UCSF Fresno Medical Education Program
School of Medicine

University of California San Francisco
Fresno Emergency Medicine
Faculty Position

The Department of Emergency Medicine at UCSF Fresno in conjunction with Central California Faculty Medical Group is seeking additional core faculty members. Our emergency medicine residency program was founded in 1974, with 40 EM residents in a PGY1-4 format and supported by UCSF and Community Regional Medical Center (CRMC) in Fresno, California.

CRMC has 630 beds, averages 115,000 ED visits a year, while being amongst the busiest Level One Trauma Centers in California. We serve as the Base Station for a four-county EMS System and provide medical direction to the National Parks Service.

Our faculty group consists of 36 full time residency trained board certified emergency physicians, many with additional fellowship training. Applicants must be board certified in Emergency Medicine (or eligible) and must be able to obtain a California medical license at time of hire. Depending on qualifications, leadership positions exist within the spheres of Ultrasound, EMS, Residency Program Leadership, Research, and Pediatrics.

Residents and faculty enjoy a high standard, low cost living. Limitless recreational opportunities and spectacular scenery is all accessible in a community with abundant affordable housing. While there is much to see and do in Fresno, the city is ideally located for convenient getaways to the majestic Sierra (60 minutes away), as well as the scenic Central Coast, just two and one-half hours away. Fresno is the only major city in the country with proximity to three national parks: Sequoia, Kings Canyon and Yosemite.

For Inquiries please contact Jim Comes, MD, Chief: jcomes@fresno.ucsf.edu

PLEASE APPLY ONLINE AT:
https://aprecruit.ucsf.edu/apply/JPF02012

Visit our websites: www.fresno.ucsf.edu/em

Academic Emergency Medicine
Official Journal of the Society for Academic Emergency Medicine

EVIDENCE-BASED DIAGNOSTICS

Risk Factors and Screening Instruments to Predict Adverse Outcomes for Undifferentiated Older Emergency Department Patients: A Systematic Review and Meta-analysis

Christopher R. Carpenter, MD, MSc, Erica Shelton, MD, Susan Fowler, MLIS, Brian Suffoletto, MD, Timothy F. Platts-Mills, MD, MSc, Richard E. Rothman, MD, PhD, and Teresita M. Hogan, MD

Abstract

Objectives: A significant proportion of geriatric patients experience suboptimal outcomes following episodes of emergency department (ED) care. Risk stratification screening instruments exist to distinguish vulnerable subsets, but their prognostic accuracy varies. This systematic review quantifies the prognostic accuracy of individual risk factors and ED-validated screening instruments to distinguish patients more or less likely to experience short-term adverse outcomes like unanticipated ED returns, hospital readmissions, functional decline, or death.

Methods: A medical librarian and two emergency physicians conducted a medical literature search of PubMed, EMBASE, SCOPUS, CENTRAL, and ClinicalTrials.gov using numerous combinations of search terms, including emergency medical services, risk stratification, geriatric, and multiple related MeSH terms in hundreds of combinations. Two authors hand-searched relevant specialty society research abstracts. Two physicians independently reviewed all abstracts and used the revised Quality Assessment of Diagnostic Accuracy Studies instrument to assess individual study quality. When two or more qualitatively similar studies were identified, meta-analysis was conducted using Meta-DiSc software. Primary outcomes were sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR–) for predictors of adverse outcomes at 1 to 12 months after the ED encounters. A hypothetical test–treatment threshold analysis was constructed based on the meta-analytic summary estimate of prognostic accuracy for one outcome.

Results: A total of 7,940 unique citations were identified yielding 34 studies for inclusion in this systematic review. Studies were significantly heterogeneous in terms of country, outcomes assessed, and the timing of post-ED outcome assessments. All studies occurred in ED settings and none used published clinical decision rule derivation methodology. Individual risk factors assessed included dementia, delirium, age, dependency, malnutrition, pressure sore risk, and self-rated health. None of these risk factors significantly increased the risk of adverse outcome (LR+ range = 0.78 to 2.84). The absence of dependency reduces the risk of 1-year mortality (LR– = 0.27) and nursing home placement (LR– = 0.27). Five constructs of frailty were evaluated, but none increased or decreased the risk of adverse outcome. Three instruments were evaluated in the meta-analysis: Identification of Seniors at Risk, Triage Risk Screening Tool, and Variables Indicative of Placement Risk. None of these instruments significantly increased (LR+ range for various outcomes = 0.98 to 1.40) or decreased (LR– range = 0.53 to 1.11) the risk of adverse outcomes. The test threshold for 3-month functional decline based on the most accurate instrument was 42%, and the treatment threshold was 61%.

Conclusions: Risk stratification of geriatric adults following ED care is limited by the lack of pragmatic, accurate, and reliable instruments. Although absence of dependency reduces the risk of 1-year mortality,

From the Department of Emergency Medicine (CRC), Washington University in St. Louis School of Medicine (CRC, SF), St. Louis, MO; the Department of Emergency Medicine, Johns Hopkins University (ES, RER), Baltimore, MD; the Department of Emergency Medicine, University of Pittsburgh Medical Center (BS), Pittsburgh, PA; the Department of Emergency Medicine, University of North Carolina–Chapel Hill (TFP), Chapel Hill, NC; and the Department of Emergency Medicine, University of Chicago (TMH), Chicago, IL.

Received April 9, 2014; revision received July 21, 2014; accepted August 24, 2014.

Dr. Carpenter, an associate editor at this journal, had no role in the peer-review process or publication decision for this journal.

The authors have no relevant financial information or potential conflicts to disclose.

Supervising Editor: Scott T. Wilber, MD.

Address for correspondence and reprints: Christopher R. Carpenter, MD, MSc; e-mail: carpenterc@wusm.wustl.edu.

doi: 10.1111/acem.12569
ISSN 1069-6563
PII ISSN 1069-6563583

no individual risk factor, frailty construct, or risk assessment instrument accurately predicts risk of adverse outcomes in older ED patients. Existing instruments designed to risk stratify older ED patients do not accurately distinguish high- or low-risk subsets. Clinicians, educators, and policy-makers should not use these instruments as valid predictors of post-ED adverse outcomes. Future research to derive and validate feasible ED instruments to distinguish vulnerable elders should employ published decision instrument methods and examine the contributions of alternative variables, such as health literacy and dementia, which often remain clinically occult.

ACADEMIC EMERGENCY MEDICINE 2015;22:1–21 © 2014 by the Society for Academic Emergency Medicine

Patients aged 65 years and older present to emergency departments (EDs) worldwide with increasing frequency due in part to intensified clinical and fiscal challenges inside an already frayed health care safety net.[1–3] Clinically, providing high-quality emergency care for older adults is challenging because older patients tend to have a greater burden of comorbidities than younger patients, higher rates of serious illnesses, and frequent communication barriers. From a financial standpoint, care of the older adult is further complicated by increasing external pressure from the federal government to reduce overall costs of medical care.[3] Taken together, emergency providers are being pressured to make accurate decisions to admit or discharge older patients, while concurrently seeing greater numbers of patients in less time.[4,5] Use of screening instruments may allow point-of-care identification of geriatric patients who are at increased risk for readmission or other adverse outcomes. Although most existing instruments were derived on discharged ED patients, accurate identification of high-risk subsets while in the ED opens opportunities for emergency clinicians to alter ED or post-ED trajectories for these vulnerable patients using observation units, mobile acute care for the elderly teams, Hospital at Home models, and other home health care resources.[5] This risk stratification allows faster and more focused use of time, testing, personnel, and resources to those most in need of these services.

Decisions to admit or discharge from the ED are generally based on the patient's risk of suffering a short-term adverse outcome. Ideally, emergency clinicians could accurately and reliably identify which older adults are at increased risk for short-term, post-ED adverse outcomes, such as preventable hospital readmissions and return ED visits, functional decline, institutionalization, and/or death. Older patients are a uniquely vulnerable population at high risk for these poor outcomes as identified by the Geriatric Emergency Medicine Residency Core Competencies and the "Geriatric Emergency Department Guidelines" (http://www.saem.org/docs/education/geri_ed_guidelines_final.pdf?sfvrsn=2).[6–8] Recognizing the increased risk of adverse outcomes among older adults, these guidelines recommend that "All geriatric patients, regardless of the presenting complaint shall be screened (on the initial index visit, not follow-up visits) using the Identification of Seniors at Risk (ISAR) tool or a similar risk screening tool."[9,10] If sufficiently accurate, appropriate use of these tools may allow clinicians to mend the tattered ED safety net for our vulnerable older patients. However, recent studies from Europe and North America suggest that these risk assessment instruments lack sufficient prognostic accuracy.[11,12] Consequently, geriatric and emergency medicine research opinion leaders list development and implementation trials of prognostic screening instruments among the highest research priorities.[13,14]

This systematic review helps define the accuracy of existing screening tools to identify older ED patients at risk of adverse outcomes. Four recent systematic reviews evaluate the content validity and prognostic accuracy of single geriatric screening instruments such as the Triage Risk Screening Tool (TRST),[15–18] but none of these systematic reviews evaluates all available instruments or all previously described individual risk factors for post-ED adverse outcomes. The primary objective of this systematic review is to quantify the prognostic accuracy of all individual risk factors and existing instruments for use in ED settings that are designed to identify geriatric adults at increased risk of short-term (1- to 12-month) adverse outcomes following ED visits. Adverse outcomes include return to the ED, hospital admission, functional decline, institutionalization, or death.

METHODS

Search Strategy

The design and manuscript structure of this systematic review conform to the recommendations from the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) statement and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[19,20] In conjunction with a medical librarian (SF), two investigators (CRC, TH) searched the medical literature from 1950 to January 2014. The medical librarian developed search strategies for the concepts of ED; people 60 years and older; screening; and adverse outcomes including functional decline, readmission, institutionalization, and death. These strategies were established using a combination of standardized terms and key words and were implemented in PubMed 1946-, Embase 1947-, Scopus 1823-, Cochrane Central Register of Controlled Trials (CENTRAL), and clinicaltrials.gov. All searches were completed in January 2014 and limited to English using database-supplied limits. To exclude animals, the librarian used the human filter for PubMed recommended in Cochrane Handbook for Systematic Reviews of Interventions[21] as a model to create similar filters for the other databases searched. All results were exported to EndNote. We used the automatic duplicate finder in EndNote and 910 duplicates

were assumed to be accurately identified and removed, yielding a total of 7,940 unique citations. Nineteen trials were located in ClinicalTrials.gov. Full search strategies for PubMed and Embase are provided in Data Supplement S1 (available as supporting information in the online version of this paper).

Two authors (CRC, TH) reviewed the titles and abstracts to identify potentially relevant articles, which were then retrieved and the full articles reviewed. These authors then independently reviewed these articles for inclusion criteria. In addition, two authors (ES, SF) reviewed abstracts accepted for presentation at national emergency medicine conferences and published in *Academic Emergency Medicine*, *Annals of Emergency Medicine, Journal of the American Geriatrics Society,* and *European Geriatric Medicine* from 1990 through March 2014.

Studies and scientific research abstracts were included if they recruited a population of general geriatric adults (age ≥ 65 years) in ED settings. We sought to identify instruments that risk stratify undifferentiated older adults regardless of their presenting complaints or ED diagnoses, so disease-specific instruments such as those that risk stratify patients with congestive heart failure[22] or pneumonia[23] were excluded. Similarly, instruments or risk factors for common geriatric syndromes such as standing level falls,[24] delirium,[25] and dementia[26] were excluded because the presence of these conditions identifies potentially vulnerable older adult patients and merits separate systematic reviews to assess each specific risk factor and instrument. Studies that reported sufficient detail on prognostic test and criterion standard results to reconstruct two-by-two tables to estimate both sensitivity and specificity were included. We contacted the authors of studies that assessed prognostic accuracy if they did not report sufficient detail to reconstruct two-by-two tables to obtain the contingency tables for our meta-analysis. If the authors responded and provided the contingency tables, then these studies were included in this systematic review. Letters or scientific abstracts with original research data were included. We excluded non–English language manuscripts, narrative reviews, case reports, and studies focused on therapy.

Individual Evidence Quality Appraisal

Two authors (CRC, TH) used the revised Quality Assessment Tool for Diagnostic Accuracy Studies (QUADAS-2) for systematic reviews to evaluate the overall quality of evidence for the identified trials.[27] Discrepant quality assessments were adjudicated by discussion. Statistical agreement between the two reviewers was assessed via a kappa analysis using SPSS 20. QUADAS-2 consists of nine signaling questions and four applicability questions that qualitatively assess patient selection, index test ascertainment and reproducibility, criterion standard timing and acceptability, and uniformity of obtainment and analysis for the index and criterion standard tests. The authors determined a priori to assess the quality of individual trials for the purposes of this prognostic meta-analysis by considering the following study characteristics. The ideal patient population would be those admitted or discharged from an ED with predischarge risk assessment for short-term adverse outcomes assessed by the ED medical staff. Studies that recruited (or obtained prognostic instrument data from) a portion of patients outside of the ED were rated as low applicability. Studies that evaluated patients exclusively in the hospital or at home following ED evaluations were excluded. If a study used research personnel to administer the prognostic screening instruments rather than standard ED clinical personnel, we rated the conduct applicability as potentially low since this administration of the instrument does not reflect real-world practice. Studies that failed to explicitly blind outcome assessors to the screening instrument results or interpretation were labeled as high risk for bias.

