so there is minimal direct overlap with the LOF scale score. The score range is 0–20, with lower scores indicating increased disability.

In the patients wearing the accelerometer, data will be recorded on the total time spent in each mobility position, the daily average time spent in each mobility position, the average duration of time for each bout of sitting, standing, and walking, and sleep duration. The step count will also be recorded. The change in skeletal muscle mass from CICU admission to hospital discharge will be recorded.

We will determine which covariates predict improvement in LOF (“responsiveness”) and which ones do not (“non-responsiveness”). We will assess the recovery of physical function at 1 month and 12 months as measured by the SF-36 physical component summary score. We will compare the SF-36 scores of the highest scoring tertile of LOF on hospital discharge with the lowest scoring tertile. We will also compare hospital readmission at 30 days and discharge home vs. healthcare facility.

For safety, we will record the composite and individual components of the number of falls, injuries, and dislodgements over the total number of attempted mobility activities. The results from the intervention cohort will be compared to the pre-intervention cohort for all results.

Data Collection Procedures

Following discharge, a member of the research team will capture the following hospitalization data from the electronic medical record (Chartmaxx, Quest Diagnostics, Madison, New Jersey) for each subject: age, sex, primary admission diagnosis, comorbidities, level of function assessments, CFS score, length of CICU stay, length of hospital stay, discharge location, and referral to cardiac rehabilitation.

Availability of Participants

In the fiscal year 2016-2017, there were 1,356 admissions to the JGH CICU (mean age 68 years old; 477 female (35%)). There were 1,034 patients (76.3%) age ≥ 60 years old. The mean CICU length of stay was 3.3 days and the mean hospital length of stay was 9.5 days. Only one in five patient stays was less than 24 hours in length.

From the pilot data, we conservatively estimate that about one-third of patients will not be eligible for the study and about 70% will agree to participate. We estimate that the loss of patients to 12 month follow-up will be approximately 10% as the vast majority of CICU patients are followed by hospital-affiliated cardiologists prior to admission or are assigned to one following CICU discharge. Given these estimates, approximately 75 patients are expected to be enrolled and followed during the pre-intervention period and 300 patients are expected to be enrolled and followed during the 12 month intervention period.

Data Analysis

Since the response variable, LOF mobility, is an ordinal variable measured at different timepoints, a cumulative logit model for repeated measurements will be fitted using generalized estimating equations. The model permits us to take into consideration the structure of the correlation between the observations. The model will then be adjusted using covariates of interest, such as age, sex, EM adherence, time spent lying in bed, and illness severity score. Predictors of change in LOF during CICU stay and following hospitalization will be assessed using linear regression. Predictors of EM adherence will also be evaluated using linear regression. All statistical analyses will be performed using SAS version 9.4 by Dr. Abbas Kezouh, a senior biostatistician affiliated with the Lady Davis Institute Center for Epidemiology.

VII. RESOURCE AVAILABILITY AND SUPPORT

The CICU at the JGH has 16 beds equipped for advanced hemodynamic support and 32 ward beds with telemetry available. Patients are admitted to the CICU mainly for acute primary cardiovascular disease.

The nurse champion's role is to attend EM team meetings, provide education to nursing and clinical partners, and ensure nursing adherence to the protocol. A review of the CICU environment conducted with physiotherapists from the EM team has ensured that the CICU is already equipped with the standard equipment necessary for patient mobilization, particularly for bedbound and immobile patients, and nurses have been trained to use the equipment.

A research assistant will be based in the Division of Cardiology at the JGH and will have a dedicated space and workstation with computer access in the clinical research department. The research assistant will be responsible for obtaining informed consent, extracting data from the patient record, putting it into the database system, auditing nursing adherence to the study protocol, publishing monthly status updates, and interviewing patients by phone. Funds to support a research assistant on a part-time basis (20 hours per week) will be provided for a one-year period by the JGH's Division of Cardiology.

The EM team has support and representation from leaders in various disciplines at the JGH including Diane Brault, the head of the CICU nursing department, Dr. Lawrence Rudski, Chief of the JGH Division of Cardiology and Director of the Integrated Cardiovascular Science Program, Dr. Jean-Francois Morin, Chief of Cardiac Surgery, and Dr. Richard Sheppard, Director of the CICU.

