Archives of Gerontology and Geriatrics 60 (2015) 89–95

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Protocol Paper

Comparison of five indices for prediction of adverse outcomes in hospitalised Mexican older adults: A cohort study

Elsa Dent [a], Mario Perez-Zepeda [b,*]

[a] Discipline of Public Health, School of Population Health, The University of Adelaide, Australia
[b] Clinical and Epidemiologic Research Department at Instituto Nacional de Geriatría, Mexico City, Mexico

ARTICLE INFO

Article history:
Received 9 June 2014
Received in revised form 17 September 2014
Accepted 19 September 2014
Available online 28 September 2014

Keywords:
Functional decline
Risk stratification
Older adults
Acute care

ABSTRACT

The aim of this prospective study was to investigate the ability of five indices of risk stratification to predict functional decline and prolonged length of stay (LOS) in older Mexicans hospitalized in the acute care setting. A total of 254 patients aged ≥60 years were followed up. Risk indices were constructed from baseline data collected during the first 48 h of ward admission, and included: Frailty Index (FI), Hospital Admission Risk Profile (HARP), Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie (SHERPA), Acute Physiology and Chronic Health Evaluation II (APACHE II) and Charlson's Co-morbidity Index (CCI). Area Under Receiver Operating Characteristic ($_{au}$ROC) curves was used to compare the ability of risk indices to predict adverse outcome, with outcomes of interest being prolonged LOS, and functional decline, the latter defined as ≥10% drop in Barthel Index score across hospitalization. Mean (SD) FI score was 0.31 (0.14). Effective in predicting long LOS were FI, SHERPA and APACHE II; effective in predicting functional decline were SHERPA and HARP. Indices generally showed high specificity values (most were >80%), although all indices lacked adequate sensitivity values for outcome prediction (<80%). Geriatricians could use information from FI, SHERPA, APACHE II, HARP to guide patient management decisions. However, given that all indices lacked accuracy of prediction, results should be interpreted with caution.

1. Introduction

Over the last five decades, human lifespan has more than doubled in many societies, resulting in the rapid increase in both the number and proportion of older people (Gutierrez-Robledo, 2002). This expansion of the older population has had a profound impact on hospital use, particularly in developing countries with a shortage of specialized resources for the care of older people (Gutierrez-Robledo, 2002). To optimize patient care and treatment in a busy hospital setting, it is important to be able to risk-stratify patients at increased risk of adverse outcomes (de Saint-Hubert, Jamart, Boland, Swine, & Cornette, 2010).

Several indices are used in the hospital setting to identify those patients who are at increased risk of adverse outcomes. Functional decline indices include the Hospital Admission Risk Profile (HARP) (Sager, Rudberg et al., 1996) and the Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie (SHERPA); (Cornette et al., 2006) co-morbidity indices include Charlson's Co-morbidity Index (CCI); and disease severity indices include the Acute Physiology and Chronic Health Evaluation II (APACHE II) (Knaus, Draper, Wagner, & Zimmerman, 1985) index. An alternate way to predict adverse outcomes in older people is by using a frailty classification. Frailty is considered to be a medical syndrome characterized by reduced physiologic reserve that increases vulnerability for adverse outcomes, including increased dependency and mortality (Morley et al., 2013). There are a number of ways to identify frailty, however the Frailty Index (FI) developed by Rockwood and Mitnitski (Rockwood, Mitnitski, & MacKnight, 2002; Rockwood et al., 1999) accounts for the multifaceted nature of frailty, incorporating not only the physical components of frailty, but also accounting for cognition and the psychosocial aspects of frailty. The FI has been found to be predictive of adverse hospital outcomes in several recent studies

Abbreviations: FI, Frailty Index from Comprehensive Geriatric Assessment; HARP, Hospital Admission Risk Profile; SHERA, Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie; APACHE II, Acute Physiology and Chronic Health Evaluation II.

* Corresponding author at: Periférico Sur 2767, Colonia San Jerónimo Lídice, México, Distrito Federal, Mexico. Tel.: +52 5555738686.
E-mail addresses: ulises.perez@salud.gob.mx, ulises.perez@me.com (M. Perez-Zepeda).

http://dx.doi.org/10.1016/j.archger.2014.09.011
0167-4943/

(Dent, Chapman, Howell, Piantadosi, & Visvanathan, 2014; Evans, Sayers, Mitnitski, & Rockwood, 2014; Pilotto et al., 2012; Singh et al., 2012).

Whilst several studies have compared risk stratification indices on their ability to prediction functional decline in hospitalised older people (Sutton, Grimmer-Somers, & Jeffries, 2008), it is not yet clearly known how the FI compares to other outcome prediction indices in the hospital setting. Therefore, the aim of this study was to determine the effectiveness of the FI to predict adverse outcomes in hospitalised older people in Mexico, and to compare the effectiveness to that of mortality and functional decline indices used in the hospital setting. Outcomes of interest were functional decline and long length of hospital stay (LOS).