Data Analysis

Two authors (CRC, TH) independently abstracted data from the included studies. Information abstracted included the individual study setting, inclusion criteria, mean patient age, study design, adverse outcomes assessed, outcome prevalence, and prognostic test properties. To compute meta-analytic summary estimates when more than one study assessed the same index test at the same threshold for the same or similar outcomes at the same follow-up interval, we combined eligible trials' data using Meta-DiSc (Hospital Univeritario Ramón y Cajal, Madrid, Spain) using a random-effects model.[28] Interstudy heterogeneity was assessed with pooled estimates of sensitivity and specificity using the DerSimonian-Laird random effects model, and statistical heterogeneity was reported using the index of inconsistency (I^2).[29–31] Pooled estimates of dichotomous positive (LR+) and negative (LR–) likelihood ratios are also reported from the random-effects model. The level of agreement between reviewers for the QUADAS-2 assessment was quantified using a kappa analysis and the qualitative level of agreement was rated as previously described by Byrt.[32] Based on the forms of bias identified by the QUADAS-2 assessment, we performed a post hoc sensitivity analysis of our results excluding all nonpublished data. Publication bias was not assessed because of the questionable validity of this approach when assessing diagnostic test meta-analyses.[33]

Test-Treatment Threshold. The Pauker and Kassirer decision threshold model is based on seven variables: false-negative and false-positive proportions, sensitivity, specificity, risk of a diagnostic test, risk of treatment, and anticipated benefit of treatment.[34] Evidence-based estimates for each of these variables were abstracted from our meta-analysis to derive theoretical test and treatment thresholds for ED management of potentially vulnerable geriatric adults. Recognizing that these estimates are likely based on inadequate and biased research, an interactive Microsoft Excel calculator is provided with this article to permit readers to alter assumptions to recompute thresholds using different estimates of test performance or anticipated risks and benefits that may be more applicable to the end users' patient populations and clinical environments (Data Supplement S2, available as supporting information in the online version of this paper).

RESULTS

The PubMed search identified 2,682 citations, the EMBASE search identified 5,683 citations, while CENTRAL and SCOPUS yielded 170 and 80 citations, respectively. The hand search of non–peer-reviewed research abstracts yielded 55 studies. When the results were combined and the duplicates removed, 7,940 citations remained. After the titles and abstracts were reviewed to identify potentially relevant articles, which were then retrieved and the full manuscripts reviewed, 34 geriatric prognostic studies were included in this systematic review (Figure 1), including two letters, four abstracts, and 28 manuscripts. We present a detailed summary of the included trials, all of which were conducted between 1999 and 2012, in Data Supplement S3 (available as supporting information in the online version of this paper).

The authors' QUADAS-2 assessment of quality had a kappa ranging from 0.52 to 1.00 (Table 1), representing fair to excellent agreement.[32] No study used a case–control design. Most of the studies excluded patients who were lost to follow-up, many of the studies had unequal numbers of patients assessed for different risk factors, and unexplained exclusions were common. The predictor variables (index test) were obtained prospectively in the weeks to months before outcomes were ascertained, so those collecting the index test were presumed to be blinded to the primary outcomes (criterion standard) unless a retrospective chart review methodology was employed. However, most studies failed to explicitly state that outcome assessors were blinded to the index tests being assessed, so there was a high risk of incorporation bias.[35] One study used a statistically derived definition of high hospital utilization,[36] and this statistical threshold might not be relevant across all health care settings, but all other outcomes were judged to be important for emergency medicine clinicians.

Individual Risk Factors

In five studies from France, Dramé et al. and Dhaussy et al. evaluated multiple risk factors for adverse outcomes in admitted medical patients following episodes of ED care.[37–41] The outcomes assessed included mortality at 6 weeks to 2 years and institutionalization at 1 year. The variables assessed included malnutrition, age, functional limitations and dependency, presence of severe comorbidities, balance issues, number of offspring, living situation, and the presence of delirium or dementia. Malnutrition risk was evaluated using the Mini Nutritional Assessment Short Form.[42] Functional ability was assessed using the Katz Activities of Daily Living scale,[43] dementia using Folstein's Mini-Mental State Examination,[44] and delirium using geriatrician application of DSM-IV criteria. Balance issues were assessed using the one leg balance test,[45] and comorbid health issues were quantified using the Charlson index.[46] Assessing prognostic accuracy using a LR+ threshold of ≥10 and a LR– threshold of ≤0.1,[47] none of the predictor variables increased or decreased the risk of mortality or nursing home placement enough to be clinically useful (Table 2). The highest LR+ was 2.8 (presence of severe comorbidity) and the lowest LR– was 0.27 (absence of dependency). Two other studies assessed isolated single risk factors. Chang et al.[48] assessed self-rated health stratified as bad ("fair" or "poor") or nonbad ("good" or "excellent") as a predictor of ED returns at 1 and 3 months. Minnee and Wilkinson[49] assessed living alone as a predictor of 1-week ED returns. Only one study assessed each risk factor for a given outcome, so no meta-analysis of individual predictors was possible.

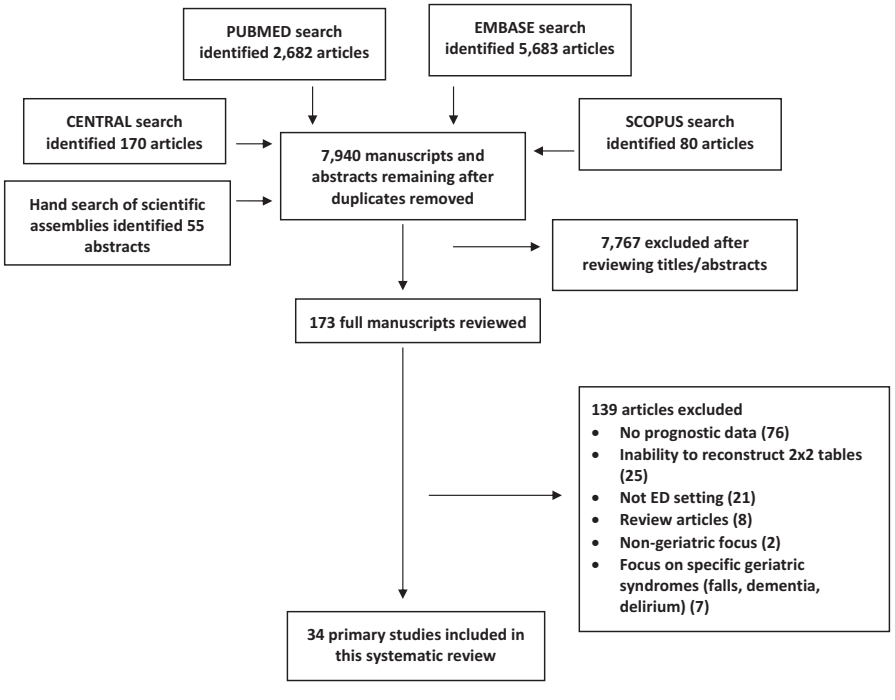

Figure 1. Study selection process.

Table 1
Overview of Quality Assessment of Included Studies

First Author, Year	Sample	Inappropriate Exclusions?	Patients and Settings Match Study Question?	Index Test Interpretation Blinded?	Index Test Conduct Applicability	Acceptable Outcome Standards?	Outcomes Assessed by Blinded Assessor?	Assessed Outcomes Pertinent?	All Patients Analyzed?
Asomaning 2014[61]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Bolanos 2010[62]	Nonconsecutive	Yes	No	Uncertain	Uncertain	Uncertain	Uncertain	Yes	No
Braes 2009[63]	Uncertain	Yes	Yes	Uncertain	No	No	Uncertain	Yes	No
Braes 2010[64]	Consecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No
Buurman 2011[65]	Consecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No
Carpenter 2009[66]	Nonconsecutive	Yes	Yes	Yes	No	No	Yes	Yes	No
Carpenter 2012[67]	Consecutive	Yes	Yes	Yes	No	No	Yes	Yes	No
Chang 2012[48]	Consecutive	Yes	Yes	Yes	No	No	Yes	Yes	No
Conroy 2013[56]	Nonconsecutive	Yes	No	Uncertain	No	No	Uncertain	Yes	No
Dendukuri 2004[68]	Consecutive	No	Yes	Yes	No	No	Uncertain	Yes	Yes
Deschodt 2011[69]	Consecutive	Yes	No	Yes	No	No	Uncertain	Yes	No
Deschodt 2012[70]	Nonconsecutive	Uncertain	No	Yes	No	Uncertain	Uncertain	Yes	Uncertain
Dhaussy 2012[40]	Nonconsecutive	Yes	No	Yes	No	No	Uncertain	Yes	Uncertain
Di Bari 2010[57]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Uncertain	Yes	Uncertain
Di Bari 2012[71]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Dramé 2008[38]	Nonconsecutive	Yes	No	Yes	No	No	Yes	Yes	No
Dramé 2008[37]	Nonconsecutive	Yes	No	Yes	No	No	Yes	Yes	No
Dramé 2011[39]	Nonconsecutive	Yes	No	Yes	No	No	Yes	Yes	No
Dramé 2011[54]	Nonconsecutive	Yes	No	Yes	No	No	Yes	Yes	No
Dramé 2012[41]	Nonconsecutive	Yes	No	Yes	No	No	Yes	Yes	No
Edmans 2013[72]	Nonconsecutive	Yes	No	Yes	No	No	Uncertain	Yes	No
Fan 2006[77]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Gentile 2013[73]	Nonconsecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No

(Continued)

Table 1 (continued)

First Author, Year	Sample	Inappropriate Exclusions?	Patients and Settings Match Study Question?	Index Test Interpretation Blinded?	Index Test Conduct Applicability	Acceptable Outcome Standards?	Outcomes Assessed by Blinded Assessor?	Assessed Outcomes Pertinent?	All Patients Analyzed?
Graf 2012[74]	Nonconsecutive	Yes	No	Yes	No	No	Uncertain	Yes	No
Graf 2012[80]	Nonconsecutive	Yes	No	Yes	No	No	Uncertain	Yes	No
Hustey 2007[78]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Lee 2008[79]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Uncertain	Yes	No
McCusker 1999[9]	Nonconsecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No
McCusker 2000[36]	Nonconsecutive	Yes	Yes	Yes	No	No	Uncertain	Uncertain	No
Meldon 2003[10]	Nonconsecutive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minnee 2011[49]	Nonconsecutive	Yes	Yes	Uncertain	Yes	Uncertain	Uncertain	Yes	No
Moons 2007[11]	Uncertain	No	Yes	Yes	No	No	Uncertain	Yes	Yes
Salvi 2009[75]	Nonconsecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No
Salvi 2012[76]	Nonconsecutive	Yes	Yes	Yes	No	No	Uncertain	Yes	No
Salvi 2012[12]	Nonconsecutive	Yes	Yes	Yes	Yes	No	Uncertain	Yes	No
Kappa	0.927	1.000	0.811	0.523	1.000	1.000	1.000	0.653	0.641

Dramé et al. also evaluated four validated measures of frailty (Winograd et al.[50] Rockwood et al.,[51] Schoevaerdts et al.,[52] and Donini et al.[53]) as prognostic risk factors for institutionalization or death at 1 year.[54] Stratifying the results by the highest level of frailty for each instrument, the highest LR+ for mortality was 2.9 (Rockwood[51]) and the lowest LR– was 0.42 (Schoevaerdts et al.[52]). In other words, the presence of "frailty" as defined by Rockwood increases the odds of death by 2.9-fold, while the absence of "frailty" as defined by Schoevaerdts et al. decreases the odds of death by 0.42. However, the Schoevaerdts et al. instrument identified 67% of patients as severely frail. None of the instruments was sufficiently prognostic for 1-year nursing home placement (Table 3). In England, 645 patients in the acute medical unit over the age of 70 years were assessed with the Canadian Study on Health and Aging (CSHA) Clinical Frailty Scale[55] as a predictor of 30- or 90-day hospital readmission.[56] The CSHA frailty assessment was a similarly inaccurate predictor of hospital readmission (Table 3).

