BMC Musculoskeletal Disorders

RESEARCH

Open Access

Partial weight bearing and long-term survival outcomes in extracapsular hip fractures treated with trochanteric Gamma3 nails

Carlos Hernández-Pascual[1*], José Ángel Santos-Sánchez[2], Jorge Hernández-Rodríguez[3], Carlos Fernando Silva-Viamonte[4], Carmen Pablos-Hernández[5], Pablo Alonso-Rodríguez[6] and José Antonio Mirón-Canelo[7]

Abstract

Background Benefits of partial weight bearing (PWB) in operated extracapsular hip fractures (ECF) have not been proved. We have assessed influence of PWB on long-term survival and the final mobility achieved, dependence and mortality-related factors.

Methods Retrospective cohort study of osteoporotic ECF in ≥ 65-year-old patients who underwent surgery with trochanteric Gamma3 nails in 2014 ($n = 218$), followed in the long-term (consolidation or stabilisation). According to Baumgaertner-Fogagnolo classification (138 good, 71 acceptable and 9 poor) a postoperative protocol was applied. 116 cases bore weight before discharge (Immediate Partial Weight Bearing, IPWB = 116; Not-IPWB = 102), and 118 did it after a month (Early PWB, EPWB = 118; Not-EPWB = 100). Variables were collected from medical records and complementary studies. We used FMS (Fracture Mobility Score) and the National Mortality Database from the Spanish Ministry of Health at > 5 years. EPWB and Not-EPWB were comparable, except for hospital stay and dependence. We used the Cox method for mortality. < 0.05 *p*-values were significant.

Results Survival improved in IPWB earlier than in EPWB, although there was no statistical significance. The final FMS was significantly favourable only in EPWB. Not-EPWB showed greater dependence. Age (per year of increment), moderate Charlson comorbidity index (not age-modified) and greater immediate post-operative estimated blood loss were independent factors for mortality, but we did not find radiological factors implied.

Conclusions Postoperative PWB in ECF may increase mid-term and long-term survival rates, but considerably delayed in EPWB. Only EPWB improved final mobility. Not-EPWB presented with greater dependence. Only clinical factors were independently related to mortality, but no radiological factors were.

Keywords Hip fracture, Fracture fixation, Intramedullary, Partial weight bearing, Dependence, Mobility, Survival

*Correspondence:
Carlos Hernández-Pascual
medcarlitos@usal.es
Full list of author information is available at the end of the article

Background

Since the early twentieth century, developed countries have faced the reality of an ageing population. A significant challenge for this demographic is the high incidence of fragility fractures, with over 85% of hip fractures occurring in individuals older than 65 [1]. These fractures are particularly devastating, as less than half of those affected regain their previous level of functionality, leading to high rates of morbidity and mortality [2].

Musculoskeletal deficits are major contributors to the overall deterioration seen in elderly people, often resulting in premature death compared to their uninjured peers [3]. This produces enormous socio-economic cost, which is why healthcare organisations and institutions have been boosting their efforts to maximize functional status, trying to enhance their wellbeing and health-related quality of life [4].

Orthogeriatrics units have shown improvements, such as reduced length of hospital stay, optimized pre-operative times, and fewer in-hospital medical complications [5]. Mid-term care hospitals are one of the most representative alternatives in medical and rehabilitating patient care after the post-operative acute phase [6], if available.

Anyway, the job of rehabilitators and physical therapists has been gaining ongoing importance [7], in spite of certain scepticism found in Cochrane [8], which states that it only helps in functional recovery and independence at early post-operative stages in cooperative patients, with previously good functional and independence levels, not suffering dementia or mood disorders, who are eligible for weight bearing (WB).

Geriatric fragility scores, especially those based on dependence like Barthel's index, are useful for predicting outcomes for hip fractures in the short and mid-term [9]. The Relative Functional Gain (RFG) is particularly reliable, being based on initial values [10].

Most authors empirically approve "WB as pain allows as early as possible…" in these patients after operated either intracapsular (ICF) or extracapsular (ECF) hip fractures. What is certain is that in ICF the vast majority are treated with arthroplasty, which achieves a rapid decrease in pain and favours a rapid functional recovery. On the contrary, after osteosynthesis treatment of ECF, pain depends on reduction and fixation, with one to three months until radiological consolidation. These substantial management differences are repeatedly ignored, including revisions of prestigious institutions [11].

Nevertheless, immediate WB as tolerated in operated ECF is a common practice, especially in Northern Europe, probably based on the influence of extensive classic studies by Koval [12, 13], and following theoretical findings like higher effective WB in other activities than standing [14], impossible effective unloading on the affected side in these patients [15], functional and mortality benefits, preventing deterioration of organic systems due to immobility [16] and no impact on major non-traumatic mechanical complications (NTMC), like cut-out [17].

However, in cases of unsatisfactory reduction, improper implant choice or mispositioning of fixation devices (especially in unstable fractures), unrestricted WB could be problematic due to pain and risk of NTMC, like Marmor has recently warned [18]. These complications could be prevented by partial weight bearing (PWB) therapies under authorised criteria. There are also more reasons behind this statement like diverse rehabilitating protocols with variable conclusions in complications [10], the proof that many works do not differentiate between ICF and ECF [11, 19] and the fact that ECF have probably worse prognosis in males [20]. Also, there is no clear benefit in certain revisions about mortality [11] and finally we mentioned not-accomplishment of WB. This is estimated to be up to 25%, mostly due to cognitive deterioration/dementia [21], poor previous functional status [22] and mood disorders, like major depression, or psychotic disorders [23].

This work aims to evaluate the influence of post-operative PWB in ECF, supported by well-known reduction criteria protocol, on long-term survival and final mobility. Specific goals include assessing differences in baseline dependence and progress after the first month and identifying clinical and radiological factors related to survival.

Methods

The Ethics Committee of Salamanca University Hospital approved the study and informed consent was obtained from all individual participants. Information was systematically gathered on ECF surgically treated with titanium Gamma 3 trochanteric nails (Stryker® Trauma GmbH, Schörnkirchen, Germany -Gamma3T from this point on-) in ≥ 65 year-old patients throughout 2014 in our Trauma and Orthopaedic Surgery unit. They were followed up until consolidation (207 cases; 94,95%; mean 6.28 weeks, SD 3.54) or stabilised major complication (11 cases; 5.05%: 7 early cut-out -occurring before 6 months, among which 2 consolidated-, 1 cut-through -consolidated-, 1 late cut-out -consolidated-, 1 pseudoarthrosis and 1 osteonecrosis).

We established a gym room next to the hospitalisation wards, given the lack of an associated mid-term care hospital. In 2013, we started an immediate post-operative rehabilitation protocol for patients with ECF, which was consolidated in 2014. Each session took place daily for 1 hour. Sessions were held at the gym in our own unit, which consists of parallel bars and walking frames, as well as stretchers for active and passive mobility gain

exercises for affected joints. All the eligible patients could complete at least one physical therapy session during their stays. The physical therapist took note of whether each patient bore weight on the operated limb before being discharged.

All fractures were unilateral, except for one patient who needed bilateral surgery (3 months went by between the two interventions). All fractures reduced by mini-open approach, except for 2 (0.91%), which needed open reduction and cerclage. No anti-rotation implants were used on the head besides the proximal locking device (PLD). The set screw was unscrewed by one quarter of a turn after tightening in all cases. The distal locking mode was based on the surgeon's preferences, according to fracture stability and surgical technique (static: 151; dynamic: 57; no distal locking: 10).

Immediate post-operative radiological control was assessed according to Baumgaertner-Fogagnolo's criteria [24], which firstly assesses alignment: anteroposterior view -normal cervico-diaphyseal angle or slight valgus- and lateral view -cervico-diaphyseal angle of less than 20º-. Secondly, it evaluates displacement of main fragments: more than 80% overlapping in both planes and less than 5 mm of shortening.

Results were good if both reduction criteria were met, acceptable if only one was met, and poor if neither was met.

Post-operative protocol included three scenarios. The first incorporated physiotherapy (PT) and immediate partial weight bearing (IPWB) –138 cases–, the second PT and only IPWB test before discharge –71 cases– and the third were not eligible for any IPWB –9 cases–.

116 patients did IPWB before discharge (84 of them with good reduction and 32 with acceptable reduction), establishing the groups IPWB -immediate partial weight bearing- ($n=116$) and not-immediate partial weight bearing group, Not-IPWB ($n=102$). The alternatives upon discharge were their homes (on their own or accompanied) and nursing homes.

Follow-up was maintained until the endpoint was completed. Medical records, blood tests and radiological studies were used at every stage of the study: 1st month, 3rd month, 5th month, 9th month, and first year ± 1 week (if conducted), with interviews to caregivers if patients were not eligible for anamnesis.

Mobility was assessed through the Fracture Mobility Score (FMS) [25]. 84 good-reduction and 34 acceptable-reduction cases bore partial weight at one month (EPWB -early partial weight bearing- group, $n=118$), and 100 cases did not manage to do it (not-early partial weight bearing group, not-EPWB group, $n=100$).

