Frailty in trauma: A systematic review of the surgical literature for clinical assessment tools

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BACKGROUND: Elderly trauma patients have outcomes worse than those of similarly injured younger patients. Although patient age and comorbidities explain some of the difference, the contribution of frailty to outcomes is largely unknown because of the lack of assessment tools developed specifically to assess frailty in the trauma population. This systematic review of the surgical literature identifies currently available frailty clinical assessment tools and evaluates the potential of each instrument to assess frailty in elderly patients with trauma.

METHODS: This review was registered with PROSPERO (the international prospective register of systematic reviews, registration number CRD42014015350). Publications in English from January 1995 to October 2014 were identified by a comprehensive search strategy in MEDLINE, EMBASE, and CINAHL, supplemented by manual screening of article bibliographies and subjected to three tiers of review. Forty-two studies reporting on frailty assessment tools were selected for analysis. Criteria for objectivity, feasibility in the trauma setting, and utility to predict trauma outcomes were formulated and used to evaluate the tools, including their subscales and individual items.

RESULTS: Thirty-two unique frailty assessment tools were identified. Of those, 4 tools as a whole, 2 subscales, and 29 individual items qualified as objective, feasible, and useful in the clinical assessment of trauma patients. The single existing tool developed specifically to assess frailty in trauma did not meet evaluation criteria.

CONCLUSION: Few frailty assessment tools in the surgical literature qualify as objective, feasible, and useful measures of frailty in the trauma population. However, a number of individual tool items and subscales could be combined to assess frailty in the trauma setting. Research to determine the accuracy of these measures and the magnitude of the contribution of frailty to trauma outcomes is needed. (*J Trauma Acute Care Surg*. 2016;80: 824–834. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review, level III.
KEY WORDS: Assessment tool; elderly trauma; frailty; geriatric trauma.

By the year 2030, at least 20% of the population in the United States is expected to be older than 65 years.[1] Concurrent with population aging, trauma centers nationwide are experiencing a disproportionate increase in the number of elderly trauma patients.[2] This is of particular concern because elderly trauma patients have worse outcomes than younger patients with similar injuries.[3,4] Although the increased vulnerability in the elderly may be a function of the effects of age and comorbidities, it is also postulated to be a result of frailty.[5–8] Frailty is a syndrome encompassing multiple domains characterized by decreased physiologic reserve and reduced resilience to stressors.[9] Unfortunately, there is lack of consensus on the operational definition of frailty and how to assess or measure it.[2] There are a number of existing frailty assessment tools for elderly patients undergoing elective surgery. There remains, however, a critical need for a valid and clinically useful assessment tool for elderly trauma patients, whose injuries may preclude testing otherwise feasible in the elective surgery patient at a preoperative appointment, such as gait speed, mobility testing, or a comprehensive geriatric assessment. We undertook a systematic review of the surgical literature to identify frailty assessment tools and evaluated the potential of each of these instruments to assess frailty in elderly patients with trauma.

PATIENTS AND METHODS

This systematic review was conducted in accordance with the PRISMA [Preferred Reporting Items for Systematic Reviews and Meta-Analyses] statement.[10] The protocol was registered with the PROSPERO international prospective register of systematic reviews[11] (registration number, CRD42014015350).

Selection Criteria

Although the purpose of the systematic review was to evaluate tools with the potential to assess frailty in the elderly trauma population, the selection of studies was not restricted to the elderly because frailty is not exclusive to patients 65 years and older. [9] Thus, studies were included if they evaluated, either prospectively or retrospectively, a frailty clinical assessment tool in adult patients of any age undergoing elective or emergent surgery or adult patients having experienced an injury. The surgical specialties included trauma, cardiothoracic surgery, urologic surgery, colorectal surgery, orthopedic surgery, neurosurgery, head and neck surgery, surgical oncology, vascular surgery, transplant surgery, and general surgery. Studies were included if the primary outcome was mortality, postoperative complications, or discharge disposition. The search was limited to the surgical literature because trauma patients are exposed to similar stressors as surgical patients, for example, hemorrhage, fractures, and wound healing. Review articles, letters, editorials, and abstracts without a published article were excluded.

Search Strategy

A literature search was conducted in Ovid MEDLINE, EMBASE, and CINAHL databases with the assistance of a certified medical librarian. Articles were limited to those published in the English language during a 20-year period from January 1, 1995, when studies on frailty in surgical patients first appeared, through October 28, 2014.

Search strategies were tailored to the requirements of the specific database; however, all were based on the initial strategy used to query Ovid MEDLINE (Table 1). The search strategy combined three concepts: frail, elderly, and assessment in combination with surgery or injury. For each concept, a list of synonyms and related words was developed with the addition of the associated standardized subject heading terms. Truncation was added to the root of the nonstandardized search terms to increase the number of search results found. Finally, the reference lists of all full-text articles accessed were manually searched to further ensure inclusion of all relevant studies.