Screening Instruments

Seven different geriatric prognostic screening instruments were assessed in the included studies: Identification of Seniors at Risk (ISAR),[9] TRST,[10] the Silver

Table 2
Individual Predictors of Post-ED Adverse Outcomes

Finding, Study	Outcome Studied	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
Malnutrition risk Dramé 2008[37] MNA-SF < 12 abnormal	Mortality at 6 weeks	90 (84–95)	28 (26–31)	1.26 (1.18–1.35)	0.35 (0.20–0.58)
Presence of delirium Dramé 2008[37]	Mortality at 6 weeks	33 (25–41)	81 (79–83)	1.74 (1.32–2.29)	0.83 (0.73–0.94)
Katz Activities of Daily Living Dramé 2008[37] ≥5 abnormal	Mortality at 6 weeks	80 (72–87)	52 (49–55)	1.68 (1.51–1.86)	0.38 (0.27–0.54)
Age ≥ 85 years Dramé 2011[39]	Institutionalization at 1 year	64 (59–69)	57 (54–60)	1.48 (1.34–1.65)	0.63 (0.55–0.73)
Inability to toilet Dramé 2011[39]	Institutionalization at 1 year	76 (71–80)	47 (44–50)	1.43 (1.32–1.56)	0.51 (0.42–0.62)
Presence of balance disorders Dramé 2011[39]	Institutionalization at 1 year	57 (52–63)	51 (48–55)	1.18 (1.06–1.32)	0.83 (0.73–0.95)
Presence of dementia Dramé 2011[39]	Institutionalization at 1 year	63 (57–67)	62 (58–65)	1.62 (1.45–1.82)	0.61 (0.53–0.70)
Lives alone Dramé 2012[41]	Institutionalization at 1 year	38 (33–43)	58 (55–61)	0.91 (0.78–1.06)	1.06 (0.97–1.17)
Inability to transfer Dramé 2012[41]	Institutionalization at 1 year	76 (71–80)	42 (39–45)	1.31 (1.21–1.42)	0.57 (0.47–0.69)
Severe comorbidity Dhaussy 2012[40]	Mortality at 1 year	5 (3–7)	98 (97–99)	2.84 (1.49–5.42)	0.97 (0.95–0.99)
Dependency Dhaussy 2012[40]	Mortality at 1 year	95 (92–97)	20 (17–23)	1.18 (1.13–1.23)	0.27 (0.18–0.41)
Pressure sore risk Dhaussy 2012[40]	Mortality at 1 year	59 (55–64)	70 (66–73)	1.96 (1.72–2.22)	0.58 (0.52–0.66)
Malnutrition risk Dhaussy 2012[40]	Mortality at 1 year	87 (83–90)	33 (30–37)	1.31 (1.23–1.39)	0.39 (0.30–0.51)
Delirium present Dhaussy 2012[40]	Mortality at 1 year	26 (22–30)	83 (80–85)	1.52 (1.23–1.39)	0.89 (0.84–0.95)
Dementia present Dhaussy 2012[40]	Mortality at 1 year	52 (48–57)	58 (55–62)	1.26 (1.11–1.41)	0.82 (0.73–0.91)
Lives alone Dhaussy 2012[40]	Nursing home placement at 1 year	38 (33–43)	58 (55–61)	0.91 (0.78–1.06)	1.06 (0.97–1.17)
<2 children Dhaussy 2012[40]	Nursing home placement at 1 year	53 (47–58)	57 (54–61)	1.23 (1.09–1.39)	0.83 (0.73–0.93)
Dependency Dhaussy 2012[40]	Nursing home placement at 1 year	95 (92–97)	19 (16–22)	1.17 (1.12–1.22)	0.27 (0.17–0.43)
Dementia present Dhaussy 2012[40]	Nursing home placement at 1 year	63 (57–67)	62 (58–65)	1.62 (1.45–1.82)	0.61 (0.53–0.70)
Delirium present Dhaussy 2012[40]	Nursing home placement at 1 year	17 (13–21)	78 (76–81)	0.78 (0.60–1.01)	1.06 (1.00–1.12)
Unplanned hospital readmission Dhaussy 2012[40]	Nursing home placement at 1 year	54 (48–59)	38 (34–41)	0.86 (0.76–0.97)	1.23 (1.06–1.44)
Severe comorbidity Dhaussy 2012[40]	Nursing home placement at 1 year	3 (1–5)	97 (96–98)	1.04 (0.52–2.09)	1.00 (0.98–1.02)
Pressure sore risk Dhaussy 2012[40]	Nursing home placement at 1 year	55 (50–60)	66 (63–69)	1.61 (1.42–1.83)	0.68 (0.61–0.77)
Self-rated health Chang 2012[48]	ED returns				
	30 days	68 (49–83)	44 (36–53)	1.21 (0.92–1.59)	0.73 (0.44–1.24)
	90 days	62 (48–75)	42 (33–51)	1.07 (0.83–1.39)	0.90 (0.60–1.35)
Self-rated health Chang 2012[48]	Functional decline				
	30 days	62 (51–72)	46 (35–58)	1.16 (0.90–1.50)	0.81 (0.57–1.16)
	90 days	59 (49–69)	41 (30–52)	1.00 (0.78–1.28)	1.00 (0.70–1.43)
Lives alone Minnee 2011[49]	ED returns				
	7 days	21 (5–51)	69 (51–83)	0.68 (0.22–2.08)	1.15 (0.80–1.63)

MNA-SF = Mini Nutritional Assessment Short-Form; LR = likelihood ratio.

Code,[57] Variables Indicative of Placement risk (VIP),[58] Mortality Risk Index, Rowland,[59] and Runciman.[60] The components, scoring, and interpretation for each of these instruments are provided in Data Supplement S4 (available as supporting information in the online version of this paper). The ISAR was assessed in 19 studies involving 14,440 patients.[9,11,12,36,61–76] The TRST was assessed in 14 studies involving 7,016 patients.[10–12,63–67,69,70,74,77–79] The VIP was assessed by four studies involving 1,765 patients.[63,64,69,70] The Runciman instrument was assessed in three studies involving 512 patients.[11,60,65] The Rowland instrument[11,65] and Silver Code[57,71] were each assessed by two studies involving 464 and 12,451 patients, respectively. The studies evaluated a wide range of outcomes at post-ED time frames ranging from 14 days to 1 year. Most studies had research teams or geriatric specialists administer the screening instruments (Data Supplement S3), but no significant prognostic accuracy difference is noted when ED personnel (nurses) administered the instruments. The outcomes assessed are detailed in Data Supplement S3 and included unanticipated ED returns, inpatient length of stay, functional decline, hospital readmission, nursing home placement, reduced mental well-being, reduced quality of life, high hospital utilization, and death. Several studies reported composite outcomes of various combinations of undesired outcomes as "any adverse outcome."[66,67,70,76,77,79]

The ISAR studies assessed the instrument's prognostic accuracy for ED return visits at 30 to 180 days, functional decline at 30 to 90 days, and hospital readmission at 30 to 180 days. In addition, multiple studies reported composite outcomes of "any adverse outcome" at 30 to 180 days, although the components of the combined endpoint varied from study to study. Several studies reported prognostic accuracy estimates at various thresholds ranging from one to three "yes" responses on the ISAR.[36,64,69,70,78] For this meta-analysis, the original ISAR threshold for "high risk" of ≥2 was used across studies. The pooled estimates of sensitivity and specificity for all outcomes at all follow-up intervals demonstrated statistically significant heterogeneity with I^2 often >50% (Data Supplement S5, available as supporting information in the online version of this paper). However, pooled estimates of LR+ and LR– generally demonstrated low heterogeneity. The pooled estimates of ISAR prognostic accuracy did not differ significantly when sensitivity analysis was performed by excluding unpublished abstracts. Based upon the summary estimates of LR+ and LR–, the ISAR is not sufficiently accurate to predict increased or decreased risk of ED return visits, functional decline, hospital readmission, or any adverse outcome (Table 4).

Two groups modified the ISAR in attempts to improve the overall prognostic accuracy of the instrument.[62,80] Graf et al.[80] made four modifications (Data Supplement S4). Item 2 was changed from "increased dependency" to "increased dependency during the past 24 hours." They edited item 3 from "history of hospital admissions during past 6 months" to "history of hospital admissions for 1 night during 6 months." Item 4 changed from "visual problems (with or without glasses)" to "visual problems not corrected by glasses," while item 6 defined polypharmacy as six or more drugs rather than three. They assessed readmissions at 1 and 12 months. Bolanos et al.[62] also changed the definition of polypharmacy to six or more drugs, and that was the only change they made to the ISAR. The modifications of the ISAR did not improve prognostic accuracy. The Graf modifications yielded a LR+ of 1.22 (95% confidence interval [CI] = 1.04 to 1.41) and 1.49 (95% CI = 1.24 to 1.79) for 1- and 12-month readmissions, as well as LR– of 0.65 (95% CI = 0.43 to 0.97) and 0.50 (95% CI = 0.37 to 0.67), respectively. Similarly, the Bolanos modifications demonstrated LR+ of 1.01 (95% CI = 0.85 to 1.20) and LR– of 0.96 (95% CI = 0.51 to

Table 3
Frailty Assessment Instruments and Post-ED Adverse Outcomes

Finding, Study	Outcome	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
Winograde Grade 3 Dramé 2011[54]	Institutionalization at 1 year	15 (11–19)	86 (84–89)	1.10 (0.81–1.51)	0.98 (0.93–1.04)
Rockwood Grade 3 Dramé 2011[54]	Institutionalization at 1 year	0 (0–1)	100 (99–100)	0.62 (0.07–5.50)	1.00 (0.99–1.01)
Schoevaerdts Grade 3 Dramé 2011[54]	Institutionalization at 1 year	85 (81–89)	40 (37–43)	1.42 (1.32–1.52)	0.37 (0.29–0.48)
Donini Grade 3 Dramé 2011[54]	Institutionalization at 1 year	76 (71–80)	32 (29–35)	1.11 (1.04–1.20)	0.76 (0.62–0.93)
Winograde Grade 3 Dramé 2011[54]	Mortality at 1 year	21 (17–25)	89 (87–91)	1.89 (1.41–2.52)	0.89 (0.84–0.94)
Rockwood Grade 3 Dramé 2011[54]	Mortality at 1 year	1 (0–2)	100 (99–100)	2.88 (0.48–17.16)	1.00 (0.99–1.00)
Schoevaerdts Grade 3 Dramé 2011[54]	Mortality at 1 year	83 (79–86)	41 (37–44)	1.40 (1.30–1.50)	0.42 (0.33–0.53)
Donini Grade 3 Dramé 2011[54]	Mortality at 1 year	75 (70–79)	32 (23–35)	1.09 (1.02–1.17)	0.80 (0.66–0.97)
CSHA Frailty Index Conroy 2013[56]	Hospital readmission				
	At 1 month	27 (19–35)	72 (69–76)	0.96 (0.70–1.31)	1.01 (0.91–1.14)
	At 3 months	25 (20–31)	72 (68–75)	0.89 (0.69–1.15)	1.04 (0.95–1.14)

CSHA = Canadian Study of Health and Aging; LR = likelihood ratio.

