J Nutr Health Aging
Volume 20, Number 2, 2016

VALIDITY, RELIABILITY AND FEASIBILITY OF TOOLS TO IDENTIFY FRAIL OLDER PATIENTS IN INPATIENT HOSPITAL CARE: A SYSTEMATIC REVIEW

R.M.J. WARNIER[1,2,3], E. VAN ROSSUM[1,5], E. VAN VELTHUIJSEN[1], W.J. MULDER[2], J.M.G.A. SCHOLS[1,4], G.I.J.M. KEMPEN[1]

1. School CAPHRI, Department of Health Services Research, Maastricht University, Maastricht, The Netherlands; 2.Department of Internal Medicine, Geriatrics, Maastricht University Medical Centre, Maastricht, The Netherlands; 3. Department of Integrated Care, Elderly care, Maastricht University Medical Centre, Maastricht, The Netherlands; 4. School CAPHRI, Department of Family Medicine, Maastricht University, Maastricht, The Netherlands; 5. Zuyd University of Applied sciences, Heerlen, The Netherlands. Corresponding author: RMJ Warnier, Maastricht University Medical Center, Department of Integrated Care, Elderly care, PO-Box 5800, 6202 AZ Maastricht, The Netherlands, Telephone: 0031-433877540, Fax: 0031-433876527, Email: ron.warnier@mumc.nl

Abstract: *Background:* The objective of this study is to identify and review screening tools for frailty in older adults admitted to inpatient hospital care with respect to their validity, reliability and feasibility. *Methods:* Studies were identified through systematically searching PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase and PsycINFO and screening reference lists till June 2014. Papers dealing with screening tools aimed at identifying frail older patients in in-hospital care, and including information about validity, reliability or feasibility, were included in the review. The quality of the included studies was critically appraised via the Quality Assessment of Diagnostic Accuracy Studies (QUADAS). *Results:* From the originally identified 2001 studies 32 studies met the inclusion criteria, in which 16 screening tools were presented. The screening tools showed different characteristics with respect to the number of items, the method of administration and the domains included. The most frequently studied tools with respect to predictive validity were the Identification Seniors At Risk (ISAR) and Triage Risk Stratification Tool (TRST). Studies retrieved poorer information about reliability and feasibility. Overall sensitivity was fairly good. The ISAR, ISAR-HP (Identification Seniors At Risk Hospitalized Patients) and Multidimensional Prognostic Index (MPI) generally had the best sensitivity. *Conclusions:* Many screening tools are available for daily practice. These tools to identify frail older patients in inpatient hospital care could be useful. For no tool, however, is clear evidence available yet regarding validity, reliability and feasibility. The overall sensitivity of the included screening tools was fairly good, whereas information on reliability and feasibility was lacking for most tools. In future research more attention should be given to the latter items.

Key words: Geriatric risk assessment, frailty indicator, hospital, elderly.

Introduction

The number of people aged 65 and over will increase in the coming decades. Worldwide it is estimated that the proportion of older people will rise from 11% in 2010 to 22% in 2050 (1).

As the proportion of older people expands, the number of people with one or more chronic illnesses and disabilities will grow as well (2). Due to such an ageing society, the use of health care services – including hospitals – by older people increases. In 2010, 16% of people aged 65 and over in the United States were admitted to hospital (3). In the Netherlands, almost 23% of the older population is admitted yearly to hospital (4). When older people with acute health problems are hospitalized, they are at risk of functional decline both during their hospital stay as well as after discharge. Approximately 30 – 60% of hospitalized older people lose the ability to perform relevant activities of daily living, compared with their pre-admission level of functioning (5). Andela and colleagues reported that 50 – 80% of elderly patients admitted are considered frail (6). Functional decline and frailty contribute to negative short and long-term health outcomes (7), a prolonged hospital stay (8), and readmission to hospital, admission to a nursing home, and increased mortality (9, 10). During acute admission, routine care focuses particularly on diagnostic and therapeutic interventions, while general geriatric problems (e.g. cognitive impairment, functional decline, etc.) are overlooked and seem to be relatively unrecognized (11). This suggests that not only the medical diagnosis but also preexistent levels of daily functioning predict negative outcomes after hospital admission (12). When elderly patients are screened in a systematic way during their admission, potential and additional geriatric problems may be identified and tackled at an early stage (13). Nowadays a substantial number of screening tools to identify potentially frail hospitalized older patients are available (14-17).

Although previously several systematic reviews have been conducted to evaluate the quality of screening tools to identify frail older people in a hospital setting, these reviews showed specific characteristics. First, searches for relevant study reports were performed in different databases. Second, different search strategies were applied. Finally, although the previous reviews retrieved information on the psychometric quality of frailty screening tools, there was either a lack of information about the feasibility of the included screening tools or feasibility was not assessed in a systematic way (9, 14-17). Therefore we performed an updated systematic review, and combined the

Received November 24, 2014
Accepted for publication January 15, 2015

strengths of earlier reviews to reach a systematic evaluation of both psychometric quality and feasibility of a larger number of screening tools.

The aim of this systematic review is to identify and review screening tools for frailty in older adults admitted to inpatient hospital care with respect to their predictive validity, reliability and feasibility.

Methods

Search Strategy

First, a systematic search of the literature was carried out using the following online databases: PubMed, Cumulative Index to Nursing and Allied Health Literature, PsycINFO and Embase. Databases were searched from the start date of the database until 1 June 2014. Second, referent links in the selected articles were searched for possible relevant studies.

