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Timing and methods of frailty assessments in geriatric trauma patients: A systematic review

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ABSTRACT

Introduction: The trauma population is aging and better prognostic measures for geriatric trauma patients are required. Frailty rather than age appears to be associated with poor outcomes. This systematic review aimed to identify the optimum frailty assessment instrument and timing of assessment in patients aged over 65 years admitted to hospital after traumatic injury. The secondary aim was to evaluate outcomes associated with frailty in elderly trauma populations.

Methods: This systematic review was registered with the PROSPERO International Prospective Register of Systematic Reviews (CRD42018090620). A MEDLINE and EMBASE literature search was conducted from inception to June 2019 combining the concepts of injury, geriatric, frailty, assessment and prognosis. Included studies were in patients 65 years or older hospitalised after injury and exposed to an instrument meeting consensus definition for frailty assessment. Study quality was assessed using criteria for review of prognostic studies combined with a GRADE approach.

Results: Twenty-eight papers met inclusion criteria. Twenty-eight frailty or component instruments were reported, and assessments of pre-injury frailty were made up to 1-year post injury. Pre-injury frailty prevalence varied from 13% (13/100) to 94% (17/18), with in-hospital mortality rates from 2% (5/250) to 33% (6/18). Eleven studies found an association between frailty and mortality. Eleven studies reported an association between frailty and a composite outcome of mortality and adverse discharge destination. Generalisability and assessment of strength of associations was limited by single centre studies with inconsistent findings and overlapping cohorts.

Conclusions: Associations between frailty and adverse outcomes including mortality in geriatric trauma patients were demonstrated despite a range of frailty instruments, administering clinicians, time of assessment and data sources. Although evidence gaps remain, incorporating frailty assessment into trauma systems is likely to identify geriatric patients at risk of adverse outcomes. Consistency in frailty instruments and long-term geriatric specific outcome measures will improve research relevance.

Level of evidence: : Level III prognostic.

Introduction

The trauma population is aging and in older trauma patients, innocuous mechanisms such as a fall from standing height, can result in severe injury and poor outcomes [1,2]. Triage measures such as systolic blood pressure and age poorly identify older patients at risk of adverse outcome and better prognostic measures for older trauma patients are required [3–5]. Frailty, described by Rockwood as “an evolving concept” without consensus definition, is an age-related vulnerable state in which the individual is at risk of adverse health outcomes [6,7]. With an aging population, frailty prevalence is also expected to increase [8]. Frailty includes physical, cognitive, social and psychological components, and is a dynamic condition that can improve or worsen over time. In the acute setting, frailty measurement has utility for early prognostication, but also provides an opportunity to identify patients whose outcomes may improve with intervention [9]. In the orthopaedic population, older patients have benefited from combined ortho-geriatric care and recently, frailty assessment and subsequent targeted interventions have been associated with improved rates of discharge home from hospital and enhanced mobility at one

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year [10]. It follows that in frail older trauma patients, similar results may be achieved.

Over the past 15 years, research into frailty, its relevance to specific patient populations, prevention and treatment has exploded, however, the optimal frailty assessment instrument for use in injured patients and other specific contexts has not been determined [11–14]. This uncertainty is driven by ongoing debate regarding a consensus definition for frailty, and thus which individuals are defined frail, at what stage and with what predicted outcomes [7]. Despite this, frailty assessments have been widely adopted, most commonly as risk stratification tools, and even incorporated into datasets able to generate automated frailty assessments [15].

In trauma, where early time critical decisions must be facilitated, feasibility, prognostic accuracy, 'ageist' restrictions to care and a perceived lack of available interventions have been cited as barriers to frailty screening [14]. A recent systematic review of frailty assessments in trauma populations included instruments used in elective surgical settings due to the limited use of frailty assessment in trauma populations [16]. The review reported concerns regarding feasibility and validity of frailty instruments in trauma populations [14]. Other groups have proposed frailty assessment tools 'fit for purpose' in the early stages of trauma patient management [17,18]. The primary aim of this systematic review therefore was to identify the optimum frailty assessment

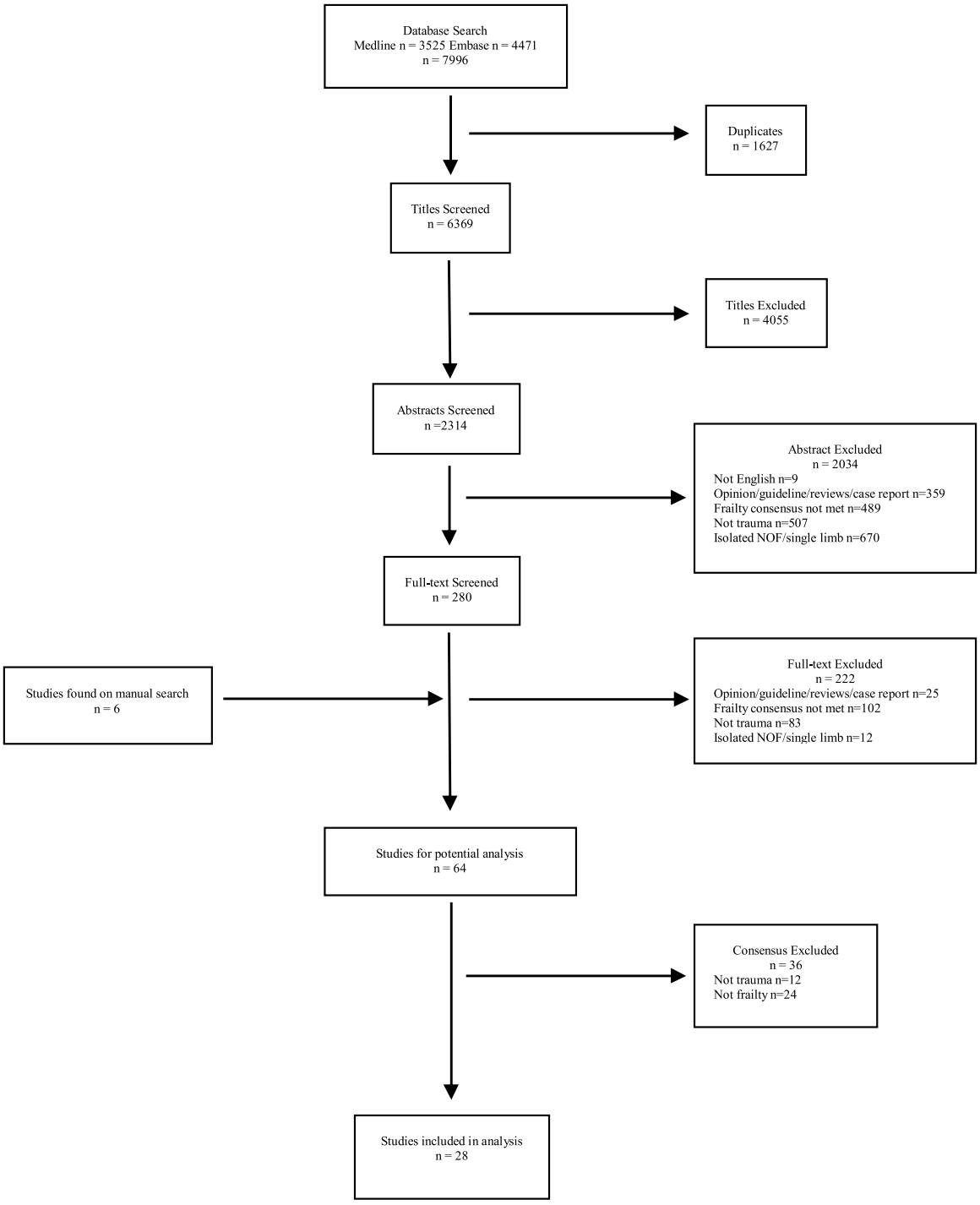

Fig. 1. PRISMA flow diagram.

