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Original Article

# Prognosis after pacemaker implantation in extreme elderly

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ABSTRACT

*Aims:* Significant comorbidities may limit the potential benefit of pacemaker (PM) implantation in extreme elderly. A short-term mortality risk prediction score, able to identify high-risk patients, may be a useful tool in this population.

*Methods and results:* We retrospectively analyzed 538 patients aged > 80 years at the time of implant who underwent PM implantation. Kaplan-Meier survival and multivariable Cox regression analyses were performed to identify patient, procedural or complication variables predictive of death. The ACP (Aging in Cardiac Pacing) Score was constructed by assigning weighted values to the variables identified by hazard ratios, combined into an additive mortality risk score equation. One, two and three-year overall mortality rate was 11%, 21% and 32% respectively. Renal failure (HR 1.63; CI 1.15–2.31; $p = .006$), active neoplasia (HR 1.78; CI 1.27–2.51; $p = .008$), connective tissue disorder (3.07; CI 1.34–7.08; $p = .048$), cerebrovascular disease (HR 1.75; CI 1.25–2.46; $p = .001$) and the use of a single lead device (HR 2.27; CI 1.6–3.24; $p < .001$) were independently associated with worse survival. The ACP Score showed discrete predictive ability (AUC 0,6792 CI 0,63-0,73). Kaplan-Meier survival curves comparing low vs high ACP Scores demonstrated that low ACP scores were associated with reduced mortality rates ($p < .001$).

*Conclusions:* Significant comorbidities were associated with worse survival after PM implantation in extreme elderly. The ACP Score is a novel tool that may help to identify patients with high mortality risk after device implantation.

## 1. Introduction

Aging is often characterized by a progressive fibrosis of the conduction system resulting in bradycardia-related symptoms requiring pacemaker (PM) implantation that are increasing worldwide [1]. It is known that > 80% of PM implantations are performed in patients > 65 years and the proportion of extreme elderly (aged ≥80 years) patients is expected to increase in the next few decades [2–4]. Few reports confirm safety and benefits of pacemaker implantation in this population, but is also known that increased age with concomitant greater burden of comorbidities are strong predictors of worse prognosis in elderly patients [1,5–12]. It follows that some old patients with multiple comorbidities may carry a short-term limited prognosis thus reducing the potential benefit of the procedure. Identification of this subgroup of patients is relevant to avoid unnecessary invasive procedures and also in view of the cost- usefulness of the indication. We have retrospectively analyzed complications, outcomes and overall mortality rates in octuagenarians after pacemaker implantation. Based on the identified clinical and procedural predictors of worse outcome, we have developed a mortality risk score (Aging in Cardiac Pacing ACP score) that may contribute to a better patient-tailored evaluation before PM implantation in elderly patients.

## 2. Methods

We retrospectively analyzed all consecutive patients aged ≥80 years that underwent pacemaker implantation in the Cardiac Electrophysiology Laboratory at the Cardiovascular Center of Ferrara University Hospital between January 2010 and October 2014. Single-, dual- and biventricular de novo PM implant are included for the analysis. No implantable cardioverter defibrillators (ICD) were included. Demographic, clinical and procedural data were obtained from electronic medical records and institutional databases. We collected patients demographics, medical history, laboratory data,

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echocardiographic principal parameters, [left ventricular (LV) end-diastolic volume, LV ejection fraction (EF), left atrial area], medications before the procedure, indication for PM implantation, type of implanted device, type of vascular access, use of antibiotic prophylaxis, need of emergent temporary pacing from our electronic database. Patient comorbidities were measured using the age-independent Charlson Comorbidity Index.

All clinical comorbidities were defined and categorized referring to the current definitions of the specific disease used for the Charlson Comorbidity Index:

- Hystory of coronary artery disease (CAD): Hystory of medical documented myocardial infarction
- Hystory of congestive heart failure (CHF): Symptomatic congestive heart failure responsive to specific treatment
- History of Peripheral vascular disease: Intermittent claudication or prior bypass for arterial insufficiency; gangrene or acute arterial insufficiency; untreated thoracic or abdominal aneurysm (≥6 cm)
- Active neoplasia: Any neoplasia with or without metastases, initially treated in the last 5 years (exclude non-melanomatous skin cancers and in situ cervical carcinoma)
- Peptic ulcer: Required treatment for ulcer disease, including bleeding from ulcers
- History of connective tissue disorder: Systemic lupus erythematous (SLE), polymiositis (PM), mixed connective tissue disease (MCTD), rheumatic polymyalgia, moderate to severe rheumatoid arthritis
- Renal failure: Creatinine > 1.3 mg (glomerular filtration rate [GFR] < 60 ml/min), dialysis, transplantation, uremic syndrome
- History of Cerebrovascular disease: Cerebrovascular accident with minor or no residual and transient ischemic attacks
- Stroke: History of medical documented stroke
- Dementia: chronic cognitive deficit
- History of chronic lung disease (COPD): symptomatic dyspnea due to chronic respiratory conditions (including asthma)