Inclusion and Exclusion Criteria

Only full articles dealing with screening tools aimed at identifying frail older patients in in-hospital care, and including information about validity, reliability or feasibility were included in the review; abstracts and symposia proceedings were excluded. The following Mesh terms (or thesaurus-terms) and text words were used in the search:

1) elderly OR aged OR aged 80 and over OR older patient OR elderly patients OR frail elderly OR frailty elderly OR geriatric patient OR older people OR older adults;

2) hospital OR hospital admission OR acute care facility OR emergency department OR emergency service OR acute hospital OR hospitalized OR hospitalization OR hospital admissions OR acute care hospital NOT outpatient clinic OR nursing home OR long-term care;

3) geriatric screening instrument OR risk assessment OR frailty indicator OR screening tool OR Questionnaire OR geriatric risk assessment OR geriatric assessment OR geriatric assessment method OR frailty assessment;

4) frailty OR functional decline OR functional status OR ADL OR activities of daily living OR adverse health outcomes OR health deficits OR geriatric problems OR geriatric syndromes;

5) validity OR validation OR validation study OR reliability OR feasibility OR feasibility study OR psychometric properties OR sensitivity OR specificity OR outcome; assessment OR predictive value test;

6) combination of 1 + 2 + 3 + 4 + 5.

To include the largest number of studies possible, only a language limitation was used: studies had to be published in English, Dutch or German.

Study Appraisals

A stepped approach was used to include potential relevant articles. In the first step articles were selected by the first reviewer (author RMJW) based on the title of the study. Titles needed to refer to both screening and the intended population. The first one-hundred randomly selected titles were reviewed independently by two reviewers to test the procedure and the agreement between both reviewers (authors RMJW and WJM). In the second step, abstracts of the included studies were independently screened by the same two reviewers. The abstracts had to report on the intended population and setting (older people admitted to a hospital), the use of a screening tool or assessment instrument, and additional information about psychometric properties (i.e. predictive validity, reliability) and/or feasibility. In case of disagreement between both reviewers, a third reviewer (author GIJMK or JMGAS) read the abstract and decided to include or exclude the study from the review process. Finally, the remaining included studies were reviewed full text, again independently by authors RMJW and WJM. If there was disagreement between the two reviewers, a third reviewer (author GIJMK or JMGAS) read the article and decided whether or not to include the article in the study.

Next, the quality of the included studies was assessed independently by two reviewers (authors RMJW and EvV). Disagreement on items related to the latter was discussed afterwards in a consensus meeting. The quality of the reported studies was scored on an assessment scale for psychometric properties by the "quality assessment of diagnostic accuracy studies" (QUADAS) (18). The QUADAS is a validated tool developed to assess the diagnostic accuracy of studies included in systematic reviews. Based on 14 items, the QUADAS assesses different aspects of diagnostic accuracy, for instance "Were withdrawals from the study explained?" Each item has to be scored with "yes", "no" or "unclear". QUADAS provides no quantification of the methodological quality of the included studies, but classifies the probable risk of bias.

The predictive validity of the included screening tools had to be reported, when available, by means of sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV) and area under receiver operating characteristics curve (AUC). If these were not provided by the authors, other measurements like odds ratios (OR) or relative risk were retrieved from the studies. Sensitivity of a screening tool refers to the ability of the tool to correctly identify the patients at risk for negative outcomes. A screening tool with 100% sensitivity correctly identifies all patients at risk. Specificity of a screening tool refers to the ability of the tool to correctly identify those patients without a high risk for negative outcomes. A screening tool with 100% specificity correctly identifies all patients without a risk on negative outcomes. The PPV refers to the percentage of the positive screened patients who were afterwards true at risk. The NPV refers to the percentage of the negative screened patients who were afterwards not at risk for negative outcomes. The AUC represents an overall accuracy of the screening tool. An AUC of 1.0 represents a maximum sensitivity and specificity, an AUC of 0.5 represents no discriminative power of the test (19). The OR is a relative measure of risk, representing how much more likely it is

that someone who is screened «at risk» for negative health outcomes will develop the outcome as compared to someone who is screened «not at risk» (20). Reliability is reported by kappa (K). K refers to the agreement between raters. A kappa of 1 refers to complete agreement. If there is no agreement among raters other than would be expected by chance, the kappa is zero. A kappa > 0.75 refers to excellent agreement, K = 0.40 – 0.75 refers to fair - good agreement, and finally a K < 0.40 refers to poor agreement (21). Internal consistency of a scale is measured by Cronbachs alpha. An accepted guideline for Cronbachs alpha is between 0.70 and 0.90. This parameter indicates wether the items of the screening tool have some degree of relationship with each other (22).

Results are presented with respect to short-term outcomes and long-term outcomes. Long-term outcomes arewere defined as the ability of a screening tool to predict negative patient outcomes like prolonged hospital stays and readmissions for a period longer than 30 days. Short term outcomes are defined as the ability of a screening tool to predict the latter negative patient outcomes for a period shorter than 30 days.

In addition, feasibility was assessed with a set of four items used by Stevens and colleagues (23): the average time needed for administration, availability of instructions given to people completing the questionnaire, necessity of training for users and free access to the instrument for users via the article, an addendum or the internet.

