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## AtoG: a simple score to predict complications and death after hip fractures, in line with the comprehensive geriatric assessment

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### ABSTRACT

#### INTRODUCTION

Proximal Femur Fractures (PFFs) are a significant public health issue and occur in the context of global frailty and aging. Recent literature identifies new patient-related prognostic factors that focus on socioeconomic environment, patient well-being, or nutrition status. Specific scores have been developed, but in most cases, they fail to be in line with the comprehensive geriatric assessment, or don't assess the newly identified prognostic factors, contain multitude collinearities, or are too complex to be used in the daily practice.

#### HYPOTHESIS

A comprehensive score with equal representation of the patient's dimensions does at least as good as the Charlson score (CCI), to predict complications and mortality.

## OBJECTIVE

To develop a new comprehensive prognostic score, predicting inpatient complications and mortality up to 5-year after PFF.

## MATERIAL AND METHODS

The patients treated surgically for PFF on a native hip, between 2005 and 2017 were selected from a French national database. The variables were the gender, age, the type of treatment (osteosynthesis or arthroplasty), and the CCI. The outcomes were the medical and surgical complications as inpatient and the mortality (up to 5-year). Variables were grouped into dimensions with similar clinical significance, using a Principal Component Analysis, for instance, bed sores and malnutrition. The dimensions were tested for 90-day mortality and complications, in regressions models. Two scores were derived from the coefficients: SCORE<sub>pond</sub> (strict ponderation), and SCORE (with loose ponderation: 1 point/ risk factors, -1 point/protective factors). Calibration, discrimination (ROC curves with Area Under Curves AUC), and cross-validation were assessed for SCORE<sub>pond</sub>, SCORE, and CCI.

## RESULTS

Analyses were performed on 7756 fractures. The factorial analysis identified seven dimensions: age; brain-related conditions (including dementia): 1738/7756; severe chronic conditions (for instance, organ failures) 914/7756; undernutrition:764/7756; environment, including social issues or housing difficulties: 659/7756; associated trauma: 814/7756; and gender. The seven dimensions were selected for the prognostic score named AtoG (ABCDEFG, standing for Age, Brain, Comorbidities, unDernutrition, Environment, other Fractures, Gender). The median survival rate was 50.8 months 95%CI[49-53]. Anaemia and urologic complications were the most prevalent medical complications (1674/7756, 21%, and 1109/7756, 14.2%). A total of 149/7756 patients (1.9%) developed a mechanical inpatient complication (fractures or dislocations), with a slightly higher risk for arthroplasties. The AUCs were 0.69, 0.68, and 0.67 for AtoG<sub>pond</sub>, AtoG, and CCI, respectively, for 90-day mortality, and 0.64, 0.63, and 0.56 for complications. Compared to patients with AtoG=0, Hazard Ratios for 90-day mortality were 2.3 95%CI[1.7-2.9], 4.2 95%CI[3.1-5.4], 6 95%CI[4.5-8.1], 8.3 95%CI[6.5-12.9], and 13.7 95%CI[8-24], from AtoG=1 to AtoG>=5, respectively ( $p < 10^{-4}$ ); the 90-day survival decreased by 5%/point, roughly. The sur-risk of mortality associated with AtoG was up to 5-year: HR= 1.51 (95%CI[1.46-1.55],  $p < 10^{-4}$ ). Compared to AtoG=0, from AtoG=1 to AtoG ≥5, the pooled Odd Ratios were 1.14 95%CI[1.06-1.2], 1.53 95%CI[1.4-1.7], 2.17 95%CI[1.9-2.4], 2.9 95%CI[2.4-3.4], and 4.9 95%CI[3.3-7.4] for any complication ( $p < 10^{-4}$ ).

## CONCLUSION

AtoG is a multidimensional score in line with the concept of comprehensive geriatric assessment. It had good discrimination and performance in predicting 90-day mortality and complications. Performances were as good as CCI for 90-day mortality, and better than it for the complications.