2. Material and methods

2.1. Setting and design

An acute care cohort study was performed in two hospitals of Mexico City. The study was originally planned to determine the effectiveness of a geriatric unit compared to the usual care provided in internal medicine ward; description of the cohort is available elsewhere (Pérez-Zepeda et al., 2012). In brief, all patients at least 60 years of age who were admitted during a two-year period (2007–2009) to one of three acute care units (two internal medicine wards and one geriatric unit) were screened for the fulfillment of the selection criteria (see fig. 1). The inclusion criteria were the presence of at least one geriatric problem (falls, slow walking speed, fatigue, sorrow, depression, memory deficit or difficulty with instrumental activities or bathing), as assessed at the first visit after admission using a simple dichotomous question (e.g., "Have you had any falls in the last six months?", answer = yes or no). Proxies were used to corroborate these questions where needed. Excluded from the study were patients who were: unable to communicate, referred from the intensive care unit, under mechanical ventilation, receiving parenteral nutrition or exhibiting altered consciousness.

2.2. Measurements

After obtaining informed consent, patients were interviewed by one of four nurses trained and standardized in study data collection procedures. Information collected from patient interview included: patient function, mood and quality of life status, and socio-demographic characteristics. The baseline interview was done in the first 48 h of admission to the ward. A final interview was performed prior to discharge date by a nurse blinded to the baseline assessment results.

Health-related variables were poor health self-perception, quality of life, and clinical data extracted from medical records. Health self-perception was evaluated as excellent, very good, good, bad or very bad using a Likert scale question. Quality of life was measured with the visual analog scale of the European Quality of Life (VAS EuroQoL), in which patients rate their quality of life on a 0-to-100-point scale, with the highest score indicating the best possible score. All indices were based on measurements collected at hospital admission, from interviews, with the exception of the FI which was derived from medical records.

A validated Spanish version of the Barthel Index was used to assess Activities of Daily Living (ADL), with scores ranging from 0 to 100 (Cid-Ruzafa and Damián-Moren, 1997). For instrumental ADLs, a validated Spanish version of the Lawton and Brody IADL scale was used (Vergara et al., 2012).

2.3. Indices

The Frailty Index of cumulative deficits designed by Rockwood and Mitnitski (Rockwood et al., 1999, 2002) is a continuous variable indicating frailty severity. It is computed by summing a list of health deficits, and then dividing by the number of health deficits. The final FI values are a number between 0 and 1. Variables in our study were predominantly selected from the Comprehensive Geriatric Assessment (CGA) (exceptions included grip strength) (see Appendix A). In our study, we had 40 health deficits; selected by using the FI construction principles set by Searle, Mitnitski, Gahbauer, Gill, & Rockwood (2008) (see Appendix A). All health deficits chosen did not plateau with age (Searle et al., 2008). FI values ≥ 0.25 were classified as frail, in accordance with previous literature (Rockwood, Andrew, & Mitnitski, 2007; Singh et al., 2012; Theou, Brothers, Mitnitski, & Rockwood, 2013) thus any patient with $\geq$10 deficits out of a possible 40 deficits was classified as frail in our study. Scores > 0.4 were classified as severe frailty as per a previous study on geriatric inpatients (Singh et al., 2012).

HARP is a commonly used weighted functional decline index, originally validated for use in patients hospitalised with an acute illness (Sager, Rudberg et al., 1996). Physical examination of the patient is not required. HAPP was scored as per its original scoring system, which included age (scored 0–2 points), the first 21 questions from the MMSE (scored 0–1 point) and IADL (scored 0–2 points) (Sager, Rudberg et al., 1996). Scores were then summed, and functional decline risk classified as low (scores 0–1), intermediate (scores 2–3) and high (scores 4–5) (Sager, Rudberg et al., 1996). HARP was initially designed for use in patients admitted to hospital with an acute illness and it does not require a physical examination of the patient (de Saint-Hubert et al., 2010; Sager, Rudberg et al., 1996).

SHERPA is a weighted functional decline index designed for acute hospital admission in older people (Cornette et al., 2006). Like the HARP, patient examination is not required to complete the SHERPA (de Saint-Hubert et al., 2010). SHERPA components include falls in the previous year (yes = 2, no = 0), the first 21 questions of the MMSE ($<$15 = 2points; $\geq$15 = 0 points), bad self-perceived health (yes = 1.5 points; no = 0 points, age ($>$84 = 1 point, 75–84 = 1.5 points, $<$75 = 0 points) and IADL (scores of 0–2 = 3 points), scores 3–4 = 2 points, score of 5 = 1 point and scores 6–7 = 0 points) (Cornette et al., 2006). Component scores were summed to calculate the final SHERPA score. Functional decline risk was classified as low (scores 0–3), mild (scores 2–3), moderate (scores 5–6) and high (scores $>$ 6) (Cornette et al., 2006).

APACHE II is designed to rank the severity of a disease during the first 24 h of hospital admission, and uses 12 routinely collected variables: age, laboratory values (sodium, creatinine, potassium (serum), haematocrit, white blood cell count), vital signs (heart rate, mean arterial pressure, respiratory rate, temperature, pH) and clinical items (Glascow coma score) (Knaus et al., 1985). A cut-off point of $>$16 was used to indicate high disease burden, as per previous literature guidelines (Knaus et al., 1985).

CCI is a weighted co-morbidity index which evaluates the presence of 19 conditions (Charlson et al., 1987). The maximum possible CCI score is 37 (Charlson et al., 1987). Low and high CCI scores were classified as scores $<$5 and $\geq$5 respectively as per previous research (Dent et al., 2014).