The JGH’s Division of Cardiology has given me approximately 50% protected research time with a salary support of \$50k per annum to pursue my research program. I also receive a salary support for research of \$20k per annum from the JGH’s Department of Medicine. Funds to support a research assistant on a part-time basis (20 hours per week) for a 1 year period – renewable for up to 3 years - will be provided by the cardiology division as well.

VIII. KNOWLEDGE DISSEMINATION

We will develop simple to follow instructional materials, including the detailed EM protocol and videos on how to perform the level of function assessment and mobility activities. These will be made available on a dedicated web portal.

We intend to publish the EM protocol and the study results in a peer-reviewed cardiology journal, as well as present the findings at a major national cardiology conference. Through membership in the Canadian Cardiovascular Critical Care Society, a member society of the Canadian Cardiovascular Society, the results of the study will be disseminated to healthcare professionals involved in acute cardiovascular care.

In order to gauge the value of the EM program in the CICU, we will use the Information Assessment Method (IAM),^{38, 39} a self-administered 1-page questionnaire endorsed by the Canadian Institute for Health Research. We will distribute the professional and patient versions of the IAM to healthcare staff and to patients involved in the EM program, respectively. The IAM is used to systematically evaluate the (1) acquisition and relevance of new information, (2) practical impact, (3) expected health benefits, and (4) intent to use the information and associated barriers or facilitators. We will review the IAM responses to understand the factors associated with the EM program and to generate recommendations and feedback to the participants.

IX. POTENTIAL CHALLENGES & MITIGATION STRATEGIES

The study will attempt to directly address frequently reported barriers to EM implementation.¹⁸ Biweekly multidisciplinary EM team meetings and availability of the physician and nurse champion will ensure any issues that arise will be dealt with promptly.

Barriers for EM	Solution Strategy
Lack of knowledge and training	Education by physician and nurse champions to healthcare staff
No written protocols or guidelines	A simple, straightforward written protocol
Inadequate equipment	Standard critical care mobility equipment is available
Requirement for intensive physiotherapy involvement	Nurse-led protocol with physiotherapist consultation availability
Requirement for physician orders prior to mobilization	No requirement for physician orders prior to mobilization
Not an institutional priority	Support and involvement by hospital leadership
Concern over medical instability	Exclusion criteria based on safety parameters
Delayed recognition of suitable patients to mobilize	Screening patients on admission for EM and re-screening each shift for suitability.

Concern over dislodgement of tubes, lines or devices	Education of nursing and clinical partners on proper mobilization techniques Education of healthcare team of low rates of adverse events found in prior studies
--	--

X. QUALIFICATIONS

I am a clinician-scientist trained in both cardiology and experimental medicine at McGill University and critical care medicine at Cedars-Sinai Medical Center. Over the past 3 years, I have had 11 publications (10 as first author) and was a co-author on the State-of-the-Art paper on the future of the field of Cardiac Intensive Care published in the Journal of the American College of Cardiology.⁴⁰ My primary research interest has been improving outcomes in older adults with acute cardiovascular disease. My Master’s thesis (in submission process) focused on the impact of frailty in older adults undergoing invasive cardiac interventions.⁴¹ I was involved with the EM program during my critical care medicine fellowship.

XI. TIMETABLE

	Months 0-3	Months 4-16	Months 17-22	Months 23-30	Months 31-36
Obtain ethics approval	X				
Pre-intervention period	X				
Intervention period		X			
Post-discharge follow-up		X	X	X	
Data analysis				X	
Manuscript submission				X	X
Knowledge translation					X

XII. POTENTIAL IMPACT OF THE STUDY

The proposed study will generate much needed evidence for the safety, efficacy, and feasibility of a structured EM program in older patients with acute cardiovascular disease. The simple, practical EM protocol and the knowledge translation plan are designed to educate cardiologists involved in acute care and encourage the implementation of EM programs as routine practice into CICUs.