Flowchart summarises the cohort of patients analysed in this study (Fig. 1).

The National Mortality Database from the Spanish Ministry of Health was used as of end-February 2020 (to prevent COVID-19 pandemic bias), with > 5-year survival. Clinical and radiological factors were studied using the Cox model, including GammaTScore index, which evaluates the reduction obtained, osteosynthesis adequacy and instability elements after immediate post-operative monitoring [26].

Statistical analysis

Results were obtained by SPSS 20.0 (SPSS, Inc., Chicago, IL, USA), and RStudio Team (2022) (RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/). Qualitative variables were described as percentages and absolute counts. Quantitative variables were described by mean, standard deviation and range. Kolmogorov–Smirnov tests were used to evaluate the Gaussian distributions of continuous variables. Comparisons of the two independent groups were performed with Mann–Whitney U tests for continuous variables. For categorical variables, Pearson chi-square tests and Fisher's exact tests were used to evaluate the significance of differences. For the American Society of Anesthesiologists (ASA) risk score, median test was used. For the estimation of survival, the non-parametric Kaplan–Meier estimator (based on the log-rank test) was used within the Cox survival model. All p-values were 2-sided, and p-values < 0.05 were considered significant.

Results

Pre-operative variables (Table 1)

EPWB and Not-EPWB were similar in all non-modifiable (age, gender, and side) and modifiable variables (social situation, dependence according to Barthel's index) [9], comorbidity according to CCI (Charlson comorbidity index) [27], cognitive deterioration according to Pfeifer's classification [28], depression, severe osteoporosis by previous fractures [29], previous osteoporosis treatment, anti-platelet/anticoagulant treatments (APT/ACT) and ASA classification [30].

Peri-operative variables (Table 2)

We detected significant differences in the average length of total and pre-operative stays, which were shorter in EPWB. More independence was observed in EPWB in all indicators.

Survival curve in IPWB (Fig. 2)

Until approximately the post-operative 6th month, survival was practically similar in both groups. After that, Not-IPWB showed worse survival than IPWB for the rest of the follow-up. Results were not statistically significant ($p=0.218$).

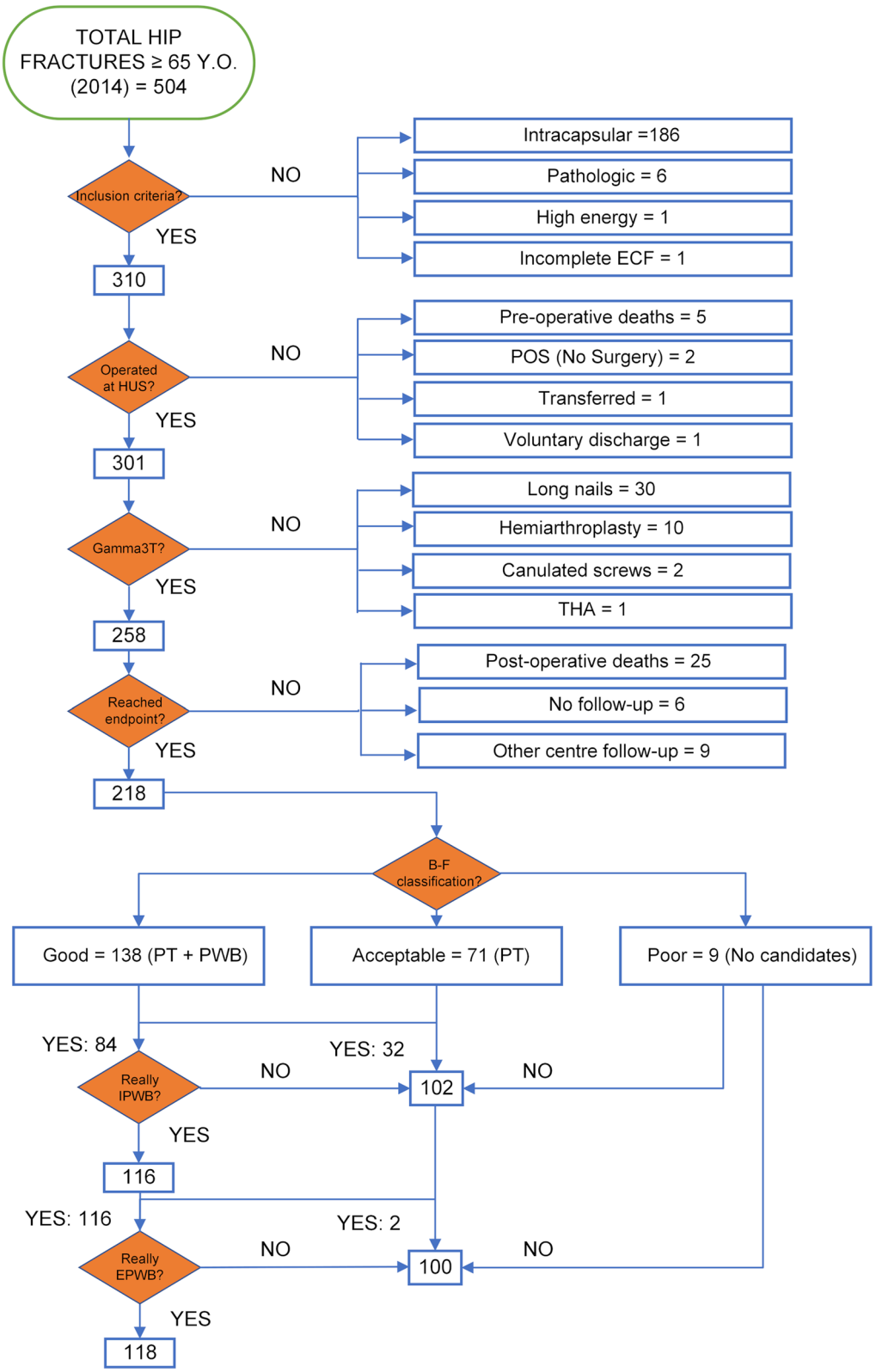

Fig. 1 Organisation chart. *Abbreviations*: *Y.O.* Years-Old, *ECF* Extracapsular fracture, *HUS* Hospital Universitario de Salamanca, *POS* Poor Overall Status, *THA* Total Hip Arthroplasty, *B-F* Baumgaertner-Fogagnolo classification, *PT* Physiotherapy, *PWB* Partial weight bearing, *IPWB* Immediate partial weight bearing, *EPWB* Early partial weight bearing

Table 1 Pre-operative variables

VARIABLE	EPWB	Not-EPWB	P
Number of cases (n)	118	100	
NON-MODIFIABLE			
Average age	86.1 (± 6.55) (65;103)	85.1 (± 6.96) (65;103)	0.304[c]
Gender (Male/Female) %			0.746[a]
- Female	93 (78.8%)	77 (77.0%)	
- Male	25 (21.2%)	23 (23.0%)	
Side			0.334[a]
- Left	52 (44.1%)	37 (37.0%)	
- Right	66 (55.9%)	63 (63.0%)	
MODIFIABLE			
Social situation			0.912[b]
- At home alone	16 (13.6%)	14 (14.0%)	
- At home accompanied	61 (51.7%)	54 (54.0%)	
- Institutionalised	41 (34.7%)	32 (32.0%)	
Dependence			
- Pre-operative Barthel´s index	78.43 (± 19.70) (15;100)	73.50 (± 23.03) (10;100)	0.195[c]
CCI			
- Not age-adjusted	2.23 (± 1.32) (0;7)	2.03 (± 1.21) (0;5)	0.347[c]
- Age-adjusted	6.19 (± 1.33) (4;11)	5.98 (± 1.22) (4;9)	0.288[c]
Cognitive impairment (Pfeiffer's)			0.421[b]
- None	23 (19.5%)	13 (13.0%)	
- Mild	74 (62.7%)	71 (71.0%)	
- Moderate	20 (16.9%)	16 (16.0%)	
- Severe	1 (0.8%)	0 (0.0%)	
Depression			0.667[b]
-No	76 (64.4%)	68 (68%)	
-Yes	42 (35.6%)	32 (32%)	
Osteoporosis (Previous fractures, Nuti's definition)			0.240[b]
- None	77 (65.3%)	53 (53.0%)	
- Traumatic (non-osteoporotic)	4 (3.4%)	2 (2.0%)	
- Osteoporotic:			
- Hip	25 (21.2%)	33 (33.0%)	
- Other locations	9 (7.6%)	7 (7.0%)	
- Both	3 (2.5%)	5 (5.0%)	
Previous Osteoporosis Treatment[#]			0.702[a]
- No	102 (86.4%)	84 (84.0%)	
- Yes	16 (13.6%)	16 (16.0%)	
APT/ACT			0.764[b]
- None	65 (55.1%)	61 (61.0%)	
- Acetylsalicylic Acid 100 mg	27 (22.9%)	15 (15.0%)	
- Acetylsalicylic Acid 300 mg	10 (8.5%)	8 (8.0%)	
- Clopidogrel	0 (0%)	1 (1.0%)	
- Acenocumarol	14 (11.9%)	13 (13.0%)	
- Direct Xa inhibitors	1 (0.8%)	1 (1.0%)	
- LMWH	1 (0.8%)	1 (1.0%)	
ASA Risk Score	3.0 (1;4)	3.0 (1;4)	0.540[d]

Abbreviations: *EPWB* Early partial weight bearing group, *Not-EPWB* Not-Early partial weight bearing group, *CCI* Charlson comorbidity index, *APT* Antiplatelet therapy, *ACT* Anticoagulation therapy, *LMWH* Low molecular weight heparin, *ASA* American Society of Anaesthesiologists

[#] Upon admission, not calcium and/or vitamin D.

