



# Revista Española de Cirugía Ortopédica y Traumatología

[www.elsevier.es/rot](http://www.elsevier.es/rot)



## ORIGINAL PAPER

# The age-adjusted Charlson comorbidity index in acetabular fracture in geriatric acetabular fractures

J.M. Bogallo<sup>a,\*</sup>, C. Castillejo<sup>a</sup>, A. Ramirez<sup>a</sup>, J.R. Cano<sup>a</sup>, F. Rivas-Ruiz<sup>b</sup>, E. Guerado<sup>a</sup>

<sup>a</sup> Department of Orthopedic Surgery and Traumatology, Hospital Universitario Costa del Sol, University of Malaga, Marbella, Málaga, Spain

<sup>b</sup> Unit Research Support, Hospital Universitario Costa del Sol, University of Malaga, Marbella, Málaga, Spain

Received 16 August 2024; accepted 16 October 2024

### KEYWORDS

Acetabular fractures;  
Older adults;  
Complication;  
Comorbidity;  
Mortality

### Abstract

**Objective:** This study aimed to analyze factors of comorbidity in older patients with acetabular fracture to know the role of disease in the treatment of this population.

**Methods:** *Design:* retrospective cohort study.

**Setting:** Single Level 2 Trauma Center.

**Patient selection criteria:** A prospective database of acetabular fractures in patients over 55 years between January 2011 and January 2021 was studied. The exclusion criteria were age, pathological fracture, associated pelvic or hip fracture, follow-up of less than one year, and not having a computed tomography.

**Outcome measures and comparisons:** Patients were categorised as low (0–2), intermediate (3–4) or high ( $\geq 5$ ) risk according to the age-adjusted Charlson comorbidity index (ACCI). The primary outcomes were risk of complications, number of complications and mortality at one year according to the ACCI scale. The difference between the pre-fracture Clinical Frailty Scale (CFS) and the one-year follow-up was also analysed. Descriptive and multivariable regression analyses were performed and ROC curves were constructed.

**Results:** A total of 119 patients with acetabular fracture were collected. Ninety-eight out of those met inclusion criteria for our study. In regard to ACCI groups, 22% were low-risk, 26% were intermediate-risk, and 52% were high-risk. Statistically significant differences were found according to age, sex, mechanism of injury, treatment type, surgical treatment type, Clinical Frailty Scale (CFS) score, readmissions, complications, and mortality. ROC curves showed an association between ACCI and CFS in terms of complications and mortality, with the exception of unadjusted Charlson comorbidity index. On the multivariable regression analysis, associations were found between ACCI and presence of complications (OR 1.37, 95% CI 1.06–1.77,  $p=0.015$ ) and mortality (OR 1.32, 95% CI 1.04–1.67,  $p=0.025$ ) and between CFS and complications (OR 2.01, 95% CI 1.30–3.11,  $p=0.001$ ) and mortality (OR 1.59, 95% CI 1.08–2.35,  $p=0.019$ ). No statistical correlation was established between ASA and complications or mortality.

\* Corresponding author.

E-mail address: [josemanuelbogallo@gmail.com](mailto:josemanuelbogallo@gmail.com) (J.M. Bogallo).

<https://doi.org/10.1016/j.recot.2024.10.009>

1888-4415/© 2024 SECOT. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Please cite this article as: J.M. Bogallo, C. Castillejo, A. Ramirez et al., The age-adjusted Charlson comorbidity index in acetabular fracture in geriatric acetabular fractures, Revista Española de Cirugía Ortopédica y Traumatología, <https://doi.org/10.1016/j.recot.2024.10.009>

*Conclusion:* Presurgical ACCI and CFS scales may serve as a risk assessment method in treatment decision-making for patients with acetabular fracture. An association is observed between patients with a pre-fracture ACCI score  $\geq 5$  (high-risk) and a pre-fracture CFS score  $>4$  (mild frailty) and mortality and complications at one year.

© 2024 SECOT. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## PALABRAS CLAVE

Fractura acetabular;  
Adultos mayores;  
Complicación;  
Comorbilidad;  
Mortalidad

## El índice de comorbilidad de Charlson ajustado por edad en fracturas acetabulares de pacientes ancianos

### Resumen

*Objetivo:* Analizar los factores de comorbilidad en pacientes con fractura acetabular y edad superior a 55 años. Estudiar su influencia en la decisión terapéutica de esta población.

*Metodología:* Se ha realizado un estudio retrospectivo de una base de datos prospectiva sobre fracturas acetabulares en pacientes de más de 55 años entre enero 2011 y enero 2021. Los criterios de exclusión fueron la edad, las fracturas patológicas, las fracturas asociadas con afectación de pelvis y cadera, pérdida de seguimiento y no tener realizada una tomografía computadorizada en el ingreso. Se clasificaron según el Índice de Comorbilidad de Charlson ajustado a Edad (age-adjusted Charlson comorbidity index (ACCI) en grupo de bajo riesgo (0-2), riesgo intermedio (3-4) y alto riesgo ( $\geq 5$ ). Se evaluaron la tasa de complicaciones y la mortalidad en el primer año según cada grupo de riesgo y el detrimento funcional en cada grupo según el estado previo a la fractura (Clinical Frailty Scale pre fractura, CFS) y tras 1 año de seguimiento. Se realizó un análisis descriptivo, un análisis de regresión multivariable y se elaboraron curvas ROC.

*Resultados:* De un total de 119 pacientes con fractura acetabular y edad superior a 55 años, 98 cumplieron criterio de inclusión. Los grupos obtenidos eran un 22% de bajo riesgo, un 26% de riesgo intermedio y un 52% de alto riesgo. Se observaron diferencias estadísticamente significativas en relación a la edad, sexo, mecanismo de lesión, tipo de tratamiento, tipo de técnica quirúrgica, Clinical Frailty Scale prequirúrgico, reingresos, complicaciones y mortalidad. Las curvas ROC muestran una asociación entre ACCI y CFS en términos de complicaciones y mortalidad, sin observar una correlación con el índice de Charlson no ajustado a edad. En el análisis de regresión multivariable, se encontró una asociación entre ACCI y la presencia de complicaciones (OR 1.37, 95%CI 1.06-1.77,  $p=0.015$ ) y mortalidad (OR 1.32, 95%CI 1.04-1.67,  $p=0.025$ ). También se encontró una asociación entre CFS y las complicaciones (OR 2.01, 95%CI 1.30-3.11,  $p=0.002$ ) y mortalidad (OR 1.59, 95%CI 1.08-2.35,  $p=0.019$ ). No se observó una relación estadística entre ASA y complicaciones/mortalidad.