Table 4
ISAR Prognostic Accuracy

Outcome	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
30-day ED returns				
Asomaning 2013[61]	47 (24–71)	38 (31–44)	0.76 (0.47–1.23)	1.40 (0.89–2.21)
Bolanos 2010[62]	86 (72–95)	10 (6–15)	0.96 (0.84–1.09)	1.40 (0.59–3.30)
Carpenter 2012[67]	63 (47–76)	25 (15–39)	0.84 (0.64–1.10)	1.47 (0.82–2.63)
Moons 2007[11]	100 (66–100)	38 (26–50)	1.52 (1.21–1.91)	0.13 (0.01–2.01)
Salvi 2012[76]	65 (49–78)	50 (41–58)	1.28 (0.98–1.68)	0.71 (0.47–1.08)
Pooled estimate	*69 (62–76)*	*39 (36–43)*	*1.06 (0.83–1.35)*	*1.09 (0.70–1.70)*
90-day ED returns				
Carpenter 2009[66]	63 (47–76)	25 (15–39)	0.84 (0.64–1.10)	1.47 (0.82–2.63)
Carpenter 2012[67]	88 (62–98)	25 (15–39)	1.17 (0.92–1.49)	0.49 (0.12–1.94)
Moons 2007[11]	80 (59–93)	40 (27–55)	1.34 (1.00–1.81)	0.50 (0.21–1.16)
Pooled estimate	*72 (61–81)*	*30 (23–38)*	*1.09 (0.83–1.43)*	*0.79 (0.34–1.84)*
180-day ED returns				
Di Bari 2010[57]	50 (47–53)	69 (66–72)	1.62 (1.44–1.81)	0.72 (0.67–0.78)
Salvi 2009[75]	73 (63–82)	43 (31–55)	1.28 (1.01–1.61)	0.63 (0.41–0.96)
Salvi 2012[76]	61 (51–71)	59 (47–70)	1.48 (1.08–2.03)	0.66 (0.48–0.91)
Salvi 2012[12]	74 (71–77)	39 (36–42)	1.21 (1.14–1.29)	0.67 (0.58–0.76)
Pooled estimate	*61 (59–63)*	*51 (49–53)*	*1.38 (1.14–1.67)*	*0.71 (0.66–0.75)*
30-day functional decline				
Braes 2009[63]	79 (63–90)	35 (27–43)	1.20 (0.99–1.47)	0.62 (0.33–1.15)
Carpenter 2012[67]	87 (78–93)	29 (20–40)	1.23 (1.05–1.43)	0.45 (0.24–0.84)
Deschodt 2011[69]	88 (84–92)	19 (16–23)	1.09 (1.03–1.16)	0.61 (0.42–0.89)
Salvi 2009[75]	78 (62–89)	47 (37–57)	1.45 (1.13–1.86)	0.48 (0.26–0.89)
Pooled estimate	*86 (83–89)*	*27 (24–30)*	*1.19 (1.07–1.34)*	*0.56 (0.43–0.72)*
90-day functional decline				
Braes 2009[63]	74 (57–87)	36 (28–45)	1.15 (0.92–1.45)	0.73 (0.41–1.30)
Carpenter 2009[66]	77 (64–88)	36 (23–51)	1.21 (0.94–1.56)	0.63 (0.34–1.17)
Carpenter 2012[67]	86 (71–95)	33 (18–52)	1.30 (0.99–1.70)	0.41 (0.16–1.05)
Edmans 2013[72]	79 (70–87)	38 (33–43)	1.28 (1.13–1.46)	0.54 (0.36–0.82)
Pooled estimate	*79 (73–84)*	*37 (33–41)*	*1.25 (1.14–1.38)*	*0.53 (0.44–0.77)*
30-day hospital readmission				
Braes 2010[64]	61 (41–78)	30 (23–38)	0.86 (0.63–1.18)	1.32 (0.79–2.23)
Deschodt 2012[70]	86 (76–93)	18 (15–22)	1.05 (0.95–1.16)	0.77 (0.42–1.41)
Graf 2012[74]	92 (84–97)	22 (17–27)	1.18 (1.07–1.29)	0.38 (0.18–0.79)
Pooled estimate	*85 (79–90)*	*21 (18–24)*	*1.08 (0.94–1.23)*	*0.75 (0.37–1.56)*
90-day hospital readmission				
Braes 2010[64]	70 (54–83)	33 (25–42)	1.04 (0.82–1.31)	0.92 (0.55–1.55)
Edmans 2013[72]	76 (69–82)	33 (29–37)	1.14 (1.02–1.26)	0.72 (0.54–0.97)
Graf 2012[74]	93 (87–97)	28 (22–35)	1.30 (1.18–1.43)	0.24 (0.12–0.47)
Pooled estimate	*82 (77–86)*	*32 (29–35)*	*1.18 (1.05–1.34)*	*0.57 (0.30–1.10)*
180-day hospital readmission				
Di Bari 2010[57]	80 (76–83)	29 (26–32)	1.12 (1.06–1.19)	0.70 (0.58–0.85)
Graf 2012[74]	91 (86–94)	32 (25–41)	1.34 (1.19–1.52)	0.28 (0.17–0.47)
Salvi 2012[12]	77 (74–80)	38 (35–41)	1.24 (1.17 – 1.32)	0.60 (0.51–0.71)
Pooled estimate	*80 (78–82)*	*34 (32–36)*	*1.22 (1.11–1.34)*	*0.54 (0.39–0.75)*
30-day any adverse outcome				
Carpenter 2012[67]	92 (75–99)	35 (21–51)	1.42 (1.11–1.81)	0.22 (0.05–0.89)
Deschodt 2012[70]	90 (83–95)	18 (15–22)	1.10 (1.03–1.18)	0.54 (0.30–0.97)
Salvi 2012[76]	70 (57–80)	50 (41–59)	1.38 (1.09–1.74)	0.61 (0.41–0.91)
Pooled estimate	*84 (78–88)*	*25 (22–28)*	*1.26 (1.03–1.55)*	*0.56 (0.40–0.77)*
90-day any adverse outcome				
Carpenter 2009[66]	85 (75–92)	30 (15–49)	1.21 (0.94–1.56)	0.50 (0.23–1.09)
Carpenter 2012[67]	88 (73–96)	37 (19–58)	1.39 (1.02–1.90)	0.34 (0.13–0.88)
Edmans 2013[72]	71 (66–75)	43 (34–52)	1.24 (1.05–1.45)	0.68 (0.53–0.88)
Pooled estimate	*74 (70–78)*	*40 (33–47)*	*1.25 (1.11–1.42)*	*0.60 (0.44–0.83)*
180-day any adverse outcome				
Di Bari 2010[57]	72 (68–76)	25 (22–28)	0.96 (0.91–1.02)	1.11 (0.94–1.31)
McCusker 1999[9]	72 (68–76)	58 (55–61)	1.71 (1.57–1.87)	0.48 (0.42–0.56)
Salvi 2012[76]	68 (59–76)	61 (48–72)	1.72 (1.25–2.38)	0.53 (0.39–0.72)
Pooled estimate	*72 (69–74)*	*44 (42–46)*	*1.40 (0.88–2.24)*	*0.66 (0.37–1.19)*

ISAR = Identification of Seniors at Risk.

1.81). Graf also derived a multiple regression model based on four risk factors (Data Supplement S4) with LR+ of 1.1 and 1.1 and LR– of 0.15 (95% CI = 0 to 0.97) and 0.25 (95% CI = 0.1 to 0.67) for readmission at 1 and 12 months, respectively.[80]

The TRST studies assessed the instrument's prognostic accuracy for ED returns at 30 to 120 days, functional decline at 30 to 90 days, and hospital readmission at 30 to 180 days. One study reported the prognostic accuracy of TRST for functional decline with the outcome

defined by either activities of daily living or instrumental activities of daily living, but the prognostic accuracy did not differ substantially, regardless of which outcome definition was used.[78] Additionally, five studies assessed a composite outcome of "any adverse outcome" at 30 days using various combinations of endpoints.[10,67,70,77,79] Two studies evaluated "any adverse outcome" at 90 days[65,66] and another two at 120 days.[77,79] Several studies reported prognostic accuracy estimates at various thresholds ranging from one to three "yes" responses on the TRST.[10,64,69,70,79] For this meta-analysis, the original threshold of ≥2 was used across studies. The pooled estimates of sensitivity and specificity for all outcomes at all follow-up intervals demonstrated statistically significant heterogeneity with I^2 often >50% (Data Supplement S6, available as supporting information in the online version of this paper). Pooled estimates of LR+ and LR– again generally demonstrated low heterogeneity. The pooled estimates of TRST prognostic accuracy did not differ significantly when sensitivity analysis was performed by excluding unpublished abstracts. Based upon the summary estimates of LR+ and LR– ratios, the TRST is not sufficiently accurate to predict increased or decreased risk of ED returns, functional decline, hospital readmission, or any adverse outcome (Table 5).

Two studies assessed the VIP instrument's prognostic accuracy for hospital readmission or functional decline at 30 days.[64,70] For this meta-analysis, we used the threshold of ≥1 to define "abnormal" across studies. The pooled estimates of sensitivity and specificity for all outcomes at all follow-up intervals demonstrated variable statistical heterogeneity with I^2 ranging from 0% to 99.5% (Data Supplement S7, available as supporting information in the online version of this paper). Based on the summary estimates of LR+ and LR–, the VIP is not sufficiently accurate to predict increased or decreased risk of either post-ED hospital readmission or functional decline (Table 6).

Five studies reported sufficient detail to reconstruct 2 × 2 tables at various thresholds (≥1, ≥2, and ≥3) for ISAR, TRST, and VIP (Table 7).[10,37,64,69,73] Assessing prognostic accuracy for these instruments at different thresholds did not improve on the summary estimates of accuracy from our meta-analysis. In addition, one trial reported sufficient detail to compute interval likelihood ratios (iLR).[64,81] For the ISAR and the outcome of 14-day readmissions, the $iLR_{1-2} = 1.68$ and $iLR_{2-3} = 0.94$, whereas for the TRST $iLR_{1-2} = 1.03$ and $iLR_{2-3} = 0.61$, and for the VIP $iLR_{1-2} = 1.09$ and $iLR_{2-3} = 1.00$. The prognostic accuracy of these three instruments does not improve using either different thresholds to define abnormal or by using iLR.

Several instruments were evaluated in single trials so meta-analysis was not performed for these (Table 8). In addition to the ISAR and TRST, Buurman et al.[65] evaluated the Rowland and Runciman instruments for 6-month ED revisits, readmissions, mortality, or any combination of these three outcomes, in Belgium. Neither instrument demonstrated significant prognostic accuracy to increase or decrease the risk of vulnerability for these outcomes. In Italy, Di Bari et al.[57,71] derived and evaluated the "Silver Code" in two trials. In the derivation trial, they assessed 1-year mortality using two thresholds of abnormal: ≥4 or ≥11.[57] The derivation and validation sets were consistent, but neither threshold was sufficiently prognostic for 1-year mortality. Di Bari et al.[71] subsequently evaluated the Silver Code for 6-month outcomes of ED revisits, readmission, mortality, or any combination of these outcomes at the same two thresholds. Again, the Silver Code lacked sufficient prognostic accuracy to increase (LR+ ranges = 1.59 to 2.47) or decrease (LR– ranges = 0.70 to 0.88) the risk of these outcomes. Dramé et al.[38] derived the "Mortality Risk Index" (Data Supplement S4) in France to evaluate for 2-year post-ED mortality among hospitalized geriatric patients. Using either of two thresholds of abnormal (≥3 or ≥5), the Mortality Risk Index lacked prognostic accuracy to increase (LR+ = 1.41 to 1.93) or decrease (LR– = 0.34 to 0.59) the 2-year mortality risk.

DISCUSSION

Adverse outcomes after an episode of ED care occur in one-third of discharged older patients.[82–84] This problem is not unique to the United States, with similar reports in Italy,[85] Hong Kong,[86] and Australia.[87] While several case management models advocate for evidence-based screening and engagement of nursing leadership to enhance older adult outcomes,[88] these principles depend on a valid and reliable risk stratification protocol.[89] Unfortunately, existing research on risk factors for unsatisfactory outcomes following an older adult ED evaluation fails to provide compelling evidence to justify recommending any screening instrument or specific geriatric case finding method.[90] Nonetheless, medical educators and guideline developers advocate for focused, evidence-based screening efforts to optimize geriatric outcomes.[6,7] Because the number of geriatric EDs is expanding[91] with concurrent efforts to quantify benefit for these geriatric EDs,[92] the demand to derive and validate more accurate risk stratification instruments will continue.

None of the individual predictors of vulnerability or published risk stratification instruments demonstrate sufficient prognostic accuracy to distinguish high-risk or low-risk subsets of geriatric patients in EDs. This systematic review included five validated measures of frailty, which some might label as risk stratification instruments or distinct geriatric syndromes that merit a separate systematic review. Our a priori exclusion criteria included the geriatric syndromes of falls, delirium, and dementia, but not frailty for two reasons. First, in the seminal essay about geriatric syndromes, Inouye et al.[93] distinguished frailty from falls and delirium. Second, unlike falls, delirium, and dementia, no well-accepted definition or criterion standard for frailty exists. However, the concept of frailty is quite valid. By including the prognostic accuracy of frailty (which was not reported in the original studies but was provided by the investigators), future studies of ED vulnerability will be able to incorporate these constructs of frailty among the constellation of intrinsic and extrinsic factors that place some patients at increased risk.

Several recent systematic reviews have assessed one or more of these instruments in EDs. The systematic review of the TRST by Cousins et al.[18] included six

Table 5
TRST Prognostic Accuracy

Outcome	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
30-day ED returns				
Carpenter 2012[67]	80 (44–97)	47 (35–60)	1.51 (1.03–2.22)	0.43 (0.12–1.51)
Fan 2006[77]	63 (35–85)	52 (42–62)	1.31 (0.85–2.02)	0.72 (0.37–1.38)
Moons 2007[11]	67 (35–90)	47 (34–60)	1.25 (0.79–1.99)	0.71 (0.31–1.65)
Pooled estimate	*68 (51–82)*	*49 (43–56)*	*1.06 (0.83–1.35)*	*1.09 (0.70–1.70)*
90-day ED returns				
Carpenter 2009[66]	63 (47–76)	38 (25–52)	1.01 (0.75–1.37)	0.98 (0.60–1.61)
Carpenter 2012[67]	64 (31–89)	47 (33–62)	1.20 (0.72–2.01)	0.77 (0.34–1.78)
Moons 2007[11]	64 (43–82)	48 (34–62)	1.23 (0.83–1.83)	0.75 (0.41–1.36)
Pooled estimate	*63 (52–73)*	*44 (36–52)*	*1.11 (0.89–1.38)*	*0.86 (0.61–1.22)*
120-day ED returns				
Buurman 2011[65]	79 (66–88)	33 (28–38)	1.17 (1.00–1.37)	0.65 (0.39–1.10)
Fan 2006[77]	60 (42–76)	54 (43–65)	1.31 (0.92–1.88)	0.74 (0.47–1.16)
Pooled estimate	*71 (61–80)*	*37 (32–42)*	*1.19 (1.03–1.38)*	*0.70 (0.50–0.98)*
30-day functional decline				
Braes 2009[63]	79 (63–90)	47 (38–55)	1.48 (1.18–1.84)	0.46 (0.25–0.84)
Carpenter 2012[67]	70 (51–84)	53 (38–69)	1.50 (1.01–2.22)	0.57 (0.31–1.02)
Deschodt 2011[69]	78 (73–83)	30 (25–34)	1.11 (1.02–1.21)	0.74 (0.56–0.96)
Hustey 2007[78]	63 (50–75)	60 (56–64)	1.58 (1.28–1.97)	0.61 (0.44–0.86)
Pooled estimate	*75 (71–79)*	*27 (24–30)*	*1.37 (1.10–1.71)*	*0.65 (0.54–0.78)*
90-day functional decline				
Braes 2009[63]	79 (63–90)	50 (41–59)	1.58 (1.24–2.00)	0.42 (0.22–0.80)
Carpenter 2009[66]	60 (46–74)	36 (23–51)	0.94 (0.70–1.28)	1.10 (0.67–1.81)
Carpenter 2012[67]	61 (42–78)	50 (31–69)	1.23 (0.78–1.93)	0.77 (0.44–1.37)
Pooled estimate	*66 (57–75)*	*47 (40–54)*	*1.23 (0.87–1.75)*	*0.73 (0.42–1.27)*
30-day hospital readmission				
Braes 2010[63]	57 (37–76)	39 (32–48)	0.94 (0.67–1.33)	1.09 (0.68–1.74)
Deschodt 2012[70]	71 (59–81)	26 (22–30)	0.95 (0.82–1.12)	1.13 (0.77–1.67)
Fan 2006[77]	75 (35–97)	52 (43–62)	1.57 (1.01–2.45)	0.48 (0.14–1.61)
Graf 2012[74]	87 (78–93)	22 (17–27)	1.11 (1.00–1.23)	0.60 (0.33–1.09)
Pooled estimate	*76 (70–82)*	*30 (27–32)*	*1.06 (0.92–1.24)*	*0.90 (0.63–1.29)*
90-day hospital readmission				
Braes 2010[64]	67 (51–81)	45 (36–54)	1.22 (0.94–1.59)	0.73 (0.45–1.17)
Graf 2012[74]	88 (81–93)	24 (18–30)	1.16 (1.05–1.27)	0.51 (0.30–0.85)
Pooled estimate	*83 (76–88)*	*32 (27–37)*	*1.16 (1.06–1.28)*	*0.62 (0.43–0.85)*
180-day hospital readmission				
Graf 2012[74]	89 (83–93)	27 (21–35)	1.22 (1.10–1.36)	0.41 (0.25–0.66)
Salvi 2012[12]	72 (68–76)	41 (38–44)	1.22 (1.14–1.30)	0.68 (0.59–0.79)
Pooled estimate	*76 (73–79)*	*40 (37–42)*	*1.22 (1.16–1.29)*	*0.56 (0.34–0.91)*
30-day any adverse outcome				
Carpenter 2012[67]	69 (52–84)	55 (38–71)	1.54 (1.03–2.31)	0.56 (0.32–0.98)
Deschodt 2012[70]	77 (68–85)	26 (22–30)	1.04 (0.93–1.16)	0.88 (0.61–1.28)
Fan 2006[77]	65 (38–86)	52 (42–62)	1.36 (0.91–2.04)	0.67 (0.34–1.31)
Lee 2008[79]	82 (74–88)	24 (21–28)	1.07 (0.98–1.17)	0.76 (0.53–1.10)
Meldon 2003[10]	64 (57–72)	63 (59–67)	1.74 (1.48–2.05)	0.57 (0.46–0.70)
Pooled estimate	*73 (69–77)*	*37 (35–40)*	*1.29 (1.03–1.62)*	*0.67 (0.55–0.81)*
90-day any adverse outcome				
Carpenter 2009[66]	64 (52–75)	33 (17–53)	0.97 (0.71–1.31)	1.07 (0.59–1.93)
Carpenter 2012[67]	61 (42–77)	48 (28–69)	1.17 (0.73–1.86)	0.82 (0.46–1.48)
Pooled estimate	*63 (53–72)*	*40 (27–54)*	*1.02 (0.79–1.32)*	*0.94 (0.62–1.42)*
120-day any adverse outcome				
Fan 2006[77]	62 (45–77)	55 (43–66)	1.37 (0.97–1.93)	0.70 (0.45–1.09)
Lee 2008[79]	56 (49–62)	58 (54–62)	1.33 (1.15–1.55)	0.76 (0.65–0.89)
Pooled estimate	*57 (51–63)*	*58 (54–62)*	*1.34 (1.17–1.53)*	*0.75 (0.65–0.87)*