XII. REFERENCES

1. Lilly CM, Zuckerman IH, Badawi O and Riker RR. Benchmark data from more than 240,000 adults that reflect the current practice of critical care in the United States. *Chest*. 2011;140:1232-1242.
2. Mattison ML, Rudolph JL, Kiely DK and Marcantonio ER. Nursing home patients in the intensive care unit: Risk factors for mortality. *Crit Care Med*. 2006;34:2583-7.
3. de Rooij SE, Abu-Hanna A, Levi M and de Jonge E. Factors that predict outcome of intensive care treatment in very elderly patients: a review. *Critical Care*. 2005;9:R307-R314.
4. Kress JP and Hall JB. ICU-acquired weakness and recovery from critical illness. *The New England journal of medicine*. 2014;371:287-8.

5. Adler J and Malone D. Early mobilization in the intensive care unit: a systematic review. *Cardiopulm Phys Ther J.* 2012;23:5-13.
6. Engel HJ, Needham DM, Morris PE and Gropper MA. ICU early mobilization: from recommendation to implementation at three medical centers. *Crit Care Med.* 2013;41:S69-80.
7. Boyd CM, Landefeld CS, Counsell SR, Palmer RM, Fortinsky RH, Kresevic D, Burant C and Covinsky K. Recovery in Activities of Daily Living Among Older Adults Following Hospitalization for Acute Medical Illness. *Journal of the American Geriatrics Society.* 2008;56:2171-2179.
8. Dolansky MA and Moore SM. Older adults' early disability following a cardiac event. *West J Nurs Res.* 2008;30:163-80.
9. Burtin C, Clerckx B, Robbeets C, Ferdinande P, Langer D, Troosters T, Hermans G, Decramer M and Gosselink R. Early exercise in critically ill patients enhances short-term functional recovery. *Crit Care Med.* 2009;37:2499-505.
10. Kayambu G, Boots R and Paratz J. Physical therapy for the critically ill in the ICU: a systematic review and meta-analysis. *Crit Care Med.* 2013;41:1543-54.
11. MacKenzie E, Patel BK, Wolfe KS, Pohlman AS, Hall JB and Kress JP. Long-Term Cognitive Outcomes of Mechanically Ventilated Patients in a Randomized Controlled Trial of Early Mobilization *A25 CRITICAL CARE: FUNCTIONAL OUTCOMES IN ICU SURVIVORS:* American Thoracic Society; 2016: A1176-A1176.
12. Lord RK, Mayhew CR, Korupolu R, Manthey EC, Friedman MA, Palmer JB and Needham DM. ICU early physical rehabilitation programs: financial modeling of cost savings. *Crit Care Med.* 2013;41:717-24.
13. Needham DM, Korupolu R, Zanni JM, Pradhan P, Colantuoni E, Palmer JB, Brower RG and Fan E. Early physical medicine and rehabilitation for patients with acute respiratory failure: a quality improvement project. *Archives of physical medicine and rehabilitation.* 2010;91:536-42.
14. Morris PE, Griffin L, Berry M, Thompson C, Hite RD, Winkelman C, Hopkins RO, Ross A, Dixon L, Leach S and Haponik E. Receiving early mobility during an intensive care unit admission is a predictor of improved outcomes in acute respiratory failure. *The American journal of the medical sciences.* 2011;341:373-7.
15. Taito S, Shime N, Ota K and Yasuda H. Early mobilization of mechanically ventilated patients in the intensive care unit. *Journal of intensive care.* 2016;4:50.
16. Sricharoenchai T, Parker AM, Zanni JM, Nelliot A, Dinglas VD and Needham DM. Safety of physical therapy interventions in critically ill patients: a single-center prospective evaluation of 1110 intensive care unit admissions. *Journal of critical care.* 2014;29:395-400.
17. Winkelman C. Inactivity and inflammation in the critically ill patient. *Critical care clinics.* 2007;23:21-34.
18. Koo KK, Choong K, Cook DJ, Herridge M, Newman A, Lo V, Guyatt G, Priestap F, Campbell E, Burns KE, Lamontagne F and Meade MO. Early mobilization of critically ill adults: a survey of knowledge, perceptions and practices of Canadian physicians and physiotherapists. *CMAJ Open.* 2016;4:E448-e454.
19. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, Abellan van Kan G, Andrieu S, Bauer J, Breuille D, Cederholm T, Chandler J, De Meynard C, Donini L, Harris T, Kannt A, Keime Guibert F, Onder G, Papanicolaou D, Rolland Y, Rooks D, Sieber C, Souhami E, Verlaan S and Zamboni M. Sarcopenia: an undiagnosed condition in older adults. *Current*

- consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc*. 2011;12:249-56.
20. Bagshaw SM, Stelfox HT, McDermid RC, Rolfson DB, Tsuyuki RT, Baig N, Artiuch B, Ibrahim Q, Stollery DE, Rokosh E and Majumdar SR. Association between frailty and short- and long-term outcomes among critically ill patients: a multicentre prospective cohort study. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*. 2014;186:E95-102.
 21. Kang L, Zhang S-Y, Zhu W-L, Pang H-Y, Zhang L, Zhu M-L, Liu X-H and Liu Y-T. Is frailty associated with short-term outcomes for elderly patients with acute coronary syndrome? *Journal of Geriatric Cardiology : JGC*. 2015;12:662-667.
 22. Zomorodi M, Topley D and McAnaw M. Developing a mobility protocol for early mobilization of patients in a surgical/trauma ICU. *Critical care research and practice*. 2012;2012:964547.
 23. Holland EM and Moss TJ. Acute Noncardiovascular Illness in the Cardiac Intensive Care Unit. *Journal of the American College of Cardiology*. 2017;69:1999-2007.
 24. Castro-Avila AC, Seron P, Fan E, Gaete M and Mickan S. Effect of Early Rehabilitation during Intensive Care Unit Stay on Functional Status: Systematic Review and Meta-Analysis. *PLoS One*. 2015;10:e0130722.
 25. G. P. Early Mobilization and Ambulation in Hospitalized Heart Failure Patients: A Rapid Review. 2013.
 26. Lauck SB, Wood DA, Baumbusch J, Kwon J-Y, Stub D, Achtem L, Blanke P, Boone RH, Cheung A, Dvir D, Gibson JA, Lee B, Leipsic J, Moss R, Perlman G, Polderman J, Ramanathan K, Ye J and Webb JG. Vancouver Transcatheter Aortic Valve Replacement Clinical Pathway. *Minimalist Approach, Standardized Care, and Discharge Criteria to Reduce Length of Stay*. 2016;9:312-321.
 27. Research CIoH. Canada's Strategy for Patient-Oriented Research: Improving health outcomes through evidence-informed care. 2011;2017.
 28. Forman DE, Arena R, Boxer R, Dolansky MA, Eng JJ, Fleg JL, Haykowsky M, Jahangir A, Kaminsky LA, Kitzman DW, Lewis EF, Myers J, Reeves GR, Shen WK, American Heart Association Council on Clinical C, Council on C, Stroke N, Council on Quality of C, Outcomes R and Stroke C. Prioritizing Functional Capacity as a Principal End Point for Therapies Oriented to Older Adults With Cardiovascular Disease: A Scientific Statement for Healthcare Professionals From the American Heart Association. *Circulation*. 2017;135:e894-e918.
 29. Hoffer LJ and Bistran BR. Appropriate protein provision in critical illness: a systematic and narrative review. *The American Journal of Clinical Nutrition*. 2012;96:591-600.
 30. Verceles AC and Hager ER. Use of Accelerometry to Monitor Physical Activity in Critically Ill Subjects: A Systematic Review. *Respiratory care*. 2015;60:1330-6.
 31. Hodgson CL, Stiller K, Needham DM, Tipping CJ, Harrold M, Baldwin CE, Bradley S, Berney S, Caruana LR, Elliott D, Green M, Haines K, Higgins AM, Kaukonen KM, Leditschke IA, Nickels MR, Paratz J, Patman S, Skinner EH, Young PJ, Zanni JM, Denehy L and Webb SA. Expert consensus and recommendations on safety criteria for active mobilization of mechanically ventilated critically ill adults. *Critical care (London, England)*. 2014;18:658.
 32. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I and Mitnitski A. A global clinical measure of fitness and frailty in elderly people. *Cmaj*. 2005;173:489-95.