*Conclusión:* Las escalas prequirúrgicas ACCI y CFS pueden servir como una herramienta que permita la toma de decisiones en el tratamiento de pacientes con fractura acetabular y edad avanzada. Una asociación es observada entre pacientes con un valor de ACCI  $\geq 5$  (alto riesgo) y un estado funcional previo a la caída (CFS prefractura)  $>4$  (fragilidad moderada) respecto a complicaciones y mortalidad al año.

© 2024 SECOT. Publicado por Elsevier España, S.L.U. Este es un artículo Open Access bajo la CC BY-NC-ND licencia (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Introduction

Acetabular fractures in older adults are increasing worldwide due to, among other reasons, population aging; this increase has spurred research on them.<sup>1-3</sup> This injury is more severe in older adults than in younger ones, due to associated comorbidities and fracture pattern.<sup>4</sup> There is no clear consensus<sup>5</sup> or clinical guidelines on the best treatment for each patient. Similarly, the influence of comorbidity on decision-making in these patients has not been investigated.

The definition of an older adult varies widely in the literature. A chronological definition is generally used, but it

ranges from 50 to 80 years of age.<sup>4-7</sup> Considering these discrepancies, establishing an age threshold for defining an older adult is not sufficient and other variables such as comorbidity should be weighed as well.

There are many scales for stratifying comorbidity.<sup>8,9</sup> The Charlson comorbidity index (CCI)<sup>10</sup> is universally accepted and establishes life expectancy at one month, three months, one year, and ten years based on the patient's comorbidity. The CCI consists of 19 items whose sum determines a survival score. It has been successfully used in studies on cancer,<sup>11</sup> elective surgery,<sup>12</sup> fractures,<sup>10</sup> and more recently on arthroplasty.<sup>13</sup> Charlson et al.,<sup>14</sup> upon revising their scale,

observed an increase in the risk of mortality with each additional decade of life. This led to a modification by some other authors: the age-adjusted Charlson comorbidity index (ACCI), which yields better predictions than the CCI.<sup>10,15,16</sup>

Frailty is described as an increase in individual vulnerability, mortality or dependency when exposed to a stressor. Therefore, assessment of frailty is necessary for all patients, especially the most vulnerable. At present, use of the Clinical Frailty Scale (CFS)<sup>17–19</sup> to evaluate frailty in older adults is becoming more common. It not only analyzes comorbidity, but also physical disability and cognitive impairment. The CFS evaluate specific disciplines to generate a frailty score ranging from 1 (very fit) to 9 (terminally ill). This scale has demonstrated excellent predictive results on mortality and institutionalization, and was more useful than the frailty index, another instrument for measuring frailty, according to the Canadian Study of Health and Aging (CSHA).<sup>18</sup>

In previous studies some authors have not observed a relationship between comorbidity prior to a fracture, complications, and mortality<sup>1,20,21</sup> whereas others describe complications and the mortality rate without analyzing prior comorbidity.<sup>22–25</sup> There are no studies which examine comorbidity as a method of treatment stratification in acetabular fracture in older adults. This paper aims to assess whether the ACCI would allow for establishing risk groups in older adult patients with acetabular fracture. This research analyses the relation of comorbidity in patients over 55 years of age with acetabular fracture. In addition, it evaluates the risk of complications and mortality at one year follow-up according to the ACCI and CFS scales.

## Materials and methods

This study was conducted based on a database which included patients attended between January 2011 and January 2021. The project was approved by the Ethics Committee and Research Unit of our Institution on the 29th of September of 2022. The study was conducted according to the Declaration of Helsinki and STROBE cohort guidelines. Patients were identified by means of the International Classification of Diseases (ICD) 9–10 diagnoses of pelvic fracture (ICD 9: 808/ICD 10: S32.8) and acetabular fracture (ICD 9: 808.0/ICD 10: S32.4). Data were collected using the HP Doctor<sup>®</sup> program (Hewlett Packard, Palo Alto, CA, USA, 2010). Images were viewed through the PACS (Picture Archiving and Communication System) Carestream (Health Spain, S.A. 2016) system.

The inclusion criteria included diagnosis of acetabular fracture, age  $\geq 55$  years, and a minimum follow-up time of one year. The exclusion criteria were age  $< 55$  years, pathological fracture, associated pelvic or hip fracture, follow-up of less than one year, and not having a computed tomography (CT) scan prior to the decision regarding treatment. The age cut-off point was established following the literature,<sup>5,21,26</sup> with 55 years being the lowest age recorded. Treatment decisions were based on health status and an evaluation by the Orthopaedic Trauma, Anesthesiology, and Internal Medicine Departments.<sup>3</sup>

Non-operative treatment consisted of 8 weeks of non-weight bearing on the injured side with active-passive assisted range of motion exercises, followed by partial

weight bearing with assistance and physiotherapy for 4–6 weeks. Variability in surgical technique depended on injury factors such as fracture pattern and associated injuries and treatment factor such as treatment timing and surgeon preference. The ilioinguinal approach was used for wall and anterior column fractures. The Kocher–Langenbeck approach was used for wall or posterior column fracture. If both columns were involved, a combined approach was used.

The variables analyzed were age, sex, tobacco use, alcohol use, American Society of Anesthesiologists' Physical (ASA), adjusted Charlson comorbidity index (ACCI), Clinical Frailty Scale (CFS), residence (home, long-term care facility), mechanism of action (low or high energy), treatment type (surgical or non-operative), surgical treatment (open reduction and internal fixation (ORIF), ORIF plus hip replacement) and post-operative care (home, long-term care facility, acute care hospital). Fractures were classified by the operating surgeons according to Letournel–Judet classification. Clinical endpoints at 1 year were early or late complications and the need for secondary reconstructive procedures. Information on complications was detailed in terms of emergency or readmission episodes. These variables are shown in [Table 1](#) and [supplemental file](#). The supplementary file contains the Letournel classification stratified according to ACCI groups, the number and type of complications per year according to ACCI groups.

The ACCI, ASA and CFS were calculated according to medical records. Patients were grouped according to ACCI score as low-risk (0–2), intermediate-risk (3–4), and high-risk ( $\geq 5$ ).<sup>11,13</sup> The CFS was measured after the fracture and at a follow-up of one year.