TRST = Triage Risk Screening Tool.

studies and adverse outcomes as the outcome. Their conclusions mirrored ours: "the TRST is limited in its ability to discriminate between older adults with or without adverse outcome following ED discharge." The systematic review by Beaton and Grimmer[16] evaluated only functional decline and no meta-analysis is reported. They did identify two instruments that we did not include in our systematic review: the Brief Risk Identification for Geriatric Health Tool (BRIGHT)[94] and the Simplified PROFUNCTION index.[95] We excluded the BRIGHT because the validation trial assessed point-of-care instrumental activities of daily living dependence rather than post-ED functional decline. We excluded the Simplified PROFUNCTION index because it has not been evaluated in ED settings. Bissett et al.[17] assessed the psychometric properties of the ISAR and TRST, as well as two longer instruments, the Older Adult Resources and Services[96] and the Functional Status Assessment of Seniors in Emergency Departments.[97] They concluded that the shorter instruments were more

Table 6
Variables Indicative of Placement Risk Prognostic Accuracy

Outcome, Study	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
30-day hospital readmission				
Braes 2010[64]	73 (52–88)	35 (27–43)	1.12 (0.86–1.45)	0.77 (0.40–1.51)
Deschodt 2012[70]	81 (70–89)	13 (10–16)	0.93 (0.82–1.04)	1.48 (0.88–2.49)
Pooled estimate	*79 (69–86)*	*18 (15–21)*	0.98 (0.83–1.17)	1.11 (0.59–2.09)
30-day functional decline				
Braes 2010[64]	43 (28–59)	88 (81–93)	3.55 (2.02–6.26)	0.65 (0.50–0.85)
Deschodt 2012[70]	88 (83–910	21 (17–25)	1.11 (1.04–1.18)	0.58 (0.41–0.84)
Pooled estimate	82 (77–86)	37 (33–42)	1.92 (0.58–6.41)	0.63 (0.50–0.78)

Table 7
Prognostic Accuracy at Different Thresholds

Instrument	Study	Outcome	Sensitivity	Specificity	Positive LR	Negative LR
ISAR						
≥1	Braes 2010[64]	Hospital readmit at 30 days	79	10	0.88	2.05
≥3	Braes 2010[64]	Hospital readmit at 30 days	43	56	0.98	1.29
≥3	Gentile 2013[73]	Hospital readmit at 30 days	83	34	1.26	0.51
≥3	McCusker 2000[36]	High hospital utilizer	50	74	1.96	0.67
≥3	McCusker 2000[36]	High hospital utilizer	23	88	1.94	0.87
TRST						
≥1	Braes 2010[63]	Hospital readmit at 30 days	75	15	0.88	1.70
≥3	Braes 2010[63]	Hospital readmit at 30 days	21	81	1.13	0.97
≥1	Meldon 2003[10]	Adverse outcome at 30 days	85	32	1.25	0.47
≥3	Deschodt 2011[69]	Functional decline at 30 days	51	59	1.23	0.84
VIP						
≥1	Braes 2010[63]	Hospital readmit at 30 days	68	35	1.04	0.92
≥3	Braes 2010[63]	Hospital readmit at 30 days	4	97	1.16	0.99

ISAR = Identification of Seniors at Risk; LR = likelihood ratio; TRST = Triage Risk Screening Tool; VIP = Variables Indicative of Placement risk

appropriate for timely screening, whereas the longer instruments provide a more comprehensive understanding of functional performance. They did not quantify prognostic accuracy.

The lack of an accurate screening instrument represents one barrier to more routine geriatric prognosis screening.[98] The ideal prognostic screening instrument would be well calibrated across a broad range of illness severity, disability, socioeconomic, and health literacy strata.[99] To be clinically useful, the instrument would be sufficiently accurate to significantly reduce (LR– $\leq$ 0.1) or increase (LR+ $\geq$ 10) the risk of an adverse outcome so that finite resources can be focused on appropriately high-risk individuals.[47] Using these parameters of efficacy, neither the ISAR, the TRST, nor the VIP is sufficiently accurate to be clinically useful, as demonstrated in Figure 2.

The complexity in assessing the risk of unexpected and suboptimal outcomes, such as short-term functional decline, return to the ED, hospitalization, nursing home placement, or death, exists at the level of the patient, the community, and the national health care system. First, chronological age is not synonymous with biological age, yet all of these studies evaluate the geriatric adult population as one homogenous group. In the future, genetic or tissue biomarkers might assist clinicians in distinguishing the frail elderly phenotype from the acutely ill but otherwise healthy geriatric adult with adequate physiologic reserve.[100–103] In addition, assessing disease-specific prognostic risk (the heart failure prognostic instruments,[22] for example) in conjunction with tools like the ISAR or TRST might yield more accurate estimates of risk for short-term adverse outcomes. Second, in many patients a return to the ED or subsequent hospitalization can be expected and appropriate, but most studies did not distinguish anticipated from unexpected readmissions. A planned readmission is a repeat hospitalization following an index hospital stay that can be foreseen at the time of discharge after the index admission (delayed surgery, for example). An unplanned readmission cannot be foreseen at the time of discharge and may occur on a nonemergent or emergent basis.[104] Third, various geriatric syndromes complicate the post-ED management of the vulnerable elder, including delirium,[105] standing-level falls,[106] and dementia.[107] For example, if assessed in non-medicated, non–critically ill older adults, researchers note abnormal cognitive function in 35% of older ED patients. However, this is only recognized by emergency physicians in 6% of cases.[107]

The next layer of complexity is at the community level. Substantial proportions of young and old patients lack adequate literacy and numeracy skills to reliably comprehend medical information in the acute health

Table 8
Other Instruments: Runciman, Rowland, and Silver Code Prognostic Accuracy

Outcome, Study	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
Mortality Risk Index				
Dramé 2008[38]				
Mortality at 2-years				
≥ 3 abnormal	87 (84–90)	38 (35–42)	1.41 (1.32–1.50)	0.34 (0.27–0.43)
≥ 5 abnormal	59 (54–63)	70 (66–73)	1.93 (1.69–2.20)	0.59 (0.53–0.66)
Rowland				
Buurman 2011[65]				
6-month				
ED returns	23 (13–36)	82 (77–86)	1.28 (0.75–2.17)	0.94 (0.81–1.09)
Readmission	23 (14–35)	83 (78–87)	1.35 (0.81–2.24)	0.93 (0.80–1.07)
Mortality	27 (6–61)	82 (78–86)	1.51 (0.56–4.05)	0.89 (0.62–1.28)
Any of above	25 (16–37)	83 (78–87)	1.49 (0.94–2.36)	0.90 (0.78–1.04)
Runciman				
Buurman 2011[65]				
6-month:				
ED returns	86 (74–94)	12 (9–16)	0.97 (0.87–1.09)	1.19 (0.59–2.41)
Readmission	85 (74–92)	12 (9–16)	0.96 (0.86–1.08)	1.28 (0.67–2.43)
Mortality	82 (48–98)	12 (9–16)	0.93 (0.70–1.23)	1.53 (0.42–5.52)
Any of above	87 (77–93)	12 (9–16)	0.99 (0.89–1.09)	1.10 (0.57–2.12)
Silver Code				
Di Bari 2010[57]				
1-year mortality				
Derivation set				
Threshold ≥ 4	84 (83–85)	33 (32–34)	1.25 (1.22–1.28)	0.49 (0.45–0.53)
Threshold ≥ 11	33 (32–35)	83 (83–84)	2.0 (1.87–2.14)	0.80 (0.78–0.82)
Validation set				
Threshold ≥ 4	84 (82–86)	32 (30–34)	1.23 (1.20–1.27)	0.50 (0.45–0.57)
Threshold ≥ 11	32 (30–34)	83 (82–84)	1.93 (1.75–2.13)	0.81 (0.79–0.84)
Silver Code				
Di Bari 2012[71]				
Threshold ≥ 4				
6-month:				
ED returns	74 (71–78)	35 (32–38)	1.15 (1.07–1.23)	0.73 (0.62–0.85)
Readmission	77 (73–81)	35 (32–38)	1.19 (1.12–1.27)	0.65 (0.54–0.78)
Mortality	90 (85–93)	35 (32–38)	1.37 (1.30–1.46)	0.30 (0.21–0.44)
Any of above	75 (72–78)	39 (35–42)	1.22 (1.14–1.31)	0.65 (0.56–0.75)
Threshold ≥ 11				
6-month:				
ED returns	27 (24–31)	84 (82–87)	1.74 (1.42–2.11)	0.86 (0.82–0.91)
Readmission	28 (24–32)	83 (80–85)	1.59 (1.31–1.93)	0.88 (0.83–0.93)
Mortality	42 (36–48)	83 (81–85)	2.47 (2.04–2.99)	0.70 (0.63–0.78)
Any of above	27 (24–30)	87 (84–89)	2.06 (1.65–2.57)	0.84 (0.80–0.88)

An 82-year-old community-dwelling and functionally independent widow presents to the ED for evaluation of unilateral hip pain. After a careful, geriatric-appropriate history and physical exam reveals no evidence of cognitive dysfunction, abuse/neglect, standing-level falls, or inappropriate polypharmacy, you obtain x-rays of the painful hip and pelvis. No radiographic pathology is identified and the pain is completely relieved with acetaminophen so you contemplate discharge home, but wonder what the risk of an unanticipated ED return is within 3 months. Based on the studies included in this meta-analysis, the 3-month ED return risk ranged from 22% to 35%, so you use a pretest probability of 35%. The most accurate prognostic instrument was the TRST (LR+ = 1.11, LR– = 0.86 from Table 5). Converting the probability to odds using the formula [odds = probability ÷ (1 – probability)] yields an odds of 0.54 [0.35 ÷ (1 – 0.35) = 0.54]. Multiplying these odds by the LR's yields 0.54 × 1.11 = 0.592 posttest odds for an individual labeled as "high risk" by TRST and 0.54 × 0.86 = 0.46 for an individual labeled as "low risk" by TRST. These posttest odds are converted back to probability using the formula [probability = odds ÷ (odds + 1). For example, the posttest probability of 3-month ED returns for a "high-risk" TRST patient is 0.592/1.592 = 0.372 or 37.2%. Remember that before the TRST score was used the baseline probability was 35% so using the TRST only increased the risk by 2.2%.