Minimum follow up was 10 months. All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Following current guidelines on cardiac pacing, the choice of pacing mode was made in relation to individual basis taking into account the increased complication risk of dual chamber pacing and evaluating the overall clinical status of the patient [7,13,14]. No VDD devices were implanted in our cohort. RV leads were preferentially implanted in a non-apical position (mostly mid-septum).

Following previous literature, procedural complications were defined and grouped as local device infection requiring treatment, device-related endocarditis, device-related hematoma requiring surgery and/or resulting in prolongation of hospitalization of at least 24 h, lead displacement requiring re-intervention, pericardial effusion, device related pneumothorax requiring drainage. Early complications were defined if occurred within 30 days from the implant.

### 2.1. Data analysis

Between-group (pts with adverse event [AE] vs pts. with no AE) comparisons for clinical and outcome variables were performed using independent samples *t*-test, Wilcoxon rank sum test, chi-square analysis, or Fisher's exact test using appropriate variable-specific denominators.

The primary study endpoint was overall mortality after device implantation. The time-to-primary outcome defined as overall mortality was computed using Kaplan-Meier estimates and log-rank test and it was used to define freedom from all cause of death after device implantation. Cox modeling was used to compute hazard ratio (with 95% confidence interval) of the primary end point. A univariable Cox regression analysis was carried-out using the following predictors: gender, age as a continuous variable, age as a categorical variable (above and below 90 years of age), height, weight, body mass index (BMI), creatinine, glomerular filtration rate calculated using the Modification of Diet in Renal Disease (GFR-MDRD) for adults, hemoglobin, International Normalized Ratio (INR), history of coronary artery disease (CAD), history of congestive heart failure (CHF), history of diabetes mellitus (DM), history of systemic arterial hypertension, active neoplasia, peptic ulcer, history of connective tissue disorder, cerebrovascular disease, history of stroke, chronic lung disease (COPD), Charlson Comorbidity Index, active smoking, indexed left ventricular diastolic volume (echocardiography), left ventricular ejection fraction (echocardiography), left atrial area (echocardiography), need of temporary pacing before device implantation, single chamber device implantation. Predictors achieving marginal significance ($p$ value < .15) were entered in a multivariable Cox regression model. The final model retained (parsimonious approach) only variables with strong significance using stepwise backward selection. Modeling diagnostics were run using visual inspection of log-log plot and Schoenfeld Residuals Test and model robustness was assessed using bootstrapping resampling of the dataset (1000 replications). Discrimination of the multivariable Cox model was assessed using Harrel's C statistics. A risk score was created by assigning weighted values to the variables identified by the final model based on their hazard ratio in the regression model. The risk score was then calculated by adding all the individual weighted values. Appropriate diagnostic performance of the risk score was assessed using Receiver Operating Curve (ROC) analysis using 3-month mortality rate after device implantation as the qualifying event. A ROC-based score partitioning (optimal criterion) was implemented to maximize diagnostic accuracy. Bootstrapping resampling of the dataset demonstrated negligible bias of the originally estimated ACP score components, nearly identical $p$ values and comparable 95% confidence interval for the estimated hazard ratios.

Data are reported as mean ± standard deviation, median (first and third quartile) or frequency (%). All tests were two-sided. A $p$-value < .05 was considered significant. Analysis was performed using STATA® 12th Release data analysis software (StataCorp LP, College Station, TX).

## 3. Results

### 3.1. Baseline characteristics

A total of consecutive 538 patients aged > 80 years (53% male; median age 85 years (1st-3rd quartile [IQ] range 82–87) received a permanent PM implantation in our Centre between January 2010 and October 2014. Baseline characteristics are depicted in Table 1. Median follow up after device implantation was 24 months (IQ range 10–39). In our cohort 75 patients were older than 90 years old. A comparison of clinical characteristics of patients receiving single-lead versus dual lead devices is described in Table 2. Only three patients received a biventricular pacemaker in our cohort of elderly patients. Single-lead PM recipients are older with a higher Charlson Comorbidity Index, history of cerebrovascular disease, previous stroke and dementia. AF with slow conduction and “ablate and pace” strategy are more frequent PM indications in patients receiving single lead device.

