English summary

Background

There is an urgent need to reduce the risk of readmission and other negative health outcomes among older medical patients. Frailty is a state of increased vulnerability that increases the risk of readmission. The tripartite Multidimensional Prognostic Index (MPI) is a valid frailty measure based on the Comprehensive Geriatric Assessment. However, it requires skilled clinicians, compliant patients, and its use is limited to real-time frailty assessment. Thus, a retrospective MPI rating method is desired and may be obtained entirely from the electronic medical record.

Multiple transitional care interventions have aimed to reduce readmission risk, with diverging results. It has been previously shown that an early post-discharge multidisciplinary geriatric team home visit-based intervention reduced readmissions among geriatric patients, when compared to usual care. A municipality nurse-led intervention following hospital discharge could be an attractive alternative, for example, in sparsely populated areas, and may be just as effective as the geriatric team intervention.

Aims

To examine the reproducibility and diagnostic accuracy of a new, retrospective record-based MPI assessment method. To examine the predictive value of the record-based MPI among older medical patients receiving usual transitional care. To compare a municipality nurse-led intervention to a multidisciplinary geriatric team intervention among frail geriatric patients.

Methods

Three studies were conducted to address these issues. Frailty was defined as a bedside MPI>1. First, the reproducibility and the diagnostic accuracy of the record-based MPI was compared to bedside. Second, we examined the record-based method's ability to predict one-year and 90-day mortality and 30-day readmission in an external cohort of older (75+) medical patients discharged from a secondary regional hospital. Third, in a randomised controlled trial (RCT), frail older geriatric patients were randomly allocated 1:1 to receive an early multidisciplinary geriatric team-based transitional care intervention *or* an early municipality nurse-led transitional care intervention after hospital discharge. The primary outcome was 30-day unplanned readmission; secondary outcomes were 90-day mortality and length of hospital stay (LOS).

Results

First, the record-based MPI was reliable and accurate among older medical patients with a frailty prevalence of 90%. The record-based MPI and the bedside MPI had good agreement. The reliability of the record-based MPI was good (intraclass correlation coefficient (ICC)=0.83). The diagnostic accuracy was considerable. Second, the record-based MPI had good discriminative ability and was predictive of short and long-term mortality. Frail patients had a hazard ratio for one-year mortality between 3.3 and 7.1, compared to patients with an MPI<1. Frailty was associated with a two-fold increased relative risk of readmission. Third, the geriatric team intervention was superior to the municipality nurse-led intervention with regard to readmission. The odds ratio was 1.27, p=0.008. There were no significant differences in mortality or LOS.

Conclusions and perspectives

The record-based MPI is a valid method for retrospective frailty assessment among older medical patients with high a priori frailty prevalence. Its predictive value with regard to mortality is comparable to the original MPI. It can be used at a distance and even among older adults with reduced cognitive capacity. Record-based multidimensional frailty assessment seems highly useful for research purposes. Frailty assessment methods may play an important role in further targeting transitional care interventions in the future. An early, multidisciplinary geriatric team-based transitional care intervention was superior to an early, municipality nurse-led transitional care intervention with regard to readmission among selected, frail older geriatric patients. Future research should aim to compare the interventions to usual care and to further target the interventions, for example, based on type of dwelling after hospital discharge.

Dansk resume

Baggrund

Der er et påtrængende behov for at reducere risikoen for genindlæggelse og andre negative følger efter hospitalsindlæggelse hos ældre medicinske patienter. Skrøbelighed er en tilstand præget af øget sårbarhed, som øger risikoen for genindlæggelse. Det validerede Multidimensional Prognostic Index (MPI) kan benyttes til vurdering af tre grader af skrøbelighed. Det er baseret på den geriatriske helhedsvurdering (Comprehensive Geriatric Assessment, CGA). Anvendelsen af MPI kræver oplæring af det kliniske personale og at patienterne er i stand til at medvirke ved vurderingen. En retrospektiv metode til vurdering af skrøbelighed med baggrund i MPI er derfor meget ønskværdig, og kan formentlig opnås ud fra den elektroniske patientjournal.

Adskillige metoder til håndtering af sektorovergange er afprøvet med henblik på at reducere risikoen for genindlæggelse. Resultaterne har været divergerende. Det er tidligere vist, at en intervention bestående af tidlig opfølgning med hjemmebesøg fra et udekørende, tværfagligt geriatrisk team kunne reducere genindlæggelsesrisikoen markant blandt geriatriske patienter. En intervention ledet af en kommunal hjemmesygeplejerske kunne være et attraktivt alternativ til opfølgning ved det udekørende geriatriske team, for eksempel i sparsomt befolkede områder, og kan muligvis være ligeså effektivt til at reducere genindlæggelsesrisikoen.

Formål

At undersøge reproducerbarheden og den diagnostiske nøjagtighed af en ny retrospektiv metode til evaluering af skrøbelighed, baseret udelukkende på den elektroniske patientjournal. At undersøge den prædiktive værdi af den journal-baserede metode blandt ældre medicinske patienter, som modtager vanlig behandling og opfølgning efter udskrivelse. At sammenligne en intervention ledet af en kommunal hjemmesygeplejerske med en intervention baseret på et multidisciplinært geriatrisk team blandt skrøbelige geriatriske patienter.

Metoder

Vi udførte tre studier for at adressere formålene. Skrøbelighed blev defineret som MPI>1. Først undersøgte vi den journal-baserede MPI-metodes reproducerbarhed og diagnostiske nøjagtighed ved at sammenligne med en MPI-vurdering foretaget mens patienten var til stede. Dernæst undersøgte vi den journal-baserede metodes evne til prædiktion af etårs- og 90-dages dødeligheden, samt 30-dages genindlæggelsesraten i en ekstern kohorte bestående af ældre (75+) medicinske patienter udskrevet fra et regionshospital. I et

randomiseret, kontrolleret studie blev skrøbelige ældre geriatriske patienter allokeret 1:1 til at modtage enten en tidlig geriatrisk team-baseret intervention *eller* en intervention ledet af en kommunal hjemmesygeplejerske efter udskrivelse fra hospitalet. Det primære effektmål var 30-dages genindlæggelse, og de sekundære endemål var 90-dages dødelighed og indlæggelsesvarighed.

Resultater

Det første studie viste at det journal-baserede MPI var pålideligt og diagnosticerede præcist blandt en gruppe af ældre medicinske patienter, hvor skrøbeligheds-prævalensen var 90%. Det journal-baserede MPI havde god overensstemmelse med MPI foretaget i patientens nærvær. Reliabiliteten (reliability) var god (intraclass correlation coefficient (ICC)=0.83). Den diagnostiske nøjagtighed var betragtelig. Det andet studie viste at det journal-baserede MPI havde god prædiktionsevne i forhold til korttids- og langtidsdødeligheden. Skrøbelige patienter havde en hazard ratio for etårs-dødelighed mellem 3.3 og 7.1, sammenlignet med patienter med et MPI<1. Skrøbelighed var associeret med en fordoblet risiko for genindlæggelse. Det tredje studie viste, at med hensyn til genindlæggelse var en geriatrisk team-baseret intervention bedre end en intervention ledet af en kommunal hjemmesygeplejerske. Odds ratio for genindlæggelse var 1.27, p=0.008. Der var ingen signifikant forskel i dødeligheden eller indlæggelsesvarigheden.

Konklusioner og perspektiver

Det journal-baserede MPI er en valid metode til retrospektiv skrøbelighedsvurdering blandt ældre medicinske patienter med en høj a priori forekomst af skrøbelighed. Metodens prædiktive værdi med hensyn til dødelighed er sammenlignelig med den originale MPI metode. Det journal-baserede MPI kan benyttes på afstand af patienten, og endda blandt ældre med nedsat kognitiv funktionsevne. Metoden synes at have høj anvendelighed til forskningsmæssige formål. Metoder til vurdering af skrøbelighed kan formentlig spille en vigtig rolle I at målrette interventionerne på sektorovergangene i fremtiden. Blandt udvalgte, skrøbelige ældre geriatriske patienter var en tidlig, tværfaglig intervention baseret på et udekørende geriatrisk team bedre til at reducere antallet af genindlæggelser end en tidlig intervention ledet af en kommunal hjemmesygeplejerske. Fremtidige studier bør sigte mod at sammenligne interventioner på sektorovergangen med vanlig opfølgning, og på at målrette indsatserne yderligere, for eksempel med udgangspunkt i patientens opholdssted efter udskrivelse.

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List of papers

I:

Hansen, TK; Damsgaard, EM; Shahla, S; Bruun, JM; Gregersen, M.
"A reliable and record-based frailty assessment method for older medical inpatients"

European Geriatric Medicine, June 2020

II:

Hansen, TK; Shahla, S; Damsgaard, EM; Bossen, SRL; Bruun, JM; Gregersen, M.
"Mortality and readmission risk can be predicted by the record-based Multidimensional Prognostic Index: a cohort study of medical inpatients older than 75 years"

European Geriatric Medicine, January 2021

III:

Hansen, TK; Pedersen, LH; Shahla, S; Damsgaard, EM; Bruun, JM; Gregersen, M.
"Effects of a new early municipality-based versus a geriatric team-based transitional care intervention on readmission and mortality among frail older patients – a randomised controlled trial"

Archives of Gerontology and Geriatrics, August 2021

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Trøjborg, Aarhus N
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Troels Kjærskov Hansen

Abbreviations

AUH	Aarhus University Hospital
AUROC	Area Under the Receiver Operating Characteristic curve (ROC)
CRS	Civil Registration System
CCI	Charlson Comorbidity Index
CGA	Comprehensive Geriatric Assessment
CI	Confidence Interval
CIRS-G	Cumulative Illness Rating Scale – Geriatrics
ED	Emergency Department
ESS	Exton Smith Scale
FRS-ADL	Functional Recovery Score – Activities of Daily Living
FRS-IADL	Functional Recovery Score – Instrumental Activities of Daily Living
GP	General Practitioner
HAH	Hospital at Home
HR	Hazard Ratio
ICC	Intraclass Correlation Coefficient
ITT	Intention-to-Treat
IQR	Inter Quartile Range
LOA	Limits of Agreement
LOS	Length of Stay
mITT	modified Intention-to-Treat
MMSE	Mini-Mental State Examination
MNA-SF	Mini Nutritional Assessment – Short Form
MPI	Multidimensional Prognostic Index
NVP	Negative Predictive Value
OR	Odds Ratio
PPI	Patient and Public Involvement
PPV	Positive Predictive Value
RCT	Randomised Controlled Trial
RR	Relative Risk
RRH	Randers Regional Hospital
SD	Standard Deviation
SPMSQ	Short Portable Mental Status Questionnaire
TCI	Transitional Care Intervention

1 Introduction and background

Pressure on the health care system in both the primary and secondary sectors is rising because of fewer hospital beds per capita, shorter length of hospital stay, shortage of healthcare personnel, and shunting of recovering patients towards the primary care sector.

Meanwhile, the demographic trend of rapidly ageing populations and increasing life expectancy further accentuates the urge for action (1). Development of the existing services and formation of new initiatives is in high demand.

It has previously been documented by colleagues in the Geriatric Department, Aarhus University Hospital (AUH), Aarhus, Denmark, that an early, geriatric team-based transitional care intervention (TCI) was able to reduce readmission risk and mortality among selected geriatric patients admitted with high-risk diagnoses, for example, infections, heart failure, and dehydration (2-5). The intervention was compared to usual care, which included varying degrees of follow-up by the municipal home care, general practitioner (GP), and the district nurse (6). On the one hand, the geriatric intervention has often been criticised for being too unrealistic to be applied outside the range of tertiary hospitals, for example, in sparsely populated areas, and for being an expensive solution to a task that is traditionally handled by primary care. On the other hand, use of the usual care follow-up model has also been disputed (7, 8). It is proposed that a home visit-based intervention conducted by nurse practitioners, who are often familiar with the patient and relatives and are at home in the primary health sector, could be effective (9-12). A nurse-based intervention could be as good as (or even better than) the hospital-based geriatric team. This question needs to be examined further because the need for feasible and effective interventions is increasing, while resources are under pressure. We therefore decided to conduct a randomised controlled trial (RCT) comparing a novel, municipality nurse-led intervention to our established geriatric team-based model (2-5).

In this PhD dissertation, three post-discharge care approaches intended for frail older medical patients during the transition from the hospital to the community will be presented and discussed. The new municipality nurse-led transitional care intervention was compared with the previously tested and ongoing geriatric team intervention (study III of this dissertation). Furthermore, we wanted to put the results into the perspective of today's usual care by looking at a comparator group from a secondary regional hospital (study II of this dissertation). This revealed the need for an easy, retrospective and record-based method to assess frailty (study I of this dissertation).

In the following, important concepts such as frailty, comprehensive geriatric assessment, and transitional care models will be briefly described to provide the background

for the following, focused literature review. Next, the aims, methods, and results are presented before the Discussion and Conclusions sections. The three studies are attached in their full length at the end of the dissertation. For a complete overview of the dissertation, please refer to the Table of Contents on pages 6-8.

1.1 The population in focus

The people in focus in this dissertation are frail older adults (75+) who were admitted to hospital because of an acute medical condition. We decided to focus on those who were either reliant on daily caretaker assistance and/or living with a minimum level of comorbidity (Charlson Comorbidity Index (CCI)≥1), as we wanted to focus on older adults with an expected need for transitional care. The population represents a wide range of older adults living in society, ranging from comorbid but self-sufficient community dwellers to 24h care-dependent, chronically ill, and terminal people in the late autumn of life.

Frailty is defined as *"a state of increased vulnerability to poor resolution of homoeostasis after a stressor event"* (13). Frail patients are prone to sudden, inappropriate health status changes because of reduced physical resilience and robustness (13). Frailty increases the risk of negative health events such as readmission (13-16). Most acute medical conditions, care-related problems, and other events leading to readmission emerge after discharge (17). Frailty and readmission may in turn lead to a vicious circle of loss of functional capacity, prolonged hospitalisation, and death (14, 18). Acute hospitalisation and transfer from the hospital environment back to the community are examples of stressful events that may lead to further deterioration of health in a frail older person.

Consequently, older persons at risk of frailty-associated events must be identified to initiate a timely and appropriate intervention, for example, by using a frailty assessment tool or a clinical assessment model including frailty evaluation.

1.2 The Comprehensive Geriatric Assessment and evaluation of frailty

The Comprehensive Geriatric Assessment (CGA) *"is a multidimensional diagnostic and therapeutic process that is focused on determining a frail older person's medical, functional, mental, and social capabilities and limitations with the goal of ensuring that problems are identified, quantified, and managed appropriately"* (19). It is considered the gold standard of multidisciplinary assessment and care planning for older patients (20). Frailty identification and assessment are important, constituent parts of the CGA.

1.3 Frailty assessment models and tools

Three main models of frailty identification and assessment exist: 1) the phenotype model (18), the cumulative deficits model (21, 22), and 3) the multidimensional model (23, 24). Another classification is based on the mode of the assessment, for example, the Clinical Frailty Scale (CFS) (22) can be assessed face-to-face with minimal interaction with the patient, whereas the Edmonton Frail Scale (EFS) (25) is an interview-based model. Other examples are the medical record audit-based Elders Risk Assessment Index (ERA) (26), and two diagnose-based measures, the Hospital Frailty Risk Score (HFRS) (27) and the electronic Frailty Index (eFI) (28).

1.4 The Multidimensional Prognostic Index

The Multidimensional Prognostic Index (MPI) was introduced in our department as part of a nationally funded project, and all staff members have been trained to collect data for the MPI (29). The MPI is a systematic, CGA-based assessment tool that combines assessment according to six standardised scales and information on medications and social support network in an aggregated score (23, 24). In a systematic review, the MPI was one of the frailty tools with the highest sensitivity (30). Moreover, multidimensional frailty scores have high agreement and low absolute error (31). The MPI score is often converted to a tripartite risk classification, defining patients at low risk (MPI score 0-0.33; MPI risk grade 1), moderate risk (MPI score 0.34-0.66, MPI risk grade 2), and high risk (MPI score 0.67-1; MPI grade 3)(24). The MPI was developed and validated to assess and predict risk of mortality (24), and has since shown its value in prediction of other frailty-associated outcomes: rehospitalisation (32-34), length of hospital stay (LOS) (35-37), and institutionalisation and access to home care services (32, 37, 38). Moreover it has turned out to be a flexible measure with great plasticity (39), allowing for replacement of the individual items with parallel scores (for example, MNA-SF (40) instead of the MNA (41, 42) and the MMSE (43) instead of the SPMSQ (44)). In addition to this, a self-assessment version for community dwelling persons (SELFY-MPI) (45, 46), a phone-based version (TELE-MPI) (47), and several other variants have been developed and applied in multiple populations (39). The method also shows flexibility regarding the timing of the assessment (48). These factors make the MPI highly applicable and instrumental in a geriatric research and clinical setting, and it was therefore chosen for the studies included in this dissertation.

Despite the many advantages, the original MPI is limited by the requirement for real-time, face-to-face assessment; compliant patients; and/or assisting relatives or caretakers. Prospective assessment of large patient cohorts requires multiple, trained raters.

These limitations call for a reliable, retrospective MPI assessment method, for example, one based on the information contained in the medical records.

1.5 Transitional Care Interventions

Transitional care can be defined as *"a set of actions designed to ensure the coordination and continuity of health care as patients transfer between different locations or different levels of care within the same location"* (49). This dissertation focuses on the clinical interventions applied in transitional care on the interface between 1) the hospital and 2) the potential post-discharge residences, for example, the patients' own homes or rehabilitation and nursing homes.

Transitional care interventions (TCIs) on the interface between the hospital and the primary care sector comprise three main categories:

1) pre-discharge interventions
2) bridging interventions containing both pre- and post-discharge components
3) post-discharge interventions

An example of a pre-discharge intervention is "early discharge planning" (50, 51), where discharge is continuously planned already from the patient's arrival at the emergency department (ED). An example of a bridging intervention is in-hospital assessment followed by home follow-up by a nurse (9). Finally, an example of a post-discharge intervention is a GP-/district nurse-based follow-up home visit (6). Multiple intervention models exist, based on a great number of health care professions such as hospital/district/practice nurses (see Table 1: Review of the literature), GPs/primary care physicians (6, 7, 52-55), occupational therapists (56, 57), social workers (58-63), pharmacists (64-84), and many more. Some interventions are conceptual frameworks, for example, Coleman's Care Transition Intervention (CTI) (85) is a four-week coaching process designed to empower and support patients towards an active role in their health care; and Naylor's Transitional Care Model (TCM) (86) is an advanced practice nurse-led, interdisciplinary discharge planning and home follow-up programme for high-risk patients. Most of the TCIs aim to prevent readmission, mortality, and reduce LOS. Other examples of outcomes of interest are physical functional capacity, type of dwelling at discharge, adverse events (for example falls, delirium, hospital acquired infections), and direct discharge from the ED. In the studies that constitute this dissertation, we focus on interventions with post-discharge contents, mainly focusing on prevention of readmission, mortality, and reduction of LOS.