Study Identification

Once the primary searches were completed, duplicate entries were removed, and the identified publications were subjected to three tiers of review. First, the titles were screened for relevance by the lead author (V.S.M.). Next, the abstracts of all relevant titles were reviewed independently by two authors (V.S.M. and K.A.T.) and were included when both reviewers

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TABLE 1. Search Strategy for Ovid MEDLINE

Number	Search Term	Fields Searched
#1	Geriatric/ or Frail Elderly/ or Aged/ or "Aged, 80 and over" / or Health Services for the Aged/	MeSH
#2	elders or elderly or oldest old or older or nonagenarian* or octogenarian* or centenarian* or aging or aged or geriatric* or infirm or frailty	Title/Abstract
#3	(senior) adjacent within 2 words (citizen* or adult*)	Title/Abstract
#4	#1 or #2 or #3	
#5	"Wounds and Injuries"/ or Trauma Centers/ or Traumatology/	MeSH
#6	trauma* or wound* or injur* or fractur* or accident* or blast* or stab or stabs or stabb* or gunshot or shot* or shoot*	Title/Abstract
#7	exp Surgical Procedures, Operative/ or General Surgery/ or Perioperative Period/	MeSH
#8	(elective or emergen* or cardiothoracic or urologic or colorectal or orthop?edic or oncolog* or vascular) adjacent within 1 word (surg* or operat*)	Title/Abstract
#9	surgical or surg* or neurosurg*	Title/Abstract
#10	#5 or #6 or #7 or #8 or #9	
#11	Geriatric Assessment/ or Health Status Indicators/ or Decision Support Techniques/	MeSH
#12	(frailty) adjacent within 3 words (criteria* or evaluat* or scor* or scale* or screen* or tool* or index* or assess* or rate* or rating or instrument* or questionnaire* or indicator* or phenotype)	Title/ Abstract/ Subject Heading/ Registry Word
#13	(Groningen* or Fried* or clinical) adjacent (frailty)	Title/ Abstract/ Subject Heading/ Registry Word
#14	geriatric assessment*	Title/ Abstract/ Subject Heading/ Registry Word
#15	#11 or #12 or #13 or #14	
#16	Retrospective Studies/ or Prospective Studies/ or Follow-Up Studies/ or Cohort Studies	MeSH
#17	Retrospective* or prospective* or follow-up or cohort stud*	Title/ Abstract/ Subject Heading/ Registry Word
#18	#16 or #17	
#19	#4 and #10 and #15 and #18	
#20	limit #19 to year="1995-2014"	
#21	limit #20 to language=English	

determined that the publication met inclusion and exclusion criteria. In the event that the two reviewers disagreed about the inclusion of a publication, a third author (P.R.L.) was available to adjudicate. Finally, the full-text articles of all included publications were assessed by one author (V.S.M.) according to the inclusion and exclusion criteria. The bibliographies of all publications undergoing full-text review were searched for pertinent references, which were subjected to the inclusion and exclusion criteria and, if selected, underwent full review. Relevant articles from the authors' libraries were also subject to inclusion and exclusion criteria. The entire selection process produced a list of full-text publications in the surgical literature reporting on frailty clinical assessment tools.

Data Abstraction and Analysis

Reflecting the lack of a single generally accepted clinical definition of frailty,[12] the studies reported a number of diverse tools to measure frailty and its multiple components. Given this heterogeneity, a meta-analysis was not possible. Therefore, a qualitative analysis of the results was undertaken to assess each tool's potential for use in the assessment of elderly patients in the trauma setting.

To aid analysis, each unique tool in the selected studies was divided into its various component subscales and individual items by the lead author (V.S.M.). A subscale was defined as a previously validated set of individual items within an assessment tool used to assess a specific aspect or component of frailty. An individual item was defined as a previously validated question or measure that is not a component of any set of items (i.e., subscale), which alone is used to assess a specific aspect or component of frailty. As an example, the Simple Frailty Score[13] was divided into three subscales (Katz Index of Activities of Daily Living, Mini-Cog, and Charlson Comorbidity Index) and four separate individual items (albumin, hematocrit, history of falls, and a Timed Up-and-Go test). A depiction of this breakdown is presented in the Appendix (see Supplemental Digital Content 1, http://links.lww.com/TA/A727).

Each subscale and individual item abstracted from the tools included in this review was evaluated by the lead author (V.S.M.) using criteria formulated for objectivity, feasibility, and utility. In the absence of a published precedent on the nature of objectivity, feasibility, and utility in the present context, these criteria were defined in practical terms by consensus of the authors, based in part on standards by Palmer et al.[14] for the selection of items to create a minimum data set for use in trauma registries. Objectivity was defined as an assessment item that was not subject to the personal judgment, bias, feelings, or cultural background of patients, their families, or medical providers. Objectivity is critical in the assessment of frailty in trauma because patients frequently have altered mental status and families are often not immediately available for questioning. Feasibility was defined as an item being applicable or generalizable to all trauma patient populations (regardless of injury pattern or severity) as well as being readily available in the standard medical record, laboratory tests routinely performed in trauma patients, and equipment routinely available at most trauma centers. For example, it would not be feasible to perform the Timed Up-and Go test to assess the mobility of a patient with a complex hip fracture, and it would not be feasible to obtain a computed