**Level of proof:** IV; retrospective cohort study.

**Keywords:** proximal femur fractures; osteoporotic fractures, epidemiology, comprehensive geriatric assessment

## 1. INTRODUCTION

Proximal Femur Fractures (PFFs) are a significant public health issue because of their prevalence and associated morbidity. In France, PFF has been steadily increasing for the last decades because of the increase in lifespan[1,2]. In the context of global frailty and aging, the management of PFF is a complex pathway[3,4]. Numerous complications can occur anytime from the trauma to the postoperative period, for instance, a crush syndrome of a deep venous thrombosis. Recent reports reveal an early 30-day mortality rate of around 10%, 1-year mortality of around 30%[5,6], and up to 50% of mortality by 5-year[7]. The rehabilitation program is demanding[8].

An accurate assessment of the patient's profile and risk is warranted. The Charlson Comorbidity Index (CCI) has been broadly used to estimate the risk of death and complications[9]. This score is exclusively focused on medical comorbidities. Recent literature identifies new patient-related prognostic factors that focus on socioeconomic environment, patient well-being, nutrition status[10–15], care-related organization[16], and place of residence or discharge[17]. Specific scores have been developed recently, such as the Nottingham[4,18,19], Orthopedic Hip Frailty[3], and Almelo[20] scores. However, the definition of the "perfect score" is complex, and a perfect score should meet numerous quality criteria. As described before, modern scores should be comprehensive and consider most of the dimensions of the comprehensive geriatric assessment[21,22], including malnutrition and deprivation. From a statistical point of view, a robust score should be performant (sensitivity and specificity), well-calibrated to provide good predictions, and reproducible[23,24]. These last parameters are almost always addressed, but other parameters should also be considered. More than 98.000 diagnoses are listed in the International Classification of Diseases (ICD), meaning a Factor Analysis[25] is mandatory to cluster the variables reflecting the same dimensions and avoid collinearities (associations between explicative variables in a regression)[26]. The ICD regroups the diagnoses into

subcategories, from A to Z[27], but syndromes can overlap between categories, for instance, malnutrition (group E) and bed sores (group L). In CCI and Almeno scores, for instance, collinearities are suspected; patients suffering from one organ failure are at risk of developing a second organ failure (for instance, heart failure and kidney failure). The American Society of Anesthesiologist's physical status classification (ASA) in the Almeno score is also correlated to all other comorbidities. Finally, the usefulness of a score depends on its simplicity. Although the previous scores are validated and robust, they require pondering the items, which can be challenging to remember. Almelo and Nottingham are composite scores, including the results of the Parker and the Abbreviated Mental scores.

The hypothesis of this study was that a comprehensive score with equal representation of patient's dimensions does at least as good as the Charlson score, to predict complications and mortality.

This study aimed to develop a new comprehensive prognostic score, predicting inpatient complications and mortality up to 5-year after PFF, and responding to all the quality criteria detailed above.

## 2. MATERIAL AND METHODS

### 2.1 Study design and setting

This a retrospective longitudinal study using the French national database of Social Security, called "Echantillon Généraliste des Bénéficiaires" (EGB), created in 2005. The EGB represents a 1/97 sample of the French population[28]. The adherence to Social Security is mandatory in France; numerous subdivisions were progressively incorporated into the EGB, and the number of participants in the EGB steadily increased from 507.000 participants in 2005 to 602.000 in 2011. Preliminary studies confirmed that the EGB is representative of the overall French population in terms of age and gender[28]. The EGB gathers information from several administrative databases. First, the EGB contains the *Programme de Médicalisation des Systèmes d'Information* (PMSI), which provides the primary diagnoses, associated diagnoses (comorbidities), and surgical procedures in case of admission. The diagnoses are classified using the International Classification of Diseases. The EGB also contains civil information, including the date of birth and death (updated periodically).

The participants of the EGP are selected blindly, according to a particular identifying characteristic of their social security number, which is kept secret by Social Security. Once entered the EGB, the civil and medical data from 2005 to 2018 were updated regularly. A patient

does not quit the EGB. If a patient dies, he will remain in the database, but his information will not be updated.