Table 1
Studies included in qualitative analysis.

	Author	Year	Study design	n	Population	Age Mean (SD) Mean (IQR)	ISS Median (IQR) Mean (SD)	MOI Fall	Outcomes	Frailty Measure	Frailty Assessor	Time of frailty assessment		Source
												Preinjury	Postinjury	
1	Bryant et al.	2019	Single centre pre- (April 2015-March 2016) and post- (Oct 2016-Sept 2017) prospective intervention study	Pre- 125 Post- 144	Patients ≥65yrs admitted to American level 1 trauma service and pre-frail or frail	84.26 (6.71) pre 82.87 (7.4) post	Pre- 11.46 (5.96) Post- 11.78 (6.18)	Pre- 92.8% (116/125) Post- 86.1% (124/144)	Delirium (Confusion Method Assessment) Major Complications (TQIP) In-hosp Mortality 30-day readmission	FRAIL Scale CGA	Surgical resident Geriatrician	In ED (FRAIL) and <72 hrs post admission (CGA) for preinjury		?
2	Chan et al.	2019	Single centre retrospective cohort 2010-2016	70	Patients ≥65yrs with C2 fracture on CT at a tertiary NZ hospital	80.6 (8.5)	?	74.3% (52/70)	H-LOS 90-day readmission rate 30-day mortality 1-yr mortality	mFI	Trained researcher	Post discharge for preinjury status		EMR
3	Cheung et al.	2017	Single centre retrospective cohort Jan 2011-Dec 2014	321*	Patients ≥65yrs admitted to Canadian level 1 trauma service	76.5 (7.8)	17 (13-24)	45% (116/260)	Adverse DC (death, DC to long term care) In-hospital complications	CFS FI-lab	Geriatrician Trained researcher	<72 hrs post admission for preinjury (CFS)	<48 hrs (FI-lab)	EMR for FI-lab
4	Curtis et al.	2018	Single centre retrospective cohort 2011-2013	1403	Patients ≥65yrs admitted to American level 1 trauma service	77.6 (8.6)	?	66.3% (930/1403)	In-hosp mortality H-LOS DC disposition	CFS	Trained researcher	Post discharge for preinjury status		EMR
5	de Lange et al.	2019	Large multicentre prospective study Oct 2016-Feb 2017	222/3730	Consecutive patients ≥80yrs admitted to 306 participating ICUs in 24 European countries (excluding elective surgical patients)	85 (81-87)	?	?	ICU-mortality 30-d mortality	CFS	Doctor	?		Surrogate
6	Engelhardt et al.	2018	Single centre pre- (Oct-Dec 2016) and post- (Dec 2016-Oct 2017) prospective intervention study	Pre-4/11 Post-34/59	TEGS patients ≥65yrs admitted to American level 1 trauma service	78 [75–86] pre 81 [73–87] post	4 (2.5-7) pre 8.5 [4–10] post	?	H-LOS LOI (decline in function or mobility, increased care needs at home or DC to rehab or SNF) Readmission	TSFI	Doctor	?		?
7	Gronewold et al.	2017	Single centre Prospective cohort	?/381	Consecutive patients ≥75yrs admitted to orthopaedics and trauma surgery	82.5 (5.5)	?	?	H-LOS Nursing workload In-hospital Falls	ISAR CGA; Barthel Index Timed up & go Tinetti mobility MMSE Clock drawing GDS	Trained nurse Geriatrician	On admission for preinjury status		Patient

Table 1 (*Continued*)

	Author	Year	Study design	n	Population	Age	ISS	MOI Fall	Outcomes	Frailty Measure	Frailty Assessor	Time of frailty assessment		Source
						Mean (SD) Mean (IQR)	Median (IQR) Mean (SD)					Preinjury	Postinjury	
8	Hall et al.	2019	Single centre retrospective cohort	173	Patients ≥80yrs whose MOI was fall and had CT head in ED, in American level 1 trauma service	?	?	?	ICH Repeat CTB ED DC disposition 30-day readmission Mortality 1, 6, 12, 24mth Recurrent falls (with ED visit)	CFS	Trained researcher	Post discharge for preinjury status		EMR
9	Hamidi et al.	2018	Single centre prospective cohort 2013-2015	267	Patients ≥65yrs admitted to American level 1 trauma service and discharged to a single rehab centre	76.9 (7)	?	55% (147/267)	Functional improvement (delta FIM) Rehab-LOS Gain FIM	TSFI	Trained researcher	<24 hrs post trauma admission for preinjury		EMR Patient
10	Hamidi et al.	2019	Large multicentre retrospective propensity matched cohort 2010-2014	34,854	Patients ≥65yrs admitted to an ICU in the ACS-TQIP database of 775 American trauma centres	76.7 (7)	17 (10-29)	61% (21261/34,854)	In-hospital complications Mortality Adverse DC disposition (SNF, rehab)	mFI	Trained researcher	Post discharge for preinjury status		EMR
11	Joseph et al.	2017	Single centre prospective cohort 2012-2013	370	Consecutive patients ≥65yrs admitted to American level 1 trauma service	78 (8)	11 (9-17)	58% (204/350)	6mth hospital readmission, 6mth # of falls, 6mth mortality	TSFI	Trained researcher	First day of admission for preinjury status		Patient 88% (308/350) surrogate 12% (42/350)
12	Joseph et al.	2016	Single centre prospective cohort 2013-2014	388	Consecutive patients ≥65yrs admitted to American level 1 trauma service	74.79 (10.76)	11 (9-17)	57.6% (212/368)	FTR Mortality In-hospital complications H-LOS ICU – LOS Ventilator days DC disposition	TSFI	Trained researcher	First day of admission for preinjury status		Patient or surrogate
13	Joseph et al.	2015	Single centre prospective cohort	167[§]	Patients ≥65yrs with GLF admitted to American level 1 trauma service	79.5 (8.3)	14 (9-17)	100% (36%, 167/458)[δ]	Incidence of fracture In-hospital complications H-LOS DC to institution (rehab or SNF)	50-Variable FI	Trained researcher	First day of admission for preinjury status		Patient or surrogate
14	Joseph et al.	2014	Single centre prospective cohort June 2011-Feb 2013	250	Consecutive patients ≥65yrs admitted to American level 1 trauma service	77.9 (8.1)	15 (9-18)	64.8% (162/250)	In-hospital complications Adverse DC disposition (SNF, in-hospital mortality)	50-Variable FI	Trained researcher	First day of admission for preinjury status		Patient or surrogate
15	Joseph et al.	2014	Single centre prospective cohort May 2012 – July 2013	200	Consecutive patients ≥65yrs admitted to American level 1 trauma service	77 (12.1)	15 (9-20)	58% (116/200)	Unfavourable DC (SNF, in-hospital mortality) Favourable DC (home, rehab)	15-variable TSFI	Trained researcher	First day of admission for preinjury status		Patient or surrogate