1.6 Usual transitional care from all departments

The municipality nurse-led intervention, the geriatric team-based intervention, and the usual post-discharge transitional care intervention will be further described in Methods, section 3. However, when evaluating a new post-discharge intervention, it should be seen in the context of the usual transitional care. The Danish Health Care system is further described in Appendix 1. Transitional care in a Danish hospital environment is complex and depends on local conditions as well as on patient-specific factors. Common features of usual transitional care are pre-discharge assessment and early discharge planning (87) combined with case-dependent bridging and post-discharge components (6, 87). Observations made during hospital admission are delivered to the municipality home-care service and the municipal referral coordinator for an individual needs assessment. Existing services are adjusted and new services are established if required. The attending physician updates the shared medication record and writes an electronic discharge letter summarising important results and medication changes. Topics requiring the GPs' special attention after discharge should be highlighted. Based on the patient's informed consent and a formalised evaluation of LOS, previous admissions, nutrition, morbidity, medication, cognitive status, substance abuse, psychiatric diseases, and coping ability, the hospital nurse may refer the patient to a GP- and district nurse-provided follow-up visit at the patient's place of residency (6, 88). The responsibility for treatment is handed over to the GP at discharge. If the hospital referred the patient to a follow-up visit, the GP decides whether a home visit should be arranged or not. The follow-up home visit must be carried out within a week after hospital discharge to receive financial remuneration from the Danish Region concerned. Once a year the GP can decide to do an outreach visit entirely at his/her own initiative. There are great variations in the use of follow-up home visits and outreach visits across municipalities (89, 90), and the feasibility and the effect of the follow-up visits on readmission risk are disputed (7, 8).

Fundamentally, transitional care in a geriatric ward is the same as described above; however, geriatric wards stand out by providing multidisciplinary, CGA-based treatment and care involving patients and relatives before discharge. The geriatric wards at AUH may be seen as equivalents to "Acute Care for Elders (ACE) units" (91). For more details about the geriatric department at AUH, please see paper III (92). An established home follow-up programme for geriatric patients is delivered by the geriatric team (2-5). Consequently, the geriatric wards at AUH do not routinely refer to GP- and district nurse-provided follow-up visits. As part of usual care, the geriatric team also offers follow-up visits to patients discharged after stroke and hip fracture.

Patients included in study I and study II all received the abovementioned usual transitional care. In study III, the included patients received usual geriatric care *while in hospital*, regardless of their random assignment.

1.7 Readmission and Hospital at Home

Readmission is defined as hospital admission that occurs between four hours and 30 days after hospital discharge (93). "Unplanned readmission" was defined as an acute readmission, except for elective or planned admissions and outpatient procedures. Throughout the dissertation and attached papers, these definitions are used unless otherwise mentioned.

Older patients living in Aarhus Municipality can be admitted and readmitted to treatment at home, here referred to as hospital at home (HAH), provided that home treatment is considered safe and beneficial to the patient. HAH *"provides active treatment by healthcare professionals in the patient's home for a condition that otherwise would require acute hospital inpatient care"* (94, 95). Two sub-types of HAH exist. "Early discharge HAH" is delivered as an alternative to continued hospital admission, aiming to reduce LOS and facilitate recovery in the patient's immediate environment. "Admission avoidance HAH" is delivered as an alternative to (index) hospital admission. Sometimes HAH occurs as a readmission according to the above definition of readmission. In our setting, provided there is a referral from a GP or an on-call doctor, admission avoidance HAH is offered by the geriatric department's outgoing team. In this dissertation and the appended papers, admission avoidance HAH is per definition ranked alongside hospital readmission.

1.8 Review of the literature with focus on bridging and post-discharge TCIs

The literature review is based on systematic searches made in Pubmed, Embase, CINAHL, and the Cochrane Library. Pilot studies, protocols, reviews, conference abstracts, poster abstracts, and editorials were excluded. No limitations on publication year or language were applied. The search was updated on 31 October 2021. The search focused on studies with:

1. original, peer-reviewed research including original patient data
2. care transitions from a hospital environment to an outside-hospital environment
3. at least one post-discharge (bridging and/or post-discharge) TCI component
4. readmission as an outcome (primary or secondary)
5. inclusion of older (65+) medical patients

Details of the search strategy are further described in Appendix 2. After the initial search, four steps of exclusion were made to narrow down the review to studies focused on older (75+) medical patients with mixed index admission causes and nurse-based and/or multidisciplinary team-based interventions.

First, studies with bridging and post-discharge TCIs targeted for patients admitted with specific diagnoses were excluded. These were studies including patients with heart failure (86, 96-127); coronary artery disease (110, 128-135); other/mixed heart disease (136-138); diabetes (139, 140); COPD/lung diseases (104, 109, 127, 141-146); cancer (147, 148); and neurologic disease, including stroke (149-155). Many of these studies included patients much younger than 75+ years, and their focus was on rehabilitation programmes following specific types of admissions.

Second, the search revealed a variety of interventions which were beyond the scope of this review, as they were not nurse-based or multidisciplinary team-based interventions (6, 7, 52-84, 156-158), or were entirely telehealth-based interventions (17, 159-177). These interventions were already a part of our usual transitional care or had a very specific focus, for example, on medication reconciliation, and were therefore irrelevant for comparison with our interventions.

Third, papers with a study population aged below 75 years (median or mean) were excluded.

Fourth, studies without a comparator or control group were excluded.

After these steps, papers with nurse-based or multidisciplinary team-based interventions were read in full text. The extracted studies are displayed and further characterised in Table 1: Review of the literature. An outline of the literature review is presented after the table:

Literature review: nurse- and multidisciplinary, hospital team-based transitional care interventions

Author, year **Country (state or region)**	**Title**	**Design**	**Participants:** Age criteria (if any) Inclusion Exclusion N (total) I: (number of participants allocated to intervention) C: (number of participants allocated to control/comparison group)	**Age*** **I** **C**	**I: Post-discharge intervention** **C: Control/comparison group**	**Readmission and other relevant outcome measures**	**Conclusions and main findings** **Comments to interpretation**
Nurse-based interventions							
Martin et al., 1994 (178) **England**	*A randomised controlled trial of a high support hospital discharge team for elderly people*	RCT	75+ Judged at particular risk of readmission. Patients needing assistance from two persons excluded. N=54 I: n=29 C: n=25	I: 80.4 (8.2) C: 82.9 (7.4)	I: Home Treatment Team: Nurse Manager (a qualified district nurse) and ten health care assistants. Home visits up to 6 weeks, 08h-21h, including personal care, domestic assistance C: conventional community services	Readmission (6 and 12 weeks)	Fewer readmissions in intervention group Envelope randomisation Very small sample No time to event
Naylor et al., 1999 (9) **USA (Pennsylvania)**	*Comprehensive discharge planning and home follow-up of hospitalised elders: a RCT*	RCT	65+ At risk of readmission; One of several listed medical/surgical reasons for admission; ≥1 of following: age ≥80, multiple, active chronic health problems, history of depression, moderate-severe functional impairment, recent hospitalisations, poor self-rated health, history of non-adherence to therapeutic regimen Excluded if unable to speak on telephone or if not alert and oriented at admission N=363 I: n=177 C: n=186	I: 75.5 (6.3) C: 75.3 (6.0)	I: Advanced practice nurse-centred discharge planning and home follow-up through four weeks after discharge; individualised patient management in collaboration with patient's physician; initial visit within 48h; second visit 7-10 days after discharge; further visits if needed; telephone contact; available 7 days/week during daytime; written summaries to patients, caregivers; physicians; etc. C: routine discharge planning, standard home care	24-week readmission Time to readmission	Fewer readmissions in intervention group (20% vs. 37%; p<0.001; RR=1.8 (95%CI: 1.3-2.6)) Longer time to first readmission in intervention group (p<0.001)
Courtney et al., 2009 (179) **Australia (Queensland)**	*Fewer emergency readmissions and better quality of life for older adults at risk of hospital readmission: a randomised controlled trial to determine the effectiveness of a 24-week exercise and telephone follow-up programme*	RCT	65+ Acute medical admission and at least one risk factor for readmission (multiple comorbidities, impaired functionality, aged ≥75 years, recent multiple admissions, poor social support, history of depression) Excluded if unable to walk or cognitively unable to manage exercise programme; home oxygen user; neurological or cognitive deficit/disease N=128 I: n=64 C: n=64	I: 78.1 (6.3) C: 79.4 (7.3)	I: Comprehensive nursing and physiotherapy assessment and individually tailored programme including exercise strategies while in hospital; nurse-conducted home visit (<48h) and weekly telephone follow-up for 4 weeks, monthly telephone follow-up for a further 5 months, in addition to usual care C: routine care, discharge planning, rehabilitation advice, referral to community health services if necessary	24-week emergency hospital readmissions and GP or allied health professional visits at 4, 12, and 24 weeks after discharge	Fewer readmissions (I: 22% vs C: 47%; p=0.007) and emergency GP visits (22% vs. 67%; p<0.001 No significant difference in LOS (4.6 (2.9)) No ITT or time to event analysis Small sample

Rosted et al., 2013 (180) **Denmark (Capital Region of Denmark)**	*Testing a two-step nursing intervention focused on decreasing rehospitalisation and nursing home admission post discharge from acute care*	Prospective RCT	70+ Identification of Seniors at Risk ≥2 Discharged from ED within 3 days Excluded if nursing home resident or terminal cancer N=271 I: n=141 C: n=130	I: 81.4 (6.5) C: 82.7 (6.7)	I: Experienced aged-care nursing specialists; Standardised Evaluation and Intervention for Seniors At Risk (SEISAR) tool; Problem oriented treatment, e.g. referral to geriatric outpatient clinic, GP, community health centre. Three visits within 180 days. C: Standard ED discharge planning and primary care follow-up	30-day and 180-day readmission, mortality and nursing home admission	No significant difference in 30-day (p=0.57) or 180-day readmission (p=0.79) No significant difference in 180-day mortality (p=0.49) No significant difference in nursing home admission
Wong et al., 2014 (10) **Hong Kong**	*Comparison of effects between home visits with telephone calls and telephone calls only for transitional discharge support: A randomised controlled trial*	RCT	No age limit. Patients discharged from regional hospital with primary diagnosis related to respiratory, diabetic, cardiac, and renal conditions; MMSE>20; can be contacted by phone Excluded if discharged to assisted care facility, other designated follow-up programme, or end-of-life care N=610 I1: n=196 I2: n=204 C: n=210	Median: 76.5	I1: Add-on to usual care: Nurse-conducted home visits week 1+3, and telephone calls week 2+4. Focus on environmental, psychosocial, physiological, and health-related behaviour. I2: Add-on to usual care: Nurse-conducted telephone calls for four weeks + usual care C: Two social placebo calls + usual care	28-day readmission rate	I1 had significantly lower readmission rate than control group (10.7% vs. 17.6%; OR=0.54 (p=0.041) I2: no significant difference in readmission
Wee et al., 2014 (181) **Singapore**	*Effectiveness of a National Transitional Care Programme in Reducing Acute Care Use*	Retrospective cohort study	65+ Inclusion based on guideline (typically ≥1 of: age ≥65; multiple comorbidities; <5 medications; impaired mobility or functional decline; impaired self-care skills; poor cognitive status; catastrophic injury/illness; lives alone or poor social support; multiple admissions) and evaluation by care coordinator during inpatient stay. Exclusion: see last column N=8,264 I: n=4,132 C: n=4,132	I: 79.2 (7.7) C: 79.2 (7.7)	I: "Aged Care Transition (ACTION)" programme: care coordinator follow-up home visits and telephone calls for an average of 1.5 months C: Propensity weighted comparison group (No ACTION programme)	15-, 30-, 180-day unplanned re-hospitalisations and ED visits 6 months mortality	30-day unplanned rehospitalisation significantly lower (27.8% vs. 15.6%; propensity adjusted OR: 0.5 (95%CI: 0.5-0.6), p<0.001 30-day unplanned ED visit significantly lower (32.0% vs. 19.3%; propensity adjusted OR: 0.81 (95%CI: 0.72-0.90), p<0.001 Significant also at 15 and 180 days. 22% mortality in intervention group vs. 14% in comparator group (reportedly accounted for in propensity score-weighted logistic regression model) Loose inclusion criteria Different inclusion/exclusion criteria for comparator group
Naylor et al., 2014 (182) **&** **Naylor et al., 2016 (183)** **USA (Pennsylvania)**	*Comparison of evidence-based interventions on outcomes of hospitalised, cognitively impaired older adults* *&* *Effects of alternative interventions among hospitalised, cognitively impaired older adults*	Comparative effective-ness study & Prospective, nonrandomised, confirmatory phase design: Three sites, two phases (first phase reported 2014, second phase reported 2016), three interven-tions	65+ Three hospitals; Patients screened as having cognitive deficits; expected to return home; family caregiver also willing to enrol Excluded if active treatment for cancer, stroke, or end-stage renal disease; enrolment in hospice; untreated substance abuse or psychiatric condition N=202 I1: n=65 I2: n=71 I3: n=66 (+205 in phase 2)	I1: 80.8 (6.4) I2: 80.9 (6.4) I3: 79.4 (6.6) - 82.2 (8.5) p=0.85	(Post-discharge intervention only in I3): I1: Augmented standard care: in-hospital cognitive screening I2: Resource nurse care (RNC): in-hospital specialist trained registered nurse; cognitive screening (same as I1) I3: Transitional Care Model (TCM): I1 + 7d/week trained advanced practice nurses; hospital and home visits for average 2 months after discharge; telephone calls; in person visit with patient and primary care physician at physician's office	First rehospitalisation or death All cause re-hospitalisations (multivariable generalised linear modelling)	Statistically significant difference in time to first rehospitalisation or death at 30 and 60 days for I1 versus I3 (non-overlapping 95% CIs from Kaplan-Meier estimates) Mean all cause rehospitalisation estimated for I1 versus I3 were 0.12 vs. 0.06

Røsstad et al., 2017 (184) **Norge (Trøndelag)**	*Generic care pathway for elderly patients in need of home care services after discharge from hospital: a cluster randomised controlled trial*	Unblinded cluster RCT	70+ Home-dwelling elders served by included cluster or scheduled to receive home care services after discharge (at home, rehabilitation facility, or nursing home) Excluded if unable to sign informed consent due to cognitive impairment N=304 I: n=163 (six clusters) C: n=141 (six clusters)	I: 83.1 (5.7) C: 82.4 (5.7)	I: Checklist-based generic care pathway, emphasising follow-up on functional ability, medical condition, medication, self-care, preventive measures, structured information exchange with GP/home care services, etc. C: usual procedures followed regarding information exchange and follow-up	30-day readmission Mortality	No significant difference in readmission (OR=0.8 (95%CI: 0.4-1.7), p=0.65) No difference in mortality Low adherence to intervention Contamination risk
Rosen et al., 2018 (11) **USA (California)**	*The enhanced care Programme: Impact of a care transition programme on 30-Day hospital readmissions for patients discharged from an acute care facility to skilled nursing facilities*	Observational retrospective cohort analysis	No age limit (12.8% were younger than 65 years) Discharged to Skilled Nursing Facility (SNF). SNF attending physician decided who to enrol in ECP programme. No clear exclusion criteria N=3951 I: n=2394 C: n=1557	I: 78.1 (12.6) C:78.2 (12.0)	I: Enhanced Care Program (ECP): 24h/7d available nurse practitioners evaluating patient within 24 h and weekly rounding (or more often if needed), dialogue with attending physician, family members, and caregivers; pharmacist-driven medication reconciliation within 72h; education for SNF staff C: Standard care	30-day same hospital inpatient readmissions	Lower 30-day readmission rate (17.2% vs 23%; p<0.001) Risk of selection bias Risk of overestimation of effect
Finlayson et al., 2018 (12) **Australia (Queensland)**	*Transitional care interventions reduce unplanned hospital readmissions in high-risk older adults*	RCT	65+ Medical patients from two hospitals; ≥1 risk factor of readmission: age≥75, ≥1 hospital admission ≤6 months; multiple comorbidities; living alone; poor social support; poor self-rated health; functional impairment; history of depression. Excluded if home oxygen user, wheelchair user, unable to walk independently, nursing home resident, cognitive deficit or progressive neurological disease. N=222 I1: n=56 I2: n=54 I3: n=57 C: n=55	I1: 77.6 (6.5) I2: 77.8 (6.2) I3: 77.1 (7.6) C: 77.9 (6.2)	Three degrees of post-discharge intervention <48h after discharge: I1: exercise; I2: nurse home visit and telephone follow-up; I3: nurse follow-up combined with exercise 24-week telephone follow-up, and home visits depending on the intervention C: standard care	Unplanned 28-day readmission	Significantly reduced risk of 28-day readmission in interventions including nurse home-visit (I2 and I3); I3 group: HR=0.28 (95%CI: 0.09-0.87), p=0.029) Still significant after 12 weeks No significant difference at 24 weeks after discharge
Arendts et al., 2018 (185) **Australia (Western Australia)**	*A randomised-controlled trial of a patient-centred intervention in high-risk discharged older patients*	Open-labelled RCT	65+ High risk of reattendance based on risk nomogram. Discharged from two EDs within 24h; at least 30% probability for 28-day reattendance. Informed written consent. Excluded if no fixed address, receiving palliative care or deemed unlikely to survive longer than six months; discharged without completed assessment; permanently residing in residential aged care N=164 I: n=82 C: n=82	I: 78 (8) C: 78 (8)	I: Contacted by nurse or allied health professional by telephone within 72h after discharge. Risk nomogram-based dialogue. Structured assessment and education session in patient's home. Additional phone contacts and home visits if required. Facilitation of self-management, contact to community care and welfare services (primary care, social support, etc.). Median duration 110 days. C: standard care, primary care physician	28-day unplanned ED reattendance And hospitalisation 1-year mortality	20% relative risk reduction of unplanned ED reattendance (p=0.26) No statistically significant differences in 28-day hospitalisation rates No difference in 12-month mortality Underpowered study (difficulties in enrolment)