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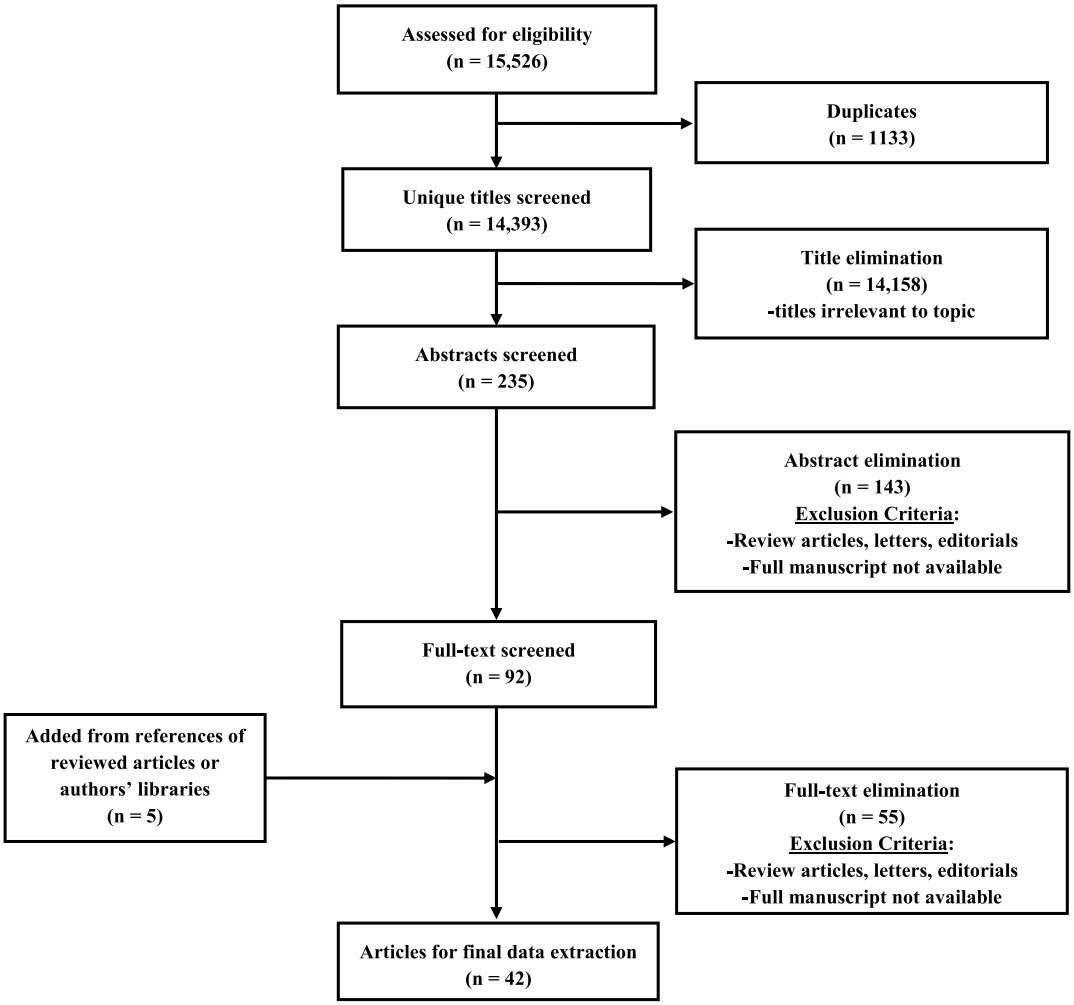

Figure 1. Flow diagram showing inclusion and exclusion of study articles.

tomographic scan not otherwise indicated on all patients simply to measure the size of the psoas muscle. If a tool, subscale, or individual item was determined to be objective and feasible, it was then assessed by the lead author (V.S.M.) using criteria for utility. Utility was defined as having an association with an adverse trauma outcome based on statistical significance on univariate or multivariate analysis. Adverse outcome was defined as postoperative mortality, morbidity, or discharge to any inpatient facility.

RESULTS

The searches retrieved 14,393 unique publications, from which 37 studies were retained along with 5 additional articles found in the bibliographies of reviewed full-text articles or the authors' libraries (Fig. 1). Thus, 42 studies were selected for data extraction.

Study Characteristics

Of the 42 studies, data were collected prospectively in 26 and retrospectively in 16 (Table 2). Surgical subspecialties included cardiothoracic surgery (9), general surgery (7), colorectal surgery (4), orthopedic surgery (3), trauma (3), surgical oncology (2), head and neck surgery (2), vascular surgery (2), and gynecologic surgery (1). Nine of the studies encompassed multiple surgical subspecialties. A total of 30 studies examined frailty in patients undergoing elective operations. Three assessed frailty in emergent hip or femoral neck fracture repair, and one focused on frailty in acute care surgery patients. Three cardiothoracic surgery studies, one colorectal study, and one otolaryngology study examined both emergent and elective surgeries. Three studies assessed frailty in a population of trauma patients, all from a single trauma center. Although all of the studies examined patients identified as adults, 15 did not specify an age range, 4 included patients 18 years and older, and 3 included patients 60 years and older. The remaining 20 studies included patients who are 65 years and older to 74 years or older.

Clinical Assessment Tools

The selected studies yielded 32 unique frailty clinical assessment tools (Table 3), representing combinations of 25 distinct subscales (Table 4) and 276 different individual items designed to assess patient cognition, function, or comorbidities along with other dimensions specific to a given study. The number of total components (subscales and individual items

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TABLE 2. Characteristics of the 42 Studies Selected for Data Extraction