Access to the EGB is highly controlled; only accredited users enrolled in labialized French research units can access the data. The treatment of the data from the EGB platform is also highly controlled. According to the French law, no Ethic committee review is mandatory.

## 2.2 Participants

The selection criteria were the patients admitted to a care facility and benefited from any surgery to treat a PFF, on a native hip, between 2005 and 2017. The selection was performed with the principal diagnosis S72 (the PFF's code in the ICD-10) and the codification of the surgical treatment (within a specified panel of codes). Then, a triage was performed to remove incoherencies; for instance, the patients having sustained three times surgery for a PFF were not included in analyses. Some patients were duplicated twice or more, and the extra lines were removed.

The follow-up was up to the discharge from the hospital when assessing the medical complications.

## 2.3 Variables

The demographic data were the gender, the age when admitted for PFF, and the type of treatment (osteosynthesis or arthroplasty).

The associated diagnostics were extracted and shortened to the letter following by two numbers. The CCI[9] was computed from the associated diagnoses.

## 2.4 Outcomes

The main outcomes were the medical and surgical complications as inpatients and the mortality. The mortality was analysed at 90-day and then up to 5-year postoperatively.

The medical complications were sought in the associated diagnoses. A table of all the associated diagnoses was produced, containing the ICD-10 codes. It included chronic comorbidities (such as I50, and congestive heart failure) and acute conditions during the admission (such as K25, acute stomach ulcers). The 904 associated diagnoses were checked one by one to mark the acute conditions and to assign them a gradation according to the Clavien-Dindo classification[29]:

- Grade 1, any postoperative deviation from the normal, not requiring unusual treatment (for instance, nausea and vomiting).
- Grade 2, complication requiring a pharmacological intervention (for instance, blood transfusion, urine infection).
- Grade 3, complication requiring a surgical revision.
- Grade 4, life-threatening condition such as heart failure.
- Grade 5, life-threatening condition resulting in death during admission.

The EGB contains information about death up to December 2018. The assessment is thorough, but there is a risk that the death of the very last patients of late 2017 was not entered in the EGB. Inpatient death during admission was coded separately, with the mode of discharge.

## 2.5 Statistical Methods

When describing the database, we reported means, medians, and standard deviations for quantitative variables and counts for categorical variables.

The main objective of this study was to provide a prognostic score predicting medical complications and 90-day mortality.

Variables were first grouped into dimensions. A first screening of the 904 types associated diagnoses (total of 39462) was performed. Only the chronic conditions were considered (so there was no overlap between the outcomes and the variables). The variables with some association with complications or death were selected. Associations were tested with Chi2 tests, and variables with a p value less than 0.2 were selected. After this first screening, a factor analysis using a Principal Component Analysis (PCA) was used to create new variables corresponding to different dimensions[25]. For instance, bed sores (L89) and malnutrition (E44) were highly correlated together, the latter being a cause of the former; these two variables were gathered in the dimension "undernutrition". Patients presenting with either a bed sore or low Albumin met the condition of undernutrition. The dimensions were expected to be poorly correlated between each other, so that they could assess different features. A correlation matrix was performed with the dimensions, and a Pearson's correlation coefficient of less than 0.2 was accepted. A Cronbach's alpha was also calculated with the dimensions, and a coefficient less than 0.70 was expected[25,30,31] (low consistency between all the items).

The dimensions were the candidates to become items of the score. A resampling of the entire cohort was performed with the method of k\_folds cross-validation (with k=9, ~10% of the cohort in each test dataset). This method reduces the risk of model overfitting.

The associations between the dimensions, the 90-day mortality, and complications were tested using training sets in univariable models. Those with a  $p < 0.2$  were entered in multivariable Cox'PH and logistic regressions to explain 90-day mortality and complications, respectively. A point-based risk score was issued from the regression coefficients[32].

The original score was simplified for simplicity and to help clinicians in their daily practice. The original score ( $SCORE_{pond}$ ) had a strict ponderation (for example, 10 points for Comorbidities and 6 points for social issues). The second score (SCORE) had a ponderation equal to 1 for risk factors and -1 for protective factors. The upper ranges of the scores were gathered if there were too few individuals, as per Sullivan's method[32].