The statistical analysis was conducted using the SPSS<sup>®</sup> program (IBM<sup>®</sup> v 28). ACCI groups (low, intermediate, or high-risk) were compared using the chi-square test for linear trends for qualitative variables and the Kruskal–Wallis test for quantitative variables. A general linear model was used to evaluate the patient's CFS before the fracture and at one year of follow-up after the fracture according to the three ACCI groups. Receiver operating characteristic (ROC) curves were calculated to evaluate the prognostic performance of CFS and ACCI regarding the presence of complications and annual mortality as well as the area under the ROC curve (AUROC). Goodness-of-fit was determined using the Hosmer–Lemeshow test and Nagelkerke's R<sup>2</sup>. Simple logistic regression models were built with the aforementioned variables, selecting independent variables adjusted in the equation through a forward stepwise regression method. The odds ratio (OR) and 95% confidence intervals were calculated. A multivariate regression model was created by selecting significant variables. Statistical significance was defined as  $p < 0.05$ .

## Results

A total of 750 pelvic and acetabular fractures were recorded during the study period. Out of them, there were 119 acetabular fractures in patients older than 55 years without an associated pelvic fracture. Twenty-one (17%) patients out of these 119 with acetabular fractures were excluded: four for not having a CT scan available and 17 due to loss of follow-up. Ninety-eight patients were finally included in the

**Table 1** Sociodemographic and clinical variables according to risk groups. The percentages of categorical variables have been calculated according to the different groups of ACCL.

ACCL	0–2	3–4	≥5	<i>p</i>
ACCL group	Low-risk	Intermediate-risk	High-risk	
<i>n</i>	21	26	51	
<i>Age (years)</i> (P25–P75)	61 (56–66)	72.5 (66.7–79)	82 (74–85)	<0.001
<i>Sex</i>				
Male (65.3%)	18 (86%)	16 (61.5%)	30 (59%)	0.045
Female (34.7%)	3 (14%)	10 (38.5%)	21 (41%)	
<i>Tobacco use</i>	4 (19%)	1 (4%)	12 (23.5%)	0.354
<i>Alcohol use disorder</i>	5 (24%)	2 (8%)	10 (19%)	0.454
<i>ASA (mean)</i>	1.6	2.6	3.4	0.265
<i>Residence</i>				
Long-term care facility	0	3 (11.5%)	8 (15.7%)	0.097
<i>Mechanism of action</i>				
High energy	12 (57%)	7 (27%)	9 (17.6%)	0.001
<i>Treatment type</i>				
Surgical	13 (62%)	9 (35%)	9 (18%)	<0.001
<i>Type of surgical treatment</i>				
ORIF	11 (53%)	3 (12%)	2 (4%)	0.031
Hip replacement plus ORIF	2	6	7	
<i>Late hip replacement</i>	1 (5%)	0	2 (4%)	>0.05
<i>Letournel classification</i>				
Annex 1	Both columns (42.3%)	Anterior col- umn + hemitransverse (34.6%)	Anterior col- umn + hemitransverse (29.4%)	0.374
<i>Post-operative care</i>				
Long-term care facility	0	4 (15%)	12 (24%)	0.097
<i>Pre-fracture CFS (mean, SD)</i>	1.9 (0.625)	3.35 (1.4)	4.17 (1.4)	0.001
<i>Post-treatment CFS (mean, SD)</i>	2.29 (0.902)	4.12 (1.98)	5.48 (1.72)	0.019
<i>Readmissions at one year</i>				
Yes	0	3 (12%)	13 (25%)	0.006
<i>Complications at one year</i>				
Yes	5 (24%)	10 (38%)	35 (69%)	<0.001
<i>Mortality at one year</i>				
Yes	1 (5%)	3 (12%)	18 (35%)	0.002

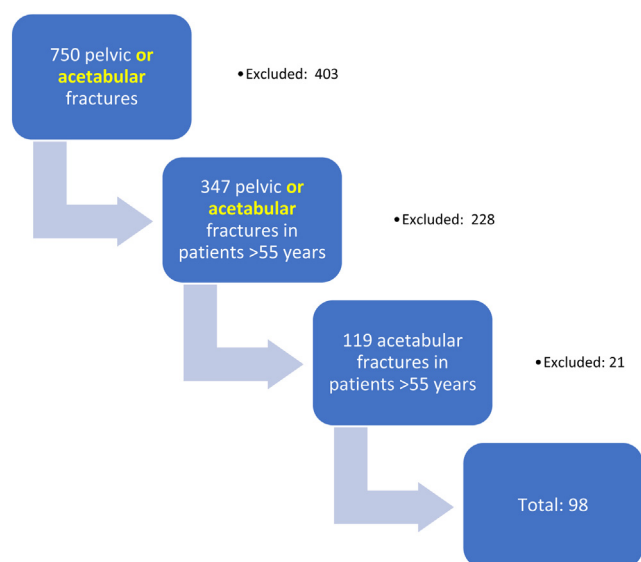
ACCL: age-adjusted Charlson comorbidity index; CFS: Clinical Frailty Scale; SD: standard deviation; ORIF: open reduction and internal fixation.

study (Fig. 1). The variables and their results are shown in Table 1 and supplemental file.

The majority of the patients were male (65.3%) and age is already included as one of the ACCL variables. ASA value increased by risk group. Residence in a long-term care facility was more common in the high-risk group (15.7%). The high-energy mechanism of action was higher in the low-risk group. Low-risk group was treated with ORIF (82%), whereas intermediate and high-risk groups were managed non-operatively (62%). Intermediate and high-risk group managed surgically, the technique was ORIF plus hip replacement. In intermediate and high-risk groups, anterior column

plus posterior hemitransverse fracture made up the majority of all fractures (34% and 29%, respectively). In low-risk group, both column was significantly more frequent (42%). The rates of complications, readmissions and mortality were higher in the high-risk group.

The three ACCL risk groups were found to have statistically significant differences in age ( $p < 0.001$ ), sex ( $p = 0.045$ ), mechanism of injury ( $p = 0.001$ ), conservative or surgical treatment ( $p < 0.001$ ), type of surgical treatment ( $p = 0.031$ ), CFS ( $p = 0.001$ ), readmission ( $p = 0.006$ ), complications ( $p < 0.001$ ), and mortality ( $p = 0.002$ ) (Table 1).



**Figure 1** Flowchart. Ninety-eight patients were finally included.

After one year of follow-up, three patients (3.1%, one with ACCI 0–2 and two with ACCI >5) treated non-operatively required a total hip arthroplasty. There were no reinterventions in patients treated surgically with ORIF, as they were in the younger age group ( $p=0.031$ ). Twenty-two patients (22%) died within one year of follow-up (Table 1).