Tests: a. Fisher's exact test. b. Pearson's chi-square test. c. Mann–Whitney U test. d. Median test

[*] *P*-value < 0.05

Table 2 Peri-operative variables

VARIABLE	EPWB	Not-EPWB	P
Number of cases (n)	118	100	
Average stay (days)	9.10 (± 3.06) (4;20)	10.1 (± 3.54) (4;26)	0.026[c*]
Pre-operative stay (days)	2.86 (± 2.54) (0;9)	3.64 (± 2.47) (0;9)	0.031[c*]
Post-operative stay (days)	6.22 (± 2.20) (3;20)	6.39 (± 3.22) (3;25)	0.608[c]
Immediate post-operative estimated blood loss (g/dl Hb)	2.06 (± 1.65) (-3.5;5.9)	1.88 (± 1.81) (-2.5;5.8)	0.552[c]
Total transfusions (red blood cell concentrate bags)	1.29 (± 1.37) (0;8)	1.34 (± 1.39) (0;8)	0.837[c]
Social situation at discharge			0.328[b]
- At home alone	0 (0.0%)	0 (0.0%)	
- At home accompanied	55 (46.6%)	40 (40.0%)	
- Institutionalised	63 (53.4%)	60 (60.0%)	
Dependence			
- Post-operative Barthel´s index	55.30 (± 19.19) (10;85)	37.65 (± 18.42) (10;75)	< 0.001[c*]
- Absolute Barthel Difference (ABD)	-23.1 (± 11.75) (-65.0;10.0)	-35.9 (± 18.2) (-80.0;0.00)	.000[c*]
- Relative Functional Gain (RFG)	-0.35 (± 0.76) (-0.83;0.78)	-0.48 (± 0.19) (-0.85;0.00)	.000[c*]

Abbreviations: *EPWB* Early partial weight bearing group, *Not-EPWB* Not-Early partial weight bearing group, *Hb* haemoglobin

Tests: a. Fisher's exact test. b. Pearson's chi-square test. c. Mann–Whitney U test. d. Median test

[*] *P*-value < 0.05

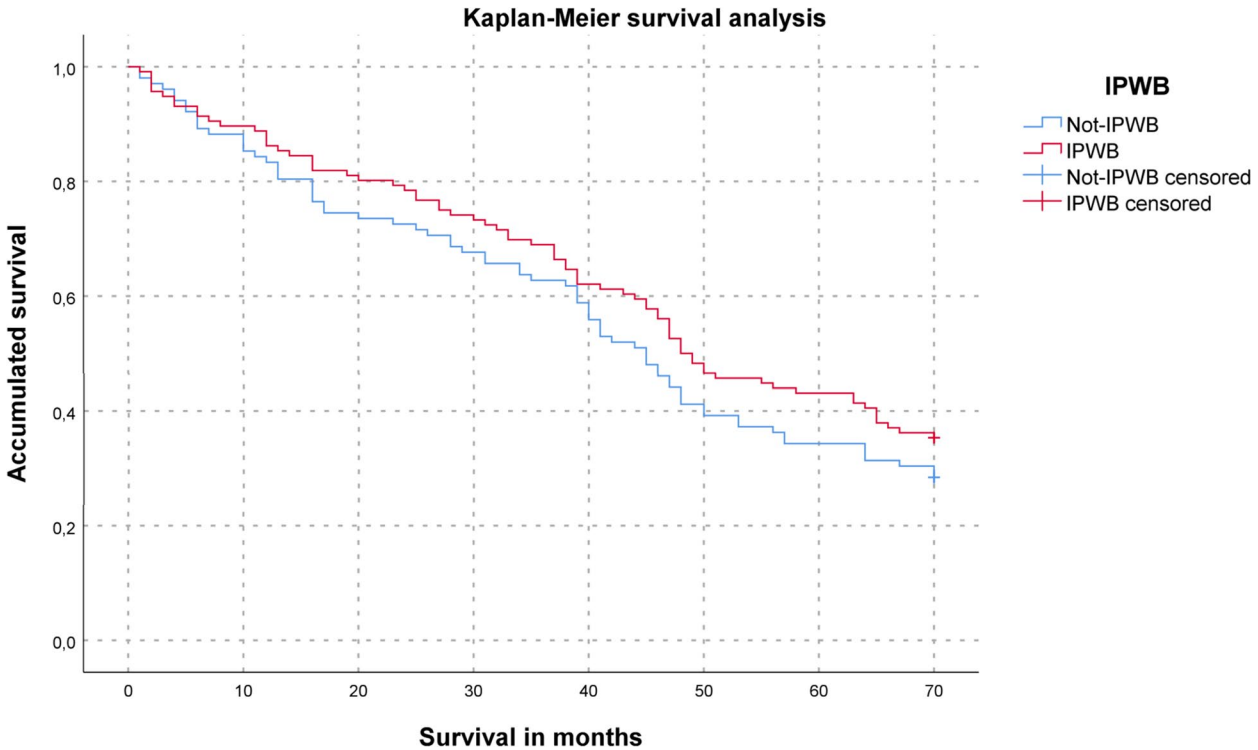

Fig. 2 Survival in IPWB and Not-IPWB after > 5 years' follow-up

Survival curve in EPWB (Fig. 3)

The outcome during the first year post surgery was worse in the EPWB group. The groups subsequently evened out until approximately the third and a half year. After that, Not-EPWB showed worse survival. Results were not statistically significant ($p=0.283$).

Final Mobility (Fracture Mobility Score, FMS) in IPWB and EPWB (Figs. 4, 5, 6 and 7)

We did not observe statistically significant differences in the final FMS between IPWB and Not-IPWB ($p=0.334$), but we did between EPWB and Not-EPWB, being the former superior ($p=0.001$).

Univariate Cox regression analysis for survival

Clinical factors (Table 3)

Age (for each year of increment), CCI (not age-adjusted), ASA score, pre-operative urinary catheter, a higher degree of immediate post-operative estimated blood loss, post-operative delirium and nursing homes as destination after discharge were related.

Radiological factors (Table 4)

No radiological factors of poor prognosis were found to be significant regarding death.

Multivariate Cox regression analysis for survival (Fig. 8)

Age (for each year of increment), not age-adjusted CCI (=2 moderate comorbidity), and a higher degree of immediate post-operative estimated blood loss were finally identified as independent risk factors for death.

Survival curves in EPWB stratified by age, gender and comorbidity

- **Age (Fig. 9)**

Age was stratified (≥65–80, 80–90, ≥90 years old), given the lack of consensus on the definition of young elderly, moderate elderly and old elderly.

- **Gender (Fig. 10)**
- **Comorbidity (Fig. 11)**

We stratified the not-age-adjusted CCI using the original version [27], classifying comorbidity as 0–1, 2 and ≥3 (absence, low and high, respectively).

Discussion

Re-establishing post-operative PWB is one of the main goals in order to reduce clinical and medical complications [31], which is the main reason for it to be