Results

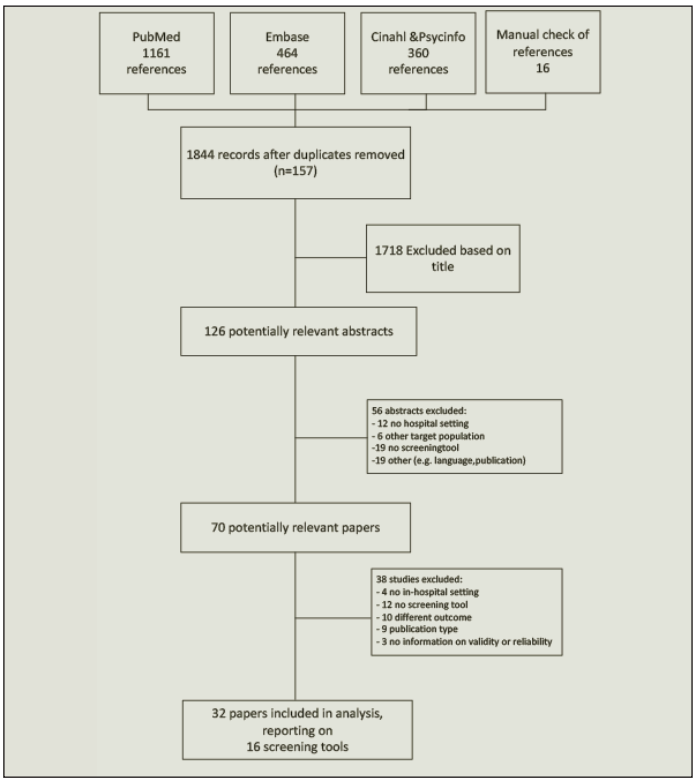
The systematic search resulted in a total of 1985 titles. Through reference checking, 16 studies that fulfilled the in- and exclusion criteria were added. After checking for duplicates, the titles of 1844 papers remained. As there was only a difference of 3% in the first 100 titles, author RMJW reviewed the full set of potentially relevant titles. One hundred and twenty-six abstracts were considered relevant, and were independently reviewed. While there was disagreement between both reviewers for 32 articles, a third reviewer was consulted here.

Seventy potentially relevant studies were included in the next step of the selection procedure. Afterwards, 38 studies were excluded as they did not fulfill the in- and exclusion criteria. Finally, 32 studies were included in this review comprising 16 screening tools. An overview of the different steps in the selection procedure is reported in Figure 1. The basic characteristic of the included tools are reported in Table 1.

Included Studies

The 16 included screening tools showed different characteristics. Most screening tools showed more or less a multi-domain approach. The number of items ranged from 3 (52) to 63 items (50). Some of the included screening tools were modifications of earlier developed tools, for instance Identification Seniors at Risk (ISAR) (24 – 33, 35) and Identification Seniors at Risk - Hospitalized Patient (ISAR-HP) (41, 55), Multidimensional Prognostic Index (MPI) (46, 50) and modified Multidimensional Prognostic Index (m-MPI) (47).

Figure 1
Flowchart of the Selection Procedure of Articles



Most screening tools were reported in one or two studies (i.e. Score Hospitalier d'Evaluation de Risque de Perte d'Autonomie (SHERPA) (5)), some screening tools were reported more often (i.e. ISAR (24 – 33, 35) or Triage Risk Stratification Tool (TRST) (24, 26, 30, 33 - 38)). Studies were performed in different continents, mainly in North America, Europe and Australia. Only one study had Asian origin (Table 2).

Critical appraisal of the included studies was conducted using the QUADAS score. Generally, all studies were well performed, except for the study on the SPICES with a QUADAS score of 5 (43). The remaining scores varied between 11 and 14. More details about the QUADAS scores are presented in Table 3.

Predictive Validity

Predictive validity was reported in different ways, ranging from likelihood ratios (39) to area under receiver operating characteristic curves (AUC) (40). Table 2 provides detailed information about the predictive validity of the included

Table 1
Basic Characteristics of the Included Screening Tools to Identify Frail Older Patients in Inpatient Hospital Care

Abbreviation	Full name	No. of items	Score-range (cutoff)	Mode of administration	Original Language	Screening domains									
						Cognition	Mood	ADL	IADL	Nutritinal-status	Mobility /falls	Comorbidity	Polyphamacy	Social support	Other domains
BRIGHT (44)	Brief Risk Identification for Geriatric Health Tool	11	1 - 11 (≥ 3 = high risk)	Self-reported	English		X	X	X		X				-Shortness of breath -Decision making
COMPRI (27,51,59)	Care complexity prediction instrument	13		Rated by physician (4 items), nurse (3 items) and by patient (6 items)	English						X	X	X		-Predictions by doctor -Predictions by nurse -Unplanned admission -Retirement - Active malignancy -Self perceived health -More than 6 doctor visits /3 month
EGS (40)	Emergency Geriatric Screening	4	0 - 4 (0 = not at risk, 3 < = at risk)	Rated by emergency-physician	English	X		X			X				
FI-CGA (42, 57)	Frailty Index based on CGA	55	0 - 1 (0 = no deficits, 1 = max. deficits)	Data abstracted out of CGA by geriatrician	Not stated	X	X	X	X	X	X	X			-Self perceived health -Peak flow -BMI -Shoulder strength -Grip strength -Pace
HARP (27, 52)	Hospital Admission Risk Profile	3	0 - 5 risk score (0 - 1 = low risk; 2 - 3 = intermediate risk; 4 - 5 = high risk)	Not stated	English	X			X						-Age
Inouye (45)	--	4	0 - 4 (no risk factor = low risk; 2 risk factors = intermediate risk; 3 - 4 risk factors = high risk)	Interview by nurse	English	X		X							-Decubitus -Low social activity level
ISAR (24-33,35)	Identification Seniors at Risk	6	0 - 6 (< 2; 0 = low risk, 6 = high risk)	Self-reported, or reported by nurse	English	X		X	X				x		-Recent hospitalization -Vision impairment