A one-point increase in the pre-fracture ACCI entailed an increase in the risk of complications by OR 1.37 (95% CI 1.06–1.77,  $p=0.015$ ) and an increase in the risk of mortality by OR 1.32 (95% CI 1.04–1.67,  $p=0.025$ ) (Table 2). Regarding CFS, a one-level increase entailed a greater risk of complications with an OR of 2.01 (95% CI 1.3–3.11,  $p<0.001$ ) and a greater risk of mortality with an OR of 1.59 (95% CI 1.08–2.35,  $p=0.019$ ) (Table 2). The CFS cut-off point for complications was 4 (mildly frail) (Fig. 2a–c). Likewise, there were differences in the mean CFS before the fracture ( $p=0.001$ ) and at one year of follow-up ( $p=0.019$ ), with outcomes becoming worse as the ACCI risk group increased (Fig. 3). On the ROC curve analysis, a correlation was observed between ACCI and CFS with complications and mortality (AUC >0.7), apart from unadjusted Charlson comorbidity index (Fig. 4).

Although significant differences were observed in several mortality and complications variables on the simple logistic regression (crude analysis), on the adjusted multiple logistic regression analysis, only ACCI and CFS showed a significant association. The Hosmer–Lemeshow test (0.441) and Nagelkerke’s R<sup>2</sup> (0.29) indicate an acceptable calibration and goodness-of-fit. Age is already included as one of the ACCI variables. There was no significant association with either residing in a long-term care facility or ASA scores (Table 2). Surgical treatment entails a greater risk of complications with an OR of 3.86 (95% CI 1.15–12.9,  $p=0.029$ ). However, this should be subject to criticism as there are statistically significant differences between the groups in terms of the type of treatment.

## Discussion

Age, functional status prior to the fracture, and comorbidity are factors that must be taken into account when deciding on individualized treatment in patients older than 55 years with an acetabular fracture.<sup>2,3,5,27–30</sup> Given that there is no consensus<sup>5</sup> or clinical guidelines that establish the best individualized treatment for patients with fractures, new researches that stratifies them into risk groups are needed.

In this study, significant differences were observed between ACCI risk groups<sup>14</sup> and the effectiveness of ACCI and CFS as risk classification methods for complications and mortality, represented on the ROC curve (AUC >7). Neuhaus et al.<sup>10</sup> obtained similar results to those shown in our paper but in patients with hip fractures. They concluded that ACCI is a predictor of mortality, though it should be evaluated together with concomitant injuries. Harrison et al.,<sup>31</sup> studying older patients sustaining pelvic or acetabular fractures, observed statistically significant differences between mortality and CCI, prior mobility status, and age.

The CFS allows for evaluating mobility and dependency, which are variables related to frailty. Church et al.<sup>19</sup> describe the widespread use of the CFS in the literature and the association between the CFS and clinical outcomes in the care of older adult patients. In this regard, Romero-Ortuno et al.<sup>32</sup> used this scale as a method for selecting older adult patients with various diagnoses who require greater care. In our study, a significant association was observed between preoperative CFS and the presence of complications and mortality at one year follow-up (Fig. 2). Likewise, a greater absolute increase in CFS score calculated before the fracture and after treatment was found in the high-risk ACCI group (Fig. 3).

Ernstberger et al.<sup>33</sup> determined that the most frequent fractures in older adults, namely anterior column plus posterior hemitransverse fracture, tend to present little displacement, which makes them more likely to be treated non-operatively. We have found that patients in the low-risk group (ACCI 0–2) most commonly presented with a fracture of the two columns compared to the medium- and high-risk groups (ACCI >2), which generally presented with an anterior column plus posterior hemitransverse fracture and were also predominantly treated non-operatively. Nonetheless, some authors currently include them for surgical treatment.<sup>34</sup> In this regard, the multivariable analysis conducted in our study showed a higher risk of complications in patients treated surgically. However, no conclusions can be drawn from these results because the type of treatment was different in each risk group. Surgical treatment was more frequent in the low-risk group (62%) and less frequent in the intermediate- and high-risk groups (35% and 18%, respectively), and this difference was statistically significant  $p<0.001$ . Therefore, further research is needed to analyze the type of treatment by risk group.

Despite the fact that the ASA classification is cited in nearly all publications,<sup>2,5,26–28,35</sup> it was originally designed to evaluate anesthetic risk prior to surgery; indeed, frailty scoring systems are more precise in regard to complications and mortality.<sup>36</sup> Kim et al.<sup>37</sup> observed a lower degree of precision in the prediction of annual mortality using the ASA classification compared to a frailty evaluation system (multidimensional frailty score model). We found that

**Table 2** Crude and multivariable logistic regression with outcome variables of complications and mortality at one year.

Variables	Complication				Mortality at 1 year			
	SLR		MLR		SLR		MLR	
	<i>p</i>	OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>	OR (95% CI)
<b>Sex</b>								
Woman		Ref.				Ref.		
Man	0.568	1.27 (0.55–2.93)			0.186	2.10 (0.70–6.30)		
<b>Age</b>	0.018	1.05 (1.01–1.09)			0.002	1.09 (1.03–1.16)		
<b>Tobacco use</b>								
Non-smoker		Ref.				Ref.		
Smoker	0.862	1.10 (0.38–3.13)			0.17	2.22 (0.71–6.90)		
<b>Alcohol use disorder</b>								
No		Ref.				Ref.		
Yes	0.481	1.46 (0.51–4.22)			0.907	1.08 (0.31–3.71)		
<b>Place of residence</b>								
Home		Ref.				Ref.		
Long-term care facility	0.028	10.6 (1.28–87.1)			0.031	4.44 (1.15–17.2)		
<b>Mechanism of injury</b>								
Low energy		Ref.				Ref.		
High energy	0.308	0.63 (0.26–1.53)			0.09	0.32 (0.88–1.19)		
<b>Treatment</b>								
Conservative		Ref.				Ref.		
Surgical	0.723	0.86 (0.37–2.01)	0.029	3.86 (1.15–12.9)	0.618	0.76 (0.27–2.19)		
<b>ASA</b>								
I–II		Ref.				Ref.		
III–IV	<0.001	6.68 (2.51–17.8)			0.016	6.52 (1.42–30.0)		
<b>ACCI</b>	<0.001	1.48 (1.21–1.82)	0.015	1.37 (1.06–1.77)	0.001	1.45 (1.17–1.78)	0.025	1.32 (1.04–1.67)
<b>Clinical Frailty Scale – preoperative</b>	<0.001	2.17 (1.50–3.14)	0.002	2.01 (1.30–3.11)	<0.001	1.84 (1.31–2.57)	0.019	1.59 (1.08–2.35)

SLR: simple logistic regression; MLR: multivariable logistic regression; ASA: American Society of Anesthesiologists; ACCI: age-adjusted Charlson comorbidity index.