16	Joseph et al.	2014	Single centre prospective cohort June 2011-May 2012	100	Consecutive patients ≥65yrs admitted to American level 1 trauma service	76.5 (8.5)	14 (9-18)	60% (60/100)	Unfavourable DC (SNF, in-hospital mortality) Favourable DC (home, rehab)	50-Variable FI(68)	Trained researcher	First day of admission for preinjury status		Patient or surrogate
17	Koizia et al.	2019	Single centre retrospective cohort 2013	28/79	Patients ≥75yrs with ISS > 15 admitted to an English level 1 trauma service	83 (75-101)	24 (16-54)	?	1-yr Mortality Pre-post injury frailty	REFS	Trained researcher	1-yr post dc for pre-injury	1-yr	Patient or surrogate Hospital record
18	Langlais et al.	2018	Single centre prospective cohort Feb 2015-Feb 2016	19/189	All patients ≥65yrs hospitalised ≥24 hrs in the ICU	74 (6)	?	?	In-hospital mortality	CFS	Doctor	<24 hrs post ICU admission for preinjury status		Patient 10% (19/189) Spouse 19% (36/189) Children 19% (35/189) Spouse and children 49% (92/189) Other 4% (7/189) EMR
19	Le Maguet et al.	2014	Multicentre prospective cohort	18/309	All patients ≥65yrs admitted for >24 hrs to four university-affiliated French ICUs	75 (6)	?	?	H-LOS ICU-LOS 6mth mortality 6mth location (home, hospital, other institution)	FP CFS	?	At ICU admission for preinjury status up to 1/12 preinjury		Patient 31% (61/196) Surrogate 61% (120/196) Both 8% (16/196)
20 21	Maxwell et al. Jeffery et al.	2016 2018	Single centre Prospective cohort Oct 2013 – March 2014	150/394	Injured patients ≥65yrs admitted to geriatric, orthopaedic or trauma surgery	77 (69-86)	10 (9-17)	67% (126/188)	6-mth mortality 1-yr mortality Composite Survival + low, med or highest function on Barthel Index	VES-13 Barthel Index LSA AD8 IQCDE	Trained researcher	<48 hrs post hospital admission for status 2 weeks preceding injury	30-days 90-days 6mth 1 yr	Patient and surrogate 41% (77/188) Surrogate only 59% (111/188) Adult children 54% (101/188) Spouses 35% (66/188) Sibling 3% (6/188) Other 8% (15/188)
22	Moran et al.	2013	Single centre prospective cohort	16	Patients ≥65yrs with isolated cervical spine fracture admitted to Australian trauma service	?	?	87.5% (14/16)	Mortality Complications Functional independence	ADL Mobility	Trained researcher	<48 hrs of admission for preinjury status	90-days	Patient or surrogate
23	Palmer et al.	2019	Single centre prospective cohort 2017-2018	100	Patients ≥65yrs admitted to American level 1 trauma service for ≥24 hrs	77.1 (9.8)	14(9-18) nonfrail 11 [8–20] frail	52% (52/100)	Levels of proinflammatory biomarkers and endocrine biomarkers In-hospital complications H-LOS ICU-LOS DC disposition Mortality	TSFI	?	“at admission”		?

Table 1 (*Continued*)

	Author	Year	Study design	n	Population	Age Mean (SD) Mean (IQR)	ISS Median (IQR) Mean (SD)	MOI Fall	Outcomes	Frailty Measure	Frailty Assessor	Time of frailty assessment Preinjury	 Postinjury	Source
24	Sadarangani et al.	2014	Single centre prospective cohort	205[§]	Consecutive patients ≥65yrs admitted to American level 1 trauma service	77.9 (?)	?	?	In-hospital complications Adverse DC disposition (SNF, in-hospital mortality)	50-Variable FI	?	?		Patient or surrogate
25	Santino et al.	2019	Single centre prospective cohort 2016-2017	296	Consecutive patients ≥65yrs admitted to American level 1 trauma service	75.1 (9.8)	Nonfrail 14 (9-18) Frail 11 (8-20)	48% (142/296)	HRQoL Delta HRQoL ($HRQoL_{30}$-$HRQoL_{Dis}$)	TSFI	Trained researcher	First day of admission for preinjury status		?
26	Schmoekel et al.	2018	Single centre retrospective cohort Jan 2014-June 2017	263	Patients ≥55yrs admitted to American level 1 trauma centre with CT chest showing ≥1 rib fracture	63 (13)	<15 80% (212/263)	?	Pneumonia Respiratory failure (mech vent ≥48 hrs) tracheostomy	mFI	Trained researcher	Post discharge for preinjury		EMR
27	Shah et al.	2019	Single centre prospective cross-sectional cohort 2016	65	Patients ≥65yrs admitted to American level 1 trauma service	79.5 (7.36) frail 76.8 (8.38)	?	?	H-LOS ICU-LOS Mortality DC destination	FRAIL CFS	Doctor (Ed or trauma service)	<72 hrs of admission		Patient or surrogate
28	Tipping et al.	2019	Single centre prospective cohort April 2015-May2016	100	Pateints ≥50yrs admitted for >24 hrs to trauma ICU in Australian MTC	69.2 (10.4)	22 (10.2)	?	H-LOS Mortality DC destination	FP CFS	Trained researcher	?		Patient 40% (40/100) Surrogate 60% (60/100)

* - 266 + 55 who had incomplete CGA; DC – discharge; CFS – Clinical Frailty Score; FI-lab – laboratory frailty index; CGA – Comprehensive Geriatric Assessment; TR – trained researcher; TSFI – Trauma Specific Frailty Index; mFI – modified Frailty Index; LOS – length of stay; SNF – skilled nursing facility; FTR– Failure to Rescue; H-LOS – Hospital LOS; ICU-LOS – Intensive Care LOS; GLF – Ground level fall; FI – frailty index; § - No cohort time period; FP – frailty phenotype; KATZ – Katz Index of Independence in ADL;? – unable to determine; ISAR – Identification of Seniors at Risk; MMSE – min-mental state examination; GDS – geriatric depression scale; VES-13 – Vulnerable Elders Survey; LSA – Life Space Assessment; AD8 Dementia Screen; IQCDE – The Short Informant Questionnaire on Cognitive Decline in the Elderly; TEGS – Trauma or Emergency General Surgery; LOI – Loss of independence; mFI – modified frailty index; REFS – Reported Edmonton Frail Scale; HRQoL – Health-related quality of life; $HRQoL_{Dis}$ – HRQoL at discharge; $HRQoL_{30}$ – HRQoL at 30-days post discharge.

instrument *and* timing of frailty assessment in patients over 65 years admitted to hospital after traumatic injury. The secondary aim was to evaluate outcomes associated with frailty in elderly trauma populations.