Lembeck et al., 2019 (186) **Denmark (Region Zealand)**	*Effect of single follow-up home visit on readmission in a group of frail elderly patients - a Danish randomised clinical trial*	RCT	65+ (78+ first 13 months) Discharged from medical, geriatric, surgical, orthopaedic wards; ≥3 of following: cognitive/psychiatric disorder. drug/alcohol abuse, lack of social network, low functional status, falls history, hospital contact ≤6 months, multiple medications, ill-suited housing, need of more personal help Excluded if discharge between 4 pm-8 am or during weekends; planned readmission; terminal care N=537 I: n=270 C: n=267	I: 82.5 C: 82.2	I: project nurse accompanied patient home where they met the municipal nurse; in patient's own surroundings: a structured assessment of cognitive skills, medicine, nutrition, home environment, mobility, level of functioning, and future health care appointments. Intervention was arranged accordingly, e.g. referral to skilled nursing specialist or conference with GP. Duration: 1 day (discharge day) C: Usual care: discharge letter to GP; electronic communication concerning medication; municipal home care and rehabilitation	Unplanned readmission at 8, 30, and 180 days; Time to event (KM survival plot) Number of readmissions LOS 180-day mortality	No difference in readmission (adjusted OR at 30 days: 1.18 (95%CI: 0.81-1.17)) No difference in number of readmissions No difference in LOS (median 12 days) No difference in mortality 88% received intervention
Lindhardt et al., 2019 (187) **Denmark (Capital Region of Denmark)**	*A targeted assessment and intervention at the time of discharge reduced the risk of readmissions for short-term hospitalised older patients: a randomized controlled study*	RCT	65+ Discharged to own home <72h after admission Excluded if terminally ill; dependency on municipality care; geriatric outpatient; discharge on Friday, weekend, or evening Randomised: N=349 I1: n=117 I2: n=116 I2: n=116 Included in analysis: N=330 I1: n=112 I2: n=109 C: n=109	I1: 74 (7) I2: 75 (7) C: 75 (7)	I1: Patients, GP and municipality preventive consultant received information about medical assessment. Oral, written, and web-based information about self-management. Info about municipality-arranged leisure activities for senior citizens. Phone call after discharge. I2: Motivational interview with municipality nurse, targeted at basic needs and activities of daily living. Nurse home visit one week after discharge. Brief narrative report to GP and municipal preventive consultant. Info about municipality-arranged leisure activities for senior citizens. C: Usual care.	Three-month readmission rate and number of days to first readmission	No significant difference in readmission risk or time to readmission in either unweighted or propensity score model for any of the compared groups No ITT analysis reported Self-sufficient participants
Gilbert et al., 2021 (188) **France (Auvergne-Rhône-Alpes)**	*A nurse-led bridging Programme to reduce 30-day readmissions of older patients discharged from acute care units*	Stepped-wedge cluster randomised trial	75+ Discharged home from one of 10 geriatric acute care wards after min. 48h admission; deemed at risk of readmission (≥2 Triage Risk Screening Tool criteria: ADL/IADL dependency; previous admissions; geriatric syndrome (falls, major cognitive disorder, etc); ≥high-risk of readmission chronic disease (e.g. heart failure); polypharmacy (≥5 daily drugs); social situation Exclusion of nursing and residential home residents, hospital-at-home scheme N=705 I: n=336 C: n=369	I: 86.8 (5.4) C: 87 (5.5)	I: External nurse-led hospital-to-home bridging programme with four weeks post-discharge follow-up (Home visit 48-72h after discharge; second visit three weeks after discharge; phone calls weeks two and four) C: Usual care	Composite 30-day unscheduled hospital readmission/ ED visits Unscheduled hospital readmission Unscheduled ED visit 30-day mortality LOS	Insignificant reduction of composite readmission (crude HR=0.61 (unilateral 95%CI: 1.11, p=0.09) No significant difference in hospital readmission or ED visits No difference in 30-day mortality (p=0.52) Increased LOS in intervention group (+1.2 day; p=0.01)

Multidisciplinary, hospital team-based interventions							
Hansen et al., 1995 (189) **Denmark (Capital Region of Denmark)**	*A model of regular geriatric follow-up by home visits to selected patients discharged from a geriatric ward: a randomised controlled trial*	RCT	All patients admitted to subacute geriatric ward, based on the criteria: simultaneous need of medical treatment, physical rehabilitation, and adjustment of social services before discharge could be accomplished. Excluded: if not included N=193 I: n=97 C: n=96	Mean age (range): I: 78.7 (59-94) C: 80.6 (49-95)	In-hospital CGA followed by: I: geriatric team member (geriatrician, nurse, or physical therapist) home visit at 1, 3, 8, and 16 weeks after discharge C: Standard care including discharge letter to GP, social support	Readmissions to hospital at six months and cumulative incidence of readmission	Fewer readmissions in intervention group (44% vs. 64%, p<0.005)
Siu et al., 1996 (190) **USA (California)**	*Post-discharge geriatric assessment of hospitalised frail elderly patients*	Block randomi-sation	65+ Medical and surgical patients; gave consent, discharged home; had "unstable medical condition" Excluded if hospital stay <48 hours; terminally ill; nursing home resident; physician refused inclusion; transferred to other facility N=354 I: n=178 C: n=176	No mean or median age reported. I: 26.7% ≥85 years C: 32.0% ≥85 years	I: Hospital-based nurse practitioner made pre-discharge CGA and home visit within 1-3 days after discharge. All patients discussed at interdisciplinary meeting (geriatrician, nurse practitioner, social worker, physiotherapist), and recommendations for primary care physician were made. C: usual care	30-day and 60-day hospital readmission Survival Nursing home placement	No difference in readmission at 60 days. 30 days not reported No difference in survival No difference in nursing home placement 84% of intervention group received intervention. Potential contamination of I and C. Risk of selection bias
Nikolaus et al., 1999 (191) **Germany (Baden-Württemberg)**	*A randomised trial of comprehensive geriatric assessment and home intervention in the care of hospitalised patients*	RCT	65+ Admitted from home; had multiple chronic conditions/ functional deterioration/at risk of nursing home placement; gave consent Terminally ill and patients with severe dementia excluded	Mean age 81.4 No table with baseline characteristics for intervention / control groups	I: In-hospital CGA and home intervention by team (nurses, physio- and occupational therapist, social worker, secretary collaborating with primary care physician. Mean treatment period 7.6 days (range 1-41) + all were visited 3 months after discharge C1: in hospital CGA and usual care C2: usual care	12-month readmission LOS 12-month Survival Nursing home placement	No significant difference in readmission rate, but shorter readmissions Shorter LOS (p=0.007) No difference in survival No difference in nursing home admission
Caplan et al., 2004 (192) **Australia (New South Wales)**	*A randomised, controlled trial of comprehensive geriatric assessment and multidisciplinary intervention after discharge of elderly from the ED - The DEED II study*	Prospective RCT	75+ Discharged home from the ED. Consent and determined fit for discharge. Nursing home residents excluded. N=739 I: n=370; C: n=369	I: 82.1 (6.6) C: 82.4 (5.2)	I: Early (<24h) home visit from member of hospital-based multidisciplinary outreach team (usually a nurse) for up to 28 days. Active involvement of GP. Weekly interdisciplinary team attended by geriatrician, nurse, physio-, and occupational therapist. C: Usual care	30-day readmission Elective and emergency admissions Nursing home admission 18-month mortality	Fewer total readmissions (p=0.048). NNT=18 No significant difference in 30-day emergency admissions (p=0.31) No difference in admission to nursing home No difference in death rate (p=0.765)
Harvey et al., 2014 (193) **Australia (Victoria)**	*Feasibility and impact of a post-discharge geriatric evaluation and management service for patients from residential care: the Residential Care Intervention Program in the Elderly (RECIPE)*	RCT (preliminary study)	65+ Medical patients admitted from permanent living in residential care facility. Excluded if severe behavioural disturbance or if expected to die during their index admission. N=116 I: n=57 C: n=59	I: 83.8 (7) C: 86.7 (7)	I: Two geriatricians and an aged care nurse consultant. Comprehensive assessment and tailored care plan. Further visits if required. C: Usual care, primary care physician.	Six-month readmission; ED presentation Feasibility	No significant difference in readmission or ED presentation Insufficient sample size

Takahashi et al., 2016 (194) **USA (Minnesota)**	*Short-term and long-term effectiveness of a post-hospital care transitions programme in an older, medically complex population*	Cohort study	60+ Prior hospitalisation; medical complexity (=Elder Risk Assessment≥16); gave consent Excluded if enrolled in other care programme, hospice, dialysis, and transplantation N=730 I: n=365 C: n=365	I: 83.1 (7.9) C: 83.3 (8.3)	I: Mayo Clinic Care Transitions program: Advanced practice clinician (APC) (nurse or physician's assistant) home visit within 1-5 business days; Registered nurse (RN) telephone coordination and triage; weekly interdisciplinary team meeting (geriatrician, APC, RN); geriatrician consultant for the team; communication with primary care provider as needed; programme duration 1-3 months. C: propensity score matched controls receiving usual care	30-, 60-, 180-day hospital readmission; ER visits; Mortality	Reduced 30-day hospital readmission (HR=0.53; p=0.002) Reduced 30-day ER visit+hospital readmission (HR=0.61, p=0.004) No significant difference in long-term (≥60-day) readmission or ER visits Reduced 30-day mortality (HR=0.31, p=0.02); no significant difference in long-term mortality
Pedersen et al., 2016 (4) **Denmark (Central Denmark Region)**	*Early geriatric follow-up after discharge reduces readmissions – A quasi-randomised controlled trial*	Quasi-RCT	75+ Admitted to ED with high-risk diagnose and assigned to geriatric care Excluded if terminal at admission, already included in geriatric follow-up or living outside Aarhus municipality N=1,330 I: n=693 C: n=637	I: 86.4 (6.6) C: 86.4 (5.9)	I: early home visit by outgoing geriatric team (nurse and doctor) <24h on weekdays C: Usual care including potential referral to GP-led follow-up	30-day unplanned readmission 30-day mortality	Reduced readmission (12% in intervention group vs. 23% in control group) (adjusted HR 0.49 (0.37-0.64), p<0.001). No difference in mortality (p=0.25)
& **Pedersen et al., 2017 (3)** **Denmark (Central Denmark Region)**	& *Early geriatric follow-up after discharge reduces mortality among patients living in their own homes. A randomised controlled trial*	RCT	Same inclusion/exclusion criteria as the above study N=2,076 I: n=1,060 C: n=1,016 Please note that the majority of these patients were also included in the above study	I: 86.4 (6.3) C: 86.4 (5.8)	Same intervention and control as the above. More patients included and subgroup analysis made.	30- and 90-day mortality	No significant difference in overall 30-day or 90-day mortality; however, a small, but significant reduction of 90-day mortality among patients discharged to their own home in the intervention group: HR=0.79 (95% CI: 0.63–0.99), p=0.04
& **Pedersen et al., 2018 (5)** **Denmark (Central Denmark Region)**	& *Early geriatric follow-up visits to nursing home residents reduce the number of readmissions: a quasi-randomised controlled trial*	Quasi-RCT	Same inclusion/exclusion criteria as the above study N=648 I: n=324 C: n=313 Please note that the majority of these patients were also included in the above studies	I: 86.5 (6.1) C: 87.0 (5.9)	Same intervention and control as the above. Focus on subgroup of nursing home residents.	30-day readmission 30- and 90-day mortality	Reduced readmissions among nursing home residents, Adjusted hazard ratio = 0.63 (95% CI 0.42–0.95), p=0.04 No difference in mortality
Parsons et al., 2018 (195) **New Zealand (Auckland)**	*Supported discharge teams for older people in hospital acute care: A randomised controlled trial*	RCT	65+ In hospital, no ongoing acute treatment, consented to home treatment, considered to have potential for recovery, able to stand and transfer with help from carer; at risk of rehospitalisation; written consent Exclusion: see inclusion N=183 I: n=97 C: n=86	I: 79.8 (7.2) C: 78.7 (8.2)	I: "Supported Transfer & Accelerated Rehabilitation Team (START)": Healthcare assistant visits up to 4 times/day, 7 days/week; registered nurses; physio- and occupational therapists; weekly case conferencing with geriatrician; focus on maximising independence; clinical care responsibility with GP and practice nurses. Max 6 weeks' attendance. C: Usual care: discharge planning and community-based services as required	Six-month hospital readmission: duration of readmission and number of readmission episodes LOS	Trend to fewer days in hospital 6 months after index admission (mean difference: 5.4 days (95%CI: -0.2-11.3)) Fewer readmission episodes within 6 months: Mean (SD) 1.3 (1.1) vs. 1.7 (2.4) episodes within 6 months Partial Eta Squared: 0.06 (0.0-0.1), indicating a small to moderate effect size on hospital readmission Mean LOS 5.9 days shorter (p=0.03) No time to event analysis No reporting of survival Vague inclusion/exclusion criteria

Cordato et al., 2018 (196) **Australia (New South Wales)**	*Management of nursing home residents following acute hospitalisation: efficacy of the "Regular Early Assessment Post-Discharge (REAP)" Intervention*	Prospective RCT	Nursing home residents recently discharged from hospital Excluded if death during index admission or if end-of-life care plan was instituted N=45 I: n=23 C: n=22	I: 90.2 (5.2) C: 86.5 (7.0)	I: "Regular Early Assessment Post-Discharge (REAP)": monthly, coordinated specialist geriatrician and nurse practitioner visits for 6 months after discharge C: Usual care by GP and nursing home staff	Readmissions; Hospital inpatient days; ED utilisation	Trend to reduced readmissions (p=0.03, bootstrap 95%CI: 0.06-0.99) Fewer inpatient days (p=0.05) Trend to fewer episodes of care in ED (p=0.06) Very small sample
Huckfeldt et al., 2019 (197) **&** **Ouslander et al., 2020 (198) (secondary analysis of Huckfeldt et al.)** **USA (Florida)**	*Evaluation of a multicomponent care transitions Programme for high-risk hospitalised older adults* *&* *Thirty-day hospital Readmissions in a Care transitions programme for high-risk older adults*	Quasi experimental quality improvement program with propensity-matched pre-intervention and concurrent comparison groups	75+ Patients with ≥1 high risk conditions: recent hospital admission; altered mental status; fall, syncope, dehydration etc.; shortness of breath; generalised weakness; failure to thrive I: n=202 C: concurrent group: n=4,142 and pre-intervention group: n=4,592	I: 86 (6.1) C: matched to I	I: "Safe Transitions for At-Risk patients (STAR)" programme: inter-professional team, including geriatricians, nurse practitioners, and home health nurses; Nurse visit at patients' residence within 96 hours after discharge; weekly follow-up phone calls; assistance with the use of the Interventions to Reduce Acute Care Transfers (INTERACT) programme C: concurrent control (no intervention) and pre-intervention control group	30-day inpatient readmission; 30-day ED visits	No significant difference in readmission when compared to concurrent (p=0.075) and pre-intervention (p=0.180) No significant difference in ED visits compared to concurrent (p=0.055) and pre-intervention (p=0.100)
Thomsen et al., 2021 (199) **Denmark (Region of Southern Denmark)**	*Does geriatric follow-up visits reduce hospital readmission among older patients discharged to temporary care at a skilled nursing facility: a before-and-after cohort study*	Before/after cohort	All patients discharged from a geriatric department: A: to skilled nursing facility (SNF): N=847 I: n=407 C: n=440 B: to non-SNF: N=5777 I: n=2434 C: n=3343	A: I: 84.2 (8.5) C: 84.2 (8.0) B: I: 83.1 (8.9) C: 82.7 (8.8)	A: Geriatric team (nurse and geriatrician) visit at SNF within 7 days after discharge B: No intended difference in pre/post intervention	30-day unplanned readmission; LOS; 30-day mortality	A: Reduced 30-day readmission: crude HR 0.68 (95% CI: 0.54-0.87); p=0.002 LOS reduced 1.8 days; p<0.001 No significant difference in mortality; p=0.896 B: No significant difference in readmission; p=0.295 LOS longer during intervention; p<0.001 No significant difference in mortality; p=0.139

Table 1: Review of the literature

Bridging and post-discharge TCI studies including older medical patients (mean or median age 75+) with either 1) nurse-based intervention (top) or 2) multidisciplinary, hospital-based intervention (bottom). Exclusions based on geographical, required consent and/or language barriers not mentioned.
I: Intervention group; C: Comparison (control) group; *Age: mean age (SD) unless otherwise mentioned; RCT: randomised controlled trial; RR: relative risk; 95% CI: 95% confidence interval; ED: emergency department; GP: general practitioner; ITT: intention-to-treat; OR: odds ratio; SD: standard deviation; LOS: length of hospital stay; HR: hazard ratio; NNT: number needed to treat; ER: emergency room; SNF: skilled nursing facility; CGA: comprehensive geriatric assessment

1.8.1 Outline of the literature review

Nurse-based interventions

Fourteen studies with nurse-based TCIs were identified. Ten were stated to be RCTs, two were cluster RCTs, and two were cohort studies with historical control groups. All but one study selected patients based on risk factors for readmission, frailty-related conditions, or other elements included in the CGA. The study by Lindhardt et al. (187) was the exception to this, patients being recruited from all those who were discharged from an ED within 72 hours. This study also had the youngest participants (median 75 years), whereas the study by Gilbert et al. (188) had a median age of 87 years. Most of the studies excluded patients with reduced physical and/or cognitive functional capacity, for example, those discharged to a nursing home. Interventions were of varying intensity, ranging from educative, motivational interventions (187) and checklist-based follow-up programmes (184) to early, home visit-based interventions supported by primary care physicians (9, 180, 182, 183, 186). The interventions had very different durations, up to a median of 110 days (185). The studies reported both short-term (28/30 days/4 weeks) and long-term readmissions with diverging results. Despite the broad spectrum of interventions presented in previous studies, the evidence regarding early, high-intensive, nurse-based interventions for frail older patients, regardless of their post-discharge place of residence, remains insufficient.