### 3.2. PM-related complications

Table 3 shows that 45 patients experienced at least one major device-related complication. An early complication occurred in 6,6% of patients. Pocket hematoma and lead displacement were the most frequent adverse events (2,7% and 2,6% respectively). Device related infections were all late complications occurring in a range between 2 and 12 months after the procedure. None of clinical pre-procedural patient' characteristics were associated with an increased risk of complication.

**Table 1**
Demographics and clinical profile of the overall study population with and without major periprocedural complications.

| Variable | Total ($n$ = 538) | No complications ($n$ = 493) | Complications ($n$ = 45) | $p$ |
|---|---|---|---|---|
| Male, n (%) | 283 (53%) | 263 (53%) | 20 (44%) | 0.25 |
| Age, years | 85 (82–87) | 84 (82–87) | 85 (83–87) | 0.31 |
| BMI | 25 (23–28) | 25 (23–28) | 25 (23–28) | 0.95 |
| CCI | 4 (2–5) | 4 (2–5) | 3 (2–5) | 0.40 |
| Pacing indication | | | | |
| AV block | 254 (47%) | 232 (47%) | 22 (9%) | 0.81 |
| SSS | 112 (21%) | 105 (21%) | 7 (16%) | 0.36 |
| AF with slow rate | 108 (20%) | 98 (20%) | 10 (22%) | 0.71 |
| Ablate and Pace | 21 (4%) | 21 (4%) | 0 (0%) | 0.15 |
| Other | 43 (8%) | 37 (8%) | 6 (13) | 0.07 |
| CAD, n (%) | 146 (27%) | 139 (28%) | 7 (16%) | 0.06 |
| CHF, n (%) | 101 (19%) | 94 (19%) | 7 (16%) | 0.56 |
| History of AF | 108 (20%) | 97 (20%) | 11 (24%) | 0.7 |
| DM, n (%) | 115 (21%) | 109 (22%) | 6 (13%) | 0.17 |
| HTN, n (%) | 470 (87%) | 431 (87%) | 39 (87%) | 0.88 |
| Dyslipidemia, n (%) | 144 (27%) | 132 (27%) | 12 (27%) | 0.98 |
| Active smoke, n (%) | 108 (20%) | 99 (20%) | 9 (20%) | 0.99 |
| Cancer, n (%) | 162 (30%) | 145 (29%) | 17 (38%) | 0.24 |
| Peptic ulcer, n (%) | 51 (10%) | 46 (9%) | 5 (11%) | 0.69 |
| Connective disease, n (%) | 19 (4%) | 16 (3%) | 3 (7%) | 0.23 |
| Renal failure, n (%) | 282 (52%) | 259 (53%) | 23 (51%) | 0.85 |
| Cerebrovascular disease, n (%) | 184 (34%) | 167 (34%) | 17 (38%) | 0.60 |
| COPD, n (%) | 95 (18%) | 92 (19%) | 3 (7%) | 0.04 |
| Dementia, n (%) | 117 (22%) | 105 (21%) | 12 (27%) | 0.40 |
| Prosthetic heart valve, n (%) | 30 (6%) | 30 (6%) | 0 (0%) | 0.09 |
| Peripheral vascular disease n (%) | 87 (16%) | 82 (17%) | 5 (11%) | 0.34 |
| GFR-MDRD, ml/min | 57 (40–73) | 57 (40–73) | 58 (41–98) | 0.93 |
| Hemoglobin | 12 (11 – 13) | 12 (11–13) | 12 (11–13) | 0.38 |
| INR | 1.2 (1.1–1.3) | 1.2 (1.1–1.3) | 1.2 (1.1–1.3) | 0.24 |
| Medical therapy, n (%) | | | | |
| ACEI-ARBs | 286 (53%) | 264 (54%) | 22 (49%) | 0.55 |
| Beta-blocker | 172 (32%) | 159 (32%) | 13 (29%) | 0.64 |
| Diuretics | 288 (53%) | 263 (53%) | 25 (56%) | 0.78 |
| VKA | 128 (24%) | 119 (24%) | 9 (20%) | 0.53 |
| ASA | 245 (46%) | 227 (46%) | 18 (40%) | 0.44 |
| Thienopyridine | 75 (14%) | 67 (14%) | 8 (18%) | 0.44 |
| DAPT | 26 (5%) | 24 (4%) | 2 (0,3%) | 0.14 |
| Heparin bridge, n (%) | 105 (20%) | 92 (19%) | 13 (29%) | 0.09 |
| Dual-chamber device, n (%) | 284 (53%) | 257 (52%) | 27 (60%) | 0.31 |
| Vascular access, n (%) | | | | |
| Cephalic vein | 302 (56%) | 276 (56%) | 26 (58%) | 0.82 |
| Subclavian vein | 271 (50%) | 251 (51%) | 20 (44%) | 0.41 |
| Emergency temporary pacing before device implantation, n (%) | 52 (10%) | 47 (10%) | 5 (11%) | 0.73 |
| LV EF, % | 59 (50–60) | 59 (50–60) | 60 (50–60) | 0.75 |
| 4-chamber LA area, cm2 | 23 (16–26) | 23 (19–27) | 21 (19–26) | 0.39 |