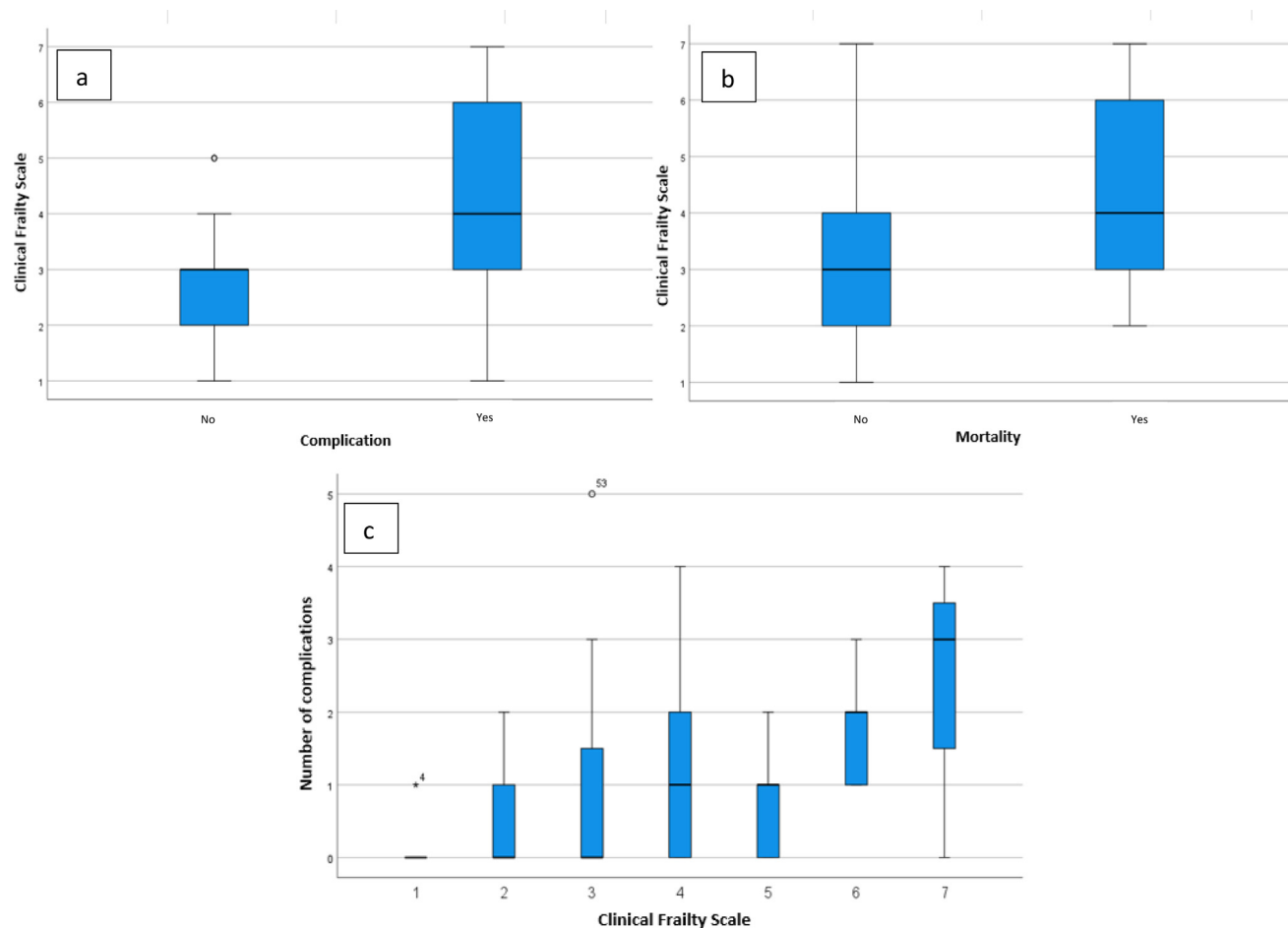


Figure 2 Representation of CFS according to complication (a), mortality (b), and number of complications (c).