2.4. Outcomes

Two outcomes were studied: functional decline over hospitalization and long length of hospital stay (LOS). Functional decline was defined as a drop in BI score $\geq$ 10% from the admission score. Patients who died during hospital were not included in the

functional decline analysis, as per previous studies (McCusker, Kakuma, & Abrahamowicz, 2002). Long LOS was defined as greater than 10 or more days (mean LOS). It was necessary to dichotomise LOS to perform our efficacy analyses. Time spent at the emergency room was not taken into account when considering LOS.

2.5. Statistical analysis

Chi-square tests were used to compare categories of each index against both outcomes. To examine differences between category proportions across different risk index classifications, Friedman tests were performed. Both of these statistical tests were used in a recent study comparing frailty indices on their ability to predict mortality and functional decline (Woo, Leung, & Morley, 2012).

The discriminative ability (accuracy) of each index to predict outcomes was determined by computing area under curve of Receiver Operating Curves ($_{au}$ROC). The higher the $_{au}$ROC value, the better the discriminative ability, up to a maximum possible score of 1.0. $_{au}$ROC values < 0.6 were considered to be very poor and to lack any predictive accuracy (Metz, 1978). Sensitivity, specificity, positive and negative prediction values (PPV and NPV respectively) were also reported. All data was analysed using SPSS 21.0 (IBM, NY), with P values < 0.05 considered to be significant.

2.6. Ethics statement

The study was reviewed and accepted by the "Comisión Nacional de Investigación Científica de la Coordinación de Investigación en Salud, del Instituto Mexicano del Seguro Social" (National Commission of Scientific Research of the Health Research Commission of the Mexican Social Security Institute), which includes the approval of the Ethics and Methodological sub commissions with the registry number: 2005-785-170. All procedures in this research complied with the Helsinki Declaration; and all patients signed informed consent. The informed consent procedure was performed by the interviewers, and included a thorough explanation of the study, in the presence of the study patient, and two independent witnesses; emphasizing the absolute freedom to make the decision to enter or not, and ensuring that this decision would not affect any of the attention given to the patient. Due to the setting (hospital), at least two visits were done in order to make sure that the patients completely understood the information given. Once this was performed, and if the patient accepted, a copy of a written explanation was handed to the study patient, the interviewer and the witnesses; after which everyone signed an original and a copy (including the interviewer). The study patient kept the original document and hardcopies were archived. Additionally, if the patient during the interview or in the rest of the process of the study felt that he or she did not want to continue, its participation was stopped, reassuring that all the care received will be exactly the same. If the patient could not give his consent, the informed consent of the caregiver was sought.

3. Results

Fig. 1 displays a flow diagram outlining patient recruitment. All patients had capacity for their own consent to study inclusion. Of the 254 patients included in the study, mean (SD) age was 72.8 (8.1) years and 135 (53%) patients were female. Thirteen (5%) patients died during hospitalization, 100 (39%) showed functional decline and 79 (31%) had a long LOS. Nine patients did not have function measured at discharge, so were not able to be included in the functional decline analysis. No patients were missing any values for the HARP, SHERPA, CCI or APACHE II. For the FI, six patients were missing between 1 and 3 variables and for these patients, FI was computed using 37, 38 and 39 variables

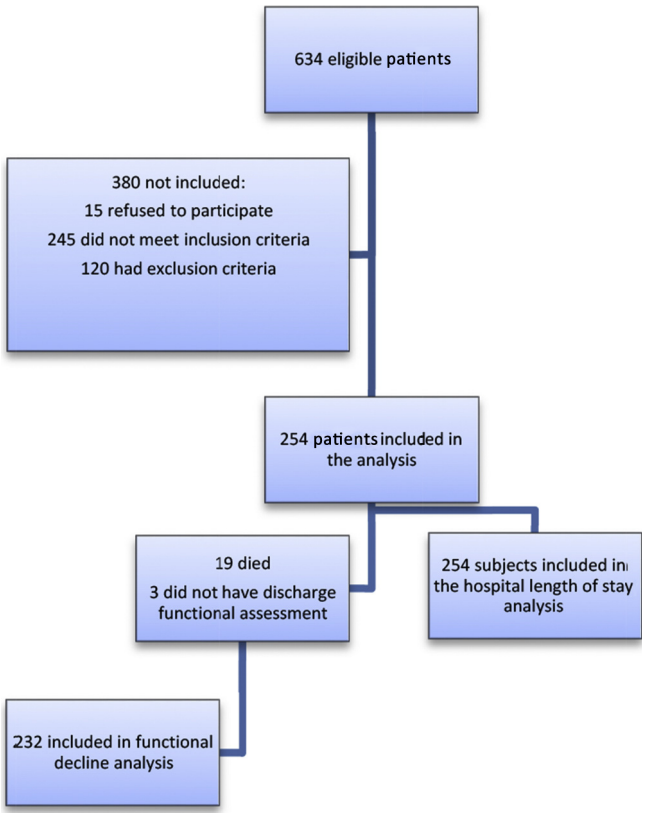

Fig. 1. Flowchart of the patients included in the analysis.

respectively. FI was normally distributed, with a mean (SD) of 0.31 (0.14) and an upper limit of 0.77.