Methods

This systematic review was registered with the PROSPERO International Prospective Register of Systematic Reviews (CRD42018090620) and conducted in accordance with ROBIS and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [19,20]. The PECO research question was; 'In patients 65 years and older (≥65) hospitalised for injury (population), which frailty assessment instrument (exposure) is most strongly associated with mortality (primary outcome) when compared to other frailty assessment instruments applied at different time points (comparator)'. Secondary outcomes were hospital and intensive care length of stay (H-LOS, ICU-LOS), in-hospital complications and discharge destination.

With librarian assistance, MEDLINE and EMBASE were systematically reviewed from inception to June 2019. The initial MEDLINE strategy combined concepts of injury (wounds, injuries, trauma,

Table 2
Quality of evidence.

		Sampling Technique	Blinding	Free from selective outcome reporting	Loss to follow-up	Duration of follow-up	Indirectness	
1	Bryant et al. 2019	+	−	?	+	−	+	Geriatrician determined presence of frailty and also some outcomes (delirium) Patients not assessed for frailty or not frail, not reported
2	Chan et al. 2019	+	+	+	+	+	+	
3	Curtis et al. 2018	+	+	+	+	−	+	Follow-up to DC only
4	Cheung et al. 2017 (38)	+	−	+	+	−	−	Retrospective chart review with no blinding of outcome
5	de Lange et al. 2019	−	−	+	+	+	+	General ICU population, with trauma cohort Outcome assessed by treating physicians and was not blinded
6	Engelhardt et al. 2018	−	−	+	+	+	+	Study cohort determined by single non-blinded "champion" screening for frailty with non-frail patients outcomes not reported
7	Gronewold et al. 2017 (47)	+	?	+	+	−	−	Index hospital admission only for H-LOS, DC disposition, nursing and allied health hours and falls.
8	Hall et al. 2019	+	?	+	+	+	+	
9	Hamidi et al. 2018	+	+	+	+	+	+	
10	Hamidi et al. 2019	−	+	+	+	−	+	Unclear why 34854/88629 were selected from methodology Follow-up to DC only
11	Jeffery et al. 2018 (37)	+	?	+	+	+	+	
12	Joseph et al. 2014 (43)	+	+	+	+	−	−	Follow-up to DC only and for composite measure
13	Joseph et al. 2014 (44)	+	?	+	+	−	+	Follow-up to DC only
14	Joseph et al. 2014 (45)	+	?	−	+	−	−	Follow-up to DC only, for composite measure, with little else reported
15	Joseph et al. 2017 (39)	+	?	+	−	+	+	Mortality rate 4% but loss to follow-up 20% and lost patients more likely to be frail
16	Joseph et al. 2016 (40)	+	?	+	+	−	+	Follow-up to DC only
17	Joseph et al. 2015 (41)	+	+	+	+	−	−	Follow-up to DC only for incidence of fractures
18	Koizia et al. 2019	−	+	+	−	+	+	22% (17/79) lost to follow-up 43% (34/79) 1yr mortality, when pt recruitment to study occurred
19	Langlais et al. 2018	−	−	+	+	−	+	46% (162/351) eligible patients not included in analysis (ICU ≤24hrs, no surrogate, lacking EMR data)
20	Le Maguet et al. 2014 (35)	−	?	+	+	+	+	Only patients accepted for ICU admissions, no patients excluded from ICU admission analysed
21	Maxwell et al. 2016 (36)	+	?	+	+	+	+	
22	Moran et al. 2013 (46)	−	+	+	+	+	−	Patient selection "requiring immobilisation on DC" determined by specialist opinion
23	Palmer et al. 2019	+	+	+	+	−	+	Follow-up to DC only
24	Sadarangani et al. 2014 (42)	+	?	−	+	−	−	Minimal results reported
25	Santino et al. 2019	−	?	+	+	−	+	362 pts consented to participate, (36/362) lost to follow-up excluded, only 296 analysed Follow-up to 30days
26	Schmoekel et al. 2019	+	?	+	+	+	+	
27	Shah et al. 2019	+	+	+	+	−	+	Follow-up to DC only
28	Tipping et al. 2019	−	?	+	+	−	+	Unable to gain consent 29% (67/235)

+ No risk of bias ? Unclear risk of bias − Risk of bias

injur*), geriatric (elder*, geriatric), frailty (frail*), assessment and prognosis (consultation*, assessment*, index*, measur*, scale*, tool*, screen*, evaluation*, score*, algorithm*, guideline*, needs assessment, risk assessment). After duplication removal, a single reviewer (MC) excluded irrelevant studies on title screen. Two independent reviewers (MC, ED) screened abstracts, full text and references to identify studies for analysis, and then extracted data and summarised the quality of evidence using standardised pre-piloted criteria suggested by Rector et al. combined with a GRADE approach (Supplementary Digital Content) [21,22]. Disagreements were resolved by a third reviewer (EC) and authors were contacted where questions on population, methodology or data remained.

Included studies comprised observational or randomised English language publications in patients ≥65 years hospitalised for injury and exposed to a frailty assessment instrument that met a consensus definition of a measure of more than one domain of health [9]. Patients with isolated neck of femur (NOF) fractures or single limb injury were excluded. While they represent a significant burden of injury in the elderly, they are managed by orthopaedic services and this systematic review wished to examine patients managed by trauma services. Due to the heterogeneity in frailty instruments and outcome measures, only qualitative analysis of studies was possible.

Results

The search retrieved 7996 studies (Fig. 1). After removal of 1627 duplications and 4055 irrelevant studies on title screen (MC), 2314 abstracts and 286 full texts were independently reviewed (MC, ED). Excluded studies included those without trauma patients (Fig. 1. “not trauma”, n = 507 at abstract exclusion, n = 83 at full text exclusion), or without frailty assessment, including when frailty was measured using a single component such as timed up and go, laboratory measures, gait speed and grip strength (Fig. 1. n = 489 at abstract exclusion and n = 102 on full text review). Consensus was required for sixty-four studies. In twelve studies, populations were considered to have substantially different trauma or management (burns [23–29], minor injury [30], chronic sub-dural [31]), or a

Table 3
Frailty assessment instruments.