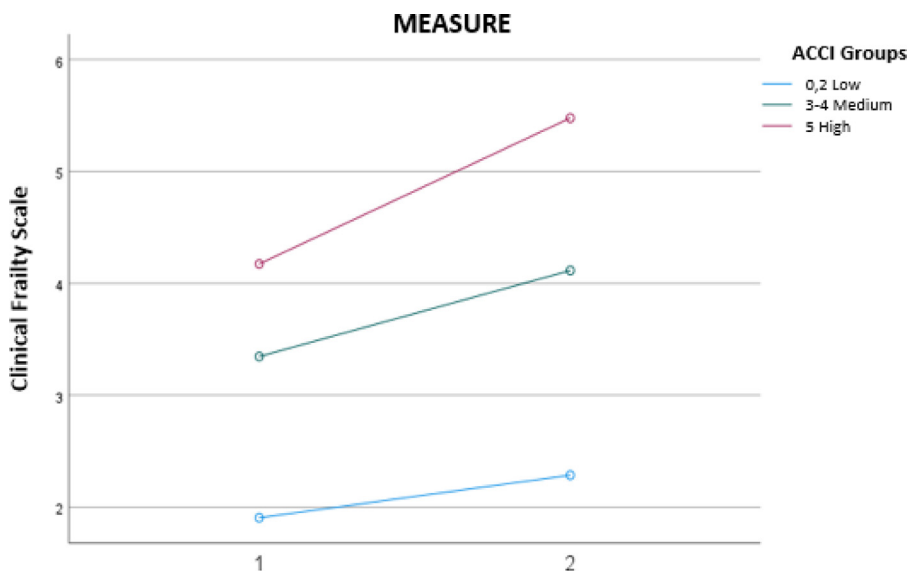


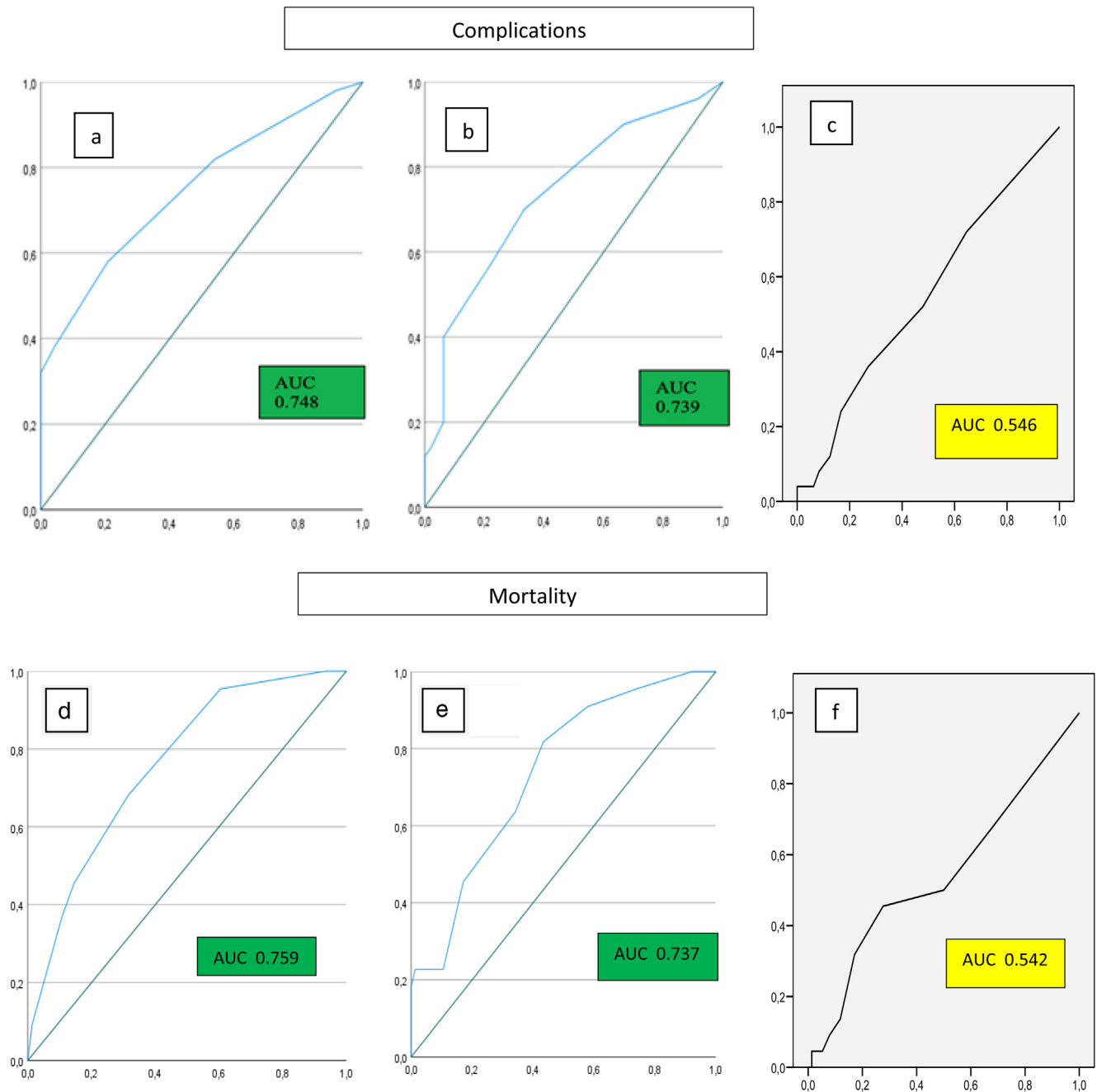
Figure 3 Differences in the mean pre-fracture (1) and post-treatment (2) CFS values, according to ACCI risk group.

the ASA classification had no statistical association with complications and mortality at one year follow-up on a multiple regression model (Table 2).

Surprisingly, no significant differences were found in the literature regarding how early the surgical intervention was

performed (48–72 h),<sup>20,29</sup> unlike what has been described in proximal and distal femur fractures.<sup>38</sup> In our research we have observed surgeries were performed after 72 h.

In regard to the mechanism of injury, except for Gary et al.,<sup>29</sup> who found that a high-energy mechanism of injury



**Figure 4** ROC curves of the prognostic performance for complications (a and b), according to ACCI (a), CFS (b) and unadjusted Charlson comorbidity index (c). And ROC curves performance for mortality, according to ACCI (d), CFS (e) and unadjusted Charlson comorbidity index (f). ACCI: age-adjusted Charlson comorbidity index; CFS: Clinical Frailty Scale.

in older adults was a predictive factor of mortality, other authors<sup>20,39</sup> have not observed differences between a low or high-energy mechanism. Furthermore, Kehoe et al.<sup>40</sup> described that in older adult patients with acetabular fracture, those between 50 and 70 years of age with a fall of less than <2m tended to be categorized as having major trauma (injury severity score >15). Heimke et al.<sup>39</sup> observed that younger patients within this age group (60–65 years) with a high-energy mechanism of injury who were treated with internal fixation, had better functional outcomes at one year, but they did not observe differences in complications

or mortality compared to older patients (>70 years). In our study, we have observed that a high-energy mechanism of injury was more frequent in the low-risk group (ACCI 0–2) and a low energy mechanism in the rest (ACCI >2), findings which were statistically significant. Nonetheless, the mechanism of injury was not found to be a predictive factor of either complications or mortality (Table 2).

A medical history of smoking or alcohol abuse disorders tends to lead to an increase in comorbidity.<sup>39,41</sup> However, the paucity of results in the literature and the heterogeneity of these findings may be due to a lack of stratification of

the variables. We have found that smoking or alcohol abuse disorders were more prevalent in the high-risk group, though not statistically significant (Table 1).

It has been published that residing in a long-term care facility has been associated with increased mortality among older adults with hip fracture,<sup>42</sup> though this factor has not been widely studied in acetabular fracture. In our study, more patients in the high-risk group lived in long-term care facilities, though this finding was not statistically significant (Table 1).

Our study has several limitations. This study is retrospective in nature and sample size of each group should have exceeded 30 patients in order to have the statistical power for a comparative study between risk groups. However, statistically significant associations were found between comorbidity scales and complications and mortality. Although a larger sample size would be desirable, this single-center registry had a loss to follow-up of just 14% (17 patients) and, unlike large registries, recorded specific data on comorbidity.<sup>1</sup> Secondly, patients' baseline nutritional status or sarcopenia status were not included.<sup>30</sup> Thirdly, although preoperative and post-operative ambulation status has been recorded, other functional outcomes were not described either.