Multidisciplinary, hospital team-based interventions

Eleven hospital-based multidisciplinary team TCIs were described. Seven studies were stated to be RCTs; one used block randomisation, and the remaining were cohort studies with historical or matched control groups. Again, all studies included patients with high risk of readmission and/or some degree of frailty or clinically assessed need for CGA. The oldest patients were recruited by Cordato et al. (196) (median age 87-90 years) and included only nursing home residents. At least seven of the interventions were preceded by in-hospital CGA or other pre-discharge interventions. The differentiation between pre-discharge intervention and usual care was not always clear. Only two studies reported use of early (<24h) post-discharge visits (4, 192). Most interventions were high-intensive, with up to several daily contacts in person and/or by phone. Seven interventions lasted for more than four weeks after discharge, and one up to 6 months after discharge (196). Accordingly, some reported short-term (30-day) and medium/long-term readmissions; again, the results were diverging. Nonetheless, the overall impression is that relatively early, high-intensive, multidisciplinary interventions were the most effective in preventing short-term readmission.

The literature review supported that 1) nurse-based interventions may effectively reduce readmission compared to usual care; 2) multidisciplinary team-based interventions may

effectively reduce readmission compared to usual care; and 3) there is a need for a robust RCT comparing an early, nurse-led TCI to an early, geriatric team-based TCI among frail older medical patients without constrains by index diagnose, type of dwelling, or physical or cognitive functional capacity.

1.9 Outline of introduction and background

Frail older adults are at particular risk of undesired health events after hospital discharge. Important outcome events are unplanned readmissions, mortality risk, and LOS. The medical conditions of geriatric patients are manifold, and targeting of resources to those who will benefit is a necessity. The concepts of CGA and the derived MPI may offer good ways to identify those in need for intervention during care transitions, without constrains such as diagnosis and type of dwelling. The MPI in its original form is resource demanding as data should be collected in real-time. A retrospective MPI rating method was desirable and could possibly be obtained from the electronic medical record. We wanted to test that hypothesis.

Furthermore, the potential benefit to frail older medical patients and the health care system of applying an effective post-discharge intervention in a Danish secondary hospital providing usual transitional care is currently unknown. To address this question, we wanted to quantify the prevalence of patients with multidimensional frailty and related outcomes among older medical patients admitted to a Danish secondary regional hospital.

An early, home visit-based intervention delivered by a multidisciplinary geriatric team has previously been shown to be superior to standard GP- and district nurse-based post-discharge transitional care. It has also been proposed that an early visit by a municipality nurse with GP back-up could be effective, and might be as good as the multidisciplinary, hospital-based geriatric team intervention. Yet, the evidence was lacking and inconsistent; hence, we wanted to compare the now established, geriatric team-based method to a new, early, municipality nurse-led intervention in a RCT.

2 Aim

The aim was to improve conditions for older adults during the time following an acute hospital admission. The intermediate aims addressed in this PhD dissertation were to:

- explore new methods to identify those at risk of negative health events, and
- examine a new intervention method targeted for those at risk.

2.1 Specific aims

We focused on acutely admitted, frail older (75+) medical patients. The outcomes of greatest interest were 30-day unplanned readmission risk, 90-day all-cause mortality risk, and length of hospital stay (LOS). We decided to focus on post-discharge transitional care interventions.

We chose to use the MPI to identify frail patients, using two different MPI variants: the bedside MPI, and a newly developed, retrospective version based on the electronic medical record.

Thereby we could study three transitional care models: 1) usual transitional care in a regional hospital, using the record-based MPI; 2) a novel, municipality-based, nurse-led transitional care intervention; and 3) a hospital-based, geriatric team transitional care intervention, using the bedside MPI. Hence, the specific aims of the three studies were to:

1. examine reproducibility and diagnostic accuracy of a new, retrospective, record-based MPI, and
2. examine the predictive value of the record-based MPI in older medical patients receiving usual transitional care, and
3. compare an early, municipality-based, nurse-led intervention to an early, hospital-based geriatric team intervention among frail geriatric patients

2.2 Hypotheses

- H1: Record-based MPI has sufficient inter-rater and inter-methods agreement, reliability, and diagnostic accuracy to provide a valid alternative to bedside MPI assessment
- H2: Record-based MPI at hospital discharge predicts mortality, readmission, and LOS among older, acutely admitted medical patients
- H3: A municipality nurse-led and geriatric team-based TCI are equally effective at preventing readmission and mortality, with no difference in LOS, among frail older geriatric patients

3 Methods

3.1 The three studies

We compared the early, municipality nurse-led intervention to the early geriatric team intervention in the RCT (study III). We wished to compare the results of the two interventions to the outcomes of usual transitional care in a secondary regional hospital. Therefore, data were collected about frailty prevalence, readmission risk, mortality risk, and LOS among acutely admitted, older medical inpatients outside the specialised geriatric department context (study II). The electronic medical record provides very comprehensive information to clinicians regarding patients. We hypothesised that the medical records would deliver sufficient information to accomplish full MPI ratings without direct access to the patient and in a less resource-consuming way (study I and study II). For the sake of clarity, an outline of the methods used in each of the three studies is displayed in Table 2 on page 30.

3.2 Designs

Study I (200) was a prospectively including, fully crossed cross-sectional study designed to establish the reproducibility and diagnostic accuracy of our novel, record-based MPI rating method. The new method was tested by two clinicians, a research nurse and a medical doctor, and compared to the established bedside rating method (201).

Afterwards, we examined the record-based MPIs' ability to predict mortality, readmission, and LOS among older medical patients in **study II** (202). Here, the record-based MPI rating method was applied to a cohort of older medical patients discharged from a large secondary regional hospital to usual, GP-based care. The study was a retrospective cohort study with follow-up on readmissions at 30 days after discharge, and mortality at 90 days and one year after admission.

Study III (92) was a 1:1 randomised controlled trial designed to compare the effects of two different TCIs on real-life risk of readmission, mortality, and LOS among frail older geriatric patients. The study had follow-up on readmissions at 30 days after discharge, and mortality at 90 days after hospital admission. The RCT was conducted within the geriatric department of a tertiary university hospital.

Outline of methods			
	Study I:	**Study II:**	**Study III:**
Title	*"A reliable and record-based frailty assessment method for older medical inpatients"*	*"Mortality and readmission risk can be predicted by the record-based Multidimensional Prognostic Index: a cohort study of medical inpatients older than 75 years"*	*"Effects of a new early municipality-based versus a geriatric team-based transitional care intervention on readmission and mortality among frail older patients – a randomised controlled trial"*
Design	Prospective, cross-sectional	Retrospective cohort	RCT
Inclusion period	December 2018 - February 2019	January 2019 - June 2019	January 2018 – August 2020
Outcomes	Reproducibility (i.e. agreement and reliability) Diagnostic accuracy	1-year and 90-day mortality 30-day readmission LOS	30-day readmission 90-day mortality LOS
Population	75+, medical inpatients Dept. of infectious diseases, AUH Dept. of cardiology, AUH	75+, medical patients Medical department, RRH	75+, frail (MPI≥2) Geriatric department, AUH
Data sources	Individual patients' electronic health record Patients and relatives	Individual patients' electronic health record	Frailty data: Patients and relatives Outcomes: Individual patients' electronic health record
Frailty rating	Bedside MPI and Record-based MPI	Record-based MPI	Bedside MPI
In-hospital treatment and care	Usual care	Usual care/CGA	CGA, usual care
Transitional Care Intervention(s)	None (usual care)	TCI: Usual care	Municipality-based nurse-led TCI *or* Hospital-based geriatric team TCI
Data collection	Research nurse Physiotherapist/occupational therapist Medical doctor	Research nurse Medical doctor	Multidisciplinary: Physiotherapists/occupational therapists Clinical nurses Medical doctors
Statistical analysis	BA plot; Cohen's Kappa ICC; Kendall's Tau AUROC	Cox regression Aalen Johansen Binary regression	Binary (logistic) regression Aalen Johansen Cox regression

Table 2: Outline of methods

Abbreviations: RCT: Randomised controlled trial; LOS: Length of hospital stay; AUH: Aarhus University Hospital; RRH: Randers Regional Hospital; MPI: Multidimensional Prognostic Index; CGA: Comprehensive Geriatric Assessment; TCI: Transitional care intervention; BA: Bland-Altman; ICC: Intraclass correlation coefficient; AUROC: Area under the receiver operating characteristic curve.

3.3 Populations

The patients included in the three **studies I-III** were all acutely admitted and aged 75 years or older. To avoid time-consuming MPI ratings of patients that were obviously non-frail, all potentially eligible patients were screened using a clinical assessment of the need for daily assistance and the CCI. This pre-inclusion assessment was carried out by the research nurses and multidisciplinary team members, who were also responsible for including the patients. The inclusion process is further described in the three attached papers (92, 200, 202). All older patients with need for assistance and/or who had a comorbidity (CCI≥1) were further assessed for inclusion. Those declared terminally ill at admission were excluded in all three studies.

In **study I,** patients who were awaiting discharge from the Department of Cardiology or the Department of Infectious Diseases at AUH were sampled. Patients who were 1) transferred to other departments before discharge, 2) had planned outpatient follow-up after discharge, or 3) had received CGA from a geriatrician within 90 days were excluded.

The cohort in **study II** was sampled among patients treated by and discharged from the medical department at RRH. Here patients were included in the cohort if: 1) he/she resided in one of the four municipalities adjacent to the hospital *and* 2) was discharged from the medical department or the ED to primary care. Patients who were admitted with stroke or receiving palliative care were excluded, as these patients are included in specialised treatment protocols after hospital discharge. Each patient could only be included in the cohort once. Previously excluded patients were re-evaluated for inclusion if they were later hospitalised during the inclusion period.

In **study III** we assessed for eligibility all patients admitted to the geriatric wards or assessed by the geriatric team in the ED at AUH. The patients could be included multiple times if their previous inclusion had ended more than 90 days before; hence, the admission *cases*, rather than the individual patients, were randomised to receive one of the two interventions. We intended to randomise older geriatric patients who: 1) were frail, *and* 2) accepted to receive post-discharge home visits, *and* 3) were not admitted with a stroke or a hip fracture, *and* 4) were not already included or referred to the geriatric team by their GP.

3.4 Frailty rating with the MPI

Patients with MPI>1 were considered frail. In the bedside MPI (201) used in this dissertation, the Cumulative Illness Rating Scale – Geriatrics (CIRS-G) (203) was used instead of the Cumulative Illness Rating Scale (CIRS), and the Functional Recovery Score (FRS) (204) instead of the Katz Index (205) and the Lawton Scale (206). Calculation of the bedside MPI

score and the tripartite MPI grade is further explained in Table 3 on page 33 (adapted from study I (200)).

In **study I**, the record-based MPI was extracted exclusively from data available in the patient's electronic health record on the rating date and up to 12 months before. The record-based ratings were made as closely to discharge as possible. The record-based ratings were made twice for each patient by two independent clinicians (research nurse and medical doctor), supported by booklets detailing the rating procedure. Some of the items in the MPI had to be replaced or modified to make the record-based MPI ratings: for example, the 10-question SPMSQ was replaced by a tripartite cognitive score: a) no; b) some or possible; and c) evident loss of cognitive functional ability. The clinicians using the record-based MPI made their ratings first, followed by the bedside rating. Each patient was bedside MPI rated by a single, random clinician, who was either a physiotherapist or an occupational therapist (n=3).

In **study II**, the retrospective, record-based MPI ratings were based on any medical record material available at the time of discharge and the same method as in study I. The clinician doing the ratings was a medical doctor.

In **study III** frailty ratings were made by a multidisciplinary team during hospital admission and updated and completed upon discharge. Nurses, occupational therapists, and physiotherapists collaboratively reported habitational status, counted the number of drugs used on a daily basis, handled cognitive and physical functional ratings (SPMSQ, FRS-ADL and FRS-IADL), as well as the assessment of pressure sore risk (ESS) and nutritional risk (MNA-SF). The assessment of morbidity (tripartite CIRS-G) was done by the attending physician. Supportive booklets were handed out to the clinicians, who were continuously supported by the research team throughout data collection.

Item	Low (value=0)	Moderate (value=0.5)	High (value=1)	Item score value:
Cohabitation status	With relative	Institution	Alone	
Number of drugs (0-∞)	0-3	4-7	≥8	
FRS-ADL (range 0-77)	60-77	37-59	0-36	
FRS-IADL (range 0-23)	17-23	13-16	0-12	
SPMSQ (range 0-10)	0-3	4-7	8-10	
ESS (range 4-16)	13-16	9-12	4-8	
CIRS-G (No. of domains with score ≥3)	0	1-2	≥3	
MNA-SF (range 0-12)	12	8-11	0-7	
MPI score (range 0-1)				
MPI grade (1/2/3)				

Table 3: Calculation of the Multidimensional Prognostic Index (bedside MPI) (200, 201)
Number of drugs: Number of daily administered drugs at admission; FRS-ADL: Functional Recovery Score activities of daily living; FRS-IADL: Functional Recovery Score instrumentalised activities of daily living; SPMSQ: Short Portable Mental Status Questionnaire; ESS: Exton Smith Scale; CIRS-G: Cumulative Illness Rating Scale – Geriatrics (the number of domains with score 3 or 4 was counted); MNA-SF: Mini Nutritional Assessment – Short Form; MPI score: summarised item score divided by 8. MPI grade: The MPI score transformed into three risk grades (MPI score 0-0.33: MPI grade 1; MPI score 0.34-0.66: MPI grade 2; MPI score 0.67-1: MPI grade 3).

3.5 Pre-discharge treatment and transitional care

In **study I** the included patients received standard, subspecialised treatment and care during and after their stay in the cardiology and infectious diseases departments at AUH.

In **study II** the included patients received standard treatment and care during their stay in the ED and the medical wards at RRH. The four wards were all internal medicine wards and were subspecialised in cardiology, respiratory medicine/rheumatic diseases, endocrinology/gastroenterology, and geriatric medicine. If transferred to one of the wards, the patient received ward-specific, subspecialised treatment and care. In geriatric medicine, the patients were treated in a setup based on the CGA and multidisciplinary teamwork.

In **study III** the patients received usual geriatric care in two geriatric wards and the ED at AUH. After acute treatment in the ED, the geriatric ED team made an initial assessment of the older medical patients. Together with representatives from other specialties, it was decided whether the patients should be discharged (by the geriatric team or other ED doctors), allocated to a geriatric ward for further comprehensive geriatric assessment, or transferred to another hospital ward.

3.6 Post-discharge TCIs

None of the outcomes observed in **study I** were dependent on the post-discharge follow-up programme.

Patients included in **study II** were offered the usual transitional care model at discharge (see section 1.6: *Usual transitional care from all departments*).

In **study III**, two post-discharge transitional care interventions were applied. The patients were randomly allocated to receive either:

1) a new, early (<24h), municipality-based, nurse-led and GP-supported TCI *or*
2) early (<24h), hospital-based, multidisciplinary geriatric team TCI

We used the randomise function embedded in REDCap (207, 208), and it applied before the patient was discharged. The new nurse-led TCI was compared to the established geriatric team-based TCI. The contents and differences between the usual transitional care offered in study II and the two TCIs applied in study III are elaborated on in Table 4 (modified table from paper III (92)):

The three post-discharge transitional care interventions applied in the dissertation

Common TCI features	Usual transitional care	Municipality-based, nurse-led, and GP-supported intervention:	Hospital-based multidisciplinary geriatric team intervention:
Early home visit	Depends on pre-discharge assessment, planning, referral and GP assessment	All days: visit <24h	Weekdays: visit <24h
Relatives	Sometimes involved	Sometimes involved	Routinely and repeatedly involved if patient gives consent
Assessment model	List of recommendations from the Danish College of GPs	Assessment according to Henderson's 14 nursing components[a] Prescription list review	CGA, including medication review
Involved health care professionals	Depends on pre-discharge planning and individual needs assessment	Home-care nurse	Multidisciplinary geriatric team: geriatric doctor and geriatric nurse/ physiotherapist, or occupational therapist Home-care nurse/health care assistant urged to partake in visit
Responsibility of post-discharge treatment	GP	GP responsible; municipality nurse takes the lead	Geriatric team
Care model	Standard, individualised care based on pre-discharge assessment and ongoing adjustments after discharge	Three standardised follow-up courses[b]: • Short-term rehabilitation (if functional capacity moderately reduced) • Complex rehabilitation (if functional capacity substantially reduced) • Permanent course (if functional capacity permanently reduced)	Individualised, CGA-based tailored treatment and care plan
Treatment options	Consult GP GP may refer to physiotherapy, occupational therapy, dietician End of life care (with GP) Home-care adjustment if needed (via referral coordinator)	Consult GP Referral to dietician Referral to physiotherapy Referral to occupational therapy End of life care (with GP) Home-care adjustment if needed	Further scheduled and/or acute follow-up visits/phone-calls if needed Referral to further diagnostic procedures Referral to other specialties' outpatient clinics Admission avoidance HAH End of life care Consult referral coordinator regarding home-care adjustments
GP	GP in charge of follow-up, collaborating with home nurse/home care	GP support	GP on hold Continuous discharge letters to municipal home-care and GP
Contact persons	GP Home-care call-centre	GP Home-care call-centre Follow-up course coordinator	Individual care-team (doctor and nurse/therapist) Geriatric team single number reach hotline
Opening hours/out of hours support	24-hour home-care service centre (all days) GP support (weekdays from 8 a.m. to 4 p.m.) On-call doctor (weekdays 4 p.m. to 8 a.m. and weekends)	24-hour home-care service centre (all days) GP support (weekdays from 8 a.m. to 4 p.m.) On-call doctor (weekdays 4 p.m. to 8 a.m. and weekends)	24-hour geriatric service (all days): Geriatric team support (weekdays 8 a.m. to 8 p.m./weekends 8 a.m. to 3 p.m.) Geriatric nurse and on duty geriatrician (weekdays 8 p.m. to 8 a.m./weekends 3 p.m. to 8 a.m.)
Duration	Individualised	Continuous re-evaluation cycles for the three standardised follow-up courses: • Short-term rehabilitation: <8 weeks • Complex rehabilitation: <12 weeks • Permanent course: <26 weeks (<56 weeks if only moderately reduced functional capacity)	<7 days; extended if further specialised geriatric treatment indicated
Transition to usual care	At hospital discharge: early discharge planning, discharge letter to GP, updated prescription list	Gradual transition	Discharge letter to GP and municipality health service Updated prescription list and rehabilitation plan Phone calls (optional) to GP, relatives and/or home-care nurse

Table 4: The three post-discharge transitional care interventions (92)
All randomised patients received standard geriatric care during hospital admission. The two transitional care interventions shared several common features (left column); however, the specific TCI characteristics differed as listed (central and right columns).
Abbreviations: TCI: transitional care intervention; GP: general practitioner; CGA: comprehensive geriatric assessment; HAH: hospital at home
Legend: [a]Henderson's 14 nursing components(209) are: 1) Breathe normally; 2) Eat and drink adequately; 3) Eliminate body wastes; 4) Move and maintain desirable postures; 5) Sleep and rest; 6) Select suitable clothes, dress and undress; 7) Maintain body temperature; 8) Keep the body clean end well-groomed; 9) Avoid dangers and avoid injuring others; 10) Communicate with others in expressing emotions, needs, fears, or opinions; 11) Learn, discover, or satisfy the curiosity that leads to normal development and health and use the available health facilities; 12) Worship according to one's faith; 13) Work in such a way that there is a sense of accomplishment; 14) Play or participate in various forms of recreation; [b]Depending on functional capacity defined using the International Classification of Functioning, Disability and Health (Danish version)(210)

3.7 Data collection

All baseline data, MPI-ratings and outcome data were collected in purpose-built REDCap databases (207, 208).