	Screening	Accumulation in Deficits	Physical Phenotype	Individual					
				Mobility	Function	Laboratory	Cognition	Mood	Comorbidity
2019									
Bryant et al.	FRAIL	CGA							
Chan et al.		mFI							CCI
de Lange et al.	CFS								
Hall et al.	CFS								✓
Hamidi et al.		mFI							✓
Koizia et al.		Reported Edmonton Frail Scale							
Palmer et al.		TSFI							✓
Santino et al.		TSFI							
Schmoekel et al.		mFI							✓
Shah et al.	FRAIL CFS								
Tipping et al.	CFS		FP						✓
2018									
Curtis et al.	CFS								
Engelhardt et al.		TSFI							
Hamidi et al.		TSFI			FIMmobility		FIMcognition		
Jeffery et al'. [37]				LSA	VES-13 Barthel Index		AD8 IQCDE		Elixhauser
Langlais et al.	CFS								CCI
2017									
Cheung et al. [38]	CFS					FI-Lab			✓
Gronewold et al [47]	ISAR	CGA		Timed Up & Go Tinetti mobility	Barthel Index		MMSE clock-draw	GDS	✓
Joseph et al. [39]		TSFI							
2016									
Joseph et al. [40]		TSFI							
Maxwell et al. [36]				LSA	VES-13 Barthel Index		AD8 IQCDE		Elixhauser
2015									
Joseph et al. [41]		50Variable-FI							
2014									
Joseph et al. [43]		50Variable-FI							
Joseph et al. [44]		TSFI							
Joseph et al. [45]		50Variable-FI							
Le Mageut et al. [35]	CFS		FP		KATZ		Memory		CCI
Sadarangani et al. [42]		50Variable-FI							
2013									
Moran et al. [46]				Mobility	ADL				✓

CFS – Clinical Frailty Scale; mFI – modified Frailty Index; ISAR – Identification of Seniors at Risk; TSFI – Trauma Specific Frailty Index; FI – Frailty Index; VES-13 – Vulnerable Elders Survey 13; FP – Frailty Phenotype; LSA – Life Space Assessment; KATZ – Index of Independence in Activities of Daily Living; ADL – Activities of Daily Living; AD8 – Dementia Screen ; IQCDE – Questionnaire on Cognitive Decline in the Elderly ; MMSE – Mini mental state exam; GDS – Geriatric Depression Scale ; CCI – Charlson Comorbidty Index; mFI – modified Frailty Index; FIM – Functional Independence Measure; mRS – Modified Rankin Scale

Table 4
Summary of findings frailty assessment in geriatric trauma patients.

		Frailty Prevalence Pre-injury	Post-injury	Mortality In-hospital	30d	6-mth	1-yr	LOS Mean days (SD) H-LOS	ICU-LOS	In-hospital Complication	Discharge Destination
1	Bryant et al. 2019	pre-intervention CGA 83% (125/150) post-intervention FRAIL 93%, (190/204) CGA 89%, (144/161)		7.2% (9/125) pre 4.17% (6/144) post						Delirium pre- 21.6% (27/125) to post- 12.5% (18/144) Comp pre- 28% (35/125) to post- 28.47% (41/144)	
2	Chan et al. 2019	mFI mean 0.21 (0-0.55) mFI >0.27 = frail			14.3% (10/70) R=0.313, p=0.008		35.7% (25/70) R=0.538, p=001	10.4 (12.5)			
3	Cheung et al. 2017	14.2%, 37/260 CFS 6 or 7	37%, 81/220 FI-lab >0.4	4.3% (11/253)						40.4% (105/260) CFS no correlation	Home 25.5% (39/153) Unfavourable OR 5.1 95% CI 2.0-13.2 p<0.001 FI-lab no association
4	Curtis et al. 2018	CFS 4.2 +/- 1.3		Frail 4.6 (1.3) v non-frail 4.2 (1.2) p<0.01				No association			Home 3.9 (1.2) v SNF 4.7 (1.1) p <0.00001 SNF OR 1.54 (95% CI 1.4-1.7 p<0.00001)
5	de Lange et al. 2019	CFS median 4 (IQR 3-6)			OR 1.19 (1.14-1.25) Trauma w/o HI OR 3.62 (0.66-19.77) Trauma w HI OR 5.06 (0.94-27.23) HI only OR 4.3 (0.84-22.09)						
6	Engelhardt et al. 2018	22% (11/49) Pre-intervention 59/? Post-intervention						9 (3-14) Pre-intervention 6 (3-12) Post-intervention p0.40			Unfavourable 8/11 (73%) Pre-intervention 24/59 (43%) Post-intervention p0.10
7	Gronewold et al. 2017	ISAR + 85.8% (327/381) ISAR +/CGA-I 14.7% (52/381) ISAR +/CGA+ 70.1% (248/381)						ISAR+/CGA+ 14 (10.3) ISAR+/CGA- 7.6 (7) ISAR- 8.1 (5.4), p<0.001			Unfavourable ISAR+/CGA abn 27% (68/248) ISAR+/CGA normal 9.8% (5/52) p0.011
8	Hall et al. 2019	CFS ≥5 65% (112/173)		Overall mortality HR 1.7 (95% CI 1.3-2.1 p<0.001)	8.9%	22.6% HR 1.8 (95% CI 1.3-2.4, p<0.001)	12mth 28% 24mth 46.7%				Home frailty score 3.9 (1.2) v SNF 4.7 (1.1) p<0.00001
9	Hamidi et al. 2018	Pre frail TSFI 0.13-0.24 37% (100/267) Frail TSFI ≥0.25 23% (61/267)									
10	Hamidi et al. 2019	Frail 20% (17427/34854)		14% (4880/34854) Frail 18.1% v non-frail 9.7%, p=<0.001						30.6% (10665/34854) Frail 34.2% v non-frail 18.1%, p=<0.001)	Frail SNF/rehab 58.7% v non-frail 21.2%, p=<0.001
11	Joseph et al. 2017	38% frail (133/350) 26% prefrail 91/350)		3.1% (11/350) No Association		4% (12/280) OR 1.1 95% CI 1.04-4.7 p0.04		No association	No association	22% (78/350) OR 1.1 95% CI 1.01-5.6 P=0.04	Unfavourable 25% SNF (88/350) Non-frail 8% (10/125) Prefrail 18% (16/90) Frail 47% (62/133) P=0.001
12	Joseph et al. 2016	37% frail (136/368) 38% pre-frail (139/368)		10% (36/368) Non-frail 6% (6/93) Pre-frail 5% (7/139) Frail 17% (23/136) P<0.001				No association	No association	30% (111/368) Non-frail 23% (21/93) Pre-frail 24% (33/139) Frail 42% (57/136) P=0.002	Unfavourable 51% (188/368) Non-frail 72% (67/93) Pre-frail 59% (82/139) Frail 29% (39/136) P<0.001
13	Joseph et al. 2015	39% frail (43/110) FI ≥0.25		2.7% (3/110) No association				No association		9% (10/110)	Home 65% (72/110) Non-frail 77.6% (52/67) Frail 46.5% (20/43) P=0.02 Unfavourable OR 1.42 95% CI 1.08-3.09 p=0.03
14	Joseph et al. 2014	44% (110/250) FI ≥0.25		2% (5/250)				Frail 7.3 (6.2) v non-frail 5.4 (4.8) p=0.01	Frail 4.6 (3.2) v non-frail 3.0 (2.1) p-0.01	28.4% (71/250) OR 2.5 95% CI 1.5-6.0 p=0.001	Home 48% (120/25) Unfavourable OR 1.6 95% CI 1.1-2.4 p=0.001
15	Joseph et al. 2014	TSFI≥0.27							No association		Unfavourable OR 1.5 95% CI 1.1-2.5 p=0.001
16	Joseph et al. 2014			3% (3/100)							Home 42% (42/100) Unfavourable OR 1.3 95% CI 1.1-1.8 p=0.001
17	Koizia et al. 2019	REFS mean 2.85 median 2.5 (0-9)	mean 7.08 (T 6.6 p<0.01)		22% (17/79)		43% (34/79)				
18	Langlais et al. 2018	CFS ≥ 5 27% (51/189)		27% (51/189) No Association							
19	Le Maguet et al. 2014	FP 22% (4/18) CFS 94% (17/18)		33% (6/18) FP≥3 HR 3.3 95% CI 1.6-6.6 p<0.001*		33% (6/18) CFS≥5 HR 2.4 95% CI 1.5-3.9 p=0.001*		No association	No association		Home 44% (8/18) at 6mths
20 21	Maxwell et al. 2016 Jeffery et al. 2018 (same cohort)	VES-13 41% (53/129) Barthel Index 2% (3/129) LSA 15% (19/129)	frailty trajectory to 1yr	9.6% (18/188)		18% (34/188) VES-13 OR 1.29 95% CI 1.01-1.66 p=0.045 Barthel Index OR 1.38 1.24-1.57 p=0.003 No correlation LSA	25% (47/188) VES-13 OR 1.33 95% CI 1.07-1.64 p=0.01 Barthel Index 1.28 1.14-1.47 p<0.001 No correlation LSA				Home 28% (53/188)
22	Moran et al. 2013			18.8% (3/16)						LRTI 69% (11/16) Dysphagia 69% (11/16) Delerium 37.5% (6/16)	Home 18.8% (3/16), 31.2% (5/16) at 3 mths
23	Palmer et al. 2019	39% (39/100)		Frail 18% (/39) v non-frail 7% (/61) p=0.03				Frail 6 (3-7) v 4 (2-6) p=0.03	Frail 2 (0-4) v 1 (0-2) p=0.12	Frail 39% (15/39) v non-frail 18% (10/61) p0.01	Unfavourable 56% (22/39) v 23% (14/61) p=0.01
24	Sadarangani et al. 2014	44% (110/250) FI ≥0.25		2% (5/250)				Frail longer H-LOS p=0.01 (insufficient data)	Frail longer ICU-LOS p=0.01 (insufficient data)	37.3% (71/250) Non-frail 21.4% (30/140) Frail 37.3% (41/110) P=0.001	Unfavourable DC disposition 37.3 v 12.9%, p=0.001
25	Santino et al. 2019	34% (100/296)						Frail 5d (3-7) v 4 (2-6) p=0.03	Frail 2 (0-4) v 1 (0-2) p=0.04		
26	Schmoekel et al. 2018	mFI 0.18 +/- 0.09		3% (6/228)						15% (35/263)	
27	Shah et al. 2019	FRAIL ≥3 23% (15/65) CFS ≥4						Frail pt longer H-LOS	Frail pt longer ICU- LOS		Frail pt less likely to go home Frail pt more likely to go to SNF
28	Tipping et al. 2019	FP 0 (0-2) 22% (22/100) CFS 2 (1-3.8) 13% (13/100)		12% (12/100) FP 8/22 or CFS 4/13							No association