## Conclusions

The use of the preoperative ACCI score to stratify older adult patients with acetabular fracture into risk groups could serve as a risk assessment method for therapeutic decision-making, as it shows a direct correlation with complications/mortality. In addition, the previous functional status (CFS) of these patients showed a statistically significant association with complications and mortality. No association was observed between ASA classification and complications and mortality, questioning the usefulness of ASA in classifying comorbidities in older adult patients with acetabular fractures. A pre-fracture ACCI score  $\geq 5$  (high-risk) and a pre-fracture CFS score  $>4$  (low fragility) imply an exponential increase in risk that should be taken into account when making therapeutic decisions. Determining which type of treatment is most appropriate for each comorbidity requires future research.

## Level of evidence

Prognostic. Level III. Retrospective cohort study.

## Funding

The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

## Conflicts of interest

None declared.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version available at <https://doi.org/10.1016/j.recot.2024.10.009>.

## References

1. Herath SC, Pott H, Rollmann MFR, Braun BJ, Holstein JH, Höch A, et al. Geriatric acetabular surgery: Letourne's contraindications then and now—data from the German pelvic registry. *J Orthop Trauma*. 2019;33 (Suppl. 2):S8–13, <http://dx.doi.org/10.1097/BOT.0000000000001406>.
2. Ferguson TA, Patel R, Bhandari M, Matta JM. Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study. *J Bone Joint Surg Br*. 2010;92:250–7, <http://dx.doi.org/10.1302/0301-620X.92B2.22488>.
3. Guerado E, Cano JR, Cruz E. Fractures of the acetabulum in elderly patients: an update. *Injury*. 2012;43 Suppl. 2:S33–41, [http://dx.doi.org/10.1016/S0020-1383\(13\)70177-3](http://dx.doi.org/10.1016/S0020-1383(13)70177-3).
4. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. *Lancet*. 2013;381:752–62, [http://dx.doi.org/10.1016/S0140-6736\(12\)62167-9](http://dx.doi.org/10.1016/S0140-6736(12)62167-9).
5. Goyal T, Singh G, Kumar Tripathy S, Schuh A, Veerappa LA, Kumar Sen R. Acetabulum fractures in elderly: a systematic review of fracture pattern and treatment. *J Clin Orthop Trauma*. 2020;11:989–1001, <http://dx.doi.org/10.1016/j.jcot.2020.09.008>.
6. Gencarelli P, Menken LG, Hong IS, Robbins CJ, Jankowski JM, Yoon RS, et al. No difference in acute outcomes for patients undergoing fix and replace versus fixation alone in the treatment of geriatric acetabular fractures. *J Orthop Trauma*. 2024;38:88–95, <http://dx.doi.org/10.1097/BOT.0000000000002733>.
7. Sabharwal S, Wilson H, Reilly P, Gupte CM. Heterogeneity of the definition of elderly age in current orthopaedic research. *Springerplus*. 2015;4:516, <http://dx.doi.org/10.1186/s40064-015-1307-x>.
8. Peña FG, Theou O, Wallace L, Brothers TD, Gill TM, Gahbauer EA, et al. Comparison of alternate scoring of variables on the performance of the frailty index. *BMC Geriatr*. 2014;14:25, <http://dx.doi.org/10.1186/1471-2318-14-25>.
9. Kojima G, Iliffe S, Walters K. Frailty index as a predictor of mortality: a systematic review and meta-analysis. *Age Ageing*. 2018;47:193–200, <http://dx.doi.org/10.1093/ageing/afx162>.
10. Neuhaus V, King J, Hageman MG, Ring DC. Charlson comorbidity indices and in-hospital deaths in patients with hip fractures. *Clin Orthop Relat Res*. 2013;471:1712–9, <http://dx.doi.org/10.1007/s11999-012-2705-9>.
11. Koppie TM, Serio AM, Vickers AJ, Vora K, Dalbagni G, Donat SM, et al. Age-adjusted Charlson comorbidity score is associated with treatment decisions and clinical outcomes for patients undergoing radical cystectomy for bladder cancer. *Cancer*. 2008;112:2384–92, <http://dx.doi.org/10.1002/cncr.23462>.
12. Shinonara K, Ugawa R, Arataki S, Nakahara S, Takeuchi K. Charlson comorbidity index is predictive of postoperative clinical outcome after single-level posterior lumbar interbody fusion surgery. *J Orthop Surg Res*. 2021;16:235, <http://dx.doi.org/10.1186/s13018-021-02377-7>.
13. Amit P, Marya SKS. Age-adjusted Charlson comorbidity index as a novel guideline for patient selection between unilateral versus bilateral simultaneous total knee arthroplasty. *Arch Orthop Trauma Surg*. 2022;142:657–63, <http://dx.doi.org/10.1007/s00402-021-03841-z>.

14. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. *J Clin Epidemiol.* 1994;47:1245–51, [http://dx.doi.org/10.1016/0895-4356\(94\)90129-5](http://dx.doi.org/10.1016/0895-4356(94)90129-5).
15. Marya SKS, Amit P, Singh C. Impact of Charlson indices and comorbid conditions on complication risk in bilateral simultaneous total knee arthroplasty. *Knee.* 2016;23:955–9, <http://dx.doi.org/10.1016/j.knee.2016.05.013>.
16. Quan H, Li B, Couris CM, Fushimi K, Graham P, Hider P, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol.* 2011;173:676–82, <http://dx.doi.org/10.1093/aje/kwq433>.
17. Ellis HL, Wan B, Yeung M, Rather A, Mannan I, Bond C, et al. Complementing chronic frailty assessment at hospital admission with an electronic frailty index (FI-Laboratory) comprising routine blood test results. *CMAJ.* 2020;192:E3–8, <http://dx.doi.org/10.1503/cmaj.190952>.
18. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ.* 2005;173:489–95, <http://dx.doi.org/10.1503/cmaj.050051>.
19. Church S, Rogers E, Rockwood K, Theou O. A scoping review of the Clinical Frailty Scale. *BMC Geriatr.* 2020;20:393, <http://dx.doi.org/10.1186/s12877-020-01801-7>.
20. Glogovac G, Le TT, Archdeacon MT. Time to surgery and patient mortality in geriatric acetabular fractures. *J Orthop Trauma.* 2020;34:310–5, <http://dx.doi.org/10.1097/BOT.0000000000001717>.
21. Baker G, McMahon SE, Warnock M, Johnston A, Cusick LA. Outcomes of conservatively managed complex acetabular fractures in the frail and elderly one year post injury. *Injury.* 2020;51:347–51, <http://dx.doi.org/10.1016/j.injury.2019.12.008>.
22. Lont T, Nieminen J, Reito A, Pakarinen TK, Pajamäki I, Eskelinen A, et al. Total hip arthroplasty, combined with a reinforcement ring and posterior column plating for acetabular fractures in elderly patients: good outcome in 34 patients. *Acta Orthop.* 2019;90:275–80, <http://dx.doi.org/10.1080/17453674.2019.1597325>.
23. Mohan K, Broderick JM, Raza H, O'Daly B, Leonard M. Acetabular fractures in the elderly: modern challenges and the role of conservative management. *Ir J Med Sci.* 2022;191:1223–8, <http://dx.doi.org/10.1007/s11845-021-02711-2>.
24. Giunta JC, Tronc C, Kerschbaumer G, Milaire M, Ruatti S, Tonetti J, et al. Outcomes of acetabular fractures in the elderly: a five year retrospective study of twenty seven patients with primary total hip replacement. *Int Orthop.* 2019;43:2383–9, <http://dx.doi.org/10.1007/s00264-018-4204-4>.
25. Wollmerstädt J, Pieroh P, Schneider I, Zeidler S, Höch A, Josten C, et al. Mortality, complications and long-term functional outcome in elderly patients with fragility fractures of the acetabulum. *BMC Geriatr.* 2020;20:66, <http://dx.doi.org/10.1186/s12877-020-1471-x>.
26. Carroll EA, Huber FG, Goldman AT, Virkus WW, Pagenkopf E, Lorich DG, et al. Treatment of acetabular fractures in an older population. *J Orthop Trauma.* 2010;24:637–44, <http://dx.doi.org/10.1097/BOT.0b013e3181ceb685>.
27. Deren ME, Babu J, Cohen EM, Machan J, Born CT, Hayda R. Increased mortality in elderly patients with sarcopenia and acetabular fractures. *J Bone Joint Surg Am.* 2017;99:200–6, <http://dx.doi.org/10.2106/JBJS.16.00734>.
28. Walley KC, Appleton PT, Rodriguez EK. Comparison of outcomes of operative versus non-operative treatment of acetabular fractures in the elderly and severely comorbid patient. *Eur J Orthop Surg Traumatol.* 2017;27:689–94, <http://dx.doi.org/10.1007/s00590-017-1949-1>.
29. Gary JL, Paryavi E, Gibbons SD, Weaver MJ, Morgan JH, Ryan SP, et al. Effect of surgical treatment on mortality after acetabular fracture in the elderly: a multicenter study of 454 patients. *J Orthop Trauma.* 2015;29:202–8, <http://dx.doi.org/10.1097/BOT.0000000000000223>.
30. Mitchell PM, Collinge CA, O'Neill DE, Bible JE, Mir HR. Sarcopenia is predictive of 1-year mortality after acetabular fractures in elderly patients. *J Orthop Trauma.* 2018;32:278–82, <http://dx.doi.org/10.1097/BOT.0000000000001159>.
31. Harrison A, Ordas-Bayon A, Chimutengwende-Gordon M, Fortune M, Chou D, Hull P, et al. Factors associated with mortality in older patients sustaining pelvic or acetabular fractures. *Arch Orthop Trauma Surg.* 2022;142:1547–56, <http://dx.doi.org/10.1007/s00402-021-03873-5>.
32. Romero-Ortuno R, Forsyth DR, Wilson KJ, Cameron E, Wallis S, Biram R, et al. The association of geriatric syndromes with hospital outcomes. *J Hosp Med.* 2017;12:83–9, <http://dx.doi.org/10.12788/jhm.2685>.
33. Ernstberger H, Pieroh P, Höch A, Josten C, Herath SC, Osterhoff G, et al. Minimally displaced acetabulum fractures in geriatric patients: a comparison of open, percutaneous and non-operative treatment from the German Pelvic Injury Register data. *Eur J Trauma Emerg Surg.* 2021;47:1763–71, <http://dx.doi.org/10.1007/s00068-020-01346-9>.
34. Riemenschneider J, Vollrath JT, Mühlenfeld N, Frank J, Marzi I, Janko M. Acetabular fractures treatment needs in the elderly and nonagenarians. *EFORT Open Rev.* 2022;7:433–45, <http://dx.doi.org/10.1530/EOR-22-0019>.
35. Boelch SP, Jordan MC, Meffert RH, Jansen H. Comparison of open reduction and internal fixation and primary total hip replacement for osteoporotic acetabular fractures: a retrospective clinical study. *Int Orthop.* 2017;41:1831–7, <http://dx.doi.org/10.1007/s00264-016-3260-x>.
36. Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status – historical perspectives and modern developments. *Anaesthesia.* 2019;74:373–9, <http://dx.doi.org/10.1111/anae.14569>.
37. Kim SW, Han HS, Jung HW, Kim KI, Hwang DW, Kang SB, et al. Multidimensional frailty score for the prediction of postoperative mortality risk. *JAMA Surg.* 2014;149:633–40, <http://dx.doi.org/10.1001/jamasurg.2014.241>.
38. Myers P, Laboe P, Johnson KJ, Fredericks PD, Crichlow RJ, Maar DC, et al. Patient mortality in geriatric distal femur fractures. *J Orthop Trauma.* 2018;32:111–5, <http://dx.doi.org/10.1097/BOT.0000000000001078>.
39. Heimke IM, Scarcella NR, Simske NM, Furdock R, Vallier HA. Surgical versus nonsurgical management of acetabular fractures with associated patterns in elderly patients: factors affecting outcomes. *J Am Acad Orthop Surg Glob Res Rev.* 2022;6, <http://dx.doi.org/10.5435/JAAOSGlobal-D-22-00014>, e22.00014.
40. Kehoe A, Smith JE, Edwards A, Yates D, Lecky F. The changing face of major trauma in the UK. *Emerg Med J.* 2015;32:911–5, <http://dx.doi.org/10.1136/emered-2015-205265>.
41. Cheraghi Z, Doosti-Irani A, Almasi-Hashiani A, Baigi V, Mansournia N, Etminan M, et al. The effect of alcohol on osteoporosis: a systematic review and meta-analysis. *Drug Alcohol Depend.* 2019;197:197–202, <http://dx.doi.org/10.1016/j.drugalcdep.2019.01.025>.
42. Guzon-Illescas O, Perez Fernandez E, Crespi Villarias N, Quirós Donate FJ, Peña M, Alonso-Blas C, et al. Mortality after osteoporotic hip fracture: incidence, trends, and associated factors. *J Orthop Surg Res.* 2019;14:203, <http://dx.doi.org/10.1186/s13018-019-1226-6>.