Study I: Patients were sampled daily on weekdays by the two involved departments' coordinating nurses and our research nurse in collaboration (200). Inclusion continued until two record-based and one bedside rating of each patient were achieved. The inclusion took place during the period 4 December 2018 to 22 February 2019.

Study II: From 1 January 2019 a research nurse consecutively evaluated all newly admitted, older patients treated by the medical department (202). Patients fulfilling the inclusion and exclusion criteria were added to the database. Subsequently, the record-based MPI ratings were made in portions of 5-35 records per day and re-assessed for eligibility by the medical doctor. Outcome data were collected from the electronic health records after the end of follow-up. Inclusion continued until the required sample was achieved on 21 June 2019. Data regarding referral to GP follow-up and outreach home visits were merged with regional remuneration data.

Study III: The patients were included by the multidisciplinary staff from 1 January 2018 to 16 August 2020 (92). After end of follow-up, outcome data were collected from the electronic health records by a research assistant (n=4). The research assistants worked independently, and were allowed to confer with each other and the researchers if needed. To assure consistency and high data quality, all outcome data were cross-checked with the electronic health records before the final data processing.

3.8 Blinding

Study I: All involved clinicians were blinded to the results of the other ratings.

Study II: The MPI ratings and outcomes were collected by the same clinician.

Study III: Taking the patients' interest in individualised early discharge planning into consideration, neither the staff members, nor researchers, nor patients were blinded to randomisation. The random allocation was usually evident when information on patients was sought in the health record, and the frailty-ratings and outcome data were collected using the same database. Because of the construction of the REDCap database, the randomisation could not be influenced or changed in any way.

3.9 Statistical analyses

Study I evaluated inter-rater and inter-method reproducibility and diagnostic accuracy. Reproducibility concerns the degree to which two ratings provide similar results (211), and includes both agreement and reliability. The agreement parameters, Cohen's kappa and the Bland-Altman plot (212, 213) with limits of agreement (LOA) are used to assess the closeness of repeated measurements. The reliability parameters, intraclass correlation coefficient (ICC) (211) and Kendall's tau, assess distinction of subjects despite measurement errors (211). The sample size calculation was based on the ICC. Assuming an ICC above 0.8 and an acceptable confidence level of ± 0.10, a sample size of 50 patients was needed in the applied two-rater setup (214). Diagnostic accuracy is the ability to discriminate whether patients were frail or not (215) using the bedside MPI (frail: bedside MPI>1) as reference standard. Sensitivity, specificity, and the area under the receiver operating characteristic curve (AUROC) quantified the diagnostic accuracy.

In **study II**, the eight parameters included in the MPI were considered a part of the exposure to frailty; hence, sex and age were the only baseline variables tested for dependence. We used binary regression models to calculate relative risk (RR) estimates for readmission with 95% confidence intervals (95% CIs). Mortality and readmission data were also analysed using time to event analysis. Mortality is intuitively well understood by the hazard ratios (HR) produced by the Cox regression model and by looking at the survival curves produced by the Kaplan-Meier survival function, whereas readmission may be more easily understood when regarded as a cumulative incidence. Moreover, the proportionality of hazards assumption was violated in the analysis of readmission; hence, use of the Kaplan-Meier survival function was inappropriate. Instead, a cumulative incidence model based on the Aalen-Johansen estimator was applied. Thirty-day post-discharge mortality is a competing risk to readmission and was added to the model.

The non-parametric Kruskal-Wallis ANOVA was used to compare the median LOS in the three MPI-defined groups.

To make external validations of prognostic models, a minimum of 100 events are recommended (216). Given a 90-day mortality rate of 20% among geriatric patients (3, 201), a cohort of a total of 500 patients would be sufficient. However, we expected the 90-day mortality rate among the patients in study II to be lower than 20%, as the patients were younger and expected to be less frail. Instead, we considered a sample of 333 patients in each of the MPI risk levels (i.e. a minimum of 999 patients in total) to be enough to reach ≥100 events and to be sufficient to provide robust estimates.

Study III: We used binary (logistic) regression models, cumulative incidence models (Aalen-Johansen) with 30-day post-discharge mortality as a competing risk, and Cox

regression models. Here, the models were tested for effect modification by age, sex, MPI sum score, and discharging department, and set to provide odds ratio (OR) estimates. The individual patient could be included more than once in study III. To accommodate for this and to relax the logistic regression assumption of independence of observations, the standard errors were allowed for intragroup correlation by using a clustered sandwich estimator, assuming independence between the clusters.

Because of the need for early discharge planning, non-eligible patients were occasionally randomised. To accommodate for these early (premature) randomisations, the analysis was divided into three parts: first an intention-to-treat (ITT) analysis in strict accordance with the intention-to-treat principle (as randomised); second, a modified ITT (mITT) analysis limited to randomised patients fulfilling the pre-specified inclusion and exclusion criteria (post-randomisation exclusion (217)); and third, an as-treated (AT) analysis accounting for cross-over between the two random allocations.

Two predefined, stratified analyses were made according to 1) type of dwelling at discharge and 2) the frailty grade. After stratification for type of post-discharge dwelling (living alone, cohabiting, or institutionalised living), the three-levelled analysis (ITT; mITT; AT) was repeated. Based on the mITT data, stratified analysis according to frailty degree (moderately (MPI=2) or severely (MPI=3) frail) was made. Furthermore, a post-hoc analysis of in-hospital readmission and readmission avoidance HAH was added during the data collection.

The non-parametric Wilcoxon rank-sum test was used to compare median LOS in the two TCIs in study III.

A type I error is to reject the null hypothesis while it is true. In study III, we accepted a risk of type I error (alpha) of 5%. A two-tailed p-value less than 0.05 was considered significant in all three studies. A type II error is to accept the null hypothesis while it is false. We accepted a risk of type II error of 20% (beta), resulting in a power of 80%. We assumed a readmission rate of 20.6% vs. 15.6% based on data from a pilot study performed in 2017 (unpublished). Given an anticipated drop-out rate of 5%, alpha 0.05, and beta 0.20, 1,019 patients in each random group were required.

4 Results

4.1 Baseline

Most of the included patients were women, except in study II, where exactly half of the cohort were female. The median age was 84 years (study I), 83 years (study II), and 85 years (study III). Study I only included patients with either heart problems or infectious disease as their index diagnosis, whereas the most common diagnoses in study II and study III were pneumonia and other respiratory diseases, mainly exacerbations of COPD. The second most common diagnoses were related to cardiovascular diseases, mainly heart failure. Core baseline characteristics are displayed in Table 5 page 40, and further elaborated in the three papers (92, 200, 202).

Core baseline characteristics				
	Study I	**Study II**	**Study III[a]**	
	Usual transitional care	Usual transitional care	Nurse-led TCI	Geriatric team TCI
Number of patients/cases (% of total)	50 (100)	1,190 (100)	1,545 (50)	1,558 (50)
Age: median (range/IQR)	84 (range: 75-96)	83 (IQR: 79-88)	85 (IQR: 80-90)	85 (IQR: 80-90)
Sex (% female)	64% female	50% female	57% female	57% female
MPI score[b]:	Mean: 0.53 (SD: 0.15)	Median 0.44 (IQR: 0.31-0.69)	Median 0.63 (IQR: 0.50-0.75)	Median 0.63 (IQR: 0.50-0.75)
MPI grade[b]: n (%)				
1 (score 0-0.33)	5 (10)	335 (28)	59 (4)[c]	72 (5)[c]
2 (score >0.33-0.66)	33 (66)	522 (44)	704 (46)	700 (45)
3 (score >0.66-1)	12 (24)	333 (28)	707 (46)	727 (47)
Diagnose[d]: n (%)	Heart disease: 40 (80) Infectious disease: 10 (20)	Respiratory disease: 366 (31%) CVD: 309 (26%) UTD: 124 (10%)	Pneumonia/COPD: 365 (24%) CVD: 212 (14%) Other infections (non-UTI): 176 (11%)	Pneumonia/COPD: 371 (24%) CVD: 201 (13%) Other infections (non-UTI): 155 (10%)

Table 5: Core baseline characteristics in the three studies
Legend: [a]: Data from the ITT analysis; [b]: according to bedside MPI in study I and III; record-based MPI in study II; [c]: 5% (n=75) were unfinished ratings in the nurse-led TCI, and 4% (n=59) in the geriatric team TCI; [d]: diagnoses were not collected in study I. In study II, the index diagnoses were retrospectively assessed. In study III, the ICD-10-based index diagnose codes assigned by the discharging doctor were collected.
Abbreviations: TCI: transitional care intervention; IQR: interquartile range; SD: standard deviation; MPI: Multidimensional Prognostic Index; CVD: cardiovascular disease; UTD: urinary tract disease (including urinary tract infections); COPD: chronic obstructive pulmonary disease; UTI: urinary tract infections

Study I: Seventy eligible patients were evaluated. Eight of the patients with incomplete ratings were discharged before the ratings could be accomplished. We found no significant differences between the included and non-included patients concerning age, sex, and discharging department. For further details about the inclusion and exclusion of patients, see paper I (200).

Study II: Of the 1,733 individuals older than 75 years who had been discharged from the involved wards, 69% (n=1,190) were eligible for complete record-based MPI rating. Increasing age and female sex were associated with higher MPI scores.

Study III: In total, 3,103 admission cases, corresponding to 2,570 individuals, were randomised. Some were readmitted after the end of follow-up, some several times. None of the reported baseline characteristics were unevenly distributed across groups, indicating successful randomisation. Post-randomisation events resulted in post-randomisation exclusion of 925 records from the mITT- and AT analyses (217). Exclusion after randomisation could, for example, be caused by in-hospital death, transfer to other wards, or the realisation that the patient was non-frail after being randomised by incident. The flow of patients is displayed in Figure 1: Flow diagram (reproduced from paper III (92)) on page 42.

Still, there was no difference in the distribution of baseline characteristics across the two intervention groups in the mITT analysis. There was a trend towards more of the patients allocated to the geriatric team TCI being discharged directly from the ED in both the ITT analysis (p=0.081) and mITT analysis (p=0.091). In the AT analysis this difference was significant (p=0.006); hence, the AT analysis was adjusted for discharging department.

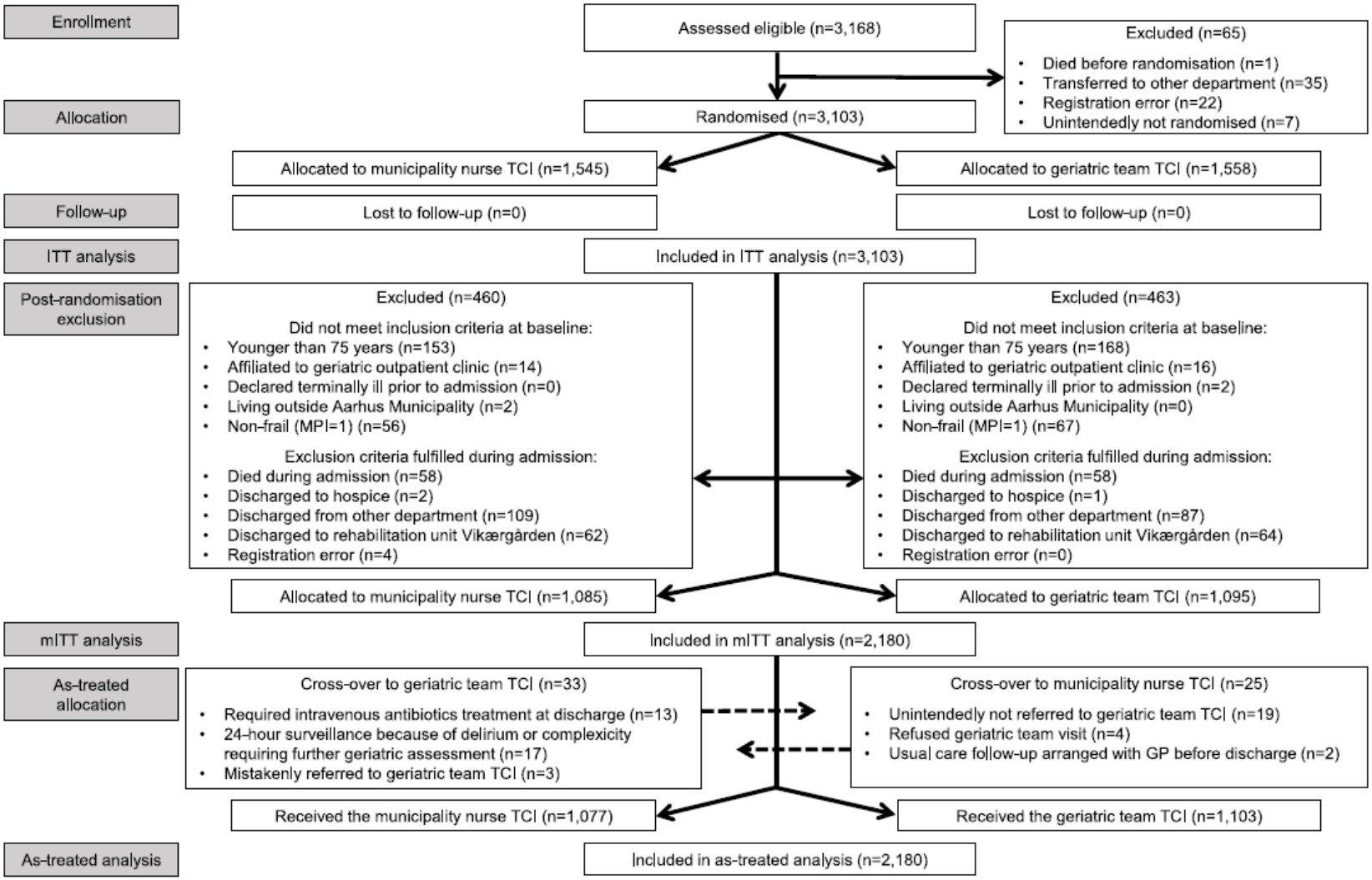

Figure 1: Flow diagram (92)
A total of 3,103 randomised records, originating from 2,570 individuals, were included in the intention-to-treat (ITT) analysis. Inclusion and exclusion criteria were not fulfilled in a total of 925 records. These records were excluded from the modified intention-to-treat (mITT) analysis. As-treated analysis: 33 of the patients allocated to the municipality-based intervention instead received the geriatric team intervention after discharge. Reversely, 25 of the patients allocated to the geriatric team intervention did not receive the allocated intervention; instead, they received the municipality-based intervention or usual care. Abbreviations: MPI: Multidimensional Prognostic Index; TCI: transitional care intervention; ITT: intention-to-treat; mITT: modified ITT.

4.2 **Study I:** Reproducibility and diagnostic accuracy of the record-based MPI

The Bland-Altman plots (Figure 1 in paper I (200)) showed good inter-rater agreement among raters using the record-based MPI. Only one observation was outside the LOA. Inter-rater reliability was acceptable, ICC=0.71. Likewise, inter-methods agreement and reliability were good. The ICC was 0.83. Ninety per cent of the patients were categorised as frail (MPI>1) according to the reference standard. Evaluations by the medical doctor had a sensitivity of 100%, specificity 80%, and AUROC 0.92, indicating good diagnostic performance. The positive predictive value (PPV) was 98% and the negative predictive value (NPV) 100%. Evaluations by the research nurse had a sensitivity 93%, specificity 60%, and AUROC 0.77. The PPV was 96% and the NPV was 100%. For further information including 95% CIs of the estimates, please see paper I(200).

Twenty-four per cent of the bedside-rated individuals were severely frail (MPI=3). Using severe frailty as reference standard, the medical doctor's evaluations had a sensitivity of 75% (95% CI: 43-95%) and a specificity of 95% (95% CI: 82-99%).

4.3 **Study II:** Prediction using the record-based MPI in a usual care setup

4.3.1 Mortality

The record-based MPI showed a high ability in predicting both 90-day and one-year mortality among the included patients. The 90-day mortality rate for frail (MPI>1) patients was 17% (n=144). The overall one-year mortality rate was 28% (n=332). The AUROC for 90-day mortality was 0.76, and 0.73 for one-year mortality. The age- and sex-adjusted Kaplan-Meier plot of survival in the three MPI-risk grades is displayed along with the hazard ratio (HR) estimates and 95% CIs in Figure 2: Kaplan-Meier curve with 1-year survival estimates (reproduced from paper II (202)).