Figure 2. Applying these results in the clinical setting.

care setting.[108,109] The result is miscomprehension of diagnoses and misunderstanding of discharge instructions, follow-up care plans, and prescription management.[108] Smaller EDs with limited access to social workers or a geriatric unit also have higher rates of return ED visits by older adults.[110] In addition, different communities provide variable levels of access to primary care or specialists for post-ED management.[111] Therefore, comparing the prognostic accuracy of one instrument across health care settings may be pointless. A patient in a setting where every citizen has health insurance and a single, identifiable primary care physician is a patient aware of whom to see in follow-up, confident that such services will be reimbursed. On the other hand, in a pay-for-service system, a fixed-income older adult without a single primary care physician lacks such ease of access. The latter patient might need to return to the ED for the same or new medical issues or have no follow-up for months, yet the return to the ED would be attributed to the patient's vulnerability rather than the health care system's limitations. Therefore, future prognostic instruments might need to differ according to a region's health care system.

Nurse and physician educators need to recognize the limitations of existing instruments as predictors of adverse outcomes following an episode of ED care. Additionally, we dissuade researchers, payers, and policy-makers from using any of these instruments as a basis for meaningful risk stratification. Designing expensive, time-consuming interventions or protocols around these instruments is illogical. The challenge then is how to risk stratify these complex patients and where to focus future efforts at education, research, and clinical policy? One response is to reemphasize the need for ED-based geriatric research to more fully illuminate evidence-based prognosis, diagnosis, and therapy decisions.[13,14] Another response is to explore prognostic instruments previously validated in non-ED settings to assess thus far untested risk factors.

Test–Treatment Threshold. Several ED-based studies have assessed geriatric prognostic screening instruments in quantitative, randomized trials and assessed outcomes such as hospital readmission, ED returns, outpatient referral patterns and service use, and functional decline. Caplan et al.[112] assessed Australian ED-based comprehensive geriatric assessment (CGA) with the intervention group receiving risk-stratified, home-based multidisciplinary assistance for up to 28 days following ED discharge. They demonstrated a 5.7% absolute risk reduction in 30-day hospital admission and a 9.9% absolute risk reduction in 18-month ED returns, but demonstrated no effect on mortality or nursing home admission. Mion et al.[113] also assessed ED-based CGA in the United States and noted a 2.3% absolute risk reduction in nursing home admissions at 30 days, but no effect on overall service use at 30 or 120 days. These studies represent the "gold standard" to which more pragmatic, ED-based geriatric screening interventions aspire, but require availability of a high-quality home health care service and skilled personnel with the time to administer the lengthy CGA in the ED. Therefore, we did not use these estimates of treatment benefit in our test–treatment computations.

Investigators in Canada used a randomized design to evaluate ISAR screening followed by nurse assessment of high-risk geriatric patients, notification of the primary care physician, and recommended home health care referrals. They demonstrated a 9.85% absolute risk reduction in 4-month functional decline, but no effect on patient depression, caregiver outcomes, or satisfaction with care.[114] In addition, ISAR-screened patients were more likely to be referred to community wellness resources, their primary care physicians, and home care services. Unfortunately, they were also 8.8% more likely to return to the ED.[115] Nonetheless, the ISAR screening model reduced the total cost of post-ED care over the subsequent 4 months.[116] Therefore, we use the estimate of 9.85% reduction in 4-month functional decline in our test–treatment computations.

In addition to estimates of treatment benefit in those with "disease" and prognostic instrument accuracy, the Pauker-Kassirer test–treatment assumption variables include estimated risks of the "test" and risk of treatment in those without "disease."[34] We use the prognostic accuracy of ISAR to predict 3-month functional decline since our outcome benefit estimate from the Canadian randomized trial is prevention of 4-month functional decline. However, the risk associated with administering the ISAR in EDs has not been formally assessed or quantified. Theoretical risks might include delayed diagnosis of time-dependent emergencies due to the time spent collecting the ISAR variables, increased patient angst related to an "abnormal" screening test result or other patient harm related to the downstream effect of further testing and referrals initiated due to ISAR screening results. However, we believe that these risks are quite small and use an estimate of 0.0001 for the test–treatment equation. One risk of treatment in those without "disease" is increased referral to the ED from home health services or primary care physicians. Although such referrals are probably indicated in the majority of cases, these ED returns would not otherwise have occurred without the ISAR-based intervention. These ED returns represent a measurable risk to patients, including exposure to ED treatment and infectious agents, transportation to and from the ED, and possibly hospital admission. The Canadian data suggest that the risk of increased ED returns at 1 month is 8.8%. For our test–treatment calculations we assume that this risk remains constant (8.8%) at 3 months. We acknowledge that this is an unlikely assumption, but no randomized trial data exists for 3-month ED returns following ISAR-based interventions.

These summary estimates were used to compute the test and treatment thresholds (Figure 3). The test threshold is 42% and the treatment threshold is 61%. In other words, when contemplating whether to develop an ED-based geriatric screening program, the investment in personnel training and time to screen is more likely to cause harm or lack direct patient benefit if the pretest risk of functional decline is less than 42% or greater than 61%. In the former case, the evidence suggests searching for other non–ISAR-related risks for functional decline. In the latter case, when the risk

exceeds 61% before any stratification instrument is used, the recommended interventions (home health referrals, etc.) should be initiated regardless. The intent of threshold estimates is not to dissuade prognostic evaluation or goal-oriented geriatric screening efforts. Instead, these estimates provide a quantitative conceptual context with which to evaluate the role of ED-based geriatric risk stratification using existing instruments. An Excel file is provided as an online supplement to this article, which readers can use to recalculate these thresholds using alternative estimates of risk, benefit, and diagnostic accuracy as new instruments and screening protocols become available (Data Supplement S2).

Another way to use the test–treatment threshold calculations is to evaluate the theoretical sensitivity and specificity at which a geriatric prognostic screening instrument would provide clinically and fiscally acceptable distinction between low-risk and non–low-risk geriatric patients based on expected benefit of screening. If we hold constant the expected benefit (9.85% reduction in 4-month functional decline), "harm" (8.8% unanticipated ED returns), test risk (0.001%), and specificity (37%), to contemplate an instrument that delineates a treatment threshold of 80% or greater (so that resources can be conserved for 20% or less of patients most likely to benefit), then the theoretical instrument sensitivity would have to exceed 93.4%. Using the same assumptions, to attain a treatment threshold of 60% would require an instrument with 80% sensitivity.

Implications for Future Research

Multiple instruments from the inpatient and outpatient settings that assess short-term adverse outcomes in older adults exist and remain untested in ED settings. These include the BRIGHT, PROFUNCTION index, the Hospital Admission Risk Profile (HARP),[117] and the Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie (SHERPA).[118] Other instruments such as the ED Gray[119] have already been developed and tested in EDs, but await formal prognostic accuracy and reliability reporting. One approach for future researchers is to test a tiered approach to assessing geriatric patients in the ED, using sufficiently brief instruments first line before progressing to longer and more complex screening protocols for those who remain in the gray zone between admission and discharge. This approach has been described by some, but remains untested.[80]

Standardizing outcomes to assess, definitions for those outcomes like "preventable readmission," and pertinent intervals to shape ED policy and protocol development are essential. By using ED-validated instruments assessing geriatric syndromes like dementia[120] and delirium,[121] future investigators are more likely to yield accurate and reliable estimates for these markers of vulnerability. Most of the included studies used geriatric syndrome instruments that were not validated in EDs. In addition, almost all of the individual risk factors and risk stratification instrument responses represented self-reported measures, which could be inaccurate or incomplete. Future studies should explore a combination of patient self-report responses and caregiver or close contact answers that might yield more accurate prognostic instruments, as well as objective assessments of cognition,[120] frailty,[122] and mobility.[123]

None of the included studies used published clinical decision rule research methods[124] or the Standards for Reporting of Diagnostic Accuracy (STARD) criteria.[125]

$$T_{\text{testing threshold}} = [(P_{pos/nd}) \times (R_{rx}) + R_t] \div [(P_{pos/nd} \times R_{rx}) + (P_{pos/d} \times B_{rx})] = 42\%$$

$$T_{\text{treatment threshold}} = [(P_{neg/nd}) \times (R_{rx}) - R_t] \div [(P_{neg/nd} \times R_{rx}) + (P_{neg/d} \times B_{rx})] = 61\%$$

Where assumptions on prognostic accuracy for the ISAR are based upon the summary estimates for functional decline at 3-months from Table 4.

$P_{pos/nd}$ = probability of a positive result in patients without disease = 1-specificity = 1-0.37 = 0.63
$P_{neg/nd}$ = probability of a negative result in patients without disease = specificity = 0.37
R_{rx} = risk of treatment in patients without disease = 0.088
R_t = risk of diagnostic test = 0.0001
$P_{pos/d}$ = probability of a positive result in patients with disease = sensitivity = 0.79
$P_{neg/d}$ = probability of a negative result in patients with disease = 1 – sensitivity = 1-0.79= 0.21
B_{rx} = benefit of treatment in patients with disease = 0.0985*

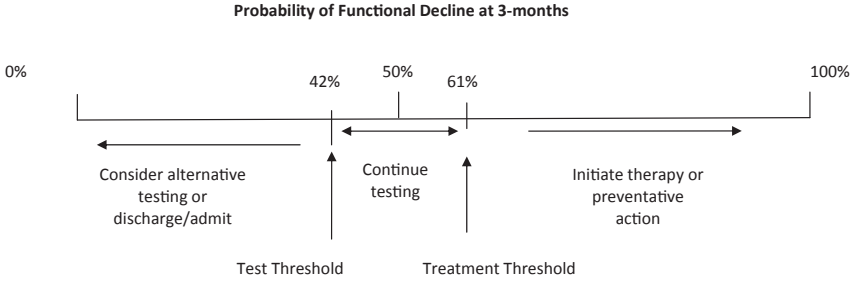

Figure 3. Test–treatment threshold assumptions.

These methods should be employed in the development, derivation, validation, and impact analysis of the next generation of prognostic instruments.[124] For example, before deriving the instrument, patients and providers should identify outcomes and potential predictors. Clinical decision rule methods also provide a tiered approach to instrument derivation, validation, and impact assessment. Barriers to implementation of standardized ED geriatric screening instruments include lack of resources and inadequate follow-up, misunderstanding the distinction between screening and assessment tools, and the need to adapt instruments to the local context.[126] In designing for implementation from the first stages of derivation, future investigators should contemplate the role of disruptive innovation in user-friendly, ED clinician–feasible instruments.[127] For example, one could use pad-based or smart phone technology to develop instruments that risk stratify patients in parallel with ongoing ED operations so as not to increase length of stay or overburden nurses and clinicians. Electronic medical record data are already being used to identify subsets of patients at increased risk for hospital readmission, and similar methods could be used to assess predischarge patient risk in ED settings in real time.[128,129]

Finally, ED researchers should view the failures detailed above as a call to use more standardized collaborative methodology and uniform outcome markers. This would enable between-study comparisons and application of findings in real-world settings. Decades of effort by dedicated geriatric ED researchers have thus far failed to yield meaningful risk stratification tools to guide treatment for vulnerable older adults. A geriatric ED research consortium to combine talents and resources would provide an essential infrastructure to develop the instruments we need for effective risk stratification of ED geriatric patients.[91]

LIMITATIONS

This meta-analysis has several limitations. First, the meta-analysis of individual studies demonstrates significant statistical heterogeneity, even when assessing the same instrument for the same outcomes on similar patient populations. This heterogeneity is partially due to inconsistent definitions for outcomes and variable methods of measuring and/or obtaining the outcome measures. In addition, some studies recruited patients solely from the ED, while others included ED patients after admission. Several articles lacked sufficient details to reconstruct 2×2 tables or to ensure that similar research strategies were used, so authors were contacted when necessary and the authors' responses are included in the reported study details, QUADAS-2 assessment, and prognostic accuracy data estimates. Nonetheless, the QUADAS-2 assessment indicates several forms of potential bias, including spectrum bias and incorporation bias, since outcome assessors sometimes lacked blinding to the index test results.[35] The failure to use STARD methods[125] and clinical decision instrument research design strategies[124] probably also resulted in lower research quality and greater inter-study heterogeneity.

Another limitation is that a lack of sufficiently similar prognostic studies existed to perform meta-analysis for some of the instruments and outcomes, but a systematic review can only analyze previously published research. We did include unpublished research abstracts, but our a priori sensitivity analysis excluding the unpublished studies from the meta-analysis did not significantly alter our estimates of prognostic accuracy. In addition, our evaluation included several different outcomes (ED returns, hospital readmissions, functional decline, nursing home admission, death). The relative importance of each outcome for patients, clinicians, and society is undefined, but likely not equal. Lacking any empiric basis by which to weight different outcomes, we report the prognostic accuracy estimate for each as if all are equally important.

Finally, multiple unmeasured and usually clinically unrecognized confounding variables at the patient and community levels exist across studies, such as cognitive impairment, limited health literacy, fixed finances, and access to primary care including transportation. These confounding variables likely limit our ability to apply results across heterogeneous health care settings and bias estimates of prognostic accuracy for these instruments. Most of the instruments and individual risk factors assess intrinsic features of the patient, but future studies should assess these hidden variables as the search for a more accurate risk stratification instrument continues.