Table 1 shows the baseline characteristics of patients. Table 2 presents the prevalence rates of each index, as per classification by each index. From this table it can be seen that FI, SHERPA, HARP and APACHE II showed an association with LOS; and SHERPA, HARP and APACHE II showed an association with functional decline. CCI did not show an association with either outcome. No indices had a ceiling effect, evidenced by the $\geq$15% of patients in the highest risk classification category for each index (Fig. 2).

Efficacy values for functional decline and LOS prediction for each index are shown in Table 3. Specificity values were generally high for each index, whilst sensitivity values were moderate. It can also be seen from this table that as the severity category of each index increased, specificity values increased for both outcomes, whilst sensitivity dropped. Overall, PPV values were only moderate for all indices in predicting both outcomes (all PPVs $< 55\%$). NPVs were only moderate for functional decline, with the exception of the APACHE II, which showed 89.4% for NPV. For LOS prediction, NPVs were moderate-high. For both outcomes and for all indices, NPVs were higher than PPVs.

Fig. 2 presents a comparison of the ROC curves for each index. It is evident from this figure that for functional decline outcome, indices with discriminatory values >0.6 were FI, SHERPA and HARP. For LOS, FI, SHERPA and APACHE II values were >0.6. There was no statistical difference in discriminative ability between SHERPA, HARP, FI and APACHE II in predicting either outcome, based on no overlapping of their confidence intervals.

4. Discussion

In this study of hospitalised older Mexican adults, several risk stratification indices were assessed on their ability to predict adverse hospital outcome. Effective in predicting long LOS were FI,

Table 1
General characteristics of the cohort, comparing characteristics between functional decline and long length of hospital stay.

Variable	Functional decline[a]			Long length of stay		
	Yes $n=100$	No $n=132$	*P*	Yes $n=79$	No $n=175$	*P*
Age, mean (SD)	74.4 (8.2)	71.8 (8.2)	0.018	72.8 (8.31)	72.9 (8.1)	0.940
Female gender, *n*(%)	61 (61)	64 (49)	0.058	32.59 (44)	67.41 (91)	0.585
Lives alone, *n*(%)	20 (20)	21 (16)	0.421	31.73 (66)	68.27 (142)	0.645
Illiterate, *n*(%)	8 (8)	20 (15)	0.099	30 (9)	70 (21)	0.890
Married, *n*(%)	48 (48)	69 (52)	0.521	27.56 (35)	72.44 (92)	0.223
Charlson's Co-morbidity Index, median (range)	5 (1–15)	4 (0–12)	0.217	5 (0–15)	4 (0–13)	0.326
EuroQOL-VAS, mean (SD)	66.7 (24.4)	71.6 (20.5)	0.236	65.93 (26.3)	69.96 (21.4)	0.466
GDS score, mean (SD)	9.9 (5.4)	8.4 (5.6)	0.042	10.37 (5.43)	8.93 (5.81)	0.062
MMSE score, mean (SD)	20.5 (5.2)	22.2 (5.0)	0.015	21.35 (6.53)	22.87 (5.6)	0.058
Handgrip strength, mean (SD)	11.6 (8.3)	16.2 (10.4)	0.001	11.81 (8.04)	14.82 (10.32)	0.022
IADL, mean (SD)	9.8 (4.8)	11.1 (4.8)	0.044	8.35 (5.05)	11.1 (4.6)	<0.001

EuroQOL, European Quality of Life; VAS, Visual Analog Scale; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Status Examination; FI, Frailty Index; SHERPA, Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie; HARP, Hospital Admission Risk Profile; APACHE II, Acute Physiology and Chronic Health Evaluation II; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; LOS, Length of Stay.

[a] Patients who died during hospitalization were not included in the functional decline analysis.

Table 2
Incidence of functional decline, mortality and long length of stay as categorized by different indices.

Index	Score	Overall *n* (%)	Functional decline *n* (%)			Long LOS *n* (%)		
			Yes	No	*P*	Yes	No	*P*
FI								
Not frail	0–0.249	104 (41)	37 (37)	63 (63)	0.263	22 (21)	82 (79)	0.004
Frail	0.25–0.4	91 (36)	40 (48)	44 (52)		30 (33)	61 (67)	
Severely frail	>0.4	59 (23)	23 (48)	25 (52)		27 (46)	32 (54)	
HARP								
Low	0.0–1.0	148 (58)	51 (36)	89 (64)	0.040	37 (25)	111 (75)	0.045
Intermediate	2.0–3.0	80 (31)	53 (37)	33 (47)		32 (40)	48 (60)	
High	4.0–5.0	26 (10)	12 (55)	10 (45)		10 (38)	16 (62)	
SHERPA								
Low	0.0–3.0	134 (53)	44 (65)	82 (35)	0.041	32 (24)	102 (76)	0.035
Mild	3.5–4.5	50 (20)	27(44)	21 (56)		17 (34)	33 (66)	
Moderate	5.0–6.0	30 (12)	13 (50)	13 (50)		14 (47)	16 (53)	
High	>6	39 (15)	16 (48)	15 (52)		16 (41)	23 (59)	
APACHE II								
Low	≤16	208 (82)	73 (38)	118 (62)	0.001	54 (26)	154 (74)	<0.001
High	>16	46 (18)	27 (66)	14 (34)		25 (54)	21 (46)	
CCI								
Low	<5	129 (51)	47 (39)	74 (61)	0.171	36 (28)	93 (72)	0.264
High	≥5	125(49)	53 (48)	58 (52)		43 (34)	82 (66)	

FI, Frailty Index from Comprehensive Geriatric Assessment; HARP, Hospital Admission Risk Profile; SHERA, Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie; APACHE II, Acute Physiology and Chronic Health Evaluation II; CCI, Charlson's Comorbidity Index.