ISAR-HP (41, 55)	Identification Seniors at Risk – Hospitalized patients	4	0 - 5 (score 2 or more = at risk)	Not stated	English				X		X				-Travel assistance needed -Educational level
MFS (48)	Multidimensional Frailty Score	9	0 - 15 (score 5 or more = high risk)	Data abstracted out of CGA by geriatrician	English	X		X	X	X					-Active malignancy -Serum Albumin -Charlson Comorbidity Index -Delirium risk -Mid-arm circumference
MPI (46, 50)	Multi prognostic index	63	0 - 1 (0 – 0.33 = low risk; 0.34 – 0.66 = moderate risk; 0.67 - 1 = high risk)	Data abstracted out of CGA by geriatrician	Not stated	X		X	X	X			X		-Decubitus -Living situation
m-MPI (47)	Modified Multi Prognostic Index	51	0 - 1 (0 – 0.33 = low risk; 0.34 – 0.66 = moderate risk; 0.67 - 1 = high risk)	Data abstracted out of CGA by geriatrician	Not stated	X		X	X	X			X		-Decubitus -Living situation
ProFunction (58)	--	7	0 - 31 0 - 7 (Simplified ProFunction)	Not stated	English			X	X			X		X	-Age
REFS (49)	Reported Edmonton Frail Scale	13	0 - 18 (0 - 5 = not frail; 6 - 7 = apparently vulnerable; 8 - 9 = mild frailty; 10 - 11 = moderate frailty; 12 - 18 = severe frailty)	Self-reported or by proxy	English	X	X		X	X	X		X	X	-General health status -Incontinence
SHERPA (5)	Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie	5	0 - 11,5 (0 = low-risk; 11.5 = high risk)	Rated by ED-staff	English	X			X		X				-Self perceived health -Age
SPICES (43)	--	6	0 - 6 (score 2 or more = at risk)	Rated by nurse	English	X				X	X				-Skin integrity -Incontinence -Sleep disturbance
TRST (24, 26, 30, 33-38)	Triage Risk Stratification Tool	6	0 - 6 (< 2; 0 = low risk; 6 = high risk)	Self-reported and/or administered by nurse	English Italian Dutch	X					X		X	X	-ED use < 30 days or hospitalization < 90 days. -RN professional recommendation

ED= Emergency Department, CGA= Comprehensive Geriatric Assessment

screening tools.

Short-term Outcomes

Several screening tools were only validated on short-term outcomes (i.e. functional decline, Emergency Department (ED) readmissions and composite outcomes) (43-45). The sensitivity of the included screening tools ranged from 51% (26) to 94% (35). The sensitivity of the more often studied tools varied from 73% (32) to 94% (35) for the ISAR, and from 51% (36) to 87% (35) for TRST. In general, screening tools with a higher sensitivity performed more poorly on specificity (Table 2).

Specificity of the included screening tools ranged from 21% (35) to 79% (44). The specificity of the TRST varied between 21% (35) and 63% (38). The specificity of the ISAR ranged between 33% (33) and 47% (32).

Inouye and colleagues reported a higher risk of functional decline (RR 12.9) for patients stratified as "high risk" by their screening tool as compared to their "low risk" counterparts (45). Aronow and colleagues reported an OR of 3.04 on adverse hospital outcomes using the SPICES (43).

Pilotto and colleagues reported an AUC of 0.83 for short-term mortality using the MPI (46). Sancarlo and colleagues redesigned the MPI into the modified-MPI. They found an AUC of 0.75 for short term mortality (47).

Long-term Outcomes

Studies varied in their follow up from one to 12 months. Sensitivity on long-term outcomes differed from 21% (27) to 94% (31), the majority ranged between 60% and 80%. Lowest sensitivity was reported by Hoogerduijn and colleagues for the Hospital Admission Risk Profile (HARP) tool: 21% for functional decline (27). The highest sensitivity was found for the ISAR: 94% (37). Hoogerduijn and colleagues reported a high sensitivity for both functional decline (85%–89%) and mortality (81%) by the use of the ISAR-HP (41). Sensitivity of the ISAR varied from 56% (24) (ED-readmission) to 94% (30). The sensitivity of TRST varied from 53% (functional decline) to 88% (functional decline) (26).

Specificity for long-term outcomes varied from 23% (35) to 89% (27). The lowest specificity was reported by Graff and colleagues for the TRST (composite outcome): 23% (35). The highest specificity was reported by Hoogerduijn and colleagues for the HARP (functional decline): 89% (27). In general, the TRST specificity ranged from 23% (35) to 66% (38), both on composite outcomes. The ISAR specificity ranged from 37% (mortality) to 63% (31).

Other studies reported the predictive validity of screening tools with other indicators. Schoenenberger and colleagues reported an OR of 12.13 for the Emergency Geriatric Screening (EGS) on nursing home admission (40). Kim and colleagues reported an AUC of 0.82 for one year mortality for the Multidimensional Frailty Score (MFS) (48).