33. Ekerstad N, Swahn E, Janzon M, Alfredsson J, Lofmark R, Lindenberg M and Carlsson P. Frailty is independently associated with short-term outcomes for elderly patients with non-ST-segment elevation myocardial infarction. *Circulation*. 2011;124:2397-404.
34. Anderson JL, Green AJ, Yoward LS and Hall HK. Validity and reliability of accelerometry in identification of lying, sitting, standing or purposeful activity in adult hospital inpatients recovering from acute or critical illness: a systematic review. *Clinical rehabilitation*. 2018;32:233-242.
35. Pfister T, Matthews CE, Wang Q, Kopciuk KA, Courneya K and Friedenreich C. Comparison of two accelerometers for measuring physical activity and sedentary behaviour. *BMJ Open Sport & Exercise Medicine*. 2017;3.
36. study C. CHILD Study. 2018.
37. Brazier JE, Harper R, Jones NM, O'Cathain A, Thomas KJ, Usherwood T and Westlake L. Validating the SF-36 health survey questionnaire: new outcome measure for primary care. *BMJ (Clinical research ed)*. 1992;305:160-4.
38. Pluye P, Grad RM, Johnson-Lafleur J, Bambrick T, Burnand B, Mercer J, Marlow B and Campbell C. Evaluation of email alerts in practice: Part 2. Validation of the information assessment method. *J Eval Clin Pract*. 2010;16:1236-43.
39. Pluye P, Granikov V, Bartlett G, Grad RM, Tang DL, Johnson-Lafleur J, Shulha M, Barbosa Galvao MC, Ricarte IL, Stephenson R, Shohet L, Hutsul JA, Repchinsky CA, Rosenberg E, Burnand B, Legare F, Dunikowski L, Murray S, Boruff J, Frati F, Kloda L, Macaulay A, Lagarde F and Doray G. Development and content validation of the information assessment method for patients and consumers. *JMIR Res Protoc*. 2014;3:e7.
40. Katz JN, Minder M, Olenchock B, Price S, Goldfarb M, Washam JB, Barnett CF, Newby LK and van Diepen S. The Genesis, Maturation, and Future of Critical Care Cardiology. *Journal of the American College of Cardiology*. 2016;68:67-79.
41. Goldfarb M, Bendayan M, Rudski LG, Morin JF, Langlois Y, Ma F, Lachapelle K, Cecere R, DeVarences B, Tchervenkov CI, Brophy JM and Afilalo J. Cost of Cardiac Surgery in Frail Compared With Nonfrail Older Adults. *Can J Cardiol*. 2017;33:1020-1026.

Appendix A: **Validation Studies of Segmental Multi-Frequency Bioimpedance (BIA)**

Study	N	Population	Fat Free Mass Mean ± SD	Correlation vs. DXA R	Bland-Altman vs. DXA Mean Difference (95% CI)
Alves 2014	55	Stable heart failure patients	57 ± 9 ♂ 39 ± 6 ♀	0.93	+0.1 (-4.9, +5.1)
Kim 2013	129	Community-dwelling women aged 75+	30.6 ± 3.5 ♀	0.92	-2.1 (-2.8, -1.8)
Furstenberg 2010	53	Hemodialysis patients	45.7 ± 10.1	-	+0.5 (-0.7, +1.7)
Bosy-Westphal 2013	254	Healthy volunteers aged 18-65	65.4 ± 6.6 ♂ 55.4 ± 11.8 ♀	0.99	+0.05 (-3.7, +3.7)
Leahy 2012	403	Healthy volunteers aged 18-29	66.7 ± 6.4 ♂ 46.2 ± 4.0 ♀	-	+0.6 (-4.9, +6.0) ♂ +2.0 (-2.1, +6.2) ♀
Ling 2011	484	Middle-aged adults from Leiden Longevity Study	63.6 ± 7.0 ♂ 46.5 ± 5.2 ♀	0.98	-1.5 (-4.0, +1.1) ♂ -0.8 (-3.2, +1.6) ♀
Shafer 2009	132	Healthy volunteers aged 19-72	68.1 ♂ 45.9 ♀	-	+0.3