Table 3
Efficacy values of frailty index scores for functional decline and prolonged length of hospital stay.

Index	Scores	Functional decline				Long LOS			
		Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
FI									
Not frail vs frail/severely frail	<0.25 vs ≥0.25	63.0	36.4	45.0	54.3	72.2	54.0	52.3	73.5
Not frail-frail vs severely frail	≤0.4 vs >0.4	23.0	81.1	47.9	58.2	34.2	81.7	45.8	73.3
HARP									
Low vs intermediate-high	≤1 vs 2–5	49.0	27.3	35.8	39.3	53.2	41.0	37.8	56.5
Low-intermediate vs high	≤2 vs 3–5	12.0	92.4	54.5	58.1	12.7	90.9	38.5	69.7
SHERPA									
Low vs mild-high	≤3 vs ≥3.5	56.0	62.6	53.3	65.1	59.5	58.6	39.5	76.1
Mild vs moderate-high	≤4.5 vs ≥5.0	29.0	78.6	50.9	59.2	38.0	77.6	43.5	73.4
Moderate vs high	≤6 vs >6	16.0	88.5	51.6	58.0	20.3	86.8	41.0	70.6
APACHE II									
Low vs high	≤16 vs >16	65.9	61.8	27.0	89.4	54.3	74.0	31.6	88.0
Charlson's Co-morbidity Index									
Low vs high	<5 vs ≥5	47.7	61.2	53.0	56.1	34.4	72.1	54.4	53.1

FI = Frailty Index from Comprehensive Geriatric Assessment; HARP = Hospital Admission Risk Profile; SHERA = Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie; APACHE II= Acute Physiology and Chronic Health Evaluation II.

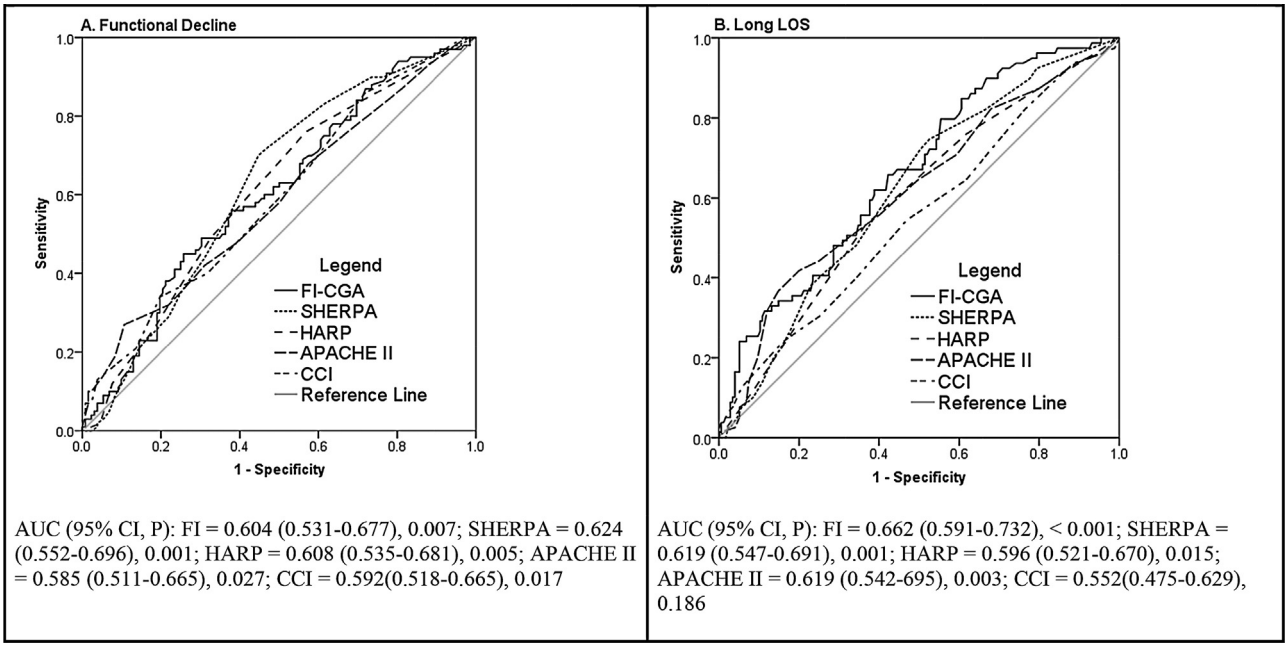

Fig. 2. Receiver operating characteristic curves of functional decline, mortality and long length of stay.