Reliability

With respect to reliability hardly any psychometric data were reported. The Brief Risk Identification for Geriatric Health Tool (BRIGHT) (44) and TRST (38) showed internal consistency coefficients of 0.73 or higher. In contrast, the internal consistency of the Reported Edmonton Frail Scale (REFS) was shown to be lower (0.68) although interrater reliability by means of Kappa was found to be 0.83 (49). In addition, the test-retest reliability of the Frailty Indicator-based on CGA (FI-CGA) was 0.78 (42).

Feasibility

The authors of the included studies reported in different ways about feasibility but generally not in a systematic way. Often a qualitative approach was used including the general opinions or impressions of the authors. In the conclusions of the studies statements appeared such as: "The scorecard of this model will be easy to use in clinical practice and will be easy to administer (41)".

The screening tools included in the present review can be administered in different ways: self-report assessments such as the REFS (49) and the BRIGHT (44), professional-administered (e.g. nurses, medical doctors) such as the SHERPA (5) and TRST (38), and use of abstracted data out of Comprehensive Geriatric Assessments (CGA) such as the MPI (50) and FI-CGA (42). Some tool used a combination of the three mentioned methods such as the ISAR (29). One screening tool (Care Complexity Prediction Instrument (COMPRI) (51) had to be completed by a nurse, a medical doctor and items collected by interviewing the patient. The number of items per screening tool varied from three (HARP (52)) to 63 items (MPI (50)). More information about the basic characteristics of the included tools is reported in Table 1.

The included studies were assessed on feasibility using four feasibility items (23). First, the time to administer varied from one minute (TRST (38)) to 35 minutes (m-MPI (47)); although for the majority of the screening tools no information was provided about administration time. Second, information about the instructions needed for completing the tool was only provided for six screening tools. Third, the issue of whether staff training was needed was mentioned for five tools. And finally, 13 of the 16 screening tools were free available (presented in the text, added in the appendix or published on the internet). Table 4 provides detailed information about feasibility.

Discussion

Previously many screening tools have been described that identify elderly patients at risk of functional decline or other adverse outcomes during and after acute hospitalization. Due to the lack of a gold standard it was difficult to evaluate and compare these screening tools. In this study we evaluated screening tools on their predictive validity, reliability and feasibility.

Table 2
Psychometric Properties of Included Screening Tools to Identify Frail Older Patients in Inpatient Hospital Care

Assessment tool	Study and country	Population	Outcome	Predictive validity		Reliability
				Short term (up to 30 days)	Long term (>30 days)	
BRIGHT	Boyd 2008 New Zealand (44)	Patients 75 years and older admitted to ED with non-urgent complaints	IADL deficits	Sens. 76% Spec. 79% PPV 87% NPV 65% AUC 0.83	Not stated	Internal Consistency Cr.alpha = 0.73
			Cognitive deficit	Sens. 78% Spec. 54% PPV 48% NPV 82% AUC 0.73	Not stated	
			ADL deficit	Sens. 83% Spec. 53% PPV 42% NPV 88% AUC 0.66	Not stated	
COMPRI	Huyse 2001 Netherlands (51) De Jonge 2003 Netherlands (59) Hoogerduijn 2010 Netherlands (27)	Patients admitted to internal medicine ward, (mean age 60 and 62) Patients 65 years and older acutely admitted to general ward	Length of stay Functional decline	AUC 0.73 Not stated	Not stated Sens. 70% Spec. 62% PPV 42% NPV 84% AUC 0.69	Not stated
EGS	Schoenenberger 2014 Switzerland (40)	Patients 75 years and older admitted to ED	ED readmission Length of in hospital stay Institutionalized after discharge	Not stated	OR 2.68 Time ratio 1.26 OR 12.13	Not stated
FI-CGA	Evans 2014 USA (42) Krishnan 2014 UK (57)	Patients 75 years and older admitted to medical hospital Patients admitted with hip fracture (mean age 81)	Mortality Discharge destination	Not stated	Death rate 0.59 (FI > 0.65) AUC 0.82	Test-retest reliability weighted K 0.78
HARP	Sager 1996 USA (52) Hoogerduijn 2010 Netherlands (27)	Patients 70 years and older admitted to hospital for acute medical illness; Patients 65 years and older acutely admitted to general ward	Functional decline	Not stated	AUC 0.65 Low Risk Sens. 61% Spec. 68% PPV 39% NPV 84% AUC 0.65 Intermediate risk Sens. 40% Spec. 81% PPV 41% NPV 80% AUC 0.60 High risk Sens. 21% Spec. 89% PPV 38% NPV 77% AUC 0.56	Not stated
Inouye	Inouye 1993 USA (45)	Patients 70 years and older admitted to general medicine ward	Functional decline Death or nursing home admission	High risk: RR 12.9 Intermediate risk RR 4.6 Low risk RR 1.0 High risk: RR 6.9 Intermediate risk RR 3.3 Low risk RR 1.0		Not stated

Table 2 (continued)