Study	Surgical Specialty	Surgery/Injury	Elective/ Emergent	Study Design	Age Criteria	Frailty Index	Outcomes of Interest
Adams et al.[15]	Otolaryngology	Inpatient head and neck procedures	Elective	Retrospective cohort	None	NSQIP Frailty Indicator	Postoperative complications
Amrock et al.[16]	Colorectal	Lower gastrointestinal surgery	Elective	Retrospective cohort	≥65	Expanded Frailty Model; Electronic Frailty Model	Mortality; postoperative complications
Badgwell et al.[17]	Oncologic	Colorectal, hepatopancreatobiliary, or gastroduodenal cancer resection	Elective	Prospective cohort	≥65	Badgwell-CGA	Postoperative complications; mortality; discharge disposition
Courtney-Brooks et al.[18]	Gynecologic	Gynecologic cancer resection	Elective	Prospective cohort	≥65	Fried-FI	Postoperative complications
Dale et al.[19]	General	Pancreaticoduodenectomy	Elective	Prospective cohort	>18	Dale-CGA	Postoperative complications
Dasgupta et al.[20]	General; neurosurgical; orthopedic; vascular	Noncardiac, nononcologic surgery	Elective	Prospective cohort	≥70	Edmonton Frail Scale	Postoperative complications; discharge disposition
Dunlay et al.[21]	Cardiothoracic	Left ventricular assist device placement	Elective	Retrospective cohort	None	Dunlay-FI	Mortality; discharge disposition
Dwyer et al.[22]	Orthopedic	Hip fracture	Emergent	Retrospective cohort	None	Minimum Data Set Mortality Risk Index-Revised	Mortality
Farhat et al.[23]	Acute care	Emergency general surgery	Emergent	Retrospective cohort	>60	NSQIP Frailty Indicator	Postoperative complications; mortality
Fukuse et al.[24]	Cardiothoracic	Multiple	Elective	Prospective cohort	≥60	Fukuse-CGA	Postoperative complications
Ganapathi et al.[25]	Cardiothoracic	Proximal aortic surgery	Both	Retrospective cohort	None	Ganapathi-FI	Mortality; discharge disposition
Hodari et al.[26]	Cardiothoracic	Esophagectomy	Elective	Retrospective cohort	None	NSQIP Frailty Indicator	Postoperative complications; mortality
Johnson et al.[27]	Otolaryngology	Tracheostomy	Both	Retrospective cohort	None	Risk Analysis Index	Mortality
Jones et al.[28]	Cardiothoracic; colorectal	Colorectal and cardiac procedures	Elective	Prospective cohort	≥65	Fall History	Postoperative complications
Joseph et al.[8]	Trauma	Trauma	Emergent	Prospective cohort	≥65	Joseph Modified-FI	Discharge disposition
Joseph et al.[29]	Trauma	Trauma	Emergent	Prospective cohort	>65	Trauma Specific-FI	Discharge disposition
Joseph et al.[30]	Trauma	Trauma	Emergent	Prospective cohort	≥65	Joseph Modified -FI	Postoperative complications; discharge disposition
Karam et al.[31]	Vascular	Inpatient vascular procedures	Elective	Retrospective cohort	None	NSQIP Frailty Indicator	Mortality; postoperative complications
Kim et al.[32]	General; gynecologic; ophthalmology; orthopedic; thoracic; vascular; urologic	Multiple, including endoscopic procedures	Elective	Retrospective cohort	≥65	Kim-CGA	Mortality; discharge disposition
Kim et al.[33]	General	Abdominal surgery	Elective	Prospective cohort	≥65	Multidimensional Frailty Score	Postoperative complications; mortality; discharge disposition
Krishnan et al.[34]	Orthopedic	Hip fracture	Emergent	Prospective cohort	None	Krishnan-CGA	Mortality
Kristjansson et al.[35]	Colorectal	Colorectal cancer resection	Elective	Prospective cohort	≥70	Kristjansson-CGA	Postoperative complications
Lasithiotakis et al.[36]	General	Laparoscopic cholecystectomy	Elective	Prospective cohort	>65	Lasithiotakis-CGA	Postoperative complications
Lee et al.[37]	Cardiothoracic	Multiple	Both	Prospective cohort	None	Lee-CGA	Mortality; discharge disposition; postoperative complications
Lee et al.[38]	Vascular	Open abdominal aortic aneurism repair	Elective	Retrospective cohort	≥18	Psoas muscle cross-sectional area	Mortality
Makary et al.[7]	General	Multiple	Elective	Prospective cohort	≥65	Fried-FI	Postoperative complications
Obeid et al.[39]	General	Colectomy	Elective	Retrospective cohort	None	NSQIP Frailty Indicator	Postoperative complications; mortality
Patel et al.[40]	Orthopedic	Femoral neck fracture	Emergent	Retrospective cohort	≥60	Patel Modified-FI	Mortality
Reisinger et al.[41]	Colorectal	Colorectal resections	Both	Prospective cohort	None	Functional Compromise Test	Postoperative complications; mortality
Revenig et al.[42]	General; oncologic; urologic	Abdominal surgery	Elective	Prospective cohort	≥18	Modified Hopkins Frailty Score	Postoperative complications
Revenig et al.[43]	General; oncologic; urologic	Minimally invasive abdominal surgery	Elective	Prospective cohort	≥18	Fried-FI	Postoperative complications; discharge disposition
Robinson et al.[44]	Cardiothoracic; colorectal	Colorectal and cardiac procedures	Elective	Prospective cohort	≥65	Timed Up-and-Go	Postoperative complications; mortality
Robinson et al.[45]	Cardiothoracic; general; urologic; vascular	Major elective operation requiring postoperative SICU admission	Elective	Prospective cohort	≥65	Robinson 2009-CGA	Mortality; discharge disposition
Robinson et al.[46]	Cardiothoracic; General; Urologic; Vascular	Major elective operation requiring postoperative SICU admission	Elective	Prospective cohort	≥65	Robinson 2011-CGA	Discharge disposition