SHERPA and APACHE II; effective in predicting functional decline were SHERPA and HARP. Other indices studied either lacked predictive ability and/or meaningful predictive accuracy ($_{au}$ROC values < 6) for study outcomes.

Risk stratification can be used in the hospital setting to guide patient treatment and care. The optimal goal of each index is to correctly identify patients at risk of adverse outcomes, whilst not misclassifying patients at increased risk of adverse outcome if they are not. In the present study, all risk stratification indices showed an above satisfactory level of specificity in order to avoid false positive classifications for both study outcomes (>60%) (Forti et al., 2012). However, sensitivity values for all indices were below 80%, which is the threshold value needed for an optimal screening test (Forti et al., 2012). What this means to the clinician is that if a patient attains a 'High Risk' index score, then based on the high specificity value of each index, the patient is likely to be at increased risk of an adverse outcome. On the other hand, if a patient attains a 'Low Risk' classification, then based on the moderate sensitivity value of each index, the patient is likely to have a false negative result (Akobeng, 2007). Thus results from the risk indices should be interpreted with caution. Rather than being used in isolation, indices of risk stratification should be used in conjunction with CGAs in order to advise patient management (de Saint-Hubert et al., 2010).

Our study adds to the recognition of SHERPA as an effective tool for prediction of functional decline in hospitalised older adults. SHERPA is a relatively recent index, designed to identify those patients at risk of functional decline index in the acute hospital setting (Cornette et al., 2006). SHERPA is advantageous to use in the hospital setting as it requires no physical examination of the patient (de Saint-Hubert et al., 2010) and only has five variables which are able to be extracted from patient medical charts. In our study, SHERPA was more effective in identifying patients at risk of adverse outcome at its lower risk levels (evidenced by sensitivity values), in agreement with a previous study of hospitalised older people (de Saint-Hubert et al., 2010).

FI was predictive of long LOS, which is consistent with recent literature (Singh et al., 2012; Evans et al., 2014). Our finding that FI was not predictive of functional decline was unexpected, but could be because patients who died during hospital were excluded from our functional decline analyses (n = 13) (McCusker et al., 2002), or because of our low sample size. This is the first study to our knowledge to look at the FI as a predictor of functional decline in hospitalised older patients. Nonetheless, previous research has found the FI to be a predictor of poor functional gain over hospitalization (Singh et al., 2012) and several studies have looked at factors influencing hospital-based functional decline, with deficits included in the FI (including cognition, social characteristics and function) often found to be predictive (Chen, Wang, & Huang, 2008; de Saint-Hubert, Schoevaerdts, Poulain, Cornette, & Swine, 2009). Importantly, the FI is commonly found to be predictive of mortality in hospitalised older people (Theou et al., 2013).

The average score of our FI (0.31) is similar to that found in a study of a geriatric rehabilitation ward in Wales (0.34) (Singh et al., 2012). The upper limit of our FI (0.77) is also in line with previously defined upper limits of the FI (Bennett, Song, Mitnitski, & Rockwood, 2013; Rockwood & Mitnitski, 2006). Our finding of no ceiling effect for each index was similar to the finding of Theou et al. (2013) who reported no ceiling effect in mortality prediction for any Frailty Index, including the FI (Theou et al., 2013).

Older people are at an increased risk of functional decline during hospitalization (Cornette et al., 2006; de Saint-Hubert et al., 2010; Sager, Franke et al., 1996). In our study, a large number of patients (39%) experienced functional decline, which is higher than that reported in European hospital studies (Hoogerduijn, Schuurmans, Korevaar, Buurman, & de Rooij, 2010). This greater decline is in despite the mean LOS (10 days) in the present study being similar to other studies. Mean Apache II score was also higher in our study than in previous studies of older people indicative of the high illness severity of our patients (Ponzetto et al., 2003).

In clinical practice, it is important to note that the diagnostic value of each index improves when it is used on populations who are likely to be at risk of adverse outcome (Akobeng, 2007). Thus results of this study may not be generalizable outside of the hospital setting. Results from this study should also be interpreted with caution due to the different proportions of patients of patients classified by each index used in the study. We chose to classify patients into the standard/commonly used categories for each index in order to investigate predictive ability. It is acknowledged

that the FI is designed for use as a continuous variable (Rockwood et al., 1999), but was stratified into a commonly used cut-off point to classify frailty in our study.

A limitation of the present study was the small sample size. Nonetheless, our study was adequately powered to answer the proposed study questions with high certainty. A further study limitation was the inclusion of only two hospitals to collect data from, which limits the generalizability of study results. Importantly, there was a high rate of end-stage renal disease in our patients, which is common in Mexican hospitals as a result of the high prevalence of diabetes and hypertension in Mexico (Paniagua, Ramos, Fabian, Lagunas, & Amato, 2007). Chronic kidney failure, by way of high inflammation, can lead to frailty (Dalrymple et al., 2013).

A major strength of the present study was the comprehensive dataset. Future studies should focus on longer term outcomes as well as look at the ease of the clinical application of instruments for clinicians, researchers and patients alike.