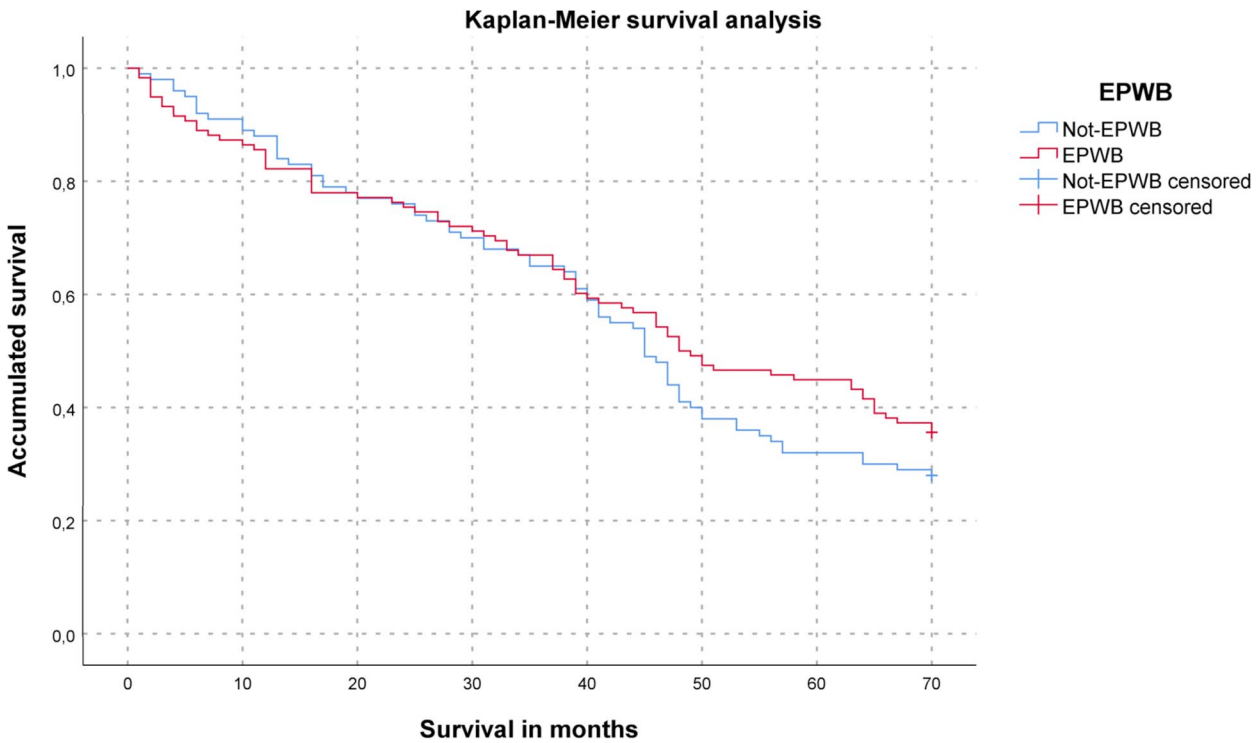

Fig. 3 Survival in EPWB and Not-EPWB after > 5 years' follow up

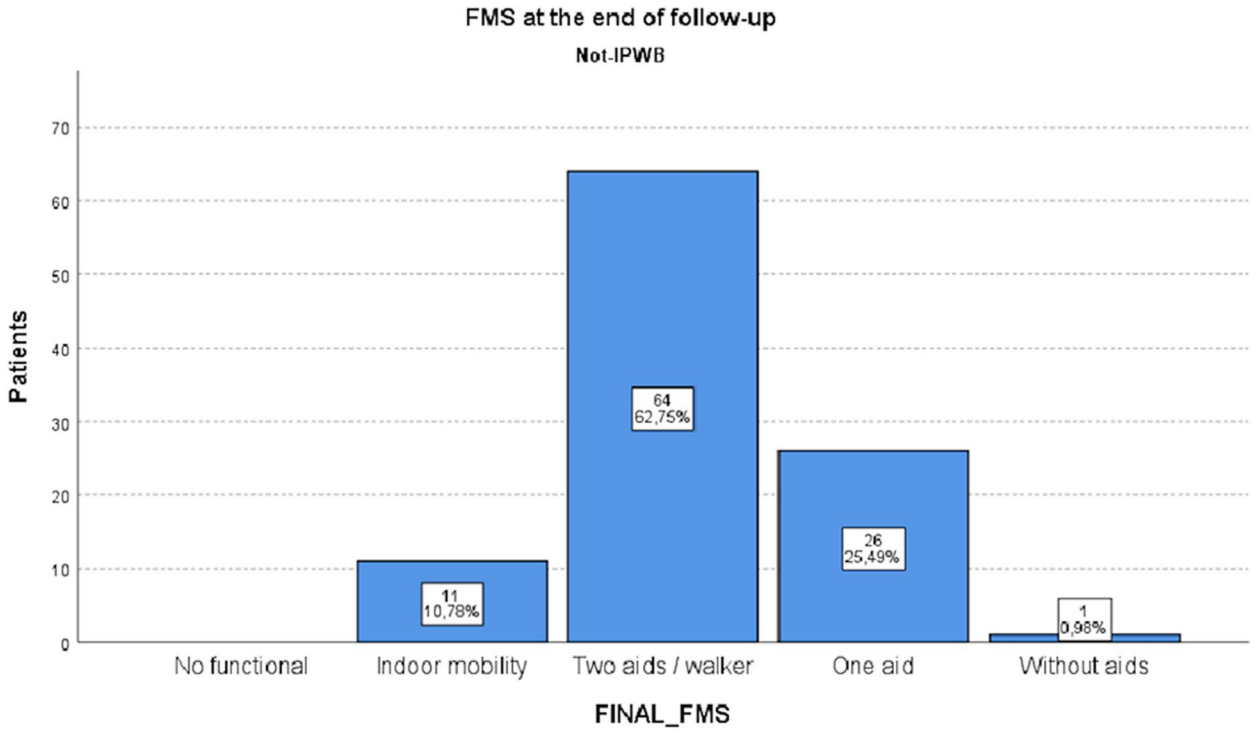

Fig. 4 Final degree of mobility obtained (FMS) in Not-IPWB

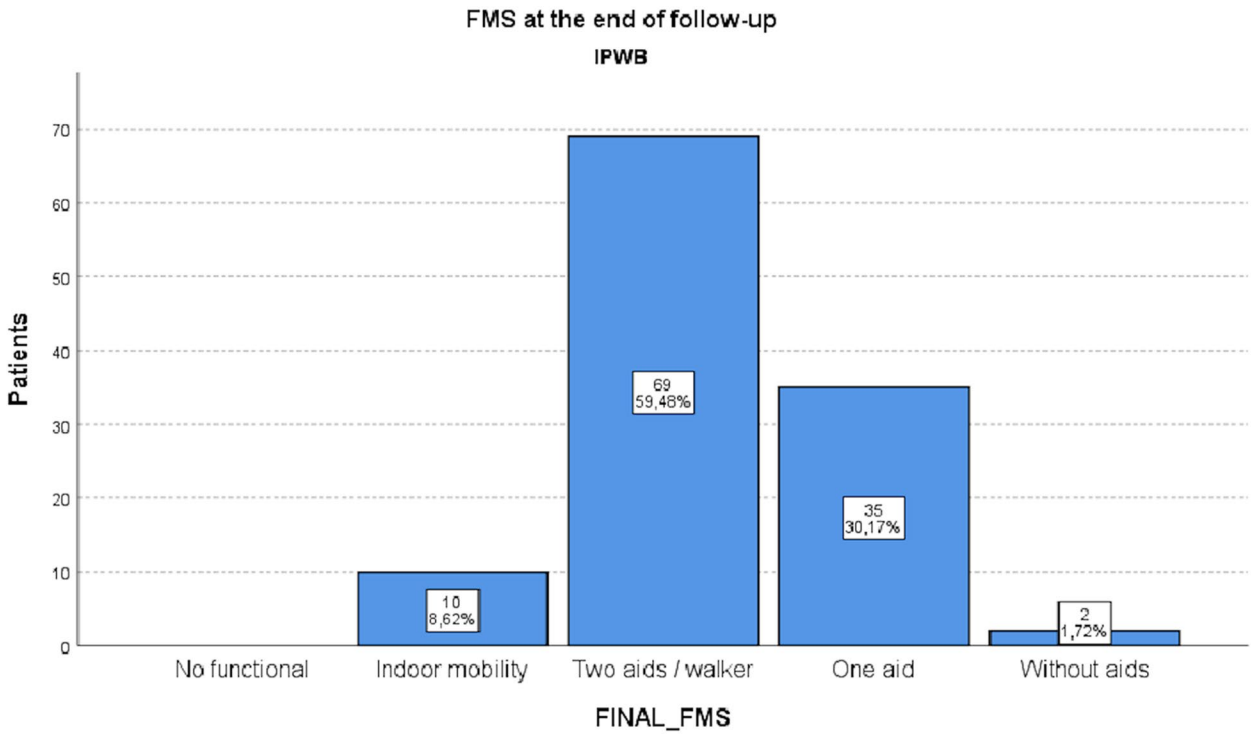

Fig. 5 Final degree of mobility obtained (FMS) in IPWB

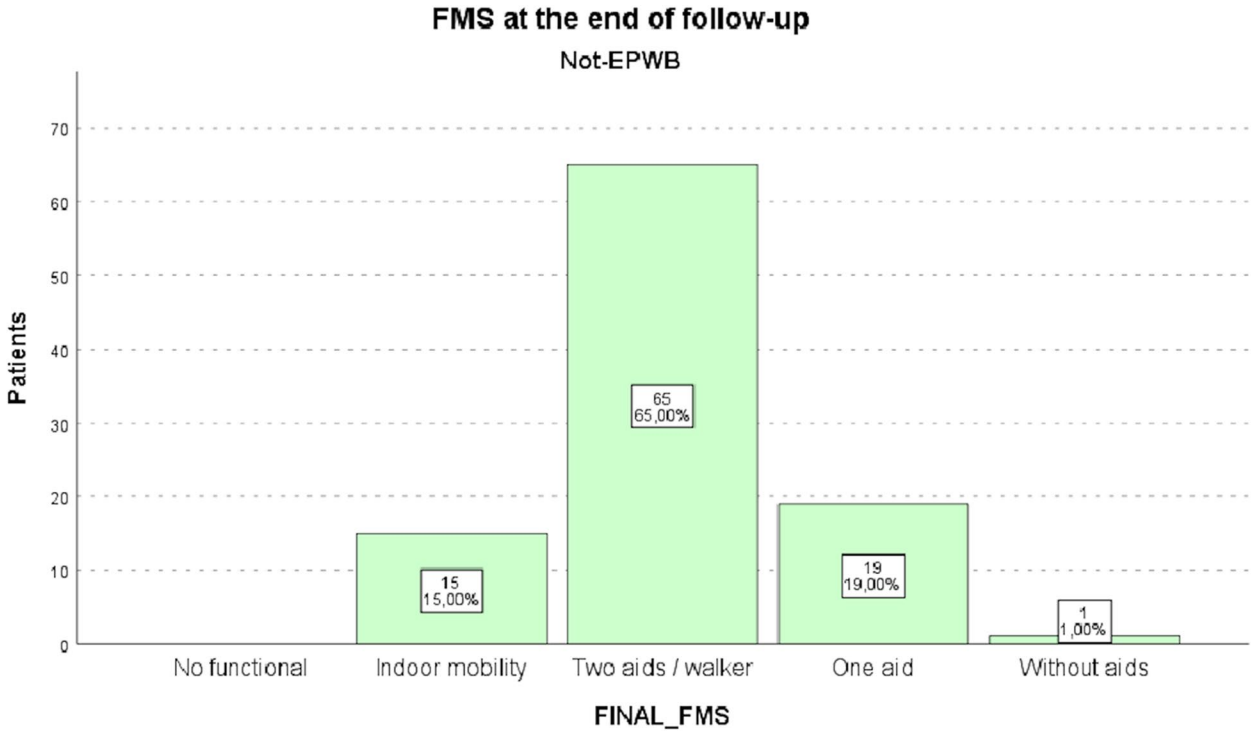

Fig. 6 Final degree of mobility obtained (FMS) in Not-EPWB

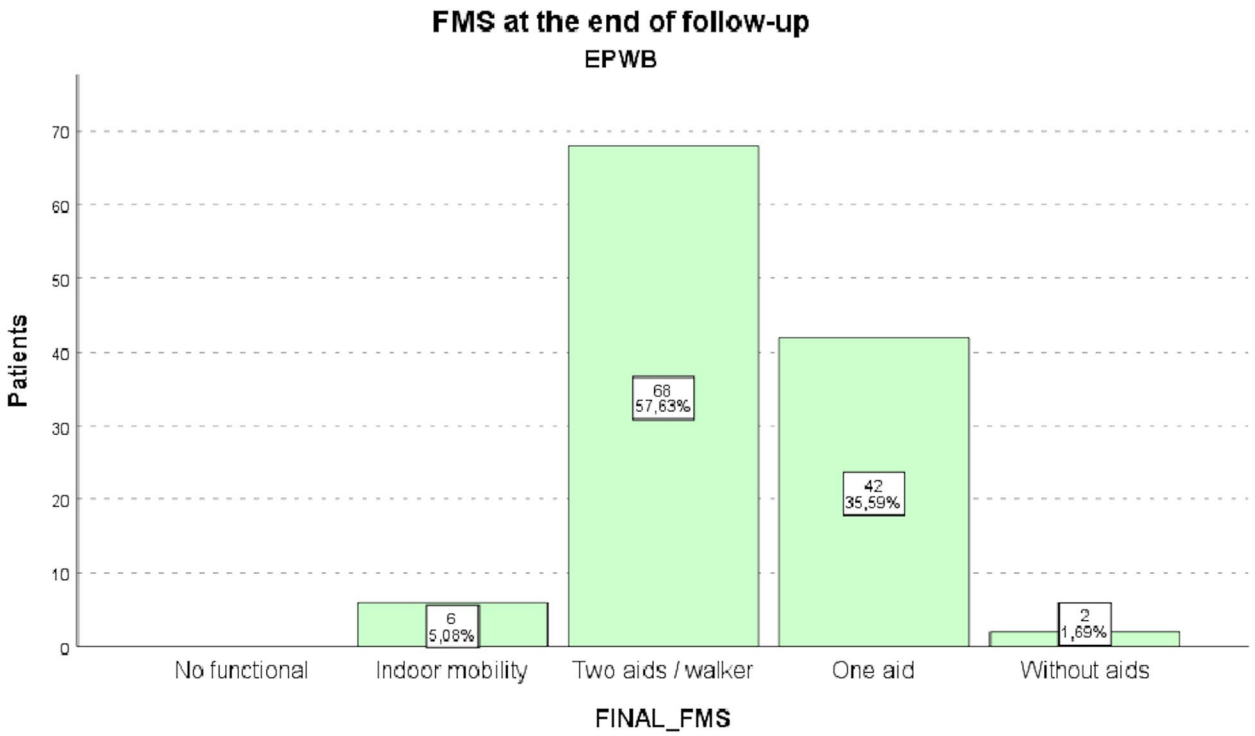

Fig. 7 Final degree of mobility obtained (FMS) in EPWB

Table 3 Univariate analysis of clinical factors

VARIABLE	HR (95% CI)	P
Age (per 1 year increase)	1.074 (1.046–1.104)	0.000*
Gender		
- Female (reference)		
- Male	1.389 (0.954–2.022)	0.087
Cognitive impairment (Pfeiffer's)		
- None (reference)		0.241
- Mild	0.761 (0.415–1.393)	0.376
- Moderate	1.264 (0.742–2.154)	0.389
- Severe	1.116 (0.627–1.987)	0.710
Pre-operative depression		
- No (reference)		
- Yes	0.866 (0.729–1.028)	0.100
Concomitant fractures		
- None (reference)		0.294
- Ipsilateral distal forearm fracture	1.369 (0.854–2.195)	0.114
- Ipsilateral arm fracture	1.799 (1.025–3.158)	0.863
- Other combinations	2.085 (0.279–15.561)	0.279
CCI non-modified by age		
- 0–1 (mild) (reference)		0.015*
- 2 (moderate)	1.566 (1.035–2.369)	0.034*
- ≥ 3 (serious)	1.745 (1.181–2.579)	0.005*
CCI modified by age	All category 3	
- 0–1 (mild) (reference)		
- 2 (moderate)		
- ≥ 3 (severe)		
ASA score		
- 1 (reference)		0.009*
- 2	0.691 (0.315–1.516)	0.357
- 3	0.956 (0.441–2.072)	0.909
- 4	2.736 (0.917–8.162)	0.071
Pre-operative waiting time (days)	1.017 (0.953–1.086)	0.603
Pre-operative time (days)	1.032 (0.977–1.091)	0.258
Total admission days	1.035 (0.987–1.086)	0.151
Pre-operative urinary catheter		
- No (reference)		
- Yes	1.806 (1.058–3.084)	0.030*
Post-operative urinary catheter		
- No (reference)		
- Yes	1.076 (0.778–1.488)	0.659
Immediate post-operative estimated blood loss (per 1g/dl Hb decrease)	0.884 (0.803–0.974)	0.013*
Total transfusions		