ISAR	Mc.Clusker 1999 Canada (29) Mc.Clusker 2000 Canada (28) Dendukuri 2004 Canada (25) Moons 2007 Belgium (30) Geyskens 2008 Belgium (26) Salvi 2009 Italy (32) Hoogerduijn 2010 Netherlands (27) Buurman 2011 (24) Graf 2012 Switzerland (35) Salvi 2012a Italy (31) Salvi 2012b Italy (33)	Patients 65 years and older admitted to ED or discharged from ED; Patients 65 years and over admitted to general internal ward	Functional decline	Sens. 78% - 94% Spec. 41% - 47% PPV 31% - 36% NPV 84% - 96% AUC 0.78	Sens. 92% Spec. 39% PPV 36% NPV 94% AUC 0.67	Concordance Correlation Coefficient = 0.78
			ED-revisit	Sens. 73% Spec. 35% PPV 27% NPV 78%	Sens. 56% - 84% Spec. 39% - 54% PPV 19% - 61% NPV 10% - %78% AUC 0.56 - 0.60	
			Hospital readmissions	Sens. 79% Spec. 37% PPV 22% NPV 89% AUC 0.61	Sens. 73% - 77% Spec. 38% - 51% PPV 36% - 44% NPV 71% - 78% AUC 0.63 - 0.68	
			Mortality	Not stated	Sens. 64% - 91% Spec. 37% - 51% PPV 4% - 18% NPV 2% - 96% AUC 0.58 - 0.74	
			Frailty	Not Stated	Sens. 94% Spec. 63% AUC 0.92	
			Composite outcome	Not stated	Sens. 72% - 86% Spec. 47% - 58% PPV 56% NPV 81% AUC 0.71	
			Combined outcome	Not stated	Sens. 65% Spec. 54% PPV 26% NPV 13% AUC 0.60	
ISAR-HP	Hoogerduijn 2012, 2014 Netherlands (41, 55)	Patients 65 years and older admitted to general internal ward Patients 65 years and older admitted for cardiac surgery	Functional decline	Not Stated	Sens. 85% - 89% Spec. 39% - 41% PPV 29% - 56% NPV 93% - 89% AUC 0.68 - 0.73	Not stated
			Mortality	Not Stated	Sens. 81%	
MFS	Kim 2014, Korea (48)	Patients 65 years and older admitted for elective surgery	Mortality Post-operative complications Nursing home admission	Not Stated	AUC 0.82 AUC 0.73 AUC 0.77	Not stated
MPI	Pilotto 2008 , 2009 Italy (46, 50)	Patients 65 years and older admitted to a geriatric unit; Patients 65 years and older admitted to a geriatric unit with Pneumonia	Mortality	Not Stated Sens. 82% Spec. 77% AUC 0.83	AUC 0.75 Sens. 77% Spec. 75% AUC 0.79	Not stated
m-MPI	Sancarlo 2011 Italy (47)	Patients 65 years and older admitted to geriatric unit	Mortality	AUC 0.75	AUC 0.71	Not stated
ProFUNCTION	Bernabeu 2012 Spain (58)	Polypathological patients (78 years mean age) admitted to hospital	Functional decline	Derivation cohort: Validation cohort:	AUC 0.57 and AUC 0.59 AUC 0.52 - 0.56	Not stated

Table 2 (continued)

REFS	Hilmer 2009 Australia (49)	Patients 70 years and older admitted to acute hospital	Frailty	Not stated	Not stated	Interrater reliability K=0.83 (weighted K=0.84). Internal Consistency Cr.alpha = 0.68
SHERPA	Cornette 2006 Belgium (5)	Patients 70 years and older, admitted to general internal ward	Functional decline	Not Stated	Sens. 68% Spec. 71% AUC 0.73	Not stated
SPICES	Aronow 2014 USA (43)	Patients 65 years and older admitted for surgical or medical reasons	Adverse hospital events Readmission Mortality	OR 3.04 OR 1.24 OR 1.03	Not stated	Not stated
TRST	Meldon 2003 USA (38) Fan 2006 Canada (34) Moons 2007 Belgium (30) Hustley 2007 USA (36) Geyskens 2008 Belgium (26) Lee 2008 Canada (37) Buurman 2011 Netherlands (24) Graf 2012 Switzerland (35) Salvi 2012b Italy (33)	Patients 65 years and older admitted to ED or discharged from ED	Functional decline	Sens. 51% - 82% Spec. 54% - 63% PPV 33% NPV 91% AUC 0.56 - 0.66	Sens. 53% - 88% Spec. 60% - 63% AUC 0.60 - 0.66	Internal Consistency =0.90 – 0.94
			ED revisit	Sens. 63% - 76% Spec. 40% - 52% PPV 17% - 21% NPV 89% - 90% AUC 0.61	Sens. 56% - 60% Spec. 54% PPV 19% - 36% NPV 10% - 76% AUC 0.56	
			Hospital readmission	Sens. 75% - 77% Spec. 33% - 52% PPV 10% - 19% NPV 13% - 97% AUC 0.55 - 0.72	Sens. 70% Spec. 55% PPV 24% NPV 83% AUC 0.65	
			Mortality		Sens. 55 % Spec. 31% PPV 2% NPV 4% AUC 0.43	
			Composite outcome (ED-revisit, hospital admission or nursing home admission)	Sens. 62% - 87% Spec. 21% - 63% PPV 18% - 26% NPV 83% - 90 AUC 0.57 - 0.65	Sens. 55% - 87% Spec. 23% - 66% PPV 40% - 41% NPV 74% - 76% AUC 0.62	
			Combined outcome (recurrent ED visit, hospitalization and mortality)		Sens. 75% Spec. 33% PPV 22% NPV 16% AUC 0.54	