Shaded cells, association with frailty found *HR from larger heterogenous cohort

major trauma cohort could not be confirmed [11,32,33]. Twenty-four were excluded for surrogate measures of frailty such as functional assessments (activities of daily living, modified Rankin Scale [34–39]), malnutrition [40,41], albumin [42], low falls [43], and sarcopenia [44–48], or where outcomes weren't consistent with the systematic review [49–51]. Studies using The Frailty Score for Trauma Triage in the Geriatric and Middle-Aged (STTGMA or $STTGMA_{FRAILTY}$) and the Geriatric Trauma Outcome Score (GTOS) were excluded on consensus that they did not meet frailty assessment requirements [52–57]. GTOS calculates age+(2.5 × ISS), +22 if packed red blood cells are transfused, and $STTGMA_{FRAILTY}$ adds mobility (preinjury ambulatory capacity, assistive device use), albumin and anticoagulation use to STTGMA parameters of mechanism and severity of injury (low or high energy, mechanism of injury MOI, Abbreviated Injury Scale AIS), age, Glasgow coma score (GCS) and comorbidity (Charlson Comorbidity Index, CCI).

Twenty-eight papers met inclusion criteria (Table 1) [17,18,58–83]. Ten studies included on consensus reported trauma cohorts from combined trauma and emergency general surgery (TEGS), orthopaedic or critical care populations [18,39,62–64,67,74–76,83]. Le Maguet et al. contributed data for trauma patients within their intensive care unit (ICU) cohort (18/309) and Maxwell et al. and Jeffery et al. confirmed an 80% trauma cohort repeated in both papers (150/188) [67,75,76].

Quality of evidence

Overall 40,883 trauma patients were studied, in cohorts from 16 to 34,854 patients (Table 1). Twenty-two of twenty-eight included studies were prospective observational studies, three were multi-centre, and two were interventional. Eleven studies were from the University of Arizona [17,18,66,68–72,78–80]. In their 2017 publication, the authors acknowledge an overlapping cohort with their 2014 publication [68,71]. Maxwell et al. and Jeffery et al. also report on the same patient cohort from Vanderbilt [67,76]. Sampling techniques consistently recruited patients relevant to trauma clinicians (Table 2), through mechanism, such as fall [65], a specific injury (cervical spine fracture [59,77]) or after admission to a trauma service. Selection bias was of concern in nine papers (Table 2). Blinding to frailty assessment was poorly confirmed and frailty assessments may have influenced management decisions.

Frailty assessment instruments and timing

Twenty-eight frailty instruments reported can be summarised as; screening tools, frailty phenotype, accumulation of deficit, or combined assessments of frailty components (Table 3). Two specific geriatric trauma frailty instruments were described; The Trauma Specific Frailty Index (TSFI) and a modified frailty index (mFI) [17,18]. Joseph et al. derived the TSFI (cut-off TSFI = 0.27) by selecting fifteen variables from a 50-variable FI with the strongest association for 'unfavourable discharge disposition' (ROC 0.829, 95% CI 0.774-0.884, sensitivity 85% specificity 75%) [17]. Hamidi et al. derived the modified frailty index (mFI) using eleven variables from the Canadian Study of Health and Aging (CSHA) matched to the American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP) database and showed a linear increase (cut-off mFI = 0.27) in frail patients' in-hospital complications (sensitivity 84%, specificity 79% $p < 0.001$), mortality (sensitivity 79%, specificity 76%, $p < 0.001$) and adverse discharge disposition (sensitivity 81%, specificity 78%, $p < 0.001$) [18].

Where specified (Table 1), frailty instruments were administered by trained researchers (eighteen studies), a doctor (five studies), or a combination of both (two studies). Sources were identified in twenty-four studies as either; patients, a surrogate, the medical record or a combination of these. Three studies further defined surrogates as spouses, adult children, siblings or other (Table 1). Shah et al. found that the Clinical Frailty Scale (CFS), when self-reported (patient or surrogate) had an AUROC of 0.91 (95% CI 0.84–0.98) versus 0.77 (95% CI 0.63–0.91) when performed by the physician. However, when both doctor and patient agreed on a CFS < 4 (not frail), the sensitivity and negative predictive value were 90% (54.1–99.5%) and 95% (73.1–99.7%) respectively [82].