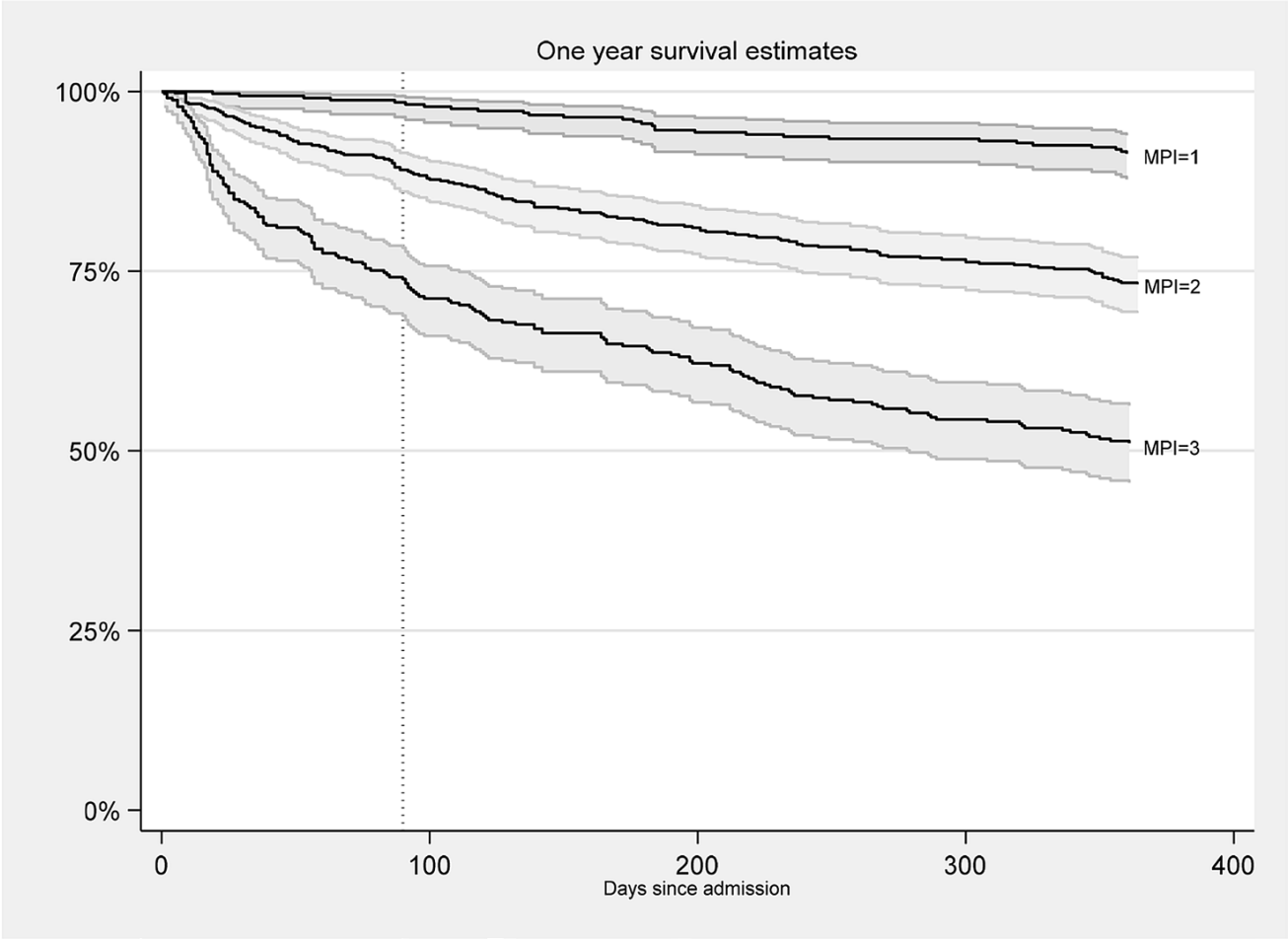

Figure 2: Kaplan-Meier curve with 1-year survival estimates (202)
Age- and sex-adjusted survival among patients in the three MPI risk grades. In- hospital mortality is not included. Legend: Compared to non-frail patients (MPI<2), the moderately frail patients (MPI=2) had more than three times higher day-to-day risk of death within the first year (HR=3.3 (95% CI: 2.2-5.0; p<0.001)). Similarly, the severely frail patients (MPI=3) had more than seven times higher day-to-day risk of death within the first year (HR=7.1 (95% CI: 4.7-10.6); p<0.001)). Within the first 90 days, male patients had 1.6 times higher day-to-day risk of mortality (HR=1.6 (95% CI: 1.3-2.0) compared to females (p<0.001).

4.3.2 Readmission

Twenty-one per cent (n=253) were readmitted to hospital before the end of the 30-day follow-up. Frail (MPI>1) patients accounted for 72% (n=855) of the cohort and 82% (n=208) of the readmissions. The receiver

for readmission was 0.57. The cumulative incidence of readmission was adjusted for mortality as a competing risk. The cumulative incidence of readmission with 95% CIs for each of the three MPI grades is displayed in Figure 3: Cumulative incidence of readmission (reproduced from paper II (202).

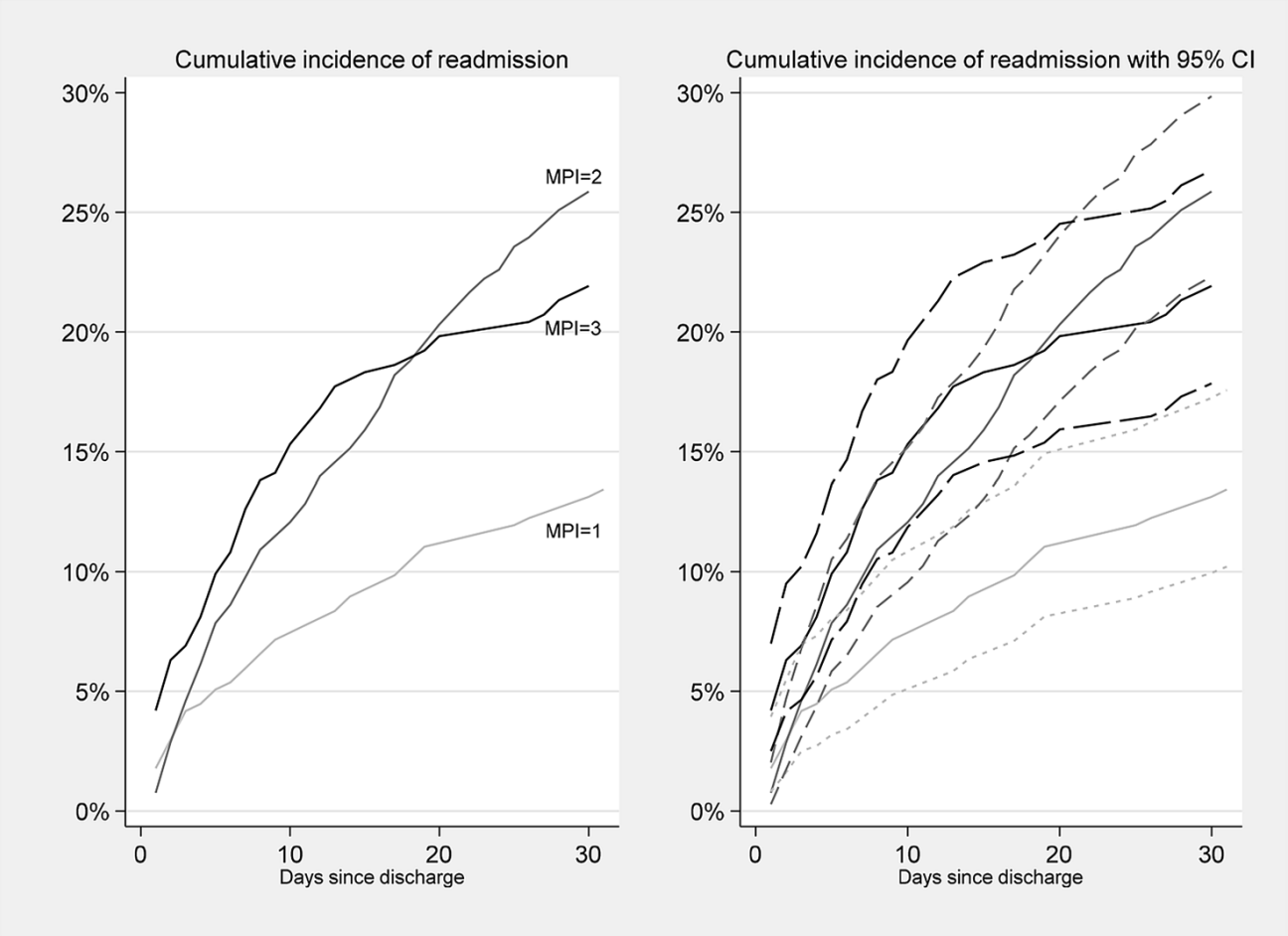

Figure 3: Cumulative incidence of readmission (202)
Aalen–Johansen plot showing mortality-adjusted cumulative incidence of acute, all-cause 30-day readmission. Abbreviations: MPI: Multidimensional Prognostic Index; 95% CI: 95% confidence interval; MPI=1: MPI score 0-0.33 (non-frail); MPI=2: MPI score 0.34-0.66 (moderately frail); MPI=3: MPI score 0.67-1 (severely frail). Light grey solid lines: cumulative incidence for MPI=1; Dark grey solid lines: cumulative incidence for MPI=2; Black solid lines: cumulative incidence for MPI=3. Short dashed light grey lines: upper and lower 95% CI for MPI=1. Dark grey medium long dashed lines: upper and lower 95% CI for MPI=2. Black long dashed lines: upper and lower 95% CI for MPI=3.

The frail patients (MPI>1) had a significant and almost two-fold increased risk of readmission compared to the non-frail (MPI=1) patients. There was no significant difference between the moderately and severely frail because the 95% CIs and estimates overlapped. The age- and sex-adjusted RRs were 2.1 (p<0.001) for the moderately frail and 1.8 (p=0.001) for the severely frail patients.

4.3.3 Length of stay

The length of stay (LOS) was significantly associated with the retrospective MPI grade (p<0.001). The overall median LOS was three days (IQR: 1-6). For non-frail patients, the median LOS was one day (IQR: 1-4); moderately frail patients were admitted for a median of three days (IQR: 1-6) and severely frail five days (IQR: 1-9). LOS and sex were not significantly associated (p=0.73), while higher age was associated with longer LOS (p=0.037).

4.3.4 The GP- and district nurse-provided follow-up programme

Of the total cohort (n=1,190), 14% (n=163) were evaluated with regard to the GP- and district nurse-performed home follow-up visit offered as a part of the usual transitional care intervention. Of these, 61% (n=99) were referred to the GP for follow-up. Eleven of the evaluated patients (7%) received a follow-up visit (n=8) or GP-initiated outreach visit (n=3) within seven days and 19 patients within 14 days after discharge (n=16 and n=3, respectively).

4.4 **Study III:** Comparison of two early TCIs for frail patients

4.4.1 Readmission

The ITT analysis showed that 22% (n=332) of the cases allocated to receive the municipality-based, nurse-led TCI were readmitted within 30 days, compared to 18% (n=276) in the group allocated to the geriatric team-based intervention. OR was 1.27 (95% CI: 1.06-1.52), p=0.008, and the NNT=27. Looking at the mITT analysis, the readmission rates were the same, 22% (n=236) vs. 18% (n=196), and the OR was still significant (p=0.025). The readmissions occurred after a median of 11 days after discharge (IQR: 5-19) in both interventions (p=0.782). In the as-treated analysis, 22% (n=241) vs. 17% (n=191) were readmitted, resulting in OR=1.38 and a NNT=20, still in favour of the geriatric team-based TCI (p=0.003).

In the following, the focus is on the mITT analysis as this included only the frail patients who were the focus of this dissertation. Information about the ITT analyses and AT analyses, along with details regarding confidence intervals and p-values, is reported in paper III (92).

Based on the mITT analysis, the cumulative incidence of readmission with mortality as a competing risk is displayed in Figure 4: Cumulative incidence of readmission in the two interventions (reproduced from paper III(92)).

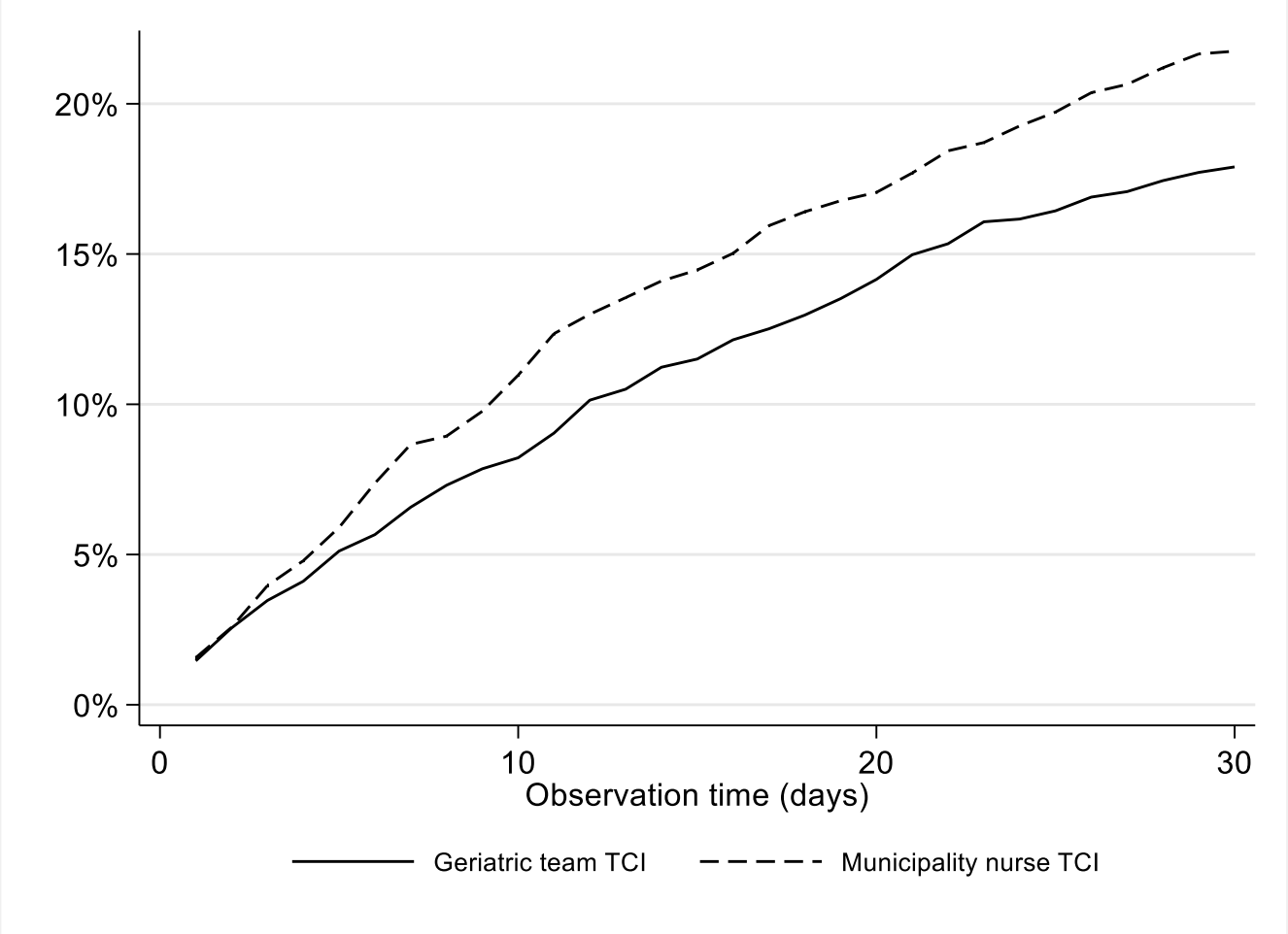

Figure 4: Cumulative incidence of readmission in the two interventions (92)
Aalen-Johansen plot showing the cumulative incidence of mortality-adjusted 30-day readmission, based on data from the modified intention-to-treat analysis (n=2,180). Legend: Dashed line: readmission among patients allocated to the municipality-based intervention. Solid line: readmission among patients allocated to the hospital-based intervention.

Stratification for type of dwelling (mITT)

The largest difference between the two TCIs was seen among patients living together with a relative (n=472). Fifty-eight (12%) of the cohabiting patients allocated to the municipality nurse-led intervention and 41 (9%) of the cohabiting patients allocated to the geriatric team were readmitted. OR was 1.65, p=0.027. For patients living alone (n=1,086), the OR was 1.21, p=0.218, and for those discharged to an institution (n=621), the OR was 1.16, p=0.508.

Stratification for frailty degree (mITT)

Some of the following results were not reported in paper III. In these cases, the 95% CIs and p-values are reported here. Among moderately frail (MPI=2), 18% (n=96) of those allocated to the geriatric team-based TCI vs. 22% (n=116) in the municipality-based TCI were readmitted; OR=1.30 (95% CI: 0.96-1.76), p=0.091. Similarly, when focusing on the severely frail (MPI=3), the readmission rates were 18% (n=100) vs. 22% (n=120); OR=1.25 (95% CI: 0.93-1.68), p=0.132.

Post-hoc analysis of in-hospital readmissions and readmission to HAH (mITT)

Of the 432 readmissions, 12% (n=51) took place in the patient's place of residency as an alternative to an in-hospital readmission. Regarding readmissions to patients' homes, HAH accounted for 16% (n=38) of the readmissions in the municipality nurse-led TCI and 7% (n=13) in the geriatric team TCI, resulting in an OR=3.02 (95% CI: 1.62-5.64), p=0.001. On the other hand, for in-hospital readmissions (n=381), the readmission rates were 17% (n=183) vs. 18% (n=198), resulting in an OR=1.11 (95% CI: 0.89-1.39), p=0.349. The corresponding calculations related to the ITT analysis are reported in paper III (92).

Looking at the two degrees of frailty, the OR for readmission to HAH was 4.47 (1.98-10.05), p<0.001, among those with severe frailty (MPI=3). No significant difference was observed in the risk of readmission to HAH among the patients with moderate frailty (MPI=2), p=0.566.

4.4.2 Mortality and LOS

The 90-day post-admission mortality rates in the ITT analysis were 22% (n=340) among patients allocated to the municipality nurse-led intervention versus 21% (n=330) among patients allocated to the geriatric team intervention. Similar mortality rates were observed in the mITT and AT analyses. The 90-day survival function is displayed in the Kaplan-Meier plot in Figure 5: Kaplan-Meier curve with 90-day survival estimates (mITT analysis; reproduced from paper III (92)).