ACEI = Angiotensin Converting Enzyme Inhibitors; AF = atrial fibrillation; ARBS = Angiotensin II Receptor Blockers; ASA = Acetylsalicylic Acid; BMI = Body Mass Index; AV = atrioventricular; CAD = Coronary Artery Disease; CCI = Charlson Comorbidity Index; CHF = Congestive Heart Failure; COPD = Chronic Obstructive Pulmonary Disease; DAPT = dual antiplatelet therapy; DM = Diabetes Mellitus; GFR-MDRD = Glomerular Filtration Rate using Modified Diet in Renal Disease; HTN = systemic HyperTeNsion; INR = International Normalized Ratio; LA = Left Atrium; LV EF = Left Ventricular Ejection Fraction; SSS sick sinus syndrome; VKA = Vitamin-K Antagonist.

In our cohort, 50% of patients with pocket hematoma had pre-procedural heparin therapy. However, the difference in overall complication events was not statistically significant regarding the use of heparin bridge (29% in AE group vs 19% in no AE group $p = .09$) (Table 1).

### 3.3. Mortality rate and predictors of mortality

One, two and three year mortality rate was 11%, 21% and 32% respectively (Fig. 1). Of 538 patients, 175 died during follow up. No significant difference in overall mortality was found between patients with and without a device-related adverse event (Fig. 2).

Several clinical and procedural variables at the time of device implantation were tested in univariable Cox-regression analysis to identify predictors of overall mortality in elderly patients. (Fig. 3A).

Increased age considered as continuous (hazard ratio [HR] 1.09; 95% confidence interval [CI], 1.05–1.14; $p < .001$) or as categorial variable (age > 90 years HR 2.25; CI 1.49–3.4; $p < .001$) was associated with worse survival in our population. The Charlson Comorbidity Index score (HR 1.14; CI 1.07–1.21; $p < .001$) and some of its clinical variables such as renal failure (HR 1.7; CI 1.2–2.41; $p = .003$), cerebrovascular disease (HR 1.97; CI 1.41–2.75; $p < .001$), dementia (HR 1.59; CI 1.11–2.29 $p = .012$), connective tissue disorder (HR 2.3; CI 1.01–5.24; $p = .048$) and active neoplasia (HR 1.63; CI 1.16–2.29; $p = .005$) were all correlated with increased mortality (Fig. 3A), whilst congestive heart failure showed just a marginal association with the outcome (HR 1.35; CI 0.91–1.99; $p = .13$). (Fig. 3A).

Procedural variables like heparin bridge before implantation (HR 1.58; CI 1.1–2.28; $p = .013$) or the use of a single lead pacemaker (HR 2.36; CI 1.67–3.33; $p < .001$) were also identified as predictors of poor survival. (Fig. 3A).

Candidate variables associated with mortality with univariable $p < .15$ were considered for further analysis. Cox multivariable regression model identified 5 significant predictors of mortality after pacemaker implantation. These are: renal failure (HR 1.63; CI 1.15–2.31; $p = .006$), active neoplasia (HR 1.78; CI 1.27–2.51; $p = .008$), connective tissue disorder (3.07; CI 1.34–7.08; $p = .048$),