CONCLUSIONS

Accurate and reliable identification of vulnerable geriatric adults during episodes of ED care is essential to focus finite resources on those most likely to benefit. Existing instruments designed to risk stratify older ED patients do not accurately distinguish high- or low-risk subsets and should not be used by key stakeholders for this purpose. Additional research is required using accepted decision instrument methods while remaining cognizant of long-term implementation in heterogeneous health care settings. Current educators and researchers should emphasize the limitations of existing instruments and individual risk factors if they disseminate these predictors. Funding organizations must support additional research if the strength of evidence-based geriatric risk screening is to improve.

The authors acknowledge the responses and data from all of the following geriatric risk factor and screening instrument investigators: Mauro Di Bari, MD, PhD (Florence, Italy); Allen Huang, MD (Ottawa, Canada); Xinia Villalobos Cambronero, MD, and Milena Bolanos Sanchez, MD (San Jose, Costa Rica); Simon Conroy, MD (Leicester, UK); Koen Milisen, PhD, RN, and Mieke Deschodt, PhD, RN (Leuven, Belgium); Christophe Graf, MD (Geneva, Switzerland); Moustapha Dramé, MCU-PH, HDR (Reims, France); Fredric Hustey, MD (Cleveland, OH); and Dr. Michal Boyd, RN, NP (Auckland, New Zealand).

References

1. Roberts DC, McKay MP, Shaffer A. Increasing rates of emergency department visits for elderly patients in the United States, 1993 to 2003. Ann Emerg Med 2008;51:769–74.

2. Pines JM, Mullins PM, Cooper JK, Feng LB, Roth KE. National trends in emergency department use, care patterns, and quality of care of older adults in the United States. J Am Geriatr Soc 2013;61:12–7.
3. Hwang U, Shah MN, Han JH, Carpenter CR, Siu AL, Adams JG. Transforming emergency care for older adults. Health Aff 2013;32:2116–21.
4. Hwang U, Morrison RS. The geriatric emergency department. J Am Geriatr Soc 2007;55:1873–6.
5. Carpenter CR, Platts-Mills TF. Evolving prehospital, emergency department, and "inpatient" management models for geriatric emergencies. Clin Geriatr Med 2013;29:31–47.
6. Hogan TM, Losman ED, Carpenter CR, et al. Development of geriatric competencies for emergency medicine residents using an expert consensus process. Acad Emerg Med 2010;17:316–24.
7. Carpenter CR, Bromley M, Caterino JM, et al. Optimal older adult emergency care: introducing multidisciplinary geriatric emergency department guidelines from the American College of Emergency Physicians, American Geriatrics Society, Emergency Nurses Association, and Society for Academic Emergency Medicine. Acad Emerg Med 2014;21:806–9.
8. Rosenberg M, Carpenter CR, Bromley M, et al. Geriatric emergency department guidelines. Ann Emerg Med 2014;63:e7–25.
9. McCusker J, Bellavance F, Cardin S, Trepanier S, Verdon J, Ardman O. Detection of older people at increased risk of adverse health outcomes after an emergency visit: the ISAR screening tool. J Am Geriatr Soc 1999;47:1229–37.
10. Meldon SW, Mion LC, Palmer RM, et al. A brief risk-stratification tool to predict repeat emergency department visits and hospitalizations in older patients discharged from the emergency department. Acad Emerg Med 2003;10:224–32.
11. Moons P, De Ridder K, Geyskens K, et al. Screening for risk of readmission of patients aged 65 years and above after discharge from the emergency department: predictive value of four instruments. Eur J Emerg Med 2007;14:315–23.
12. Salvi F, Morichi V, Lorenzetti B, et al. Risk stratification of older patients in the emergency department: comparison between the Identification of Seniors at Risk and Triage Risk screening tool. Rejuvenation Res 2012;15:288–94.
13. Carpenter CR, Gerson L. Geriatric emergency medicine. in: LoCicero J, Rosenthal RA, Katic M, Pompei P, eds. A Supplement to New Frontiers in Geriatrics Research: An Agenda for Surgical and Related Medical Specialties, 2nd ed. New York, NY: The American Geriatrics Society, 2008:45–71.
14. Carpenter CR, Heard K, Wilber ST, et al. Research priorities for high-quality geriatric emergency care: medication management, screening, and prevention and functional assessment. Acad Emerg Med 2011;18:644–54.
15. Graf CE, Zekry D, Giannelli S, Michel JP, Chevalley T. Efficiency and applicability of comprehensive geriatric assessment in the emergency department: a systematic review. Aging Clin Exp Res 2011;23:244–54.
16. Beaton K, Grimmer K. Tools that assess functional decline: systematic literature review update. Clin Interv Aging 2013;8:485–94.
17. Bissett M, Cusick A, Lannin NA. Functional assessments utilised in emergency departments: a systematic review. Age Ageing 2013;42:163–72.
18. Cousins G, Bennett Z, Dillon G, Smith SM, Galvin R. Adverse outcomes in older adults attending emergency department: systematic review and meta-analysis of the Triage Risk Stratification Tool. Eur J Emerg Med 2013;20:230–9.
19. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283:2008–12.
20. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Ann Intern Med 2009;151:W65–94.
21. Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions: Cochrane Book Series. Chichester, UK: John Wiley & Sons, Ltd., 2008.
22. Hsieh M, Auble TE, Yealy DM. Validation of the acute heart failure index. Ann Emerg Med 2008;51:37–44.
23. Welte T. Risk factors and severity scores in hospitalized patients with community-acquired pneumonia: prediction of severity and mortality. Eur J Clin Microbiol Infect Dis 2012;31:33–47.
24. Ganz DA, Bao Y, Shekelle PG, Rubenstein LZ. Will my patient fall? JAMA 2007;297:77–86.
25. LaMantia MA, Messina FC, Hobgood CD, Miller DK. Screening for delirium in the emergency department: a systematic review. Ann Emerg Med 2014;63:551–60.
26. Holsinger T, Deveau J, Boustani M, Williams JW. Does this patient have dementia? JAMA 2007;297:2391–404.
27. Whiting PF, Rutjes AW, Westwood ME, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med 2011;155:529–36.
28. Zamora J, Abraira V, Muriel A, Khan K, Coomarasamy A. Meta-DiSc: a software for meta-analysis of test accuracy data. BMC Med Res Methodol 2006;6:31.
29. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986;7:177–88.
30. Deeks JJ, Altman DG, Bradburn MJ. Statistical Methods for Examining Heterogeneity and Combining Results From Several Studies in Meta-analysis. in: Egger M, Smith GD, Altman DG, eds. Systematic Reviews in Health Care: Meta-Analysis in Context, 2nd ed. London, UK: BMJ Books, 2001:285–312.
31. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–60.

32. Byrt T. How good is that agreement? Epidemiology 1996;7:561.
33. Deeks JJ, Macaskill P, Irwig L. The performance of tests of publication bias and other sample size effects in systematic reviews of diagnostic test accuracy was assessed. J Clin Epidemiol 2005;58:882–93.
34. Pauker SG, Kassirer JP. The threshold approach to clinical decision making. N Engl J Med 1980;302:1109–17.
35. Kohn MA, Carpenter CR, Newman TB. Understanding the direction of bias in studies of diagnostic test accuracy. Acad Emerg Med 2013;20:1194–206.
36. McCusker J, Bellavance F, Cardin S, Belzile E, Verdon J. Prediction of hospital utilization among elderly patients during the 6 months after an emergency department visit. Ann Emerg Med 2000;36:438–45.
37. Dramé M, Jovenin N, Novella JL, et al. Predicting early mortality among elderly patients hospitalised in medical wards via emergency department: the SAFES cohort study. J Nutr Health Aging 2008;12:599–604.
38. Dramé M, Novella JL, Lang PO, et al. Derivation and validation of a mortality-risk index from a cohort of frail elderly patients hospitalised in medical wards via emergencies: the SAFES study. Eur J Epidemiol 2008;23:783–91.
39. Dramé M, Fierobe F, Lang PO, et al. Predictors of institution admission in the year following acute hospitalisation of elderly people. J Nutr Health Aging 2011;15:399–403.
40. Dhaussy G, Drame M, Jolly D, et al. Is health-related quality of life an independent prognostic factor for 12-month mortality and nursing home placement among elderly patients hospitalized via the emergency department? J Am Med Dir Assoc 2012;13:453–8.
41. Drame M, Lang PO, Jolly D, et al. Nursing home admission in elderly subjects with dementia: predictive factors and future challenges. J Am Med Dir Assoc 2012;13:83.
42. Rubenstein LZ, Harker JO, Salva A, Guiqoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). J Gerontol A Biol Sci Med Sci 2001;56:M366–72.
43. Katz S, Ford A, Moskowitz R. Studies of illness in the aged. The index of ADL: a standardized measure of biological and psychosocial function. JAMA 1963;185:914–9.
44. Folstein MF, Folstein SE, McHugh PR. "Mini-mental State: a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–98.
45. Vellas B, Wayne SJ, Romero L, Baumgartner RA, Rubenstein LZ, Garry PJ. One-leg balance is an important predictor of injurious falls in older persons. J Am Geriatr Soc 1997;45:735–8.
46. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–83.
47. Hayden SR, Brown MD. Likelihood ratio: a powerful tool for incorporating the results of a diagnostic test into clinical decision making. Ann Emerg Med 1999;33:575–80.
48. Chang S, Balaban D, Passo R, Carpenter CR. Self-rated health as a predictor of emergency department recidivism and functional decline among geriatric patients [abstract]. Ann Emerg Med 2012;60:S31.
49. Minnee D, Wilkinson J. Return visits to the emergency department and related hospital admissions by people aged 65 and over. N Z Med J 2011;124:67–74.
50. Winograd CH, Gerety MB, Chung M, Goldstein MK, Dominguez F, Vallone R. Screening for frailty: criteria and predictors of outcomes. J Am Geriatr Soc 1991;39:778–84.
51. Rockwood K, Stadnyk K, MacKnight C, McDowell I, Hébert R, Hogan DB. A brief clinical instrument to classify frailty in elderly people. Lancet 1999;353:205–6.
52. Schoevaerdts D, Biettlot S, Malhomme B, et al. Early identification of the geriatric profile in the emergency department: presentation of the Short Emergency Geriatric Assessment (SEGA) [in French]. Rev Gériatrie 2004;29:169–76.
53. Donini LM, Savina C, Rosano A, et al. MNA predictive value in the follow-up of geriatric patients. J Nutr Health Aging 2003;7:282–93.
54. Drame M, Novella JL, Jolly D, et al. Rapid cognitive decline, one-year institutional admission and one-year mortality: analysis of the ability to predict and inter-tool agreement of four validated clinical frailty indexes in the SAFEs cohort. J Nutr Health Aging 2011;15:699–705.
55. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ 2005;173:489–95.
56. Conroy S, Dowsing T. The ability of frailty to predict outcomes in older people attending an acute medical unit. Acute Med 2013;12:74–6.
57. Di Bari M, Balzi D, Roberts AT, et al. Prognostic stratification of older persons based on simple administrative data: development and validation of the "Silver Code", to be used in emergency department triage. J Gerontol A Biol Sci Med Sci 2010;65:159–64.
58. Vandewoude MF, Geerts CA, Paridaens KM, d'Hooghe AH. A screening tool for activating liaison geriatrics in general hospitals: the "Variable Indicative of Placement Risk." Eur J Geriatrics 2008;10:120–6.
59. Rowland K, Maitra AK, Richardson DA, Hudson K, Woodhouse KW. The discharge of elderly patients from an accident and emergency department: functional changes and risk of readmission. Age Ageing 1990;19:415–8.
60. Runciman P, Currie CT, Nicol M, Green L, McKay V. Discharge of elderly people from an accident and emergency department: evaluation of health visitor follow-up. J Adv Nurs 1996;24:711–8.
61. Asomaning N, Loftus C. Identification of Seniors at Risk (ISAR) screening tool in the emergency