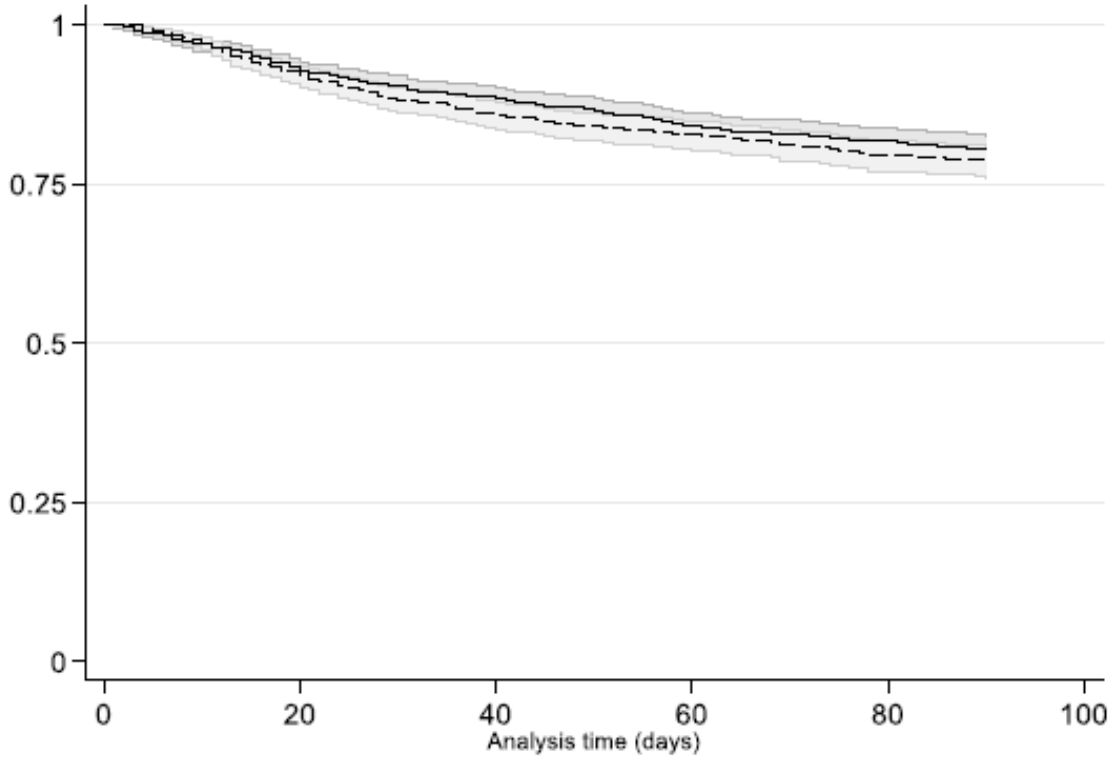

Figure 5: Kaplan-Meier curve with 90-day survival estimates (92)
90-day mortality with 95% confidence intervals, based on data from the modified intention-to-treat analysis (n=2,180). Legend: Solid line: survival among patients allocated to the hospital-based intervention. Dashed line: survival among patients allocated to the municipality-based intervention. Opaque areas: 95% confidence intervals.

The median LOS for patients included in the mITT analysis was six days in both groups, with no significant difference (p=0.179), and no significant differences were observed in any of the dwelling subgroups either.

4.5 Adverse events

Apart from the described outcome measures, no specific adverse events were noted. Danish health care professionals have an obligation to report any actual or suspected adverse event through the incident reporting system hosted by the Danish Health Authorities. Patients, relatives, and other lay persons can also report incidents (anonymously) through this system. No adverse events related to any of the studies or interventions were reported directly to the researchers or through the incident reporting system.

5 Outline of results

Study I is the first study to report on a record-based version of the well-established MPI. The method's reproducibility and diagnostic accuracy were reported. The method was accurate and reliable, both in the hands of clinicians with different educational backgrounds and when compared to the bedside MPI. The results indicated that the record-based MPI is very useful to diagnose frailty (bedside MPI>1).

Study II is the first study to put the record-based MPI into use among older medical inpatients. The predictive value of the record-based MPI was reported. This was also the first study to report the prevalence of multidimensional frailty in a cohort consisting of older medical patients discharged from a Danish secondary hospital (n=1,190). The study focused on mortality, readmission, and LOS, and the patients received usual transitional care. The record-based MPI was a good predictor of one-year mortality and, in retrospect, associated with LOS. Moreover, frailty (MPI>1) measured by the record-based MPI at discharge was associated with a double risk of 30-day unplanned readmission, compared to the non-frail (MPI=1) patients in the cohort. The mortality rate and readmission rate among the included frail older medical patients were quantified. Furthermore, the number of referrals to the GP-based usual care follow-up home visit was quantified, and the number of accomplished home visits was assessed. The record-based MPI was a feasible and valid measure for predicting frailty-associated clinical outcomes among older medical patients at discharge from a secondary regional hospital.

Study III is the first study to compare a municipality nurse-led TCI to a multidisciplinary geriatric team-based TCI in a RCT. To our knowledge, it is the only study using multidimensional frailty as an inclusion criterion in a transitional care study. The study included frail (bedside MPI>1) older (75+) patients discharged from the ED or a geriatric ward after receiving in-hospital, CGA-based treatment (n=3,103). Compared to patients receiving a municipality nurse-led TCI, a significantly lower risk of 30-day unplanned readmission was observed among those receiving a multidisciplinary, hospital-based geriatric team TCI. No significant difference was seen in 90-day mortality or LOS. The observed effect of the hospital-based TCI on readmission was more pronounced and significant only among those living together with a relative. The patients' degree of frailty (MPI=2 or MPI=3) did not seem to alter the OR of readmission in the two TCIs. When looking further into two post-hoc added subtypes of readmission, the effect of the geriatric team TCI seemed to reduce the risk of readmission to hospital at home significantly, and no significant difference was observed between the two TCIs when looking at in-hospital readmissions alone.

6 Discussion

6.1 Methodological considerations related to the three studies

6.1.1 **Study I:** Reproducibility and diagnostic accuracy of the record-based MPI

As reported in paper I (200), several limitations apply to the methods used in study I. The pre-inclusion assessment criteria discarded the self-sufficient patients with a low comorbidity burden (CCI<1), implying a study sample with 90% frail (MPI>1). This approach introduced a ceiling effect and may have reduced the validity of the record-based MPI in populations with a lower frailty prevalence. For example, using severe frailty (MPI=3) with a prevalence of 24% as reference standard, the sensitivity estimate dropped to only 75% (95% CI: 43-95%). Furthermore, we excluded patients in whom less than all three ratings had been accomplished (n=20; see section 3.4, or paper I (200)). This may further have reduced the variability in the study sample, although the excluded patients were not significantly different with regard to age, sex, or hospital department (see paper I for details (200)). However, the sample size was sufficient to accurately estimate the sensitivity in our sample, although it was not enough to obtain a reliable specificity estimate (218). Likewise, the high PPV and NPV should be interpreted very cautiously. Nonetheless, the sample was sufficient to attain inter-method reliability (ICC) estimates with a confidence level of ±0.20 (214, 219).

The clinicians doing the bedside MPI ratings were two physiotherapists and one occupational therapist. A research nurse and a medical doctor did the record-based ratings. The clinicians were familiar with the rating methods and the medical record system. However, the content of the medical records was not always interpreted uniformly or precise information was not available. Similar to the "positive results bias" phenomenon known from the scientific literature, clinicians tend to report only positive findings in the medical record. If nothing was noted in the record about one or more of the parameters included in the MPI, the clinician would have to do the rating based on his or her best judgment. For example, reproducibility of the record-based assessment of FRS-IADL (research nurse vs. medical doctor) was lower than the inter-method reproducibility (medical doctor vs. one of the bedside raters). The medical doctor systematically rated the CIRS-G higher than the research nurse (200). This indicates that training and clear guidelines are required to assess the parameters included in both the bedside and the record-based ratings. Face-to-face interaction with the patient may reveal more precise information than the historical data in the medical record and may be less sensitive to interpretation bias.

Ideally, a larger group of clinicians should have been randomly assigned to do both types of ratings (220). Thereby, we would know more about the reproducibility and diagnostic accuracy between different professions, which would have heightened the generalisability of the results.

6.1.2 **Study II:** Prediction using the record-based MPI in a usual care setup

The pre-inclusion assessment criteria excluded 31% (n=543) of all older (75+) patients who were admitted to the medical ward and ED during the inclusion period. The frailty level of these individuals is unknown, but most likely they would have been categorised as non-frail (MPI=1) if they underwent the full assessment. The resulting frailty prevalence was 72% in our cohort. Expectedly, 49% of the 1,733 admitted, older medical patients would be considered frail. Excluding the self-sufficient patients from the comparator group has likely affected the RR estimates for the moderately and severely frail groups, resulting in underestimation of their relative mortality and readmission risk. As described above in relation to study I, the lower frailty prevalence could be problematic because the record-based method might not accurately diagnose frailty given a frailty prevalence below 90%. Still, for the following reasons, we are convinced that the record-based ratings in study II were at least as accurate and reliable as the ratings in study I. First, the record-based MPI ratings were all done by the medical doctor from study I, who now had experience with the record-based MPI. Thereby the ratings were not susceptible to inter-clinician measurement error, although intr**a**-rater variability could not be accounted for. Second, because the ratings were made after discharge, the available medical record material was far more comprehensive in study II. Although the pre-admission assessments from the municipalities were not reported in the same way in all municipalities, and had not always been recently updated, valuable information from the primary care sector was available in all cases. For example, the evaluation methods used to assess physical functional capacity differed between wards, but they still provided valuable information. Together with the updated pre-discharge needs assessment and the discharge letter, this information turned out to be very useful and improved the quality of the ratings.

The medical doctor was not blinded to the results of the ratings when he recorded the outcome data, and sometimes the outcome had occurred by the time the record-based MPI was assessed. Nonetheless, mortality and readmission are sensitive, binary outcome measures. Both were retrieved from the medical record, which is linked to the Civil Registration System (please refer to Appendix 1 for further information about the interconnection of Danish registries and the electronic medical record). Likewise, LOS could usually be assessed very accurately from the medical records. Despite these methodological limitations, we find the applied methods appropriate to assess the predictive ability of the record-based MPI.

6.1.3 **Study III:** Comparison of two early TCIs for frail patients

The number of patients discarded because of the pre-inclusion assessment criteria in study III is not known. However, because all the patients in study III received routine CGA-based assessment before allocation to further geriatric treatment(92), the number of discarded patients due to the pre-inclusion assessment was low in study III compared to study II. A random check during the inclusion period showed that all the discarded patients were non-frail and/or would have been excluded for other reasons.

As described in Methods section 3.3, some patients were included more than once. Although the number of patients included more than once was equally distributed in the two random groups, including such patients could have introduced the risk of survivor bias. The applied statistical correction method specified that the standard errors allow for intra-group correlation. It may not fully have compensated for the lack of independence between individuals required for the logistic regression. However, our setup mimics the real world where some patients have repeated admissions.

The bedside MPI ratings were made continuously by multiple clinicians with different educational backgrounds: nurses, physiotherapists, and occupational therapists. Randomly mixing the rating clinicians reduced the risk of systematic bias of ratings and increased the quality of the ratings. However, most of the patients discharged directly from the ED were rated by a single clinician, except for the CIRS-G, which was always made by the attending physician. To capture frailty as closely as possible to the discharge hour, the clinicians were instructed to keep the ratings up to date during the admission.

The outcome data collectors could not be blinded to the bedside MPI ratings, though they were not directly involved in the bedside MPI rating (92). The lack of blinding could have caused confirmation bias. However, as described above in relation to study II, the outcome data were highly reliable. Thus the risk of bias was inconsiderable.

Post-randomisation exclusions

Ideally, the randomisation should take place just before discharge. However, due to the need for individualised discharge planning, we had to accept to randomise the cases early during hospital admission. This led to the inclusion of patients that did not fulfil the inclusion criteria, for example, patients that were younger than 75 years, non-frail, and patients who died during admission. This could have affected the readmission and mortality rates in the ITT analysis negatively but evenly in the two TCI groups. In accordance with the ITT principle, all the randomised patients were analysed. However, we wanted to focus our analysis on frail older patients fulfilling the inclusion and exclusion criteria. Consequently, 925 admitted patients were excluded in the modified (mITT) analysis. The post-randomisation exclusion is precisely accounted for in the flow chart (Figure 1 in the dissertation and in paper

III (92)). Another consequence of the early randomisation was that more patients were included to reach the predefined sample size in the mITT analysis.

6.2 Combined methodological considerations for the studies

6.2.1 The bedside MPI (study I and study III)

In our bedside MPI, the Katz index (ADL) and the Lawton scale (IADL) were replaced with the FRS, containing both ADL and IADL domains, and the CIRS was replaced with the geriatric version, the CIRS-G(201). As presented in section 1.4: the Multidimensional Prognostic Index, the MPI is a flexible tool with great plasticity. Other studies have successfully made adjustments to this multidimensional score (39, 41, 44). Replacement of the Katz index and Lawton scale with other ADL and IADL assessment scales was previously validated (45). The CIRS-G itself was validated against other scores and clinical outcomes, and the inter-rater reproducibility was assessed (221). Our adjusted bedside MPI was comparable to the original MPI in predicting mortality (201), which was not surprising as the replaced and introduced scores are almost identical. As we were not constructing a new prediction model, we did not conduct a full development and validation process in accordance with the TRIPOD guidelines (222) before the bedside MPI was put into use. This might limit the comparison of our results to other studies using the original MPI and other fully validated MPI versions. Still, we consider our bedside MPI (201) fully comparable with the original MPI (24).

6.2.2 The record-based MPI (study I and study II)

Some adjustments of the data collection had to be made to obtain the required information from the medical records. Please refer to paper I, Table 1 for further elaboration (200). The original MPI divides all item scores into tripartite scores to calculate the MPI score (24). As expected, changing the ten-question SPMSQ and the neuropsychological evaluation embedded in the MNA-SF to tripartite ratings did not affect the aggregated MPI score. Consequently, it is not necessary to run the full SMPSQ in older hospitalised medical patients if the only purpose is to calculate the MPI score.

6.2.3 Frailty definition

We defined frailty as MPI>1, subdividing the patients into groups of non-frail (MPI=1), moderately frail (MPI=2), and severely frail (MPI=3). This is in contrast to a recent review defining a pre-frail group as patients with a MPI=2 and frail as those with a MPI=3 (39). MPI=2 and MPI=3 are suitable cut-points when looking at mortality (24). As demonstrated in our studies, MPI>1 may be a reasonable cut-point for readmission, although we did not set our frailty cut-point based on a validated cut-point for readmission. The "optimal" cut-point for a diagnostic test is highly dependent on the sample in which it is

estimated. Furthermore, the MPI was not developed to predict readmission, and our definition of readmission is not universally valid. Moreover, a dichotomous definition of frailty based on the MPI is conflictual considering the MPI's status as a multidimensional approach in contrast to the dichotomous phenotype frailty model. However, cut-points are needed to compare frailty measures, for example, in regard to predictive ability. The definition of frailty we used was meaningful in our setup. Using MPI<2 as comparator in study II would have minimised the observed differences in RR for readmission. In study III, a higher cut-point would have excluded more patients from the study, drastically reducing the generalisability of the results.

6.2.4 Selected outcomes

Mortality

We used 90-day post-*admission* mortality as an outcome measure because the randomisation in study III was done shortly after admission. Examining the effect of post-discharge interventions, we were interested only in patients who were discharged alive. Hence, in-hospital mortality was not reported. In-hospital death would result in exclusion; thus the patients that were included in the studies were practically "immortal" while hospitalised. This could cause "immortal time bias" (223) in studies II and III. In study III, this could be particularly problematic if the open randomisation or other factors resulted in a difference in LOS, which would mean a difference in "immortal time". However, there were no significant differences in baseline parameters (including the LOS) in the two groups at discharge. The successful randomisation seems to have eliminated the potentially severe consequences of our disadvantageous choice of mortality outcome measure. The Cox proportional hazards model and the Kaplan-Meier survival curve were an obvious choice to illustrate the mortality hazards.

Readmission

We defined unplanned readmission to hospital or HAH occurring between four hours and 30 days after discharge as the primary outcome in study III and as the secondary outcome in study II. We recorded the first event and the time to first event within the follow-up period. Thirty-day post-discharge mortality was a competing risk for readmission. The Cox regression was not a good choice for the analysis of readmission for three reasons. First, the Cox proportional hazards assumption was violated in study II. Second, it was difficult to add a competing risk to the model in study III, and third, readmission is intuitively better interpreted when reported as a cumulative incidence. Thus, we used the Aalen-Johansen estimator to provide the graphic presentation of our data. An alternative to using time to first event is to use a recurrent event method such as Poisson regression for count data, or the Andersen-Gill model for assessing event times (224). These models would better account for the patients' burden related to *repeated* readmissions, and would increase the power of the analysis.

However, the Poisson regression does not take time to event into consideration, assuming that rates are constant within time periods (225), and the Andersen-Gill model assumes that one event does not affect the risk of a subsequent event (224). Recent admission (and readmission) is a well-known risk factor for readmission (226); hence, the assumption would be violated, and the Andersen-Gill model would combine direct and indirect effects. The duration of follow-up and the appropriateness of the selected outcome measures were further discussed in paper III (92).

6.3 Results

6.3.1 **Study I:** Reproducibility and diagnostic accuracy of the record-based MPI

We found high agreement and good reliability of the record-based MPI compared to the bedside MPI. The record-based MPI could accurately diagnose frailty (bedside MPI>1). There was good agreement and acceptable reliability between ratings made by a research nurse and a medical doctor (200). The most important limitations lie in the generalisability to other populations, clinicians, and medical record systems, as discussed above in section 6.1.1. The results are valid in populations of older (75+) hospitalised medical patients with a high frailty prevalence and some degree of comorbidity (CCI≥1) or reliance on daily caretaker assistance.

A limited number of studies have compared record-based frailty measures to bedside measures, and these studies have reported only fair to moderate agreement between methods (200). The reliability measures are not directly comparable between populations. When compared to the original MPI, other versions of the MPI had better agreement than our record-based method (45, 46). This was not surprising, as our population was older and far more frail (200). The results and limitations were further discussed in paper I (200). Based on study I, the record-based MPI is considered an accurate and reliable method for identification and quantification of multidimensional frailty that can be used for research purposes. However, the method needed further validation in a larger, external study sample to be valid for clinical prediction. This was examined in study II.

6.3.2 **Study II:** Prediction using the record-based MPI in a usual care setup

We found that the record-based MPI obtained at hospital discharge had good predictive and discriminative value regarding mortality risk among older (75+), acutely admitted medical patients discharged from a secondary regional hospital. Frailty (MPI>1) was associated with a two-fold increased risk of 30-day readmission. The method was not suitable to identify individuals at risk of readmission, but it could be used to separate high-risk and low-risk patients, as we discussed in paper II (202). The frailty level at discharge was retrospectively associated with LOS (202).