**Table 2**
Comparison of clinical characteristics of patients receiving single-lead versus dual lead devices.

| Variable | Single lead (*n* = 254) | Dual lead (*n* = 284) | *p* |
|---|---|---|---|
| Male, n (%) | 127 (50%) | 156(55%) | 0.25 |
| Age, years | 86 (83–89) | 84 (81–86) | < 0.001 |
| BMI | 24.8(22.5–27.5) | 26 (23.9–28.3) | 0.004 |
| CCI | 4 (2–5) | 3 (2–5) | 0.01 |
| CAD, n (%) | 64 (25%) | 82 (29%) | 0.3 |
| CHF, n (%) | 51 (20%) | 50 (18%) | 0.46 |
| History of AF (%) | 96 (38%) | 12 (4%) | < 0.001 |
| DM, n (%) | 41 (16%) | 74(26%) | 0.05 |
| HTN, n (%) | 219 (86%) | 251 (88%) | 0.45 |
| Dyslipidemia, n (%) | 53 (21%) | 91 (32%) | 0.003 |
| Active smoke, n (%) | 43 (20%) | 65 (23%) | 0.09 |
| Peripheral vascular disease, n (%) | 35 (14%) | 52 (18%) | 0.15 |
| Cancer, n (%) | 77 (30%) | 85 (30%) | 0.92 |
| Peptic ulcer, n (%) | 23 (9%) | 28 (10%) | 0.75 |
| Connective disease, n (%) | 7 (3%) | 12 (4%) | 0.36 |
| Renal failure, n (%) | 140 (55%) | 142 (50%) | 0.23 |
| Cerebrovascular disease, n (%) | 112 (44%) | 72 (24%) | < 0.001 |
| COPD, n (%) | 53 (21%) | 42 (15%) | 0.07 |
| Dementia, n (%) | 68 (27%) | 49 (17%) | 0.008 |
| INR | 1.24 (1.15–1.36) | 1.17 (1.1–1.26) | < 0.001 |
| Vascular access, n (%) | | | |
| Cephalic vein | 141 (56%) | 161 (57%) | 0.78 |
| Subclavian vein | 114 (45%) | 160 (55%) | 0.02 |
| Emergent temporary pacing before device implantation, n (%) | 24 (9%) | 28 (10%) | 0.87 |
| LV EF, % | 60 (52–60) | 58 (50–60) | 0.27 |
| 4-chamber LA area, cm2 | 24 (21–28) | 21 (18–25) | < 0.001 |

AF = atrial fibrillation; BMI = Body Mass Index; CAD = Coronary Artery Disease; CCI = Charlson Comorbidity Index; CHF = Congestive Heart Failure; COPD = Chronic Obstructive Pulmonary Disease; DM = Diabetes Mellitus; HTN = systemic HyperTeNsion; INR = International Normalized Ratio; LA = Left Atrium; LV EF = Left Ventricular Ejection Fraction.

**Table 3**
Major adverse periprocedural events.

| Major adverse periprocedural complications | Study population (n = 538) |
|---|---|
| Device infection, n (%) | 5 (0.9%) |
| Device-related endocarditis, n (%) | 1 (0.2%) |
| Device-related hematoma, n (%) | 15 (2.7%) |
| Lead-displacement, n (%) | 14 (2.6%) |
| Pericardial effusion, n (%) | 9 (1.7%) |
| Device-related pneumothorax, n (%) | 6 (1.1%) |

cerebrovascular disease (HR 1.75; CI 1.25–2.46; $p = .001$) and the use of a single lead device (HR 2.27; CI 1.6–3.24; $p < .001$) (Fig. 3B).

### 3.4. The ACP mortality risk score

Using the clinical variables found to be predictive of survival in the multivariable Cox regression analysis, a mortality risk prediction score was developed assigning weighted values to the predictive variables based on their hazard ratio in the regression model (Table 4).

Frequency distribution of the risk score was concentrated in the intermediate values with few patients with very high ACP score values in our cohort. (supplementary data).

A Receiver Operating Curve (ROC) analysis characterized the sensitivity and specificity of the ACP score in predicting 3-month mortality rate after device implantation showing a significant predictive area under the curve value (area under the curve [AUC] 0.6792 CI 0.63–0.73). (Fig. 4).