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TABLE 2. *(Continued)*

Study	Surgical Specialty	Surgery/Injury	Elective/ Emergent	Study Design	Age Criteria	Frailty Index	Outcomes of Interest
Robinson et al.[13]	Cardiothoracic; colorectal	Colorectal and cardiac procedures	Elective	Prospective cohort	≥65	Simple Frailty Score	Postoperative complications
Saxton et al.[47]	General	Abdominal surgery	Elective	Retrospective cohort	None	Rockwood-FI	Postoperative complications; mortality
Sündermann et al.[48]	Cardiothoracic	Multiple	Both	Prospective cohort	≥74	Comprehensive Assessment of Frailty	Mortality; postoperative complications
Sündermann et al.[49]	Cardiothoracic	Multiple	Elective	Prospective cohort	≥74	Comprehensive Assessment of Frailty	30-day postoperative mortality
Sündermann et al.[50]	Cardiothoracic	Multiple	Elective	Prospective cohort	None	Comprehensive Assessment of Frailty	Mortality
Tan et al.[51]	Colorectal	Colorectal cancer resection	Elective	Prospective cohort	>75	Fried-FI	Postoperative complications
Tegels et al.[52]	Oncologic	Gastric cancer resections	Elective	Retrospective cohort	None	Gronigen Frailty Indicator	Mortality; postoperative complications
Tsiouris et al.[53]	Cardiothoracic	Pulmonary lobectomy	Elective	Retrospective cohort	None	NSQIP Frailty Indicator	Postoperative complications

CGA, Comprehensive Geriatric Assessment; FI, Frailty Index; NSQIP, National Surgical Quality Improvement Program.

combined) in a single tool ranged from 1 to 141, with a mean of 28 components and a median of 18.

The tools identified fell into one of two general approaches. The rules-based approach, based on the five domains in the frailty phenotype paradigm, defined frailty as the presence of a threshold number of impairments (e.g., ≥3 of the following: weak grip strength, slow walking speed, unintended weight loss, exhaustion, low activity).[9] Five of the 32 frailty tools measured frailty using this approach. The remainder more closely followed an accumulation of deficits model, defining frailty as a sum of the number of impairments present and dividing the sum by the total number of deficits evaluated, creating a dose-response relationship between the deficits and frailty. [54]

Of the 32 tools, 3 were not assessed as a whole for predictive validity;[17,19,24] however, their component subscales and individual items were independently assessed for the ability to predict adverse outcomes. These three tools showed that poor performance on five subscales (Short Physical Performance Battery, American Society of Anesthesiologist [ASA] Scale, Barthel Index, Mini–Mental Status Examination, and Eastern Cooperative Oncology Group Performance Status) as well as two individual items (self-reported exhaustion and unintentional weight loss) were predictive of adverse outcomes. Of these, only the ASA Scale was deemed to be both feasible and objective.

Of the 29 tools assessed as a whole, 27 (93%) were found to be predictive of adverse patient outcomes. Of the 27 tools, 7 (26%) were determined to meet criteria for objectivity, and 6 were determined to meet criteria for feasibility. However, only 4 (15%) of the 27 were found to be both objective and feasible. These included the Electronic Frailty Model, the Fall History, the Patel Modified Frailty Index, and the National Surgical Quality Improvement Program (NSQIP) Frailty Index. Each of these four tools was found to meet criteria for utility, as determined by a statistically significant association with an adverse outcome. Three of the four tools were evaluated in retrospective studies, and one (Fall History) was evaluated prospectively. These four tools are highlighted in Table 3.

The 25 selected subscales represented five dimensions of assessment: functional status (11), cognition (5), comorbidity/comorbidities (3), emotional status (3), and nutrition (3). The number of individual items within each subscale ranged from 1 to 22. When evaluating the subscales on either objectivity or feasibility, if one item in a subscale failed to meet criteria, the entire subscale was rated as not objective or feasible. Seven subscales were determined to be objective. Two were found to meet criteria for feasibility. Of those, two were both objective and feasible: the ASA Scale and the Charlson Comorbidity Index. When rated on criteria for utility, both subscales were judged useful based on statistically significant associations with poor outcomes. These two subscales are highlighted in Table 4.

The 276 selected individual items represented seven categories of assessment: functional status (101), cognition (54), comorbidity/comorbidities (54), emotional status (47), nutrition (15), demographics (3), and social support (2). In all, 103 items met criteria for objectivity, and 54 met criteria for feasibility. Fifty-four satisfied both criteria, and 19 were also rated as useful. An additional 11 items that were not individually assessed in the studies for an association with adverse outcomes were deemed to be of intermediate utility. From the 30 items determined to be objective, feasible, and of at least intermediate utility, a single indicator for hemoglobin/hematocrit (considered one and the same for the purposes of this study) was excluded because such values can be heavily affected by injury and thus are a poor measure of a trauma patient's preinjury state. As a result, 29 individual items were deemed objective, feasible, and useful in elderly trauma patients. These 29 items are listed in Table 5.