Pre-injury frailty prevalence ranged from 13% (13/100) to 94% (17/18) (Table 1). Timing of pre-injury frailty assessment was in the emergency department [58], "on admission" [64,75,78], within twenty-four [66,68–72,74,80], forty-eight [67,76,77], or seventy-two hours [58,60,82] and post discharge [18,59,65,81], including 1-year post discharge [73]. Two studies further defined the timing of pre-injury assessment to either two or four weeks prior to admission [75,76].

Five studies assessed post-injury frailty (Table 1) [60,67,73,76,77]. Maxwell et al. described comprehensive assessments of multiple components of frailty at time points out to 1-year post-injury [76]. Frailty increased after hospitalisation and remained significantly increased in those who were not frail pre-injury (VES-13, Barthel Index), moderately frail pre-injury (VES-13, LSA) and very frail pre-injury (LSA). Koizia et al. also found that 1-year post-injury, patients were significantly more frail (88%, T score 6.6, $p < 0.01$) [73].

Five direct comparisons of frailty instruments were described [60,64,75,82,83]. In Le Maguet et al.'s small cohort of ICU trauma patients, pre-injury frailty prevalence was either 22.2% (4/18, FP ≥ 3) or 94.4% (17/18, CFS ≥ 5) [75]. However, in their larger heterogenous cohort, there was significant correlation between CFS and FP score (R^2 0.66 $p < 0.001$). Tipping et al. also compared CFS and FP in a trauma ICU cohort and found correlation (rs = 0.77; 95% CI 0.66-0.85, $p < 0.001$) [83]. Gronewold et al.'s heterogenous orthopaedic and trauma population had high frailty prevalence of 70.1% (248/381) when defined by ISAR+/CGA (Comprehensive Geriatric Assessment) abnormal, but only 14.7% (52/381) when ISAR + but CGA normal [64]. Consistent with our exclusion criteria, Shah et al. found measures of muscle function and size (dominant hand grip strength, mid-upper arm circumference) and sarcopenia, did not correlate with the FRAIL assessment reference standard [82]. Cheung et al. compared pre-injury CFS with a post-injury (up to 48 h) laboratory frailty (FI-lab) and found that frailty prevalence did not correlate [60]. Langlais et al. showed that the addition of frailty (CFS) to the sequential organ failure assessment (SOFA) score, SOFA-CFS, did not improve prognostication of in-hospital mortality (AUC 0.66, 95% CI 0.58–0.74 v 0.63 95% CI 0.55–0.72, $p = 0.082$) [74].

Outcome measures and strength of association

Mortality rates ranged from 2 to 33% in-hospital, 8.9–22% at 30 days, 4–33% at 6-mths, 25–35% at 12-mths and 46.7% at 24-mths. (Table 4). Eleven studies found an association between frailty and mortality (Table 4), seven studies with in-hospital mortality (CFS, FP, TSFI, mFI), two with 30-day mortality (CFS, mFI), five with 6-mth mortality (CFS, VES-13, Barthel Index, TSFI), and three with 12-mth mortality (mFI, VES-13, Barthel Index).

The most common mechanism of injury (MOI) was fall (48%–92.8%). Fall was sometimes associated with frailty and in one study, was an independent predictor of mortality (OR 1.3 95% CI 1.04–4.5, $p = 0.03$) [60,61,68,69,71,78]. Hall et al. described a Kaplan–Meier curve, where frail patients over 80-years were more likely to die following a fall [65]. Maxwell et al. found an association between falls, cognitive impairment, physical frailty,

comorbidities, lower ISS and higher 1-year mortality rates (34% v 16%, p = 0.003) [76]. ISS was found to be higher in frail patients [69,71], but also lower [78,80] and Koizia et al. showed a trend towards greater post-injury frailty with higher ISS (R = 0.377, p0.057) Comorbidities were assessed in thirteen studies (Table 3), with minimal reporting of medications and anti-coagulation.

Hall et al. found that the best-fit model for mortality was; age, GCS, systolic BP and frailty score (OR 1.52, 95% CI 1.37–1.69), and discharge home was; age, GCS and frailty score (OR 1.56 95% CI 1.39–1.73) [65]. Maxwell et al. summarised 1-year mortality as increased; 9% for each year of age (OR 1.09 95% 1.04–1.14; p 0.001), 7% for each point increase in ISS (OR 1.07 95% CI 1.02–1.12; p = 0.009), and 28% for each point in frailty assessment on the Barthel Index (OR 1.28 95% CI 1.14–1.47; p < 0.001) [76]. De Lange et al. found that 'reason for ICU admission' and SOFA score were the two most important factors influencing 30-day mortality in ICU patients and reported high 30-day mortality in admissions for trauma that included head injury (OR 5.06, 0.94–27.23) [62]. In a cervical spine fracture cohort, Chan et al. found that the highest predictors of 30-day (creatinine, haemoglobin, CCI, R2 0.431) and 1-yr mortality (CCI, age, albumin female gender), did not include frailty [59]. In a rib fracture cohort, Schmoekel et al. found that combing all three of anatomic (RibScore), frailty (mFI) and laboratory (PaCO2) scores gave the highest concordance in the prediction of complications (0.90, 95% CI 0.81–0.97, p < 0.001) [81].

Maxwell et al. and Jeffery et al. used a composite outcome where mortality was combined with a functional measure (Barthel Index) to describe mortality as the lowest functional outcome (R^2 0.96) [67,76]. Hamidi et al. used the Functional Independence Measure (FIM) and found that frailty was associated with lower FIM at hospital discharge (FIM_{DIS} B= −3.7, p = 0.001) and less change in FIM per days at rehab (FIM_{gain} B= -2.9, p = 0.001) [66]. Koizia et al. described negative comments in 29% of geriatric trauma patients 1-yr post their injury including; "unable to play golf", "unable to drive", "loss of sense of purpose", feeling "like a prisoner", "anxious" or "frustrated" [73]. Santino et al. found frailty negatively associated with health-related quality of life (HRQoL) at 30-days post discharge ($HRQoL_{30}$ β = -0.698, 95% CI -0.963 to -0.329, p = 0.01) [80].

Secondary outcomes reported included H-LOS, ICU-LOS, in-hospital complications, failure to rescue (FTR), discharge destination, re-admission rates and proinflammatory markers. A number of papers reported an association between frailty and H-LOS or ICU-LOS, but a nearly equal number found no association (Table 4). Gronewold et al. described CGA as an independent predictor of H-LOS [64]. In-hospital complication rates ranged from 9 to 69%, with six studies reporting an association with frailty [18,68,69,71,78,79]. Readmission rates were reported by some studies. Hall et al. found that readmission was 2.9 times higher for patients living at home compared to those in a nursing facility (p = 0.02, 95% CI 1.28–7.31) [65]. Palmer et al. compared the serum levels of proinflammatory (IL-1β, IL-6, IL-2Rα, TNF-α) and endocrine (IGF-1, GH) markers between frail and non-frail elderly trauma patients and demonstrated higher levels of TNF-α, IL-1β and IL-6 and lower IGF-1 and GH in frail patients (78).