AUC = Area under the Receiver operating curve; Cr.alpha = Cronbachs Alpha; ED = Emergency Department; IADL = Instrumental Activities of the Daily Living; NPV = negative predictive value; OR = odds ratio; PPV = positive predictive value; RR = relative risk; Sens. = Sensitivity, Spec. = specificity. BRIGHT = Brief Risk Identification for Geriatric Health Tool; COMPRI = Care Complexity Prediction Instrument; EGS = Emergency Geriatric Screening; FI-CGA = Frailty Index based on Comprehensive Geriatric Assessment; HARP = Hospital Admission Risk Profile; IASR = Identification Seniors at Risk; ISAR-HP = Identification Seniors at Risk – Hospitalized Patient; MFS = Multidimensional Frailty Score; MPI = Multi Prognostic Index; mMPI = Modified Multi Prognostic Index; REFS = Reported Edmonton Frail Scale; SHERPA = Score d'Evaluation du Risque de Perte d'Autonomie; TRST = Triage Risk Stratification Tool.

Table 3
Quality Assessment of Included Studies

Index Test (no. studies included)	No. of Studies Scored Positive on QUADAS (18) Items*														Mean Score (Observed Range**)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
BRIGHT (1) (44)	1	1	1	1	0	0	1	1	1	1	1	1	1	1	12
COMPRI (3) (27, 51, 59)	3	3	3	2	3	3	3	2	2	1	1	3	3	3	11 (9 - 14)
EGS (1) (40)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
FI-CGA (2) (42, 57)	2	2	2	2	2	2	1	1	0	1	1	2	2	2	11
HARP (2) (27, 52)	2	2	2	2	2	2	1	2	2	0	0	2	2	2	12
Inouye (1) (45)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	13
ISAR (10) (24-33, 35)	10	10	10	10	10	10	10	10	10	4	4	10	10	10	13 (12 - 14)
ISAR-HP (2) (41, 55)	2	2	2	2	2	2	0	2	2	0	0	2	1	2	11 (10 - 11)
MFS (1) (48)	1	1	1	1	1	1	0	1	1	0	0	1	1	1	11
MPI (2) (46, 50)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	14
m-MPI (1) (47)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
ProFunction (1) (58)	1	1	1	1	1	1	1	0	1	0	0	1	1	1	11
REFS (1) (49)	1	1	1	0	1	1	1	0	1	1	1	1	1	1	12
SHERPA (1) (5)	1	1	1	1	1	1	1	1	1	0	0	1	1	1	12
SPICES (1) (43)	1	0	0	0	1	1	0	0	0	0	0	1	1	0	5
TRST (9) (24, 26, 30, 33-38)	9	9	9	9	9	9	9	9	9	7	7	9	9	7	13 (12 - 14)

* 1: Was the spectrum of patient's representative of the patients who will receive the test in practice? 2: Were selection criteria clearly described? 3: Is the reference standard likely to correctly classify the target condition? 4: Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests? 5: Did the whole sample or a random selection of the sample, receive verification using the standard of diagnosis? 6: Did patients receive the same references standard regardless of the index test result? 7: Was the reference standard independent of the index test? (i.e. the index test did not form part of the reference standard)? 8: Was the execution of the index test described in sufficient detail to permit replication of the test? 9: Was the execution of the reference standard described in sufficient detail to permit its replication? 10: Were the index test results interpreted without knowledge of the result of the reference standard? 11: Were the reference standard results interpreted without knowledge of the results of the index test? 12: Were the same clinical data available when the test results were interpreted as would be available when the test is used in practice? 13: Were uninterpretable/intermediate test results reported? 14: Were withdrawals from the study explained? ** Theoretical range 0-14. Higher scores indicate higher quality; BRIGHT = Brief Risk Identification for Geriatric Health Tool; COMPRI = Care Complexity Prediction Instrument; EGS = Emergency Geriatric Screening; FI-CGA = Frailty Index based on Comprehensive Geriatric Assessment; HARP = Hospital Admission Risk Profile; IASR = Identification Seniors at Risk; ISAR-HP = Identification Seniors at Risk – Hospitalized Patient; MFS = Multidimensional Frailty Score; MPI = Multi Prognostic Index; mMPI = Modified Multi Prognostic Index; REFS = Reported Edmonton Frail Scale; SHERPA = Score d'Evaluation du Risque de Perte d'Autonomie; TRST = Triage Risk Stratification Tool.

Predictive Validity

The included studies reported their predictive validity in different ways. The AUC, sensitivity and specificity were the most frequently used indicators (Table 2). No assessment tool had a perfect discriminative power. In general, the reported AUC varied between insufficient and excellent and ranged from 0.43 (24) to 0.92 (31). Tools with a high sensitivity generally reported a lower specificity and vice versa. Hamaker and colleagues reported similar findings in their systematic review on frailty assessments in older cancer patients (53).

Although TRST and ISAR are the most often studied screening tools, their predictive validity is generally not different from the other included tools. Several studies did not comprise validity information using sensitivity, specificity or AUC at all (40, 42, 45, 49). Sometimes odds ratios or relative risks were then reported. As a result, it is hard to compare outcomes between the tools.