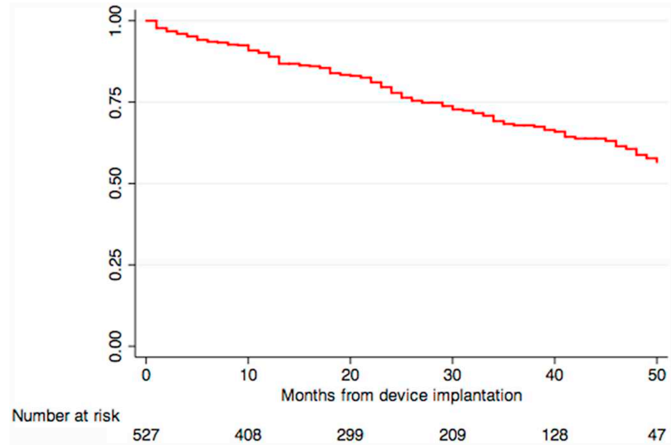


**Fig. 1.** Kaplan-Meier analysis of survival of elderly patients aged > 80 years after pacemaker implantation.

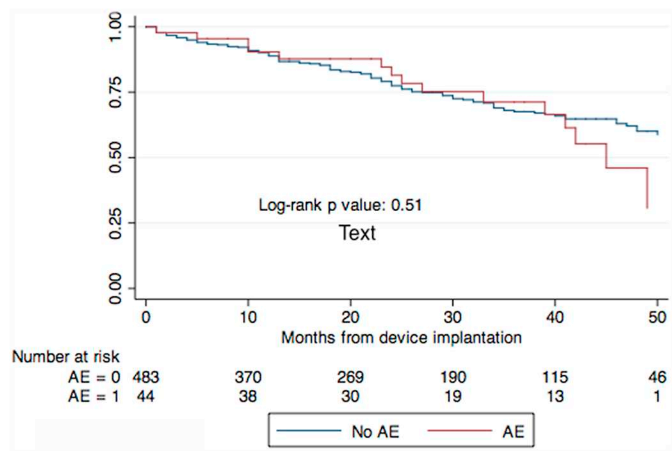


**Fig. 2.** Kaplan-Meier analysis of survival of elderly patients aged > 80 years with or without device-related adverse event after pacemaker implantation (AE adverse event).

A subgroup test according to gender and age showed no significant association of gender (HR 1.13; CI 0.8–1.58; $p = 0{,}47$) with freedom from overall mortality whereas age at implant was independently associated with the study endpoint (HR 1,07; CI 1.03–1.11; $p < 0{,}001$).

The ACP score showed a linear behavior over the range of risk, identifying a 17% 3-months mortality risk for patients with ACP score 0 or 1 and > 50% for patients with ACP score > 5. (Fig. 4B and supplementary data).

Kaplan-Meier survival curves comparing patients with low (ACP 1–4 n° of patients: 418) vs high (ACP 5–10 n° of patients: 120) ACP score showed that the score was associated with lower mortality in patients with an ACP score < 5, even at long-term follow up ($p < .001$) (Fig. 4B).

## 4. Discussion

We analyzed a cohort of patient > 80 years who underwent PM implantation to evaluate complications, survival rates and potential predictors of worse outcome. Procedural complications occurred in 8,3% of all patients at any time after implant. Previous reports described lower complication rates, mostly because only the events occurring at 30 days from implant were considered. In addition, previous analysis included patients with a broader ages range and device replacement procedures [5,11,15,16]. The early complication rate of 6,6% in our population is comparable with data from Mandawat et al.