5. Conclusion

FI, SHERPA, APACHE II, and to a lesser extent, HARP were predictive of adverse outcomes in hospitalised Mexican older adults. However, all indices lacked adequate sensitivity values, limiting their effectiveness in correctly identifying patients at risk of functional decline and long LOS. Geriatrician advice is recommended to be used in conjunction with risk stratification indices in the hospital setting.

Author contributions

Dr. Elsa Dent conceived the idea, ran the main analyses, interpreted data and prepared the final manuscript.

Dr. Mario Ulises Pérez-Zepeda recruited the patients, conceived the idea, ran the analyses, interpreted data and reviewed the final manuscript.

Sponsor's role

There was no sponsor's role in the design, methods, patient recruitment, data collections, analysis and preparation of paper.

Conflict of interest

Authors declare no conflict of interest.

Appendix A

Cumulative health deficits used in the Frailty Index.

Deficit count	Health deficit
1	Difficulty eating
2	Difficulty bathing
3	Difficulty dressing
4	Difficulty grooming
5	Difficulty toileting
6	Difficulty moving bed/chair
7	Difficulty walking (around house)
8	Difficulty climbing stairs
9	Dependent on others for telephone use
10	Dependent on others for shopping
11	Dependent on others for cooking
12	Dependent on others for housework
13	Dependent on others for laundry
14	Dependent on others for transportation
15	Dependent on others medication use
16	Dependent on others for management of finances
17	Self-perceived health: Score 1 = 0 points; 2 = 0.25; 3 = 0.5; 4 = 0.75; 5 = 1 point
18	Pressure sores
19	MMSE: Scores 0–9 = 1 point; 10–17 = 0.75; 18–20 = 0.5; 21–23 = 0.25; 24–30 = 0
20	Handgrip strength (<18 kg women; <30 kg men)
21	Swallowing difficulty during hospitalization
22	Polypharmacy (≥5 drugs at baseline)
23	Lives alone
24	Previous myocardial infarction
25	Congestive heart failure
26	Peripheral arterial disease
27	Chronic obstructive pulmonary disease
28	Connective tissue disorders
29	Peptic ulcer disease
30	Moderate or severe kidney failure
31	Diabetes
32	Cancer
33	Feeling helpless
34	Acute physiologic score (sum of the first APACHE II variables)
35	Feeling full of energy
36	Feeling happy
37	Abandoned interests and activities
38	Feeling nervous
39	EuroQOL anxiety/depression
40	EuroQOL general health

Abbreviations: MMSE, Mini Mental State Examination; EuroQOL, European Quality of Life Questionnaire; APACHE II, Acute Physiology and Chronic Health Evaluation II.

References

Akobeng, A. K. (2007). Understanding diagnostic tests 1: Sensitivity, specificity and predictive values. *Acta Paediatrica (Oslo, Norway: 1992), 96*, 338–341.

Bennett, S., Song, X., Mitnitski, A., & Rockwood, K. (2013). A limit to frailty in very old, community-dwelling people: A secondary analysis of the Chinese longitudinal health and longevity study. *Age and Ageing, 42*(3), 372–377.

Charlson, M. E., Pompei, P., Ales, K. L., & MacKenzie, C. R. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *Journal of Chronic Diseases, 40*, 373–383.

Chen, C. C., Wang, C., & Huang, G. H. (2008). Functional trajectory 6 months post-hospitalization: A cohort study of older hospitalized patients in Taiwan. *Nursing Research, 57*, 93–100.

Cornette, P., Swine, C., Malhomme, B., Gillet, J. B., Meert, P., & D'Hoore, W. (2006). Early evaluation of the risk of functional decline following hospitalization of older patients: Development of a predictive tool. *European Journal of Public Health, 16*, 203–208.

Dalrymple, L. S., Katz, R., Rifkin, D. E., Siscovick, D., Newman, A. B., Fried, L. F., et al. (2013). Kidney function and prevalent and incident frailty. *Clinical Journal of the American Society of Nephrology, 8*, 2091–2099.

de Saint-Hubert, M., Jamart, J., Boland, B., Swine, C., & Cornette, P. (2010). Comparison of three tools predicting functional decline after hospitalization of older patients. *Journal of the American Geriatrics Society, 58*, 1003–1005.

de Saint-Hubert, M., Schoevaerdts, D., Poulain, G., Cornette, P., & Swine, C. (2009). Risk factors predicting later functional decline in older hospitalized patients. *Acta Clinica Belgica, 64*, 187–194.

Dent, E., Chapman, I., Howell, S., Piantadosi, C., & Visvanathan, R. (2014). Frailty and functional decline indices predict poor outcomes in hospitalised older people. *Age and Ageing, 43*, 477–484.

Evans, S. J., Sayers, M., Mitnitski, A., & Rockwood, K. (2014). The risk of adverse outcomes in hospitalized older patients in relation to a frailty index based on a comprehensive geriatric assessment. *Age and Ageing, 43*, 127–132.

Forti, P., Rietti, E., Pisacane, N., Olivelli, V., Maltoni, B., & Ravaglia, G. (2012). A comparison of frailty indexes for prediction of adverse health outcomes in an elderly cohort. *Archives of Gerontology and Geriatrics, 54*, 16–20.