- No (reference)		
- Yes	1.195 (0.857–1.668)	0.294
Post-operative delirium		
- No (reference)		
- Yes	1.477 (1.069–2.041)	0.018*
Post-operative medical complications		
- No (reference)		
- Yes (≥ 1)	1.104 (0.794–1.534)	0.556

Table 3 (continued)

VARIABLE	HR (95% CI)	P
IPWB		
- No (reference)		
- Yes	0.818 (0.593–1.130)	0.223
Social Situation at discharge		
- At home alone	-	-
- At home accompanied (reference)		
- Institutionalised	1.676 (1.198–2.344)	0.003*
Relative Functional Gain (RFG)	0.534 (0.244–1.165)	0.115
EPWB		
- No (reference)		
- Yes	0.839 (0.608–1.159)	0.288

Abbreviations: *HR* Hazard ratio, *CI* Confidence interval, *CCI* Charlson comorbidity index, *ASA* American Society of Anaesthesiologists, *Hb* haemoglobin, *IPWB* Immediate partial weight bearing, *EPWB* Early partial weight bearing

* *P*-value < 0.05

immediately authorised in ECF with the objective of restoring these patients' autonomy and independence.

The benefits of preventing organic system deterioration caused by immobility seem to have been really proven only in operated ICF [32]. We did not find a fast improvement in ECF survivorship with IPWB and EPWB, but rather a progressive positive turn towards the end of the follow-up period, which happens earlier the earlier it is started. IPWB could set the favourable survival turning point in about 2.5 years post-operative earlier than EPWB, since our work evaluated really long-term survival in comparison to previous similar studies [16]. These initial results might be related to the need of supervising and/or protecting WB when the conditions (patient, reduction and/or osteosynthesis) are not completely favourable, whereas the final outcomes would be in accordance with the theoretical concept of its beneficial physiological effect. These findings are compatible with the last Handoll revision [11], but more reliable evidence is still needed, supporting the increasingly criticised universal IPWB.