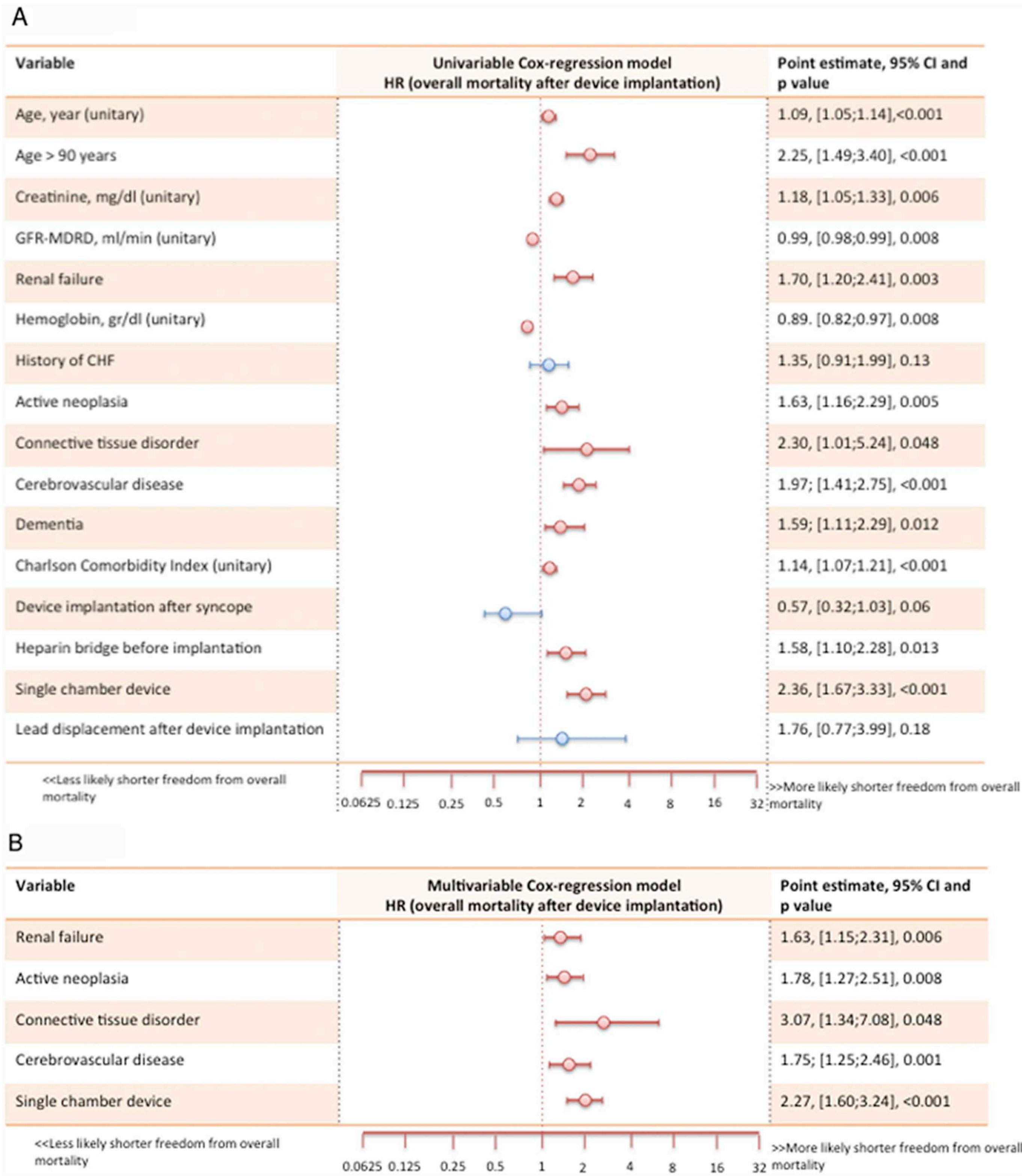


**Fig. 3.** Univariable (A) and multivariable (B) Cox regression analysis of overall mortality predictors after pacemaker implantation. (GFR-MDRD = Glomerular Filtration Rate using Modified Diet in Renal Disease; CHF = Congestive Heart Failure; HR = hazard ratio; CI = confidence interval).

reporting a complication rate of 6,13% in patients > 80 years [7]. No demographic or clinical pre-procedural characteristics were associated with higher rate of complications. In our cohort, the presence of pocket hematoma was partially related to the use of heparin bridge therapy before the procedure, because the majority of our patients were implanted before the publication of papers that highlighted the increased risk of bleeding linked to bridging therapy [17–19]. Survival rates were not affected by those device related complications.

Previous studies described long-term survival after PM implantation but are limited by the small sample size, the use of old data or broad age's range [6,10,11]. Mandawat et al. indicated that elderly patients comorbidity is a stronger predictor of worsening outcome than

**Table 4**
Definition and component of the risk score.

| Variable | Point(s) |
|---|---|
| Renal failure | 1 |
| Active neoplasia | 2 |
| Cerebrovascular disease | 2 |
| Single-chamber device | 2 |
| Connective tissue disorder | 3 |