The overall sensitivity of the included screening tools is fairly good and varied from 21% to 94%. The ISAR (24–33, 35), ISAR-HP (41, 55) and MPI (46, 50) showed the highest sensitivity. In contrast, their specificity is relatively low. Depending on the purpose of screening, an appropriate balance of sensitivity and specificity is expedient. If the purpose of screening is to decide whether preventive interventions should be considered, lower specificity seems to be acceptable. In this domain high sensitivity seems more important than a high specificity. Classifying non-frail patients as frail has no major impact on patients. Interventions for patients classified as frail generally relate to basic care like reorientation or mobilization and would not harm the falsely positive screened patients. Otherwise low specificity could lead to problems in health care systems. A high number of false positive screens will lead to inefficient use of care resources such as staff. The latter could limit the willingness of health systems to implement these screening tools.

Reliability

There was hardly any information available with respect to the reliability of the included screening tools such as inter-rater reliability, test–retest reliability and internal consistency. Some studies reported internal reliability in terms of Cronbach's alpha as reliability parameter (38, 44). However, such

Table 4
Assessment of Feasibility Items of Included Screening Tools to Identify Frail Older Patients in Inpatient Hospital Care

	BRIGHT (44)	COMPRI (27, 51, 59)	EGS (40)	FI-CGA (42, 57)	HARP (27, 52)	Inouye (45)	ISAR (24-33, 35)	ISAR-HP (41, 55)	MFS (48)	MPI (46, 50)	m-MPI (47)	ProFunction (58)	REFS (49)	SHERPA (5)	SPICES (43)	TRST (24, 26, 30, 33-38)
Time to administer (time in minutes)	-	-	5	10 - 25	-	-	-	-	-	30	25 - 35	-	< 5	-	-	1 - 5
Instructions reported	+	-	+	-	+	-	+	-	-	-	-	-	+	-	-	+
Training needed	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	+
Free available	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+

+ Information is provided / - no information provided, unknown; Bright = Brief Risk Identification for Geriatric Health Tool; COMPRI = Care Complexity Prediction Instrument; EGS = Emergency Geriatric Screening; FI-CGA = Frailty Index based on Comprehensive Geriatric Assessment; HARP = Hospital Admission Risk Profile; IASR = Identification Seniors at Risk; ISAR-HP = Identification Seniors at Risk – Hospitalized Patient; MFS = Multidimensional Frailty Score; MPI = Multi Prognostic Index; mMPI = Modified Multi Prognostic Index; REFS = Reported Edmonton Frail Scale; SHERPA = Score d'Evaluation du Risque de Perte d'Autonomie; TRST = Triage Risk Stratification Tool.

parameter only suggests that the items of the tool have some degree of relationship with each other and has less to do whether the screening tool is reliable in practice. In this respect, future research should include in-depth analyses of issues related to reliability such as interrater reliability or test-retest reliability.

Feasibility

After aspects of validity and reliability, feasibility may play an important role in the choice of a specific tool in daily practice. Feasibility refers to the practical use of the screening tool by professionals and several aspects of the tool itself (23), for instance the mode of administration or the number of items. In general there was a lack of information about the feasibility of the included screening tools. Studies including the EGS (40), the REFS (49) and TRST (38) reported information on different feasibility items. The time taken to administer these tools varied from 1 to 5 minutes. Screening tools with a broader scope and a larger number of items (i.e. MPI (50) or FI-CGA (42)) were clearly more time consuming than short form assessments (i.e. ISAR (29) or TRST (38)). Despite their short administration time and small number of items, the sensitivity of these screening tools was fairly good.

Limitations of this Study

We performed a systematic search in different databases and although a broad search strategy was applied, it is possible that some studies were missed in this review. In the first phase of the review process titles were included if they comprised information about the population (elderly patients), the intervention (screening) and setting (in-hospital). Possibly relevant studies could have been missed if the title did not comprise this information (56). Although a comprehensive literature search was performed, 16 studies were found via reference checking. Second, some of the included screening tools were validated in a specific hospital setting like an emergency department (i.e. TRST (38) and ISAR (29)) or internal medicine ward (i.e. ISAR-HP (55)). This should be taken in account when the assessment tools are used in other hospital settings (general wards, long term care, etc.).

Conclusion and Implications of Key Findings

Our review on screening tools to identify frailty in hospitalized older adults included 16 different tools. Through a broad search strategy we included more screening tools as compared to previous reviews (9, 14-17). In addition, we assessed the feasibility of the 16 tools on four structured items.

With respect to predictive validity, the sensitivity of the tools is fairly good, but their specificity is rather poor. No systematic differences were found between screening tools that were studied multiple times and tools that were only studied once or twice. Best sensitivity scores were reported in studies on the ISAR (24-33, 35), ISAR-HP (41, 55) and MPI (46, 50). Of the most frequently studied tools (the ISAR and the TRST) the predictive validity of the ISAR seems somewhat better than that of the TRST.

A good comparison between studies is hampered because of the variations in the outcome criteria between studies. When similar outcomes or criteria were used, e.g. functional decline, authors used a different definition of the outcome or criterion. In addition hardly any information is reported with respect to reliability of the included screening tools. As such tools may be, for example, applied by different professionals, information about inter-rater reliability is important. And finally, in general little information is reported with respect to feasibility of the screening tools. As feasibility of screening tools is relevant it should be included in future studies in a more structured way.

Screening tools to identify frail older patients in inpatient hospital care could be useful in daily practice. For no tool,

however, is clear evidence regarding validity, reliability and feasibility available yet. In future research in this field items like reliability and feasibility should be studied in a structured way.

Conflict of Interest Disclosures: No conflicts of interest to report on all authors.

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