Calibration, discrimination, and internal validation were tested[23]. The  $SCORE_{pond}$ , SCORE, and CCI were calculated on test sets. Area Under the Curve calculation (AUC) was calculated for performances, and calibration plots were produced to assess predictions[24]. In calibration plots, the slope should be the closest possible to 1, meaning a good prediction. The intercepts represent the overall prediction, being overall too low or too high; they should be close to 0. When providing the risks, estimates of the Cox'PH regression (for 90-day death) and logistic regression (for complications) from all the test sets were pooled to provide global estimates.

The risk alpha was set at 5%, and the analyses were performed on R Software (R Studio 4.2.1; R Core Team 2021, Vienne, Austria).

### 3. RESULTS

#### 3.1 Descriptive data

The original dataset contained 8034 fractures. There were 6188/8034 women (77%), and the mean age was 84 years (min 60, max 108, Q1: 84,5, Q3: 89). When analysing the comorbidities and complications, the analyses were performed on 7756/8034 patients (96.5%), because 278 patients couldn't be properly matched.

The mean CCI was 5.4 (median 4.9, Q1 4.1, Q3 6.3). The factorial analysis identified seven dimensions (Figure 1). The first dimension was age, which was used as a binary variable, above (1) or below (0), the population's median age. The second dimension grouped all the brain-related conditions, including all types of dementia, psychiatric diseases, especially depression, and post-stroke neurological sequelae. A total of 1738 patients had this dimension, among them 1441 with dementia. The third dimension gathered the chronic serious conditions; a total of 914 patients had either a heart, kidney, or lung chronic condition, or a tumour. The fourth dimension involved 764 patients and reflected undernutrition, either with a clinical or a biological diagnosis



(for instance, low Albumin and bed sore). The fifth dimension was the environment, corresponding to social issues, housing difficulties, or difficulties in accessing care; 659 patients met this criterion. The sixth dimension was the associated trauma, and 814 cases had at least one other associated injury (for instance ankle or shoulder fractures). The last item was gender. The correlations between these dimensions were less than 0.2, and Cronbach's alpha was 0.28.

### 3.2 Main outcomes

A total of 3341 patients died, and the median survival rate was 50.8 months 95%IC[49-53]. There were 3273 subjects who developed a least one complication during their admission, among which 188, 2209, 471, 367, and 266 complications Clavien Dindo 1, 2, 3, 4, 5, respectively. Three hundred-sixty-one and 822 cases died before 30 days and 90 days postoperatively, respectively.

The main medical complication was postoperative anemia, with a rate of 1674/7756 (21%), followed by urologic complications (infection: 676/7756, 8.7% and retention: 433/7756, 5.6%). The details for inpatient complications are given in table 1. A total of 149/7756 patients (1.9%) developed mechanical complications, including fractures or dislocations, during their admission. The risk of mechanical complication was slightly higher for the arthroplasties, compared to the osteosyntheses: 54/2820 (1.9%) for arthroplasties, and 50/3953 (1.2%) for the osteosyntheses,  $p=0.03$ . A total of 289/7756 patients (3.7%) developed a hematoma or infection. The risk for hematoma or infection did not significantly differ between the arthroplasties and osteosyntheses: 116/2820 (4.1%) for arthroplasties, and 152/3953 (3.8%) for the osteosyntheses,  $p=0.57$ .

All the dimensions were significantly associated with the risk of any complication (table 2). Comorbidities had the highest Odd Ratio (OR 2.64, 95%IC[2.25-3],  $p < 10^{-4}$ ). Odd ratios for Age, Brain, unDernutrition, Environment, other Fractures and Gender were 1.24 95%IC[1.2-1.35], 1.82 95%IC[1.6-2], 2.4 95%IC[2.3-3], 1.58 95%IC[1.3-1.8], and 1.78 95%IC[1.5-2], 1.07 95%IC[1-1.15] (for males), respectively.