It is currently unknown what the best post-operative rehabilitating protocol is for hip fractures [8]. Anyway, monitoring of elderly patients' WB is really complex. We have introduced that up to 25% of patients do not comply with loading due to various reasons, but it is often systematically ignored in many works through the statement "all patients bore weight" [17, 18]. In our investigation, with an age average around 85 years-old, moderate-high comorbidities and important cognitive impairment, almost 40% (54/138) of good reduction cases did not achieve IPWB (upon discharge), remarking valuable load differences described between ICF and ECF [34]. On the other hand, some patients for whom WB is not initially authorised but do it, especially when he/she remains without direct supervision in the ward. This event happened in 15% (12/80) of our cases, although none of them belonged to the group not eligible for any PWB. Recent works about compliance in PWB have reported this problem, especially frequent in elderly [15, 35]. Finally, it is difficult to know the absolute true value of PWB in these patients, but recent advances noted that approximately 25–30% overload, especially in obese people [36].

The final FMS obtained was not influenced by IPWB, but it was by EPWB, which leads to suspect the relatively scarce importance of the former regarding evaluation of gait in ECF. Lahtinen has reported a certain delay in the improvement of functional status after post-operative rehabilitation protocols, although he only has recorded it for ICF [7].

We propose to standardise and correctly register time and type of PWB in this population[15]. This would allow to use the same language, avoiding the currently existing confusion, even more so in the context of enormous international inequality among healthcare models [10, 37]. This trend is already presented, also complemented with the recommendation of checking the quality of reduction and fixation in ECF [18, 38].

EPWB kept a significantly better degree of independence after a month. The interrelation existing between gait capacity and dependence has been previously reported [39] and has been given increasing importance, as a more reliable influence for short-term functional recovery than PWB itself. The causes why benefit in dependence does not immediately translate into survival are unknown, but they may be related to the relatively

Table 4 Univariate analysis of radiological factors

VARIABLE	HR (95% CI)	P
AO/OTA classification (1997)	0.883 (0.433–1.800)	0.731
- A1 (reference)		0.624
- A2	1.016 (0.712–1.449)	0.932
- A3	0.713 (0.371–1.371)	0.310
- B2	0.755 (0.357–1.595)	0.462
Basicervical-equivalent (Massoud classification)		
- No (reference)		
- Yes	1.174 (0.835–1.651)	0.355
Baumgaertner-Fogagnolo classification		
- Good (reference)		0.257
- Acceptable	2.115 (0.762–5.869)	0.150
- Poor	2.294 (0.843–6.239)	0.104
GammaTScore classification		
- Good (reference)		0.791
- Moderate	1.071 (0.598–1.920)	0.817
- Poor	1.188 (0.644–2.191)	0.580
Reduction		
- Good (reference)		0.419
- Moderate	1.318 (0.830–2.093)	0.242
- Poor	1.330 (0.850–2.080)	0.212
Osteosynthesis		
- Good (reference)		0.504
- Moderate	1.178 (0.744–1.865)	0.485
- Poor	1.299 (0.836–2.017)	0.245
Instability		
- Good (reference)		0.653
- Moderate	1.051 (0.616–1.795)	0.854
- Poor	0.881 (0.499–1.555)	0.662
Tip-apex distance (TAD), mm		
- ≤ 25 mm (reference)		
- > 25 mm	0.990 (0.965–1.016)	0.457
PLD position (Cleveland classification)		
-Centre-centre (reference)		0.266
-Superior-central	0.379 (0.139–1.032)	0.058
-Posterosuperior	-	-
-Anterior-central	0.619 (0.332–1.157)	0.133
-Anterosuperior	0.404 (0.099–1.639)	0.204
-Posterior-central	0.532 (0.216–1.309)	0.170
-Anteroinferior	0.563 (0.079–4.042)	0.568
-Inferior-central	0.735 (0.426–1.268)	0.269
-Posteroinferior	0.884 (0.513–1.524)	0.657

Abbreviations: *HR* Hazard ratio, *CI* Confidence interval, *AO/OTA* AO Foundation/Orthopaedic Trauma Association, *PLD* Proximal locking device (cephalic screw)

* *P*-value < 0.05

long time to achieve final consolidation in ECF, the possible additional stress implied by WB, and the presence of residual pain or inflammation [11, 40]. Therefore, we believe that post-operative protocols must be soft, related with patient's physiological recovery, and properly supervised [41].

Old age, male gender, institutionalisation, or even blood transfusions during hospitalisation have traditionally related with lower survival, although many studies do not differentiate between ICF and ECF [42]. Our univariate study maintains age and institutionalisation, and adds other elements, except for male gender

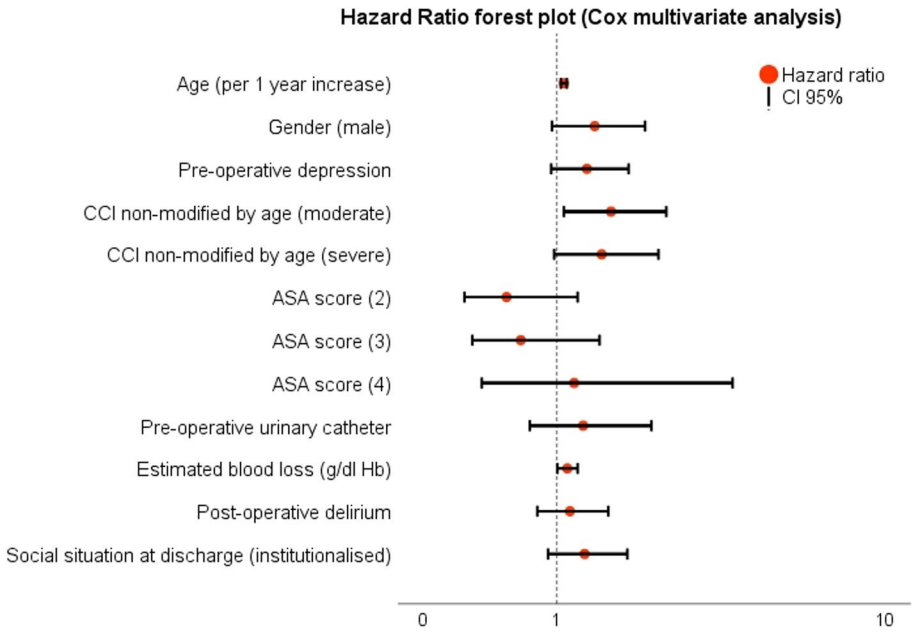

Fig. 8 Forest-plot of multivariate Cox analysis. *Abbreviations*: *CCI* Charlson comorbidity index, *ASA* American Society of Anaesthesiologists, *CI* Confidence interval

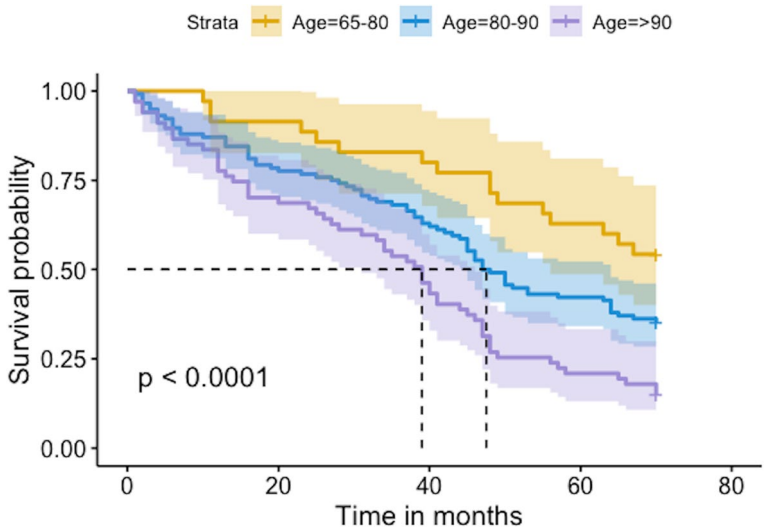

Fig. 9 Mortality stratified by age

(most of our sample has been female, so it has probably led to its lack of significance, although in Fig. 10 difference was obvious). Other possible factors are also reflected, like post-operative delirium -related to cognitive impairment [43]-, or even nursing homes as destination, although the different facilities and protocols existing in them [44].

There is a negative growing criticism for universal post-operative WB, especially in which unsatisfactory reductions are exposed [26], as well as deficient surgical techniques and/or unstable fractures [38]. This could all increase the potential risk of NTMC and associated morbidity and mortality, an aspect that has been suggested in recent studies [33], but hardly to be proved yet. However, in our outcomes no poor-prognosis radiological factors regarding NTMC were related to death, probably due to the low ratio of major NTMC registered (11/218).