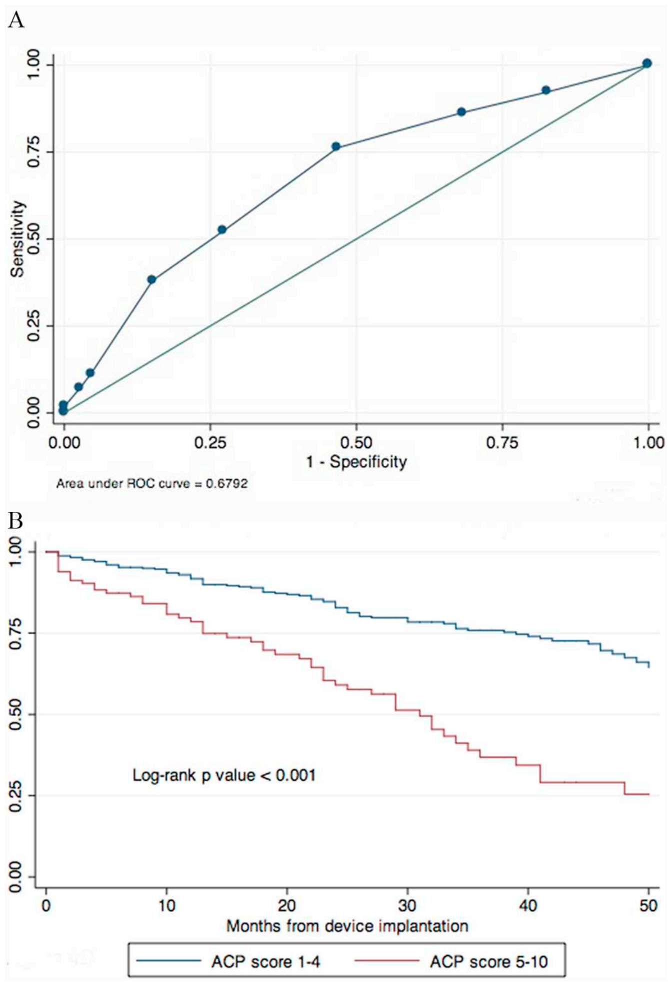


**Fig. 4.** (A) The receiver operating characteristic (ROC) for 3 month mortality after device implantation by ACP score. Area under ROC curve = 0.6792. (B) Kaplan-Meier survival curves comparison between patients with low (ACP 1–4) and high (ACP 5–10) ACP score.

increasing age, but specific prognostic factors that can affect survival after PM implantation are not yet defined [7]. This was the aim of our analysis. Comorbidities such as renal failure, active neoplasia, connective tissue disorder and cerebrovascular disease were predictive of overall mortality in our octogenarian population. Previous studies highlighted the importance of history of coronary artery disease (CAD), and congestive heart failure (CHF) at implantation as strong predictors for mortality in the general population [12,20]. In our ≥80 years patients, history of CHF was just as a marginal predictor of mortality, CAD showing no association with prognosis. It is reasonable that in extreme elderly other clinical comorbidities are more relevant for survival than cardiovascular disease.

The choice of a VVI pacing was also a predictor of mortality in our octuagenarian patients. Although atrial fibrillation (AF) was the most common indication in single lead PM, AF was not associated with a worse outcome in the overall population. Comparing patients receiving single lead versus dual-lead PM, it emerges that single-lead recipients are older than dual-lead PM patients; they have a higher Charlson Comorbidity Index, history of cerebrovascular disease, previous stroke and dementia. Our results probably reflect common clinical practice to prefer VVI devices in the more fragile patients.

Taking advantages from our findings, we created a mortality risk score to stratify survival rates after PM implantation in extreme elderly. The idea was to identify a subset of patients carrying a > 50% mortality at 3 months. The ACP Score showed a good predictive ability just using clinical data readily available to any physician planning a PM implantation. Kaplan-Meier survival curves comparing patients with low (ACP 1–4 $n = 418$) vs high (ACP 5–10 $n = 120$) ACP Scores showed better survival rates in patients with a low Score. For instance, a patient aged > 80 years with an ACP score ≥ 5 has a predicted 3-month all cause mortality of > 50%.

Even though a careful evaluation of the comorbidities should be performed in elderly patients, if confirmed by a prospective study, the ACP short-term mortality risk score could help to identify patients with higher short-term mortality risk.

## 5. Limitations

The retrospective nature of the research with no comparison group is a major limitation of the study. The presence of missing data regarding the exact causes of death and rate of pacing is another important limitation of the study. Therefore, our data have to be considered an hypothesis-generating. A prospective study will be necessary to confirm our results.

Although the ACP Score showed a good predictive ability to identify patients with low and high risk of mortality, lack of external validation is the most important limitation of the study. The Score, once is validated prospectively, shall be tested in other populations and in younger patients. The highest risk cohort was small compared to the overall study population. Since the largest clinical impact of the ACP Score is focused on patients with high scores, a prospective study powered to analyze this subset of patients is necessary to confirm the potential role of the Score in clinical practice.

## 6. Conclusions

This retrospective study reports long-term survival rates of extreme elderly patients after PM implantation. Significant comorbidities, including renal failure, connective tissue disorder, active neoplasia, cerebrovascular disease and the use of single chamber device rather than complications were identified as predictors of mortality after PM implantation in extreme elderly. The ACP Score was created to identify patients carrying high short-term mortality risk.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejim.2019.04.020.

## Declaration of interest

None

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