DISCUSSION

This systematic review yielded 32 unique tools that could potentially be applicable to the assessment of frailty in the trauma patient. Of those, 4 tools as a whole, 2 subscales,

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TABLE 3. Frailty Clinical Assessment Tools

Frailty Clinical Assessment Tool	Reference	Subscales	Individual Items (n)	Feasible	Objective	Useful
Badgwell-CGA	[17]	ECOG, GDS, LBI, BFI, Mini-cog, ASA Scale, 4 IC	64	No	No	
Comprehensive Assessment of Frailty	[48–50]	None	22	No	No	
Dale-CGA	[19]	HFS, VES-13, SPPB, BMT	50	No	No	
Dunlay-FI	[21]	None	31	No	No	
Edmonton Frail Scale	[20]	TUG, 17 IC	18	No	No	
Electronic Frailty Model	[16]	None	9	Yes	Yes	Yes
Expanded Frailty Model	[16]	None	23	Yes	No	
Fall History	[28]	None	1	Yes	Yes	Yes
Fried-FI	[7,18,43,51]	None	11	No	No	
Fukuse-CGA	[24]	BI, MMSE, 11 IC	45	No	No	
Functional Compromise Test	[41]	GFI, SNAQ, 1 IC	19	No	No	
Ganapathi-FI	[25]	None	6	No	Yes	
Gronigen Frailty Indicator	[52]	None	15	No	No	
Joseph Modified-FI	[8,30]	None	50	No	No	
Kim-CGA	[32]	LBI, BI, MMSE, GDS, TUG, MNA, 4 IC	63	No	No	
Krishnan-CGA	[34]	AMTS, 46 IC	56	No	No	
Kristjansson-CGA	[35]	BI, NEADL, CIRS, MNA, MMSE, GDS	141	No	No	
Lasithiotakis-CGA	[36]	LBI, KADL, CCI, MUST, MMSE, 1 IC	57	No	No	
Lee-CGA	[37]	KADL, 2 IC	8	No	No	
Minimum Data Set Mortality Risk Index-Revised	[22]	None	15	Yes	No	
Modified Hopkins Frailty Score	[42]	ASA Scale, CCI, KADL, mFC, MNA, ECOG, CES-D	74	No	No	
Multidimensional Frailty Score	[33]	CCI, BI, LBI, MMSE, Nu-DESC, MNA, 3 IC	72	No	No	
NSQIP Frailty Indicator	[15,23,26,31,39,53]	None	15	Yes	Yes	Yes
Patel Modified-FI	[40]	None	19	Yes	Yes	Yes
Psoas Cross-Sectional Area	[38]	None	1	No	Yes	
Risk Analysis Index	[27]	None	11	No	No	
Robinson 2009-CGA	[45]	Mini-Cog, KADL, CCI, 3 IC	31	No	No	
Robinson 2011-CGA	[46]	CCI, ASA Scale, KADL, Mini-cog, TQDS, 6 IC	39	No	No	
Rockwood-FI	[47]	None	70	No	No	
Simple Frailty Score	[13]	TUG, KADL, Mini-cog, CCI, 3 IC	32	No	No	
Timed Up-and-Go	[44]	None	1	No	Yes	
Trauma Specific-FI	[29]	None	15	No	No	

AMTS, Abbreviated Mental Test Score; BFI, Brief Fatigue Inventory; BI, Barthel Index; BMT, Blessed Memory Test; CCI, Charlson Comorbidity Index; CES-D, Center for Epidemiologic Studies Depression Scale; CGA, Comprehensive Geriatric Assessment; CIRS, Cumulative Illness Rating Scale; ECOG, Eastern Cooperative Oncology Group Performance Status; FI, Frailty Index; GDS, Geriatric Depression Scale; GFI, Gronigen Frailty Indicator; HFS, Hopkins Frailty Score; IC, Individual Component; KADL, Katz' Index of Activities of Daily Living; LBI, Lawton & Brody Index; mFC, Modified Fried Criteria; Mini-Cog, Mini-Cognition Test; MMSE, Mini–Mental Status Examination; MNA, Mini–Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; NEADL, Nottingham Extended Activities of Daily Living; NSQIP, National Surgical Quality Improvement Program; Nu-DESC, Nursing Delirium Screening Scale; SNAQ, Short Nutritional Assessment Questionnaire; SPPB, Short Physical Performance Battery; TQDS, Two Question Depression Screen; TUG, Timed Up-and-Go; VES-13, Vulnerable Elders Survey.

and 29 individual items met the requisite criteria as objective, feasible, and useful. Together, they provide a platform from which to select specific indices that can be used for research in determining the effect of frailty on trauma outcomes in the elderly.

Although not exclusive to the elderly, frailty is prevalent in patients 65 years and older. The ability to assess and measure frailty is important because it can assist clinicians in stratifying risk for operative intervention, starting early alimentation, or predict a patient's risk of death or need for posthospital care, thus guiding clinical decision making. Once validated, measures of frailty can be used in clinical research to investigate therapies directed at improving fitness and decreasing frailty. A timely identification of frailty is thus critical to improve patient outcomes. Taking the construct of frailty from conceptual to operational is challenging, however.