All the dimensions were significantly associated to the risk of 90-day mortality (table 2). Environment became a protective factor (HR 0.62, 95%IC[0.45-0.81],  $p=0.001$ ). Hazard ratios were 1.4 95%IC[1.2-1.7], 2.2 95%IC[1.9-2.7], 1.24 95%IC[1.07-1.4], 1.23 95%IC[1.02-1.51], and 2.1, 95%IC[1.76-2.46], for Brain, Comorbidities, unDernutrition, other Fractures, and Gender male, respectively.

The seven dimensions were selected for the prognostic score named ABCDEFG, abbreviated AtoG (Age, Brain, Comorbidities, unDernutrition, Environment, other Fractures, Gender).

Based on the coefficients, the points for AtoG<sub>pond</sub> when considering the complications were A: 2 points, B: 6 points, C: 10 points, D: 9 points, E: 5 points, F: 6 points, G: 4 points. When considering the 90-day mortality Environment was protective and the 5 points for this item were removed. AtoG had one point per item, when considering complications; there was 1 point for every item except -1 point for E when considering 90-day mortality (table 2).

### 3.3 Calibration, Discrimination, Validation

When predicting the 90-day mortality, the pooled AUCs were 0.69, 0.68, and 0.67 for AtoG<sub>pond</sub>, AtoG, and CCI, respectively.

The pooled AUCs when predicting all complications were 0.64, 0.63, and 0.56 for AtoG<sub>pond</sub>, AtoG, and CCI, respectively.

The pooled AUCs when predicting complications Clavien Dindo 3, 4, and 5 were 0.68, 0.67, and 0.60 for AtoG<sub>pond</sub>, AtoG, and CCI, respectively.

On the calibration plots, when performing the cross-validation for the 90-day mortality and testing AtoG, the AUCs were stable around 0.70, and the slopes were close to 1, except for one test set, for which the slope was 0.77 and AUC 0.63 (Figure 2). When cross-validating for the complications, plots showed reliable parameters, with an AUC around 0.68, except for one test set, with poor AUC=0.6, slope=0.53, and intercept = -1.1 (Figure 3).

### 3.4 Risks associated with AtoG

The risk of 90-day death progressively increased with AtoG score; compared to patients with AtoG =0, those with a score equal to 1, 2, 3, 4, and  $\geq 5$  had HRs equal to 2.3 95%CI[1.7-2.9], 4.2 95%CI[3.1-5.4], 6 95%CI[4.5-8.1], 8.3 95%CI[6.5-12.9], and 13.7 95%CI[8-24], respectively,  $p < 10^{-4}$ . The 90-day survival rates were 96%, 91%, 85%, 80%, 75%, and 62% from scores 0 to 5 (Figure 4). AtoG was associated with a sur-risk of mortality up to 5-year postoperatively: HR= 1.51 95%CI[1.46-1.55],  $p < 10^{-4}$  (table 1). Compared to AtoG =0 and from AtoG = 1 to AtoG  $\geq 5$ , the pooled ORs were 1.14 95%CI[1.06-1.2], 1.53 95%CI[1.4-1.7], 2.17 95%CI[1.9-2.4], 2.9 95%CI[2.4-3.4], and 4.9 95%CI[3.3-7.4] for any complication ( $p < 10^{-4}$ ), Figure 5.

## 4. DISCUSSION

### 4.1 Main results

This study developed a new prognostic score to predict complications and death after PFF. AtoG allows a comprehensive assessment of patients, including recently identified prognostic factors

such as socioeconomic issues. The score items were poorly correlated with low internal consistency, allowing a multidimensional assessment of the patients. AtoG was as performant as the CCI in predicting 90-day mortality, and more performant when predicting complications. AtoG, the score with a “loose” ponderation (a risk factor +1, and a protective factor -1) had good outcomes for calibration, performance, and simplicity to predict serious complications and mortality up to 5-year. From 0 to 5 points, each point of AtoG decreased by at least 5% the 90-day survival. Social issues (Environment) were a risk factor for complications but became protective for 90-day mortality.