Discharge home was lowest in a cervical spine fracture cohort (18.8% 3/16) and highest in a ground level fall (GLF) cohort (65%, 72/110) [70,77]. Four studies found that frail patients were less likely to be discharged home [61,65,70,82]. Le Maguet et al. reported non-frail patients were more likely living at home at six months post admission [75]. Eleven studies (Table 4) found frailty (CFS, FI, TSFI, ISAR+/CGA+) associated with a composite outcome of "unfavourable discharge disposition" combining mortality with discharge to a skilled nursing (SNF).

Discussion

This contemporary systematic review identified that prevalence of pre-injury frailty in geriatric trauma patients varies significantly across study populations and instruments used. Findings reveal a lack of consensus in frailty instruments, timing of assessment and long-term outcome measures meaningful to geriatric trauma patients. There was evidence of an association between frailty and in-hospital and long-term mortality, discharge disposition, post-injury frailty and recovery to pre-injury function. There was conflicting evidence regarding association with H-LOS or ICU-LOS. The generalisability and assessment of the strength of these associations is limited by single centre studies with overlapping cohorts and inconsistent findings within similar populations.

Frailty assessment instruments and timing

Four broad types of validated frailty assessments were reported including; screening, accumulation of deficit, frailty phenotype and combinations of individual components of frailty (mobility, function, cognition, mood, comorbidities). The variety of instruments, timing and source of information demonstrated makes establishing a single optimum instrument and strength of association with outcomes across trauma populations challenging [9]. This also weakens the utility of frailty assessment in prognostic counselling for critical management decisions in individual trauma patients. Despite this, frailty assessment instruments in this systematic review consistently identified a frail trauma population and some association with adverse outcome.

The most robust evidence of an association between frailty and outcomes was provided in Maxwell et al.'s prospective cohort showing the influence of pre-injury physical frailty and cognitive impairment on post-injury functional trajectories, ability to recover to pre-injury function and mortality out to 1-year [76]. Hamidi et al. also described poor functional outcomes and rehabilitation gains in frail individuals. Given the compelling logic of the frailty trajectories and functional impact described, including establishing potential reversibility, a lack of consensus on assessment instrument and timing should not be a barrier to screening a minimum of pre-injury functional and cognitive assessment in geriatric trauma patients. Early frailty screening of older trauma patients should identify those who require timely comprehensive geriatric assessment. This may enable subsequent management decisions that translate frailty research into models of care and interventions that improve health outcomes for elderly trauma patients [84].

Outcome measure and strength of association

The majority of studies reported outcome measures for the index hospital admission only. In-hospital mortality rates were variable, and when low, did not find an association with frailty [85]. Where reported, longer term mortality was more consistently associated with frailty. Fleischman et al. described that in injured geriatric patients, in-hospital mortality was less than half the 30-day post injury mortality rate and daily mortality rates did not stabilise until 180-days post injury [86]. Brohi et al. discussed the challenges of long-term patient centred outcome measures including; multiple tools in use, the cost, and poor validation and acceptance within trauma communities [87]. Capturing post injury mortality, including responses to future interventions, will only occur with adequate length of follow-up [86]. Maxwell et al. demonstrated that it is feasible to follow comprehensive outcomes to one-year post injury [76].

The outcome most associated with preinjury frailty, and used in the validation of the TSFI, was the composite measure of "unfavourable discharge disposition". This outcome appears to assume that discharge to a SNF is surrogate for poor functional outcome where death is the lowest functional status. This is in contrast to "favourable" discharge home or to rehabilitation being surrogate for higher functional status with less support required. The generalisability of this outcome is limited and confounded by socioeconomic status, existing family, cultural and spiritual support networks, private insurance and government funding schemes such as Veteran's support. In Australia for example, patients assessed by an Aged Care Assessment Team (ACAT) and approved for level four government funded home care packages, can be supported in their own home with significant functional needs, whereas patients without existing assessments may require discharge to SNF units for interim "complex discharge planning" despite having similar or lower support needs [88]. Variation in H-LOS may also be explained by these patient and community factors and potentially the conflicting evidence of association with frailty in this systematic review.

Joseph et al. found that frailty was associated with FTR, a common measure of the quality of healthcare delivery [69]. This finding is supported by evidence that frailty is associated with increased in-hospital complications [11,13,89]. It is possible that specific injury patterns in combination with frailty predict complications likely to lead to FTR, for example aspiration secondary to dysphagia in patients immobilised for cervical spine fracture. This is an area warranting more research.

Patient centred outcomes relevant to this population were poorly described. 'Geriatric syndromes' (pressure ulcers, incontinence, falls, functional decline and delirium) are highly prevalent in geriatric populations and along with their risk factors (older age, baseline cognitive impairment, baseline functional impairment and impaired mobility) are also relevant in geriatric trauma patients [33,90]. Where measured, cognitive impairment rates were high. Cognitive impairment has been suggested as a potential surrogate marker for frailty and warrants further investigation [91]. Marasco et al. also described significant pain in patients followed out to 24-months after rib fractures [92]. These types of patient centred outcomes are meaningful to patients and their families and would help to communicate the potential best and worst-case outcomes for frail geriatric patients in their post-injury recovery (93).

Finally, limitation of treatment orders (LOTO) were not reported in these studies, despite it being probable that many geriatric trauma patients have pre-existing LOTO and that hospital admission and frailty assessment is associated with LOTO [39].

Limitations

This study used MEDLINE and EMBASE but not Cochrane, CINAHL or Pubmed as is commonly suggested for systematic reviews. It was challenging to find studies where frailty did not impact on outcome. This may represent publication bias, or selection bias with only significantly impaired frail geriatric patients admitted to trauma services after low force trauma. The majority of included studies did not report a mortality odds ratio and 95% confidence intervals, which precluded the possibility of a meta-analysis. It remains likely, given the variation in prevalence seen in this systematic review, that the validity and discriminatory power of frailty assessment in trauma patients is affected by the timing, choice of instrument and population it is administered to. The diversity of the geriatric trauma population poses challenges to future research of the prognostic associations and effectiveness of interventions. However, Maxwell et al. provide a promising model for assessing patient trajectory within specific frailty assessments that could equally be applied to specific injury patterns to create opportunities for meta-analysis to enable a more global understanding of geriatric trauma outcomes.

Conclusions

This systematic review reported findings from twenty-eight studies, all showing some association between frailty and adverse outcomes including mortality in geriatric trauma patients despite a range of frailty instruments, variation in administering clinician, time of assessment and data sources. Although evidence gaps remain, an early assessment of at least pre-injury function, and cognition, for example the Clinical Frailty Scale, will improve identification of geriatric trauma patients at risk of potentially preventable adverse outcomes and those likely to benefit from modified trauma care and specific frailty interventions. Demonstrating cost effective geriatric specific trauma care will rely on establishing consistency in long-term geriatric specific outcomes. Improving our ability to prognosticate, inform realistic expectations and describe future functional trajectories in terms meaningful to patients and families is crucial in advancing holistic geriatric trauma care.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.07.026.

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