The Geriatric Trauma Committee of the American Association for the Surgery of Trauma identifies frailty as a topic that warrants research.[2] To date, only a few studies from a single trauma center have examined the assessment of frailty in trauma.[8,29,30]

To our knowledge, this is the first systematic review to evaluate frailty tools previously studied in surgical populations for their use in the assessment of elderly trauma patients. Given the number of diverse tools identified and the variety of surgical specialties represented, one of the most important outcomes of our review is that frailty can be satisfactorily assessed in multiple ways.[55] The studies reviewed evaluated the ability of

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TABLE 4. Frailty Clinical Assessment Subscales

Subscale	Reference	Abbreviation	Individual Items (n)	Feasible	Objective	Useful
Abbreviated Mental Test Score	[34]	AMTS	10	No	No	
American Society of Anesthesiologist Scale	[16,17,39,42,45,46]	ASA	2	Yes	Yes	Yes
Barthel Index	[24,32,33,35]	BI	10	No	No	
Blessed Memory Test	[19]	BMT	27	No	Yes	
Brief Fatigue Inventory	[17]	BFI	8	No	No	
Center for Epidemiologic Studies Depression Scale	[42]	CES-D	20	No	No	
Charlson Comorbidity Index	[13,17,33,36,42,46]	CCI	19	Yes	Yes	Yes
Cumulative Illness Rating Scale	[35]	CIRS	13	Yes	No	
Eastern Cooperative Oncology Group Performance Status	[13,17,42]	ECOG	5	No	No	
Geriatric Depression Scale	[17,32,35]	GDS	15	No	No	
Katz Index of Activities of Daily Living	[13,36,37,42,45,46]	KADL	6	No	No	
Lawton & Brody Index	[17,32,33,36]	LBI	8	No	No	
Malnutrition Universal Screening Tool	[36]	MUST	3	No	Yes	
Mini Mental Status Exam	[24,32,33,35,36]	MMSE	20	No	No	
Mini Nutritional Assessment	[13,32,33,35,42]	MNA	7	No	No	
Mini-Cognition Test	[13,17,45,46]	Mini-Cog	3	No	Yes	
Minnesota Leisure Time Activities Questionnaire	[43]	MLTAQ	6	No	No	
Modified Fried Criteria	[19]	mFC	5	No	No	
Nottingham Extended Activities of Daily Living	[35]	NEADL	22	No	No	
Nursing Delirium Screening Scale	[33]	Nu-DESC	5	No	No	
Short Nutritional Assessment Questionnaire	[41]	SNAQ	3	No	No	
Short Physical Performance Battery	[19]	SPPB	5	No	Yes	
Timed Up-and-Go	[32]	TUG	1	No	Yes	
Two Question Depression Screen	[46]	TQDS	2	No	No	
Vulnerable Elders Survey	[19]	VES-13	13	No	No	

BFI, Brief Fatigue Inventory; BI, Barthel Index; BMT, Blessed Memory Test; CCI, Charlson Comorbidity Index; CES-D, Center for Epidemiologic Studies Depression Scale; CIRS, Cumulative Illness Rating Scale; ECOG, Eastern Cooperative Oncology Group Performance Status; GDS, Geriatric Depression Scale; KADL, Katz' Index of Activities of Daily Living; LBI, Lawton & Brody Index; mFC, Modified Fried Criteria; Mini-Cog, Mini-Cognition Test; MLTAQ, Minnesota Leisure Time Activities Questionnaire; MMSE, Mini–Mental Status Examination; MNA, Mini–Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; NEADL, Nottingham Extended Activities of Daily Living; NSQIP, National Surgical Quality Improvement Program; Nu-DESC, Nursing Delirium Screening Scale; SNAQ, Short Nutritional Assessment Questionnaire; SPPB, Short Physical Performance Battery; TQDS, Two Question Depression Screen; TUG, Timed Up-and-Go; VES-13, Vulnerable Elders Survey.

32 frailty tools to predict mortality, morbidity, and discharge disposition, and 93% were predictive of these outcomes. It should therefore be possible to adapt or create an evidence-based, objective, feasible frailty tool to fit the needs of trauma patients and trauma clinicians. The vast majority of studies applied the tools in patients undergoing elective surgery. As a result, the tools largely failed to meet our threshold criteria for objectivity and feasibility in the trauma setting. Many indices (e.g., gait speed, grip strength) or techniques (e.g., lengthy questionnaires) common to these tools cannot reasonably and reliably be accomplished among injured patients arriving to a busy trauma bay with an altered state of consciousness.

The only tool found in this review that was developed specifically to assess frailty in trauma patients, the Trauma-Specific Frailty Index (TSFI),[29] failed to meet evaluation criteria. The brief, 15-item instrument measured deficits in multiple domains that characterize frailty (e.g., comorbidity/comorbidities, functional status, nutrition status, cognition, and emotional status). In the tool validation study, a score greater than 0.27 (odds ratio, 1.5; 95% confidence interval, 1.1–2.5; $p = 0.001$) independently predicted in-hospital death or discharge to a skilled nursing facility in a sample of 200 elderly trauma patients. However, 11 of the 15 items in the TFSI were subjectively assessed by patient (or family) self-report. The reliance on personal judgment risked inaccurate data reporting and jeopardized the prediction of patient outcomes. Moreover, intubated or unresponsive patients (with or without family) unable to complete the assessment were excluded from the study, further limiting the tool's validity. As a result, the TSFI failed to meet the threshold criteria for objectivity and feasibility in this review.

The four tools, two subscales, and various items that met all of our evaluation criteria have yet to be validated in trauma. Because time is critical in the management of trauma and a frail patient is uniquely challenged by the stress of injury, an early, efficient, and effective identification of frailty is critical to patient management. It is unknown which of the indices and in what combination is best suited to the task of frailty assessment. However, it is apparent from this review that neither a simple inventory of comorbidities[54] nor age alone[30] is sufficient. In a study evaluating three tools (ASA Scale, Lee Score, and Eagle Score) focusing on the assessment of comorbidities in patients undergoing general surgery,[7] the addition of indices measuring several other domains, notably sarcopenia and weakness, substantially improved the predictive ability of all three scoring systems for poor outcomes.