#### 4.2 Interpretation and generalization

The mortality rates were plausible compared to the literature data, roughly 10%, 30% and 50% mortality rates at 30-day, 1-year, and 5-year, respectively[5–7]. It's more complex to compare the rates for complications, as the endpoints differ, as well as the severity of complications. Our thromboembolism rate of 2.3% was 1% less than in Beauchamp-Chalifour et al's series, but their endpoint was 30-day while our series was limited to inpatient complications[33]. Also, the administration of Tranexamic acid modifies the risk of a thromboembolism event, and we couldn't control this parameter[34]. The urine infection rate of 8.7% was similar to Ronfeldt's rate of 7.7%[35]. For arthroplasties, in a recent cohort issued from the French PMSI, Pangaud et al. found a dislocation rate of 5.7% at 2-year[36]. We cannot strictly compare our mechanical complication rates with this last series, but our 2% rate suggests that up to 35% of the mechanical complications for arthroplasties might occur as an inpatient. Regarding pertrochanteric fractures, our early mechanical complication rate was 1.2%, while the rate varies between 0% and 16% in the literature[37].

AtoG presents with some innovative features. Each of its items is a composite variable and not a singular diagnosis. As a result, this score introduces the operator *OR* or *ANY* and allows a greater degree of freedom for the clinicians, who won't have to compromise and choose between two comorbidities (for instance, ischemic heart failure or hypertrophic heart failure). AtoG relies on the “clinical good sense” more than the weight of the prognostic factors; AtoG had almost as good results as AtoG without an accurate ponderation, which facilitates its employment in daily practice. Similarly, Souza et al. demonstrated that the CCI, even if calculated with one randomly selected comorbidity, or calculated considering only the highest weighted comorbidities, was still a strong prognostic factor for mortality[38]. AtoG does not integrate any other scores, like ASA for Almelo[20], Mini-Mental State, or Mobility score for Nottingham[4,18,19], which improves its simplicity. Comparison with these scores remains mandatory.

The “clinical good sense” and the simplicity were already illustrated a couple of decades ago with the RISK-VAS: it is a visual analogue scale for intuitively appreciating the global risk. Arvidsson et al. and Burgos et al. demonstrated that RISK-VAS is a powerful prognostic tool[39,40].

AtoG's AUC for 90-day mortality was as good as the validated scores Nottingham, Almelo, Oxford Hip Score, and Sernbo[3,41–44]. Some similarities between these scores exist. They are all multidimensional and assess cognitive frailty. Nottingham and Almelo scores group the comorbidities as one prognostic factor. Nevertheless, AtoG includes social deprivation and undernutrition, two well-identified risk factors for both the occurrence[10–12,45] and the outcomes[13,14,46,47] of hip fractures. AtoG is in line with Rokwood's Comprehensive Geriatric Assessment model[21,22,48], which "captures" a wide panel of dimensions involved in the elderly population.

The reasons why the dimension Environment, reflecting the social deprivation, became protective when predicting 90-day mortality in the multivariable model remains unclear. It is possible that these patients had housing issues and stayed longer in a medical environment with prolonged care.

The factorial analysis led to classifying the comorbidities in dimensions according to their relationship [31]. The new variables created after the factorization had an internal consistency because they assessed the same dimensions[30]. However, the overall consistency of the score variables was low, with a very low Cronbach's alpha value; this approach is a complete opposite paradigm compared to the "usual" method for developing questionnaires[31]. In fact, in psychology, for instance, researchers look for the highest overall consistency possible because they aim to address an unobserved phenomenon. The more the questionnaire is consistent, the more it will converge toward the unobserved dimension it aims to assess. In a prognostic study, the aim is to discriminate patients[23]. In this context, the overall consistency between items should be as low as possible so that several dimensions can be captured, and several combinations could be possible in the same way primary colours can be combined. This is probably why AtoG had better results than CCI; CCI focuses only on the comorbidities, which were grouped in the same area on the spheric representation of the component analysis. Collinearities, meaning associations between the explicative variables, are suspected in the Modified Frailty Index score, in which at least 5 items are related to a vascular condition. Collinearities are also suspected in Nottingham, Almelo, and Sernbo scores because institutionalized patients are more likely to have a cognitive impairment. Collinearity makes the interpretation of the coefficients of regressions biased, and the scores issued from the coefficients are automatically impacted[26].