After all, only age, moderate comorbidity and a higher rate of immediate post-operative estimated blood loss

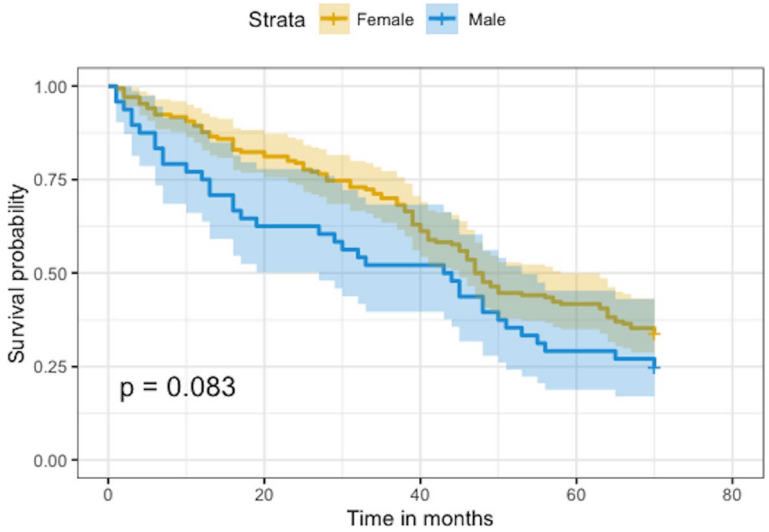

Fig. 10 Mortality stratified by gender

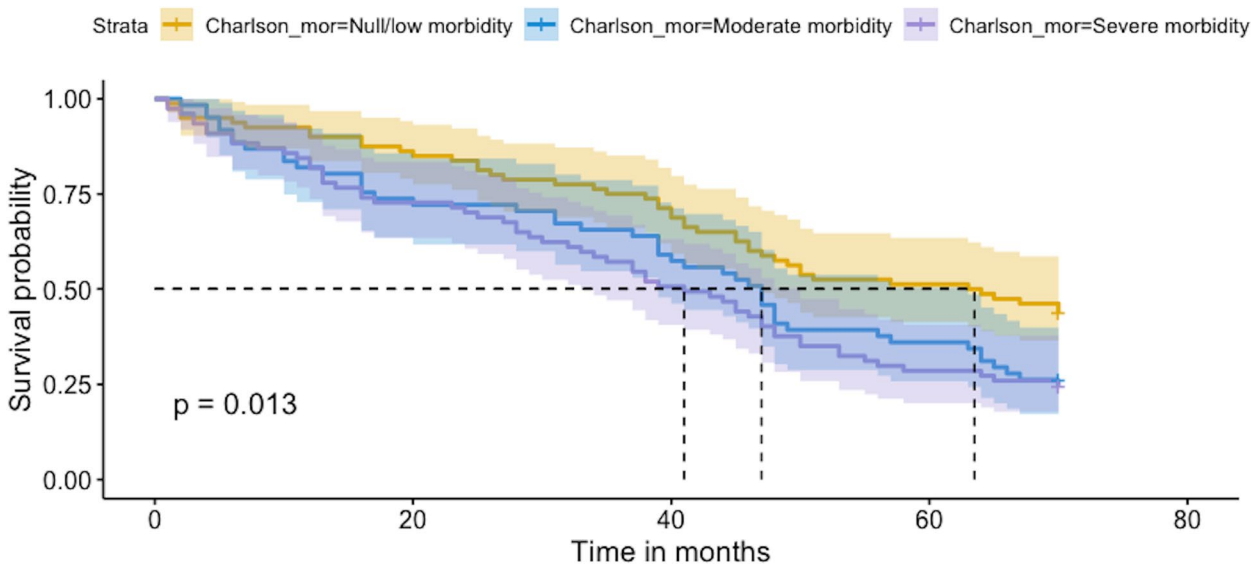

Fig. 11 Mortality stratified by comorbidity (not-age-adjusted CCI)

finally get an independent impact. Many others are borderline significant, which is compatible with existing literature [45], with regional marked differences.

This research has certain limitations, such as its retrospective, non-randomised design, the relatively low statistical potency, its monocentric character and the disavantage of not counting on a mid-term care hospitalisation unit. Nevertheless, we must highlight its strengths: inclusion/exclusion criteria to prevent bias; one single type of fracture (ECF), surgical treatment and implant; exhaustive post-operative monitoring included WB and a comprehensive and systematic long-term follow-up. Additionally, no great loss to follow-up has been reported.

Conclusions

IPWB and EPWB could produce some benefit on the survival of elderly patients surgically treated ECF with a cephalomedullary short femoral nail, but only in the mid/long-term and with an at least acceptable degree of reduction. The FMS achieved were influenced only by EPWB. Dependence seems to be more useful than PWB

in short-term functional prognosis. Numerous clinical but not radiological factors related to early death, but the multivariate model only gives real relevance to age, moderate comorbidity and the higher degree of post-operative estimated blood loss. Therefore, PWB should be optimally supervised and adapted individually.

Abbreviations

WB	Weight bearing
RFG	Relative functional gain
ICF	Intracapsular fracture
ECF	Extracapsular fracture
PWB	Partial weight bearing
PT	Physiotherapy
IPWB	Immediate partial weight bearing
EPWB	Early partial weight bearing
PLD	Proximal locking device
FMS	Fracture Mobility Score
ASA	American Society of Anaesthesiologists
CCI	Charlson comorbidity index
APT	Antiplatelet therapy
ACT	Anticoagulant therapy
NTMC	Non-traumatic mechanical complications

Acknowledgements
We thank Mrs. María Teresa Prendes-González, Secretary of the Department of Trauma and Orthopaedic Surgery, and Mrs. María Ángela Centeno-Garrido, Head of Physiotherapy Unit, for their collaboration in data collection and Mr. Ángel Sánchez-Hernández, Ph.D. in Mathematics, for his valuable support with source data handling and database improvements.

Author's contributions
C.H-P. was involved in the conception and design of the study and oversaw and provided quality assurance on all the study output. C.H-P., J.A.S–S. and J.A.M-C. were involved in the conception and design of the study and drafted the manuscript. J.H.R. and C.F.S-V. assisted in statistical analysis. C.P–H. and P.A.R. revised the article critically for important intellectual content. All authors read and approved the final manuscript.

Funding
Not applicable.

Data availability
There is a total availability of fata and material (data transparency, open access science). The dataset supporting the conclusions of this article can be visited/used in the Gredos Universidad de Salamanca repository at https://doi.org/10.14201/gredos.160675 in http://hdl.handle.net/10366/160675.

Declarations

Ethics approval and Consent to participate
The present study was approved by the Institutional Review Board (Ethics Committee of the Salamanca Health Area for Research with Medicines and Health Care, reference code: PI 2021 05 789) and was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.
Informed consent was obtained from all individual participants included in the study.

Consent for publication
The research results are published at a general level. It is not possible to identify an individual from the results. The manuscript does not contain data of individuals in any form (including personal data, images or videos).

Competing interest
The authors declare no competing interests.

Author details
[1]Department of Trauma and Orthopaedic Surgery, Hospital Universitario de Salamanca, Paseo de la Transición Española, 37007 Salamanca, Spain. [2]Department of Radiology, Hospital Universitario de Salamanca, Paseo de la Transición Española, 37007 Salamanca, Spain. [3]Department of Medical Physics and Radiation Protection, Hospital Universitario de Salamanca, Paseo de la Transición Española, 37007 Salamanca, Spain. [4]Department of Statistics, Faculty of Medicine, Universidad de Salamanca. Campus Miguel de Unamuno, Avda. Alfonso X El Sabio S/N, 37007 Salamanca, Spain. [5]Department of Geriatrics, Hospital Universitario de Salamanca, Paseo de la Transición Española, 37007 Salamanca, Spain. [6]Department of Rehabilitation, Hospital Universitario de Salamanca, Paseo de la Transición Española, 37007 Salamanca, Spain. [7]Department of Biomedical and Diagnostic Sciences. Preventive Medicine and Public Health, Faculty of Medicine, Universidad de Salamanca. Campus Miguel de Unamuno, Avda. Alfonso X El Sabio S/N, 37007 Salamanca, Spain.

Received: 21 April 2024 Accepted: 8 November 2024
Published online: 07 February 2025