The focus on sarcopenia and weaknesses is important because of its potential as a basis to develop an objective,

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TABLE 5. Individual Items Determined to be Useful

Item	Category	Useful
Albumin	Nutrition	Yes
Age	Demographic	Yes
Body mass index	Nutrition	Yes
Calf circumference	Nutrition	Yes
Congestive heart failure	Comorbidity	Yes
Chronic kidney disease/renal failure	Comorbidity	Yes
Chronic obstructive pulmonary disease	Comorbidity	Yes
Creatinine	Comorbidity	Yes
Cerebral vascular disease/stroke	Comorbidity	Yes
Dementia	Cognition	Yes
Diabetes	Comorbidity	Yes
Falls	Functional status	Yes
Malignant disease	Comorbidity	Yes
Myocardial infarction	Comorbidity	Yes
Mid-arm circumference	Nutrition	Yes
Peripheral vascular disease	Comorbidity	Yes
Sex/gender	Demographic	Yes
SNF admission within last 3 mo/transfer from acute care facility	Functional status	Yes
Acquired immunodeficiency syndrome	Comorbidity	Intermediate
Connective tissue disorder	Comorbidity	Intermediate
Delirium	Cognition	Intermediate
Depression	Emotional status	Intermediate
High cholesterol	Comorbidity	Intermediate
Hip fracture	Comorbidity	Intermediate
Hypertension	Comorbidity	Intermediate
Liver disease	Comorbidity	Intermediate
Osteoarthritis/osteoporosis	Comorbidity	Intermediate
Polypharmacy (>5 medications)	Comorbidity	Intermediate
Peptic ulcer disease	Comorbidity	Intermediate

SNF, skilled nursing facility.

feasible, and useful indicator of frailty. Three studies in our review[25,38,41] evaluated sarcopenia via muscle mass on computed tomography. Although the studies differed in the specific muscles scanned (i.e., total psoas volume, cross-sectional skeletal muscle surface area at L3, and psoas cross-sectional area at L4), in each study, a reduced core muscle mass was associated with adverse outcomes. However, the patients in these studies all routinely received abdominal computed tomographic imaging for preoperative evaluation (i.e., proximal aortic replacement, abdominal aortic aneurysm repair, colorectal cancer surgery). Relying on computed tomography to assess frailty in trauma is problematic. Trauma patients typically receive abdominal scans only when clinically indicated. Obtaining an abdominal scan for data as an indicator to assess frailty in most trauma patients would not be feasible. However, ultrasound or other technology ubiquitous in the trauma bay might be a more feasible alternative to measure muscle mass for the determination of frailty.

Limitations

This systematic review has several limitations. Study articles were accessed only in English. Ideally, it would have been informative to add "weights" to the various tools based on an assessment of the quality of the study in which they appear using a validated scale such as GRADE.[56] Given the heterogeneity of the study designs (Table 2), the widely differing patient populations (e.g., gynecologic, colon, and rectal, head and neck) and outcome measures, such an assessment would have been difficult and the results likely not valid. Although study inclusion was accomplished for the most part by two independent reviewers, data abstraction was performed by only one reviewer. The approach to tool evaluation was structured, and the evaluation criteria were well defined. However, they were specifically formulated for this study and were not validated. Thus, there is subjectivity in the definition and application of the concepts of feasibility, objectivity, and utility and in the evaluation process itself such that different decisions regarding the tools might be rendered by other authors. It is important, however, to limit the influence of bias in an assessment measure. In addition, no effort was made to assess the relative strength of the associations linking measures of frailty to the study outcomes or the psychometrics of the tools examined as a basis to restrict the number of tools deemed suitable in the trauma setting. However, this was by design. The goal of finding all possible candidate tools available in the surgical literature necessarily involved casting as wide a net as possible.

Furthermore, the definition of adverse outcome included "discharge to *any* inpatient facility," which encompassed skilled nursing facilities as well as acute rehabilitation centers. We acknowledge that while discharge to a skilled nursing facility bodes a poor outcome, discharge to acute rehabilitation can be favorable. Unfortunately, it was not possible to differentiate between the two locations because many of the studies that used discharge disposition as an outcome measure did not specify the type of inpatient facility, and simply described it as such.

Finally, the quality of each reviewed study was not specifically assessed. Therefore, when assessing for utility based on statistically significant associations with adverse outcomes, there may be instances where type 1 or 2 statistical errors exist. Consequently, there may be items that were judged to be useful, when in fact no association exists between that component and the adverse outcome. Conversely, an item may have been dismissed as not useful, when in fact an association does exist with an adverse outcome.

CONCLUSION

Few frailty assessment tools in the surgical literature qualify as objective, feasible, and useful measures of frailty in the trauma population. However, a few tools as a whole along with a number of individual items and subscales could conceivably be combined to assess patient frailty in the trauma setting. Given the anticipated growth in the number of vulnerable elderly trauma patients, research to determine the accuracy of these measures and the magnitude of the contribution of frailty to trauma outcomes is needed.

AUTHORSHIP

V.S.M., K.A.T., P.R.L., and S.R.S. designed this study. V.S.M., K.A.T., and P.R.L. searched the literature. V.S.M. collected and analyzed the data. V.S.M., K.A.T., P.R.L., S.R.S., M.J.S., and C.B.S. participated in the data interpretation and manuscript preparation.

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DISCLOSURE

The authors declare no conflicts of interest.

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