Gutierrez-Robledo, L. M. (2002). Looking at the future of geriatric care in developing countries. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 57*, M162–M167.

Hoogerduijn, J. G., Schuurmans, M. J., Korevaar, J. C., Buurman, B. M., & de Rooij, S. E. (2010). Identification of older hospitalised patients at risk for functional decline, a study to compare the predictive values of three screening instruments. *Journal of Clinical Nursing, 19*, 1219–1225.

Cid-Ruzafa, J., & Damián-Moren, J. (1997). Valoración de la Discapacidad Física: el Índice de Barthel. *Revista Española de Salud Pública, 71*, 127–137.

Knaus, W. A., Draper, E. A., Wagner, D. P., & Zimmerman, J. E. (1985). APACHE II: A severity of disease classification system. *Critical Care Medicine, 13*, 819–829.

McCusker, J., Kakuma, R., & Abrahamowicz, M. (2002). Predictors of functional decline in hospitalized elderly patients: A systematic review. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 57*, M569–M577.

Metz, C. E. (1978). Basic principles of ROC analysis. *Seminars in Nuclear Medicine, 8*, 283–298.

Morley, J. E., Vellas, B., van Kan, G. A., Anker, S. D., Bauer, J. M., Bernabei, R., et al. (2013). Frailty consensus: A call to action. *Journal of the American Medical Directors Association, 14*, 392–397.

Paniagua, R., Ramos, A., Fabian, R., Lagunas, J., & Amato, D. (2007). Chronic kidney disease and dialysis in Mexico. *Peritoneal Dialysis International, 27*, 405–409.

Pérez-Zepeda, M. U., Gutiérez-Robledo, L. M., Sánchez-Garcia, S., Juárez-Cedillo, T., Gonzalez, J. J., Franco-Marina, F., et al. (2012). Comparison of a geriatric unit with a general ward in Mexican elders. *Archives of Gerontology and Geriatrics, 54*, e370–e375.

Pilotto, A., Rengo, F., Marchionni, N., Sancarlo, D., Fontana, A., Panza, F., et al. (2012). Comparing the prognostic accuracy for all-cause mortality of frailty instruments: A multicentre 1-year follow-up in hospitalized older patients. *PLoS ONE, 7*, e 29090.

Ponzetto, M., Zanocchi, M., Maero, B., Giona, E., Francisetti, F., Nicola, E., et al. (2003). Post-hospitalization mortality in the elderly. *Archives of Gerontology and Geriatrics, 36*, 83–91.

Rockwood, K., & Mitnitski, A. (2006). Limits to deficit accumulation in elderly people. *Mechanisms of Ageing and Development, 127*, 494–496.

Rockwood, K., Andrew, M., & Mitnitski, A. (2007). A comparison of two approaches to measuring frailty in elderly people. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 62*, 738–743.

Rockwood, K., Mitnitski, A. B., & MacKnight, C. (2002). Some mathematical models of frailty and their clinical implications. *Reviews in Clinical Gerontology, 12*, 109–117.

Rockwood, K., Stadnyk, K., MacKnight, C., McDowell, I., Hebert, R., & Hogan, D. B. (1999). A brief clinical instrument to classify frailty in elderly people. *Lancet, 353*, 205–206.

Sager, M. A., Rudberg, M. A., Jalaluddin, M., Franke, T., Inouye, S. K., Landefeld, C. S., et al. (1996). Hospital admission risk profile (HARP): Identifying older patients at risk for functional decline following acute medical illness and hospitalization. *Journal of the American Geriatrics Society, 44*, 251–257.

Sager, M. A., Franke, T., Inouye, S. K., Landefeld, C. S., Morgan, T. M., Rudberg, M. A., et al. (1996). Functional outcomes of acute medical illness and hospitalization in older persons. *Archives of Internal Medicine, 156*, 645–652.

Searle, S. D., Mitnitski, A., Gahbauer, E. A., Gill, T. M., & Rockwood, K. (2008). A standard procedure for creating a frailty index. *BMC Geriatrics, 8*, 24.

Singh, I., Gallacher, J., Davis, K., Johansen, A., Eeles, E., & Hubbard, R. E. (2012). Predictors of adverse outcomes on an acute geriatric rehabilitation ward. *Age and Ageing, 41*, 242–246.

Sutton, M., Grimmer-Somers, K., & Jeffries, L. (2008). Screening tools to identify hospitalised elderly patients at risk of functional decline: A systematic review. *International Journal of Clinical Practice, 62*, 1900–1909.

Theou, O., Brothers, T. D., Mitnitski, A., & Rockwood, K. (2013). Operationalization of frailty using eight commonly used scales and comparison of their ability to predict all-cause mortality. *Journal of the American Geriatrics Society, 61*, 1537–1551.

Vergara, I., Bilbao, A., Orive, M., Garcia-Gutierrez, S., Navarro, G., & Quintana, J. M. (2012). Validation of the Spanish version of the Lawton IADL Scale for its application in elderly people. *Health and Quality of Life Outcomes, 10*, 130.

Woo, J., Leung, J., & Morley, J. E. (2012). Comparison of frailty indicators based on clinical phenotype and the multiple deficit approach in predicting mortality and physical limitation. *Journal of the American Geriatrics Society, 60*, 1478–1486.