Our results regarding prediction of mortality risk were comparable to other studies using face-to-face MPI assessment (24, 32, 201). With regard to the prediction of readmission risk, the record-based MPI was comparable to the bedside MPI (201). The record-based MPI was inferior to most other readmission prediction models, for example, machine learning-based models (227). Still, it is useful to identify older adults at high risk of negative events using a structured, CGA-based approach which is linked to geriatric care and intervention. The retrospective association between frailty and LOS was not surprising, as frailty and LOS are well-known correlated factors (228). The record-based method overrules previous versions of the MPI by permitting multidimensional frailty assessment and prediction of mortality risk whenever the patient is not available for bedside assessment. All patients could be assessed regardless of their cognitive status (200). It was up to five minutes faster to run than the original MPI (24, 39). Hence, the record-based MPI method is highly useful for quality development purposes, and may be used for clinical identification of high-risk patients in similar populations of older medical patients, provided the patient gives informed consent.

In addition to examining the predictive and discriminative ability of the record-based MPI, the study also quantified mortality and readmission rates among the patients included in the cohort. The generalisability of the results was limited to the cohort. However, it allowed us to make reasonable comparisons between frail older patients receiving usual transitional care and frail older patients receiving alternative transitional care interventions, as will be discussed later in the combined discussion, section 6.4.

Included in usual care for older patients is an offer of home-visits by the GP and a district nurse within a week after discharge. Only 14% of the total cohort were offered such follow-up home visits, and in only 11 patients was they accomplished within the scheduled time frame after discharge. Compared to the number of follow-up home visits in other municipalities (229), our results confirm that the usual transitional care model is not equitably offered to all older adults at discharge. Local circumstances, for example, the distance to the hospital, affects the use and feasibility of the GP-based follow-up model, as has previously been discussed by others (7, 8). Our findings strongly imply a basis for alternative, feasible, and effective transitional care interventions for older medical patients.

6.3.3 **Study III:** Comparison of two early TCIs for frail patients

We found that the geriatric team-based intervention was superior to the municipality nurse-led intervention in preventing unplanned readmissions within the first 30 days after discharge (92). The NNT in the ITT analysis was 27, and the resulting, significant OR was 1.27, p=0.008 (92). When the data were stratified for type of dwelling, the result was significant only among cohabiting patients. Stratified with regard to frailty grade, the results were not significant in the smaller sub-groups; however, the trend was still in favour of the

geriatric team intervention. No significant difference was observed between the interventions regarding LOS or mortality. Both TCIs were considered practically and clinically feasible, and were well accepted by the included patients (92, 230).

The results and the two interventions were discussed thoroughly in paper III (92). We have previously discussed the results of our studies of the geriatric team intervention vs. usual care (3-5), other studies using the Danish usual care intervention (6, 7), nurse-based interventions (9, 12, 180, 185, 186), and multidisciplinary team-based interventions (192, 196). The focused literature review (section 1.8 and Table 1 in this dissertation) showed that the existing literature regarding nurse-based and geriatric team-based TCIs for older patients is rather limited. However, a few illustrative examples of nurse-based interventions should be discussed here. In a recent stepped-wedge cluster RCT, an early (48-72h) post-discharge nurse follow-up home visit combined with weekly phone calls and a second visit within four weeks was compared to usual care (188). The included patients were geriatric patients with defined readmission risk factors and high age (mean 87 years). The nursing home residents were excluded. Although the intervention was initiated early and the patients were at high risk, no significant difference was seen with regard to readmissions. This could be explained by the relatively low intensity of the applied intervention compared to usual care, and the fact that the included patients were not frail. Another RCT reported a significant reduction in readmissions among older patients receiving a pre-discharge comprehensive nursing and physiotherapy programme followed by early (<48h) nurse-conducted home visits (179). This intervention is comparable to our early, municipality nurse-led TCI in that it included both pre- and post-discharge components and focused on both exercise and nurse-based follow-up. However, the study sample was relatively small, the included patients were younger, all were able to exercise, and all were cognitively well. The authors later reported on three combinations of telephone-, nurse- and exercise-based interventions compared to usual care in a RCT, concluding that interventions that included a nurse home visit significantly reduced readmission (12). Still, the populations and health care systems were different than those in our study, hindering a direct comparison to the nurse-led intervention applied in our study.

Highlighting the unmet need for transitional care approaches building on stringent academic approaches and sufficient data, not all the previous RCTs listed in Table 1 were reported according to the ITT principle, and the results of these trials are divergent. This was supported by a recent systematic review including only bridging TCIs (231). Based on our sample size calculations, many studies were simply too underpowered to provide robust estimates (92). Several studies reported on the basis of less than 200 individuals (178, 179, 185, 189, 191, 193, 195, 196). These studies will not be further discussed here. Older studies are relevant to fully understand the background; however, both the interventions and usual care have developed dramatically since the reporting of some of the earliest RCTs comparing

nurse-based intervention (178) and a geriatric team intervention (189). Discussing the results of a RCT in the context of a cohort study (11, 194) or propensity-matched control groups (197, 198) should be done cautiously. Nonetheless, one large, recently published, Danish cohort study attracts attention. Thomsen et al. reported on patients discharged from a geriatric department (199). In this study a geriatrician and a nurse visited patients discharged to skilled nursing facilities within a week after discharge. Compared to a historic control group, this intervention resulted in significantly reduced 30-day unplanned readmission (HR=0.69 (95% CI: 0.54-0.87); p=0.004). Although this cannot be directly compared to the results of our RCT, it is nonetheless supportive of the effect of a geriatric team-based TCI in a Danish context. Although a similar trend was observed, our data did not show a significant effect of the geriatric team-based TCI for patients discharged to nursing home or other types of institution when the geriatric team intervention was compared to our new nurse-led intervention.

Although the pre-discharge care (including the CGA) was the same in both interventions, there might be a synergistic effect of the combination of pre-discharge care and the post-discharge interventions. This could have confounded the results in both directions. It can also be argued that the observed superiority of the geriatric team intervention was only marginal, compared to the dramatic effect we saw previously in our studies comparing the geriatric team intervention to usual care(4). Some degree of contamination between the interventions has very likely developed during the years since our first studies of the geriatric team, potentially introducing bias towards the null. This may especially be the case among the patients living in nursing homes. It has previously been observed that the risk of readmission and the type of dwelling are associated (226). Thus, we stratified for the three types of dwelling that were included in the MPI: living alone, living in an institution, or cohabitating. The effect of the geriatric team-based intervention was higher and significant among those discharged to cohabiting with a relative. These results are all further explained and discussed in paper III (92).

To further explore the MPI's ability to identify those at risk of negative events, we made pre-specified subgroup analyses based on frailty. The trend was still in favour of the geriatric team-based intervention among the moderately frail and the severely frail; however, the estimated difference between the interventions was not significant. The degree of frailty itself (MPI=2 or MPI=3) and the MPI score (range 0.33-1) did not predict readmission risk in study III.

As the data collection progressed, it became clear that HAH played an important role in the post-discharge transition of care. Patients readmitted to HAH could represent a specific subgroup of geriatric patients with specific needs best met by one of the interventions. To look deeper into this, we divided the readmissions into two groups, depending on the type of readmission. The external validity of the results was limited because the analysis was added

post hoc, and the numbers of events were small. Hence, our results about the use of HAH related to our two interventions should be interpreted very cautiously and may only be useful for generating hypotheses for future studies. However, the results indicate that the geriatric team plays an important role in treating a subgroup of severely frail patients at home, accounting for approximately 10% of readmissions that would otherwise be referred to hospital. A recent, large RCT concluded that HAH is a safe alternative to hospital admission for "old older" persons (232). We do not know much about the patients who receive what we call "readmission hospital at home" as an alternative to readmission to hospital during the 30 days after an index admission. The HAH intervention itself and the reasons for allocating the patient to readmission avoidance HAH are unknown.

6.4 Combined discussion of the two TCIs and usual transitional care

We now know from study I that there was good agreement and reliability between the two MPI rating methods, and study II demonstrated that the record-based MPI and the original MPI were equally predictive for mortality. It is tempting to compare the outcomes for the frail older medical patients receiving usual transitional care in study II to the outcomes for the frail geriatric patients randomly allocated to the two TCIs in study III.

Interestingly, 24% of the frail (MPI>1) patients receiving usual care were readmitted within 30 days. For comparison, 22% of the frail patients allocated to the municipality nurse-led intervention and 18% of the frail patients allocated to the geriatric team intervention were readmitted within the same observation time. The higher readmission rate among the frail patients receiving usual transitional care (study II) was surprising, as the frail patients in study II had a significantly lower MPI score (range 0-1) than the frail patients included in study III.

Mortality was 17% among the frail patients in study II, compared to 21% and 22% in the two groups in study III. A satisfactory explanation for this is that the MPI score was lower in the frail patients in study II, compared to study III. In addition to this, the LOS was longer in study II than in study III, meaning that the frail patients in study II had more "immortal time" than the patients in study III; hence, the difference in LOS contributes to the higher 90-day post-admission mortality observed in study III.

Though the above comparisons are interesting, the MPI was not rated using exactly the same method in both studies, and despite the good reproducibility between the methods, the three groups of frail older patients were not entirely comparable. The nurse-led intervention and the geriatric team-based intervention might both be effective compared to usual transitional care, but the design of the RCT in our study did not allow us to reach separate conclusions regarding the effects of the two interventions. Other factors, for example,

the pre-discharge CGA, different admission diagnoses, and local variations in primary care could explain the observed differences.

6.5 Ethical considerations

The three studies were approved as quality development projects by the Regional Research Ethics Committee (197/2017) and the Danish Data Protection Agency (general approval for the Central Denmark Region: 2012-58-006), and the individual studies were all approved by the local hospital administrations, hence, further approval was not required. The approval as quality development projects allowed us to include all patients, including patients with reduced cognitive functional capacity. This is a major strength of our results, and a great advantage to the frail older adults. The study protocol for study III is available at www.clinicaltrials.gov (NCT03796923).

7 Conclusions

We hypothesised that the record-based MPI had sufficient inter-rater and inter-methods agreement, reliability, and diagnostic accuracy to provide a valid alternative to bedside MPI assessment. We conclude that the hypothesis cannot be rejected, and the method is considered valid under specific conditions with regard to frailty prevalence, the electronic medical record, and the clinicians doing the ratings.

We hypothesised that the record-based MPI at hospital discharge predicts mortality, readmission, and LOS among older, acutely admitted medical patients. This hypothesis was not rejected, and we consider the record-based MPI valid in predicting the listed outcomes provided the specific conditions listed in the discussion are met.

We hypothesised that a municipality nurse-led and geriatric team-based TCI are equally effective at preventing readmission and mortality, with no difference in LOS, among frail older geriatric patients. This null-hypothesis was rejected with regard to readmission, as the geriatric team-based intervention was significantly superior to the municipality nurse-led intervention. Further analyses suggested that the geriatric team-based intervention may be more effective among specific sub-groups of frail patients, but these results need further experimental investigation. The null-hypothesis could not be rejected with regard to mortality and LOS.

8 Future perspectives

This work demonstrated the need for alternatives to usual transitional care for frail older medical patients. Two alternative models were presented and compared. An early geriatric team-based intervention was superior to a new, early, municipality nurse-led intervention among older, acutely admitted geriatric patients. The geriatric team intervention is currently being offered to selected patients at discharge from AUH, and the team is continuously engaged in elective and hospital at home treatment for referred geriatric patients. The nurse-led intervention is now a standard procedure at discharge for older patients in Aarhus Municipality as an add-on to usual transitional care. We cannot conclude whether the potential effect of introducing an early, municipality nurse-led intervention was superior to that of a multidisciplinary geriatric team intervention in a usual care setting. Future research should aim to address this important question.

Our studies suggest that the geriatric team intervention may be more effective than the nurse-led intervention among specific groups of frail older patients. For example, studies designed for comparing the effects of interventions and usual care among nursing home residents, or patients assessed eligible to be treated at home as an alternative to hospitalisation, may enable further targeting of the interventions. We are currently in the process of further characterising the patients that were readmitted to HAH. Future work from our department will concentrate on the geriatric team's activities with regard to home treatment. Furthermore, we are conducting secondary analyses based on our cohort receiving usual care to further elucidate distribution of frail patients across medical specialties and the potential effects of in-hospital CGA on readmission. Further work needs to be done to establish the direct and derived economic aspects of usual transitional care and other transitional care interventions.

We successfully included frail older medical patients without being constrained by diagnosis, type of dwelling, and cognitive or physical functional status. Our record-based method was faster than previous bedside assessment methods, and it could be undertaken retrospectively and regardless of the patient's cognitive status. It facilitates multidisciplinary frailty assessment of large study populations. Since the first studies, the method has been further validated and compared to the CFS (22) among older inpatients with COVID-19 (233). Currently, the record-based MPI is being applied in a cohort study of more than 400 older patients with *C. difficile* infection (Unpublished data). Development of the MPI continues, and we are currently involved in the validation of a new short-form version of the MPI, the BRIEF-MPI, together with nine other European geriatric centres (Personal communication). Prospectively, this will save time and work needed to make the face-to-face MPI ratings and will be more convenient for the patient.

A fully digitised, CGA-based frailty tool is required to further investigate the aspects of transitional care among the whole population of hospitalised, frail, older adults. Flagging frail individuals, regardless of their allocation to (medical) specialties, could further qualify the referral for in-hospital geriatric evaluation and post-discharge transitional care. Such a tool would be clinically useful, time-saving, and could potentially expand the reach of the sparse geriatric competences to all older patients.

Patient and Public Involvement (PPI) has many advantages, but how to best involve frail patients in research was not established when we launched our project. We unsuccessfully attempted to involve frail patients and their relatives as fellow researchers (234). Though it was too late to be included in the work presented in this dissertation, relevant outcomes for transitional care research were identified in collaboration with frail older patients and their relatives. We recommend involvement of patients, relatives, and other stakeholders from the earliest planning phases in future geriatric research.

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Appendices

Appendix 1: The Danish Health Care System

The Danish healthcare system is tax-financed and available to all Danish residents on a free and equal basis. Each patient is listed with a GP functioning as a gatekeeper to the secondary sector. The GPs are the first point of contact for the patients, except in emergencies and outside of regular office hours (235). On-call GPs deliver acute treatments during weekends and on weekdays from 4 p.m. to 8 a.m.

The municipalities

The 98 Danish municipalities deliver home care, home nursing care, rehabilitation in people's homes and rehabilitation units, and temporary and long-term care in nursing homes. Independent referral coordinators in each municipality manage the assignment to municipal services. Since 2019, about 2/3 of Danish nursing homes offer regular assistance from affiliated GPs on a weekly basis (236). One exception to this is Vikærgården, a highly specialised, post-acute facility for rehabilitation and short-term care located in Aarhus Municipality. Here the local hospital-based geriatric team provides weekly consultations for residents recently discharged from the geriatric wards and to those referred by their own GP to the geriatric team.

The Regions

The five Danish Regions are responsible for the hospitals' service. In Central Denmark Region (1,335,289 citizens; 9% aged 75+ (237)), there are four main regional hospital units providing secondary care (outpatient, inpatient, and intensive care), and one tertiary care centre (Aarhus University Hospital) also providing secondary care to residents in Aarhus Municipality. Geriatric functions are currently progressing in Danish regional hospitals, and nowadays most regional hospital units employ geriatric specialists. However only a few secondary hospital units have dedicated geriatric wards. Just as is the case with GPs, there is a generalised demand for geriatricians and nurses. There is no collective agreement for geriatricians working outside hospitals.

The Civil Registration system and the electronic medical record

All Danish citizens are given a unique personal identification number based on their birthdate and sex. The 10-digit number links health data, domiciliary data, vital status, etc. together through the national Civil Registration System (CRS) (238). All Danish hospitals use electronic health record systems. Hospitals in the Central Denmark Region use Columna Clinical Information System ("Midt-EPJ") since 2015. The system connects the hospitals' health data (biochemistry, radiology, microbiology, pathology, medication chart) to data from the CRS, other hospitals, and the primary sector via the unique personal identification number. At hospital admission, the municipality delivers data regarding preadmission assessment, need for assistive remedies, and allocation of home care. Referrals from GPs and other practicing specialists are also visible in the electronic medical record, and medication charts from primary care are linked to the medical record's medication list via the shared medication record (239). Thereby data from primary care and all hospitals in the Central Denmark Region are linked to national data, giving hospital clinicians access to accurate and comprehensive health related data, including regional data on readmissions and LOS, as well as precise data on vital status.

Appendix 2: Details of the literature search strategy

Pubmed
The search in Pubmed used MeSH terms and produced 274 results:
((("Frail Elderly"[Mesh]) OR (frail*[Title/Abstract])) AND ((("Clinical Trial" [Publication Type]) OR ("Cohort Studies"[Mesh])) AND (((((((("Health Transition"[Mesh]) OR ("Continuity of Patient Care"[Mesh])) OR (transition*[Title/Abstract])) OR (discharge[Title/Abstract])) OR (handover*[Title/Abstract])) AND ((((("Aged"[Mesh]) OR (aged[Title/Abstract])) OR (older[Title/Abstract])) OR (elderly[Title/Abstract]))) AND ((((("Patient Readmission"[Mesh]) OR (readmission*[Title/Abstract])) OR (rehospitalization*[Title/Abstract])) OR (rehospitalisation*[Title/Abstract]))) NOT ((("Review" [Publication Type]) OR ("Systematic Review" [Publication Type])) OR ("Meta-Analysis" [Publication Type]))))

Embase
The search in Embase used Emtree terms and produced 276 results (#4):
#1: "clinical handover"/exp
#2: "aged"/exp
#3: "hospital readmission"/exp
#4: #1 AND #2 AND #3

CINAHL
The search in CINAHL produced 196 results:
(older adults or elderly or geriatric or geriatrics or aging or senior or seniors or older people or aged 65 or 65+) AND
(readmission or rehospitalization or readmittance or re-hospitalization or re-admittance or re-admission) AND
("transitional care" or "transition of care")

Cochrane Library
The search in Cochrane Library used MeSH terms and produced 260 results (#4):
#1: (Aged) in all MeSH products
#2: (Patient readmission) explode all trees
#3: (Continuity of Patient Care) explode all trees
#4: #1 AND #2 AND #3 in Cochrane Reviews and Trials

The search results were combined with my private Endnote reference library, and duplicates were removed. All titles and abstracts were then screened using Covidence (240), an online tool developed for systematic reviews.