References

1. Herrera A, Martínez AA, Ferrandez L, Gil E, Moreno A. Epidemiology of osteoporotic hip fractures in Spain. Int Orthop. 2006;30(1):11–4.
2. Smith T, Pelpola K, Ball M, Ong A, Myint PK. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing. 2014;43(4):464–71.
3. González-Montalvo JI, Alarcón T, Hormigo Sánchez AI. Why do hip fracture patients die? Med Clin (Barc). 2011;137(8):355–60.
4. Roberts KC, Brox WT, Jevsevar DS, Sevarino K. Management of hip fractures in the elderly. J Am Acad Orthop Surg. 2015;23(2):131–7.
5. Kristensen PK, Thillemann TM, Søballe K, Johnsen SP. Can improved quality of care explain the success of orthogeriatric units? A population-based cohort study Age Ageing. 2016;45(1):66–71.
6. Baztán JJ, Domenech JR, González M, Forcano S, Morales C, Ruipérez I. Functional gain and length of hospital stay at a medium-stay geriatric care unit at the Central Red Cross Hospital in Madrid, Spain. Rev Esp Salud Publica. 2004;78(3):355–66.
7. Lahtinen A, Leppilahti J, Harmainen S, Sipilä J, Antikainen R, Seppänen ML, et al. Geriatric and physically oriented rehabilitation improves the ability of independent living and physical rehabilitation reduces mortality: a randomised comparison of 538 patients. Clin Rehabil. 2015;29(9):892–906.
8. Handoll HH, Sherrington C, Mak JC. Interventions for improving mobility after hip fracture surgery in adults. Cochrane Database Syst Rev. 2011;3:CD001704.
9. Mahoney F, Barthel D. Functional Evaluation: the Barhel index. Md State Med J. 1965;14:61–5.
10. Lizano-Díez X, Keel MJB, Siebenrock KA, Tey M, Bastian JD. Rehabilitation protocols in unstable trochanteric fractures treated with cephalomedullary nails in elderly: current practices and outcome. Eur J Trauma Emerg Surg. 2020;46(6):1267–80.
11. Handoll HH, Cameron ID, Mak JC, Panagoda CE, Finnegan TP. Multidisciplinary rehabilitation for older people with hip fractures. Cochrane Database Syst Rev. 2021;11(11):CD007125.
12. Koval KJ, Sala DA, Kummer FJ, Zuckerman JD. Postoperative weight-bearing after a fracture of the femoral neck or an intertrochanteric fracture. J Bone Joint Surg Am. 1998;80(3):352–6.
13. Koval KJ, Friend KD, Aharonoff GB, Zukerman JD. Weight bearing after hip fracture: a prospective series of 596 geriatric hip fracture patients. J Orthop Trauma. 1996;10(8):526–30.
14. Nordin M, Frankel V. Biomechanics of the hip. In: Nordin M, Frankel V, editors. Basic Biomechanics of the Musculoskeletal System. 2nd ed. Malvern, PA: Lea & Febiger; 1989. p. 135–61.
15. Yu S, McDonald T, Jesudason C, Stiller K, Sullivan T. Orthopedic inpatients' ability to accurately reproduce partial weight bearing orders. Orthopedics. 2014;37(1):e10–8.
16. Ariza-Vega P, Kristensen MT, Martín-Martín L, Jiménez-Moleón JJ. Predictors of long-term mortality in older people with hip fracture. Arch Phys Med Rehabil. 2015;96(7):1215–21.

17. Aguado-Maestro I, Escudero-Marcos R, García-García JM, Alonso-García N, Pérez-Bermejo DD, Aguado-Hernández HJ, et al. Results and complications of pertrochanteric hip fractures using an intramedullary nail with a helical blade (proximal femoral nail antirotation) in 200 patients. Rev Esp Cir Ortop Traumatol. 2013;57(3):201–7.
18. Marmor M, Guenthner G, Rezaei A, Saam M, Matityahu A. Reporting on quality of reduction and fixation of intertrochanteric fractures-A systematic review. Injury. 2021;52(3):324–9.
19. Barone A, Giusti A, Pizzonia M, Razzano M, Oliveri M, Palummeri E, et al. Factors associated with an immediate weight-bearing and early ambulation program for older adults after hip fracture repair. Arch Phys Med Rehabil. 2009;90(9):1495–8.
20. Xu BY, Yan S, Low LL, Vasanwala FF, Low SG. Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. BMC Musculoskelet Disord. 2019;20(1):568.
21. Ariza-Vega P, Lozano-Lozano M, Olmedo-Requena R, Martín-Martín L, Jiménez-Moleón JJ. Influence of Cognitive Impairment on Mobility Recovery of Patients With Hip Fracture. Am J Phys Med Rehabil. 2017;96(2):109–15.
22. Mayoral AP, Ibarz E, Gracia L, Mateo J, Herrera A. The use of Barthel index for the assessment of the functional recovery after osteoporotic hip fracture: One year follow-up. PLoS ONE. 2019;14(2): e0212000.
23. Atay İ, Aslan A, Burç H, Demirci D, Atay T. Is depression associated with functional recovery after hip fracture in the elderly? J Orthop. 2016;13(2):115–8.
24. Fogagnolo F, Kfuri M, Paccola CA. Intramedullary fixation of pertrochanteric hip fractures with the short AO-ASIF proximal femoral nail. Arch Orthop Trauma Surg. 2004;124(1):31–7.
25. Voeten SC, Nijmeijer WS, Vermeer M, Schipper IB, Hegeman JH, group DTs. Validation of the Fracture Mobility Score against the Parker Mobility Score in hip fracture patients. Injury. 2020;51(2):395–9.
26. Hernández-Pascual C, Santos-Sánchez J, Hernández-Rodríguez J, Silva-Viamonte CF, Pablos-Hernández C, Villanueva-Martínez M, et al. New Prognostic Factors in Operated Extracapsular Hip Fractures: Infection and GammaTScore. Int J Environ Res Public Health. 2022;19(18):1-13.
27. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40(5):373–83.
28. Martínez de la Iglesia J, Dueñas Herrero R, Onís Vilches MC, Aguado Taberné C, Albert Colomer C, Luque Luque R. [Spanish language adaptation and validation of the Pfeiffer's questionnaire (SPMSQ) to detect cognitive deterioration in people over 65 years of age]. Med Clin (Barc). 2001;117(4):129–34.
29. Nuti R, Brandi ML, Isaia G, Tarantino U, Silvestri S, Adami S. New perspectives on the definition and the management of severe osteoporosis: the patient with two or more fragility fractures. J Endocrinol Invest. 2009;32(9):783–8.
30. Fitz-Henry J. The ASA classification and peri-operative risk. Ann R Coll Surg Engl. 2011;93(3):185–7.
31. Ariza-Vega P, Jiménez-Moleón JJ, Kristensen MT. Non-weight-bearing status compromises the functional level up to 1 yr after hip fracture surgery. Am J Phys Med Rehabil. 2014;93(8):641–8.
32. Peeters CM, Visser E, Van de Ree CL, Gosens T, Den Oudsten BL, De Vries J. Quality of life after hip fracture in the elderly: A systematic literature review. Injury. 2016;47(7):1369–82.
33. Yamamoto N, Tsujimoto Y, Yokoo S, Demiya K, Inoue M, Noda T, et al. Association between Immediate Postoperative Radiographic Findings and Failed Internal Fixation for Trochanteric Fractures: Systematic Review and Meta-Analysis. J Clin Med. 2022;11(16):1–12.
34. Pfeufer D, Grabmann C, Mehaffey S, Keppler A, Böcker W, Kammerlander C, et al. Weight bearing in patients with femoral neck fractures compared to pertrochanteric fractures: A postoperative gait analysis. Injury. 2019;50(7):1324–8.
35. Seo H, Lee GJ, Shon HC, Kong HH, Oh M, Cho H, et al. Factors Affecting Compliance With Weight-Bearing Restriction and the Amount of Weight-Bearing in the Elderly With Femur or Pelvic Fractures. Ann Rehabil Med. 2020;44(2):109–16.
36. Eickhoff AM, Cintean R, Fiedler C, Gebhard F, Schütze K, Richter PH. Analysis of partial weight bearing after surgical treatment in patients with injuries of the lower extremity. Arch Orthop Trauma Surg. 2022;142(1):77–81.
37. Braun BJ, Veith NT, Rollmann M, Orth M, Fritz T, Herath SC, et al. Weight-bearing recommendations after operative fracture treatment-fact or fiction? Gait results with and feasibility of a dynamic, continuous pedobarography insole. Int Orthop. 2017;41(8):1507–12.
38. Macdonald H, Brown R, Gronager M, Close J, Fleming T, Whitehouse M. Quality of fracture reduction is associated with patient survival at one year, but not 30 days, following trochanteric hip fracture fixation. A retrospective cohort study Injury. 2022;53(3):1160–3.
39. da Casa C, Pablos-Hernández C, González-Ramírez A, Julián-Enriquez JM, Blanco JF. Geriatric scores can predict long-term survival rate after hip fracture surgery. BMC Geriatr. 2019;19(1):205.
40. Moldovan F. Sterile Inflammatory Response and Surgery-Related Trauma in Elderly Patients with Subtrochanteric Fractures. Biomedicines. 2024;12(2):1–15
41. Tarrant SM, Attia J, Balogh ZJ. The influence of weight-bearing status on post-operative mobility and outcomes in geriatric hip fracture. Eur J Trauma Emerg Surg. 2022;48(5):4093–103.
42. Bajracharya R, Guralnik JM, Shardell MD, Rathbun AM, Yamashita T, Hochberg MC, et al. Long-term sex differences in all-cause and infection-specific mortality post hip fracture. J Am Geriatr Soc. 2022;70(7):2107–14.
43. Schaller F, Sidelnikov E, Theiler R, Egli A, Staehelin HB, Dick W, et al. Mild to moderate cognitive impairment is a major risk factor for mortality and nursing home admission in the first year after hip fracture. Bone. 2012;51(3):347–52.
44. Becker N, Hafner T, Pishnamaz M, Hildebrand F, Kobbe P. Patient-specific risk factors for adverse outcomes following geriatric proximal femur fractures. Eur J Trauma Emerg Surg. 2022;48(2):753–61.
45. Stewart NA, Chantrey J, Blankley SJ, Boulton C, Moran CG. Predictors of 5 year survival following hip fracture. Injury. 2011;42(11):1253–6.

Publisher's Note