department: implementation using the Plan-Do-Study-Act Model and validation results. J Emerg Nurs 2014;40:357–64.
62. Bolanos M, Villalobos X, Huang AR. The use of the ISAR screening tool in San Jose, Costa Rica. J Am Geriatr Soc 2010;58:S28.
63. Braes T, Flamaing J, Sterckx W, et al. Predicting the risk of functional decline in older patients admitted to the hospital: a comparison of three screening instruments. Age Ageing 2009;38:600–3.
64. Braes T, Moons P, Lipkens P, et al. Screening for risk of unplanned readmission in older patients admitted to hospital: predictive accuracy of three instruments. Aging Clin Exp Res 2010;22:345–51.
65. Buurman BM, van den Berg W, Korevaar JC, Milisen K, de Haan RJ, de Rooij SE. Risk for poor outcomes in older patients discharged from an emergency department: feasibility of four screening instruments. Eur J Emerg Med 2011;18:215–20.
66. Carpenter CR, DesPain RW, Keeling T, Rothenberg M, Shah M. Single-center validation of two prognostic screening instruments for older emergency department patients [abstract]. Acad Emerg Med 2009;16(Suppl 1):S91.
67. Carpenter CR, Abboud S, Feng D, et al. Do prognostic screening instruments predict adverse short-term outcomes among geriatric emergency department patients with dementia or low health literacy? [abstract]. Acad Emerg Med 2012;19(Suppl 1):S289.
68. Dendukuri N, McCusker J, Belzile E. The identification of seniors at risk screening tool: further evidence of concurrent and predictive validity. J Am Geriatr Soc 2004;52:290–6.
69. Deschodt M, Wellens NI, Braes T, et al. Prediction of functional decline in older hospitalized patients: a comparative multicenter study of three screening tools. Aging Clin Exp Res 2011;23:421–6.
70. Deschodt M, Flamaing J, Wellens N, Boonen S, Moons P, Milisen K. Comparison of three screening tools to predict hospital readmission in older adults [abstract]. Eur Geriatr Med 2012;3:S130.
71. Di Bari M, Salvi F, Roberts AT, et al. Prognostic stratification of elderly patients in the emergency department: a comparison between the "Identification of Seniors at Risk" and the "Silver Code". J Gerontol A Biol Sci Med Sci 2012;67:544–50.
72. Edmans J, Bradshaw L, Gladman JR, et al. The Identification of Seniors at Risk (ISAR) score to predict clinical outcomes and health service costs in older people discharged from UK acute medical units. Age Ageing 2013;42:747–53.
73. Gentile S, Lacroix O, Durand AC, et al. Malnutrition: a highly predictive risk factor of short-term mortality in elderly presenting to the emergency department. J Nutr Health Aging 2013;17:290–4.
74. Graf CE, Giannelli SV, Herrmann FR, et al. Identification of older patients at risk of unplanned readmission after discharge from the emergency department - comparison of two screening tools. Swiss Med Wkly 2012;141:w13327.
75. Salvi F, Morichi V, Grilli A, et al. Predictive validity of the Identification of Seniors At Risk (ISAR) screening tool in elderly patients presenting to two Italian emergency departments. Aging Clin Exp Res 2009;21:69–75.
76. Salvi F, Morichi V, Grilli A, et al. Screening for frailty in elderly emergency department patients by using the Identification of Seniors At Risk (ISAR). J Nutr Health Aging 2012;16:313–8.
77. Fan J, Worster A, Fernandes CM. Predictive validity of the triage risk screening tool for elderly patients in a Canadian emergency department. Am J Emerg Med 2006;24:540–4.
78. Hustey FM, Mion LC, Connor JT, Emerman CL, Campbell J, Palmer RM. A brief risk stratification tool to predict functional decline in older adults discharged from emergency departments. J Am Geriatr Soc 2007;55:1269–74.
79. Lee JS, Schwindt G, Langevin M, et al. Validation of the triage risk stratification tool to identify older persons at risk for hospital admission and returning to the emergency department. J Am Geriatr Soc 2008;56:2112–7.
80. Graf CE, Giannelli SV, Herrmann FR, et al. Can we improve the detection of old patients at higher risk for readmission after an emergency department visit? J Am Geriatr Soc 2012;60:1372–3.
81. Brown MD, Reeves MJ. Evidence-based emergency medicine skills for evidence-based emergency care. Interval likelihood ratios: another advantage for the evidence-based diagnostician. Ann Emerg Med 2003;42:292–7.
82. Hastings SN, Schmader KE, Sloane RJ, Weinberger M, Goldberg KC, Oddone EZ. Adverse health outcomes after discharge from the emergency department–incidence and risk factors in a veteran population. J Gen Intern Med 2007;22:1527–31.
83. Hastings SN, Oddone EZ, Fillenbaum G, Sloane RJ, Schmader KE. Frequency and predictors of adverse health outcomes in older Medicare beneficiaries discharged from the emergency department. Med Care 2008;46:771–7.
84. Hastings SN, Whitson HE, Purser JL, Sloane RJ, Johnson KS. Emergency department discharge diagnosis and adverse health outcomes in older adults. J Am Geriatr Soc 2009;57:1856–61.
85. Salvi F, Morichi V, Grilli A, Giorgi R, De Tommaso G, Dessi-Fulgheri P. The elderly in the emergency department: a critical review of problems and solutions. Intern Emerg Med 2007;2:292–301.
86. Chiu SL, Lam FM, Cheung C. Admission gatekeeping and safe discharge for the elderly: referral by the emergency department to the community nursing service for home visits. Hong Kong J Emerg Med 2007;14:74–82.
87. Schnitker L, Martin-Khan M, Beattie E, Gray L. Negative health outcomes and adverse events in older people attending emergency departments: a systematic review. Australas Emerg Nurs J 2011;14:141–62.
88. Sinha SK, Bessman ES, Flomenbaum N, Leff B. A systematic review and qualitative analysis to inform the development of a new emergency department-based geriatric case management model. Ann Emerg Med 2011;57:672–82.

89. Haas LR, Takahashi PY, Shah ND, et al. Risk-stratification methods for identifying patients for care coordination. Am J Manag Care 2013;19:725–32.
90. Pines JM, Carpenter CR, Raja A, Schuur J. Evidence-based Emergency Care: Diagnostic Testing and Clinical Decision Rules, 2nd ed. Oxford, UK: Wiley-Blackwell Publishing, 2013.
91. Hogan TM, Olade TO, Carpenter CR. A profile of acute care in an aging America: snowball sample identification and characterization of United States geriatric emergency departments in 2013. Acad Emerg Med 2014;21:337–46.
92. Keyes DC, Singal B, Kropf CW, Fisk A. Impact of a new senior emergency department on emergency department recidivism, rate of hospital admission, and hospital length of stay. Ann Emerg Med 2013;63:517–24.
93. Inouye SK, Studenski S, Tinetti ME, Kuchel GA. Geriatric syndromes: clinical, research, and policy implications of a core geriatric concept. J Am Geriatr Soc 2007;55:780–91.
94. Boyd M, Koziol-McLain J, Yates K, et al. Emergency department case-finding for high-risk older adults: the Brief Risk Identification for Geriatric Health Tool (BRIGHT). Acad Emerg Med 2008;15:598–606.
95. Bernabeu-Wittel M, Ollero-Baturone M, Ruiz-Cantero A, et al. Functional decline over 1-year follow-up in a multicenter cohort of polypathological patients: a new approach to functional prognostication. Int J Gerontol 2012;6:68–74.
96. McCusker J, Bellavance F, Cardin S, Belzile E. Validity of an activities of daily living questionnaire among older patients in the emergency department. J Clin Epidemiol 1999;52:1023–30.
97. Veillette N, Demers L, Dutil E, McCusker J. Development of a functional status assessment of seniors visiting emergency department. Arch Gerontol Geriatr 2009;48:205–12.
98. Carpenter CR, Griffey RT, Stark S, Coopersmith CM, Gage BF. Physician and nurse acceptance of geriatric technicians to screen for geriatric syndromes in the emergency department. West J Emerg Med 2011;12:489–95.
99. Carpenter CR. Deteriorating functional status in older adults after emergency department evaluation of minor trauma–opportunities and pragmatic challenges. J Am Geriatr Soc 2013;61:1806–7.
100. Nickel CH, Ruedinger J, Misch F, et al. Copeptin and peroxiredoxin-4 independently predict mortality in patients with nonspecific complaints presenting to the emergency department. Acad Emerg Med 2011;18:851–9.
101. Nickel CH, Messmer AS, Geigy N, et al. Stress markers predict mortality in patients with nonspecific complaints presenting to the emergency department and may be a useful risk stratification tool to support disposition planning. Acad Emerg Med 2013;20:670–9.
102. O'Sullivan E, Callely E, O'Riordan D, Bennett K, Silke B. Predicting outcomes in emergency medical admissions–role of laboratory data and comorbidity. Acute Med 2012;11:59–65.
103. Romero-Ortuno R, Silke B. Use of a laboratory only score system to define trajectories and outcomes of older people admitted to the acute hospital as medical emergencies. Geriatr Gerontol Int 2013;13:405–12.
104. Landrum L, Weinrich S. Readmission data for outcomes measurement: identifying and strengthening the empirical base. Qual Manag Health Care 2006;15:83–95.
105. Han JH, Zimmerman EE, Cutler N, et al. Delirium in older emergency department patients: recognition, risk factors, and psychomotor subtypes. Acad Emerg Med 2009;16:193–200.
106. Close JC, Hooper R, Glucksman E, Jackson SH, Swift CG. Predictors of falls in a high risk population: results from the prevention of falls in the elderly trial (PROFET). Emerg Med J 2003;20:421–5.
107. Carpenter CR, DesPain B, Keeling TK, Shah M, Rothenberger M. The six-item screener and AD8 for the detection of cognitive impairment in geriatric emergency department patients. Ann Emerg Med 2011;57:653–61.
108. Hastings SN, Barrett A, Weinberger M, et al. Older patients' understanding of emergency department discharge information and its relationship with adverse outcomes. J Patient Saf 2011;7:19–25.
109. Carpenter CR, Kaphingst KA, Goodman MS, Lin MJ, Melson AT, Griffey RT. Feasibility and diagnostic accuracy of brief health literacy screening instruments in an urban emergency department. Acad Emerg Med 2014;21:137–46.
110. McCusker J, Ionescu-Ittu R, Ciampi A, et al. Hospital characteristics and emergency department care of older patients are associated with return visits. Acad Emerg Med 2007;14:426–33.
111. Agarwal S, Banerjee J, Baker R, et al. Potentially avoidable emergency department attendance: interview study of patients' reasons for attendance. Emerg Med J 2012;29:e3.
112. Caplan GA, Williams AJ, Daly B, Abraham K. A randomized, controlled trial of comprehensive geriatric assessment and multidisciplinary intervention after discharge of elderly from the emergency department–the DEED II study. J Am Geriatr Soc 2004;52:1417–23.
113. Mion LC, Palmer RM, Meldon SW, et al. Case finding and referral model for emergency department elders: a randomized clinical trial. Ann Emerg Med 2003;41:57–68.
114. McCusker J, Verdon J, Tousignant P, de Courval LP, Dendukuri N, Belzile E. Rapid emergency department intervention for older people reduces risk of functional decline: results of a multicenter randomized trial. J Am Geriatr Soc 2001;49:1272–81.
115. McCusker J, Dendukuri N, Tousignant P, Verdon J. Poulin de Courval L, Belzile E. Rapid two-stage emergency department intervention for seniors: impact on continuity of care. Acad Emerg Med 2003;10:233–43.
116. McCusker J, Jacobs P, Dendukuri N, Latimer E, Tousignant P, Verdon J. Cost-effectiveness of a

brief two-stage emergency department intervention for high-risk elders: results of a quasi-randomized controlled trial. Ann Emerg Med 2003;41:45–56.
117. Sager MA, Rudberg MA, Jalaluddin M, et al. Hospital admission risk profile (HARP): identifying older patients at risk for functional decline following acute medical illness and hospitalization. J Am Geriatr Soc 1996;44:251–7.
118. Cornette P, Swine C, Malhomme B, Gillet JB, Meert P, D'Hoore W. Early evaluation of the risk of functional decline following hospitalization of older patients: development of a predictive tool. Eur J Public Health 2006;16:203–8.
119. Post LA, Conner T, Moore C, et al. Developing and validating the ED GRAY (geriatric readmission assessment at Yale) [abstract]. Acad Emerg Med 2013;20:S293–4.
120. Carpenter CR, Bassett ER, Fischer GM, Shirshekan J, Galvin JE, Morris JC. Four sensitive screening tools to detect cognitive impairment in geriatric emergency department patients: Brief Alzheimer's Screen, Short Blessed Test, Ottawa3DY, and the Caregiver Administered AD8. Acad Emerg Med 2011;18:374–84.
121. Han JH, Wilson A, Vasilevskis EE, et al. Diagnosing delirium in older emergency department patients: validity and reliability of the Delirium Triage Screen and the Brief Confusion Assessment Method. Ann Emerg Med 2013;62:457–65.
122. Syddall H, Cooper C, Martin F, Briggs R, Aihie-Sayer A. Is grip strength a useful single marker of frailty? Age Ageing 2003;32:650–6.
123. Schoene D, Wu SM, Mikolaizak AS, et al. Discriminative ability and predictive validity of the timed up and go test in identifying older people who fall: systematic review and meta-analysis. J Am Geriatr Soc 2013;61:202–8.
124. Stiell IG, Wells GA. Methodologic standards for the development of clinical decision rules in emergency medicine. Ann Emerg Med 1999;33:437–47.
125. Bossuyt PM, Reitsma JB, Bruns DE, et al. The STARD statement for reporting studies of diagnostic accuracy: explanation and elaboration. Ann Intern Med 2003;138:W1–12.
126. McCusker J, Verdon J, Veillette N, Berg K, Emond T, Belzile E. Standardized screening and assessment of older emergency department patients: a survey of implementation in Quebec. Can J Aging 2007;26:49–57.
127. Brownson RC, Jacobs JA, Tabak RG, Hoehner CM, Stamatakis KA. Designing for dissemination among public health researchers: findings from a national survey in the United States. Am J Public Health 2013;103:1693–9.
128. Billings J, Blunt I, Steventon A, Georghiou T, Lewis G, Bardsley M. Development of a predictive model to identify inpatients at risk of re-admission within 30 days of discharge (PARR-30). BMJ Open 2012;2:e001667.
129. Gildersleeve R, Cooper P. Development of an automated, real time surveillance tool for predicting readmissions at a community hospital. Appl Clin Inform 2013;4:153–69.

Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. Detailed electronic search strategy.

Data Supplement S2. Excel Test-Treatment Threshold Calculator.

Data Supplement S3. Summary of included studies.

Data Supplement S4. Components of the instruments to risk-stratify older adults in the emergency department for short-term adverse outcomes.

Data Supplement S5. Forest plots for the Identification of Seniors at Risk.

Data Supplement S6. Forest plots for the Triage Risk Screening Tool.

Data Supplement S7. Forest plots for the Variables Indicative of Placement Risk.