### 4.3 Limitations

This study has several limitations. For technical reasons, we could not perform the analyses with the complete number of patients when considering the type of treatment (arthroplasties or osteosyntheses). This was responsible for roughly 50 mechanical complications not attributed to a type of treatment. There is also a risk of coding error, defect, or inaccuracy. This bias is

complex to predict and can have several features. Before 2009 (at least), the French healthcare system funding consisted of lump sums, while progressively after 2009, the funding relied on coding the acts and diagnoses. Consequently, some surgeries or associated diagnoses were expected to be overlooked before 2009. Coding defect is responsible for missing values, and it is a certainty that some diagnoses or procedures have been overlooked in many cases. There are three types of missing values: "missing completely at random", "missing at random" and "missing not at random". In the two first situations, there is a simple decrease in statistical power; our study included a large number of patients, which may counteract the decrease in power. The third situation means there is an unknown pattern for the missing values, and unfortunately, there is no way to analyse this situation without further data. The inaccuracy may involve the surgical procedures, for instance, a femoral shaft fracture encoded hip fracture, and hence directly impair the accuracy of the selection of the participants. Inaccuracy was also deficient when accurately describing the surgical complication, for instance, differentiating the fractures and the dislocations. In daily practice, for instance, the diagnosis T840 represents a "mechanical complication", which is not specific and may represent a dislocation or a fracture; also, there is a code for a fracture after surgery: M96.6, but it isn't used systematically. The place of residence before admission (institution or personal home, and if personal home, with or without car assistance), and the mode of discharge were barely accurate while they both have been identified as prognostic factors[17]. The cross-validation theoretically homogenizes the code errors and discrepancies but exposes to a lack of power in the test sets. The lack of power may have been responsible for the lability of the highest figures of the score in the calibration plots, frequently being either too high or too low (figure 2). The lack of clinical data is inherent in the administrative databases; there is no direct information about biology, and some factors, such as haemoglobin have been well-identified. This study only focused on inpatient complications, so the readmissions have been overlooked; without clinical details, it's complex to reliably link two admissions together and make sure the readmissions for complications are formally related to the PFF surgery. The comorbidities we considered were the most serious ones, easily identifiable with the codes: organ failures or tumours. This is an approximation; some diseases, such as complicated diabetes were overlooked. Finally, this study didn't consider the organizational factors, such as the surgical delay, and only focused on patient-based prognostic factors. Further studies will be mandatory to identify changeable prognostic factors, including organizational parameters; AtoG will be employed to accurately match the patients together.

## 5. CONCLUSION

ABCDEGF is a multidimensional score in line with the concept of comprehensive geriatric assessment. It has shown good discrimination and performance in predicting 90-day mortality and inpatient complications after upper femoral fractures. Performances were as good as the

Charlson Comorbidity Index for 90-day mortality, and better than it for the complications. The development of this score was based on a paradigm change, targeting an internal consistency as low as possible to improve its multidimensional feature and discrimination performances. AtoG, the non-pondered score, demonstrates the value of the "clinical good sense" and simplicity because its performances were as good as the pondered score and did not integrate any other score. Undernutrition and social deprivation were two items that stood out compared to the other scores of the literature.

### **Links of interest**

In a context independent of this article, BB has received benefits from Corin, Sanofi and Coloplast. In a context independent of this article, DB received remuneration and benefits from the companies Lilly, Sanofi, Johnson & Johnson Medical, SERF, Stryker and Zimmer.

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### **Detailed contribution of the authors**

BB: method development, data collection, statistical analyses, writing the article.

FG: data collection, methodological and statistical support, and writing contribution.

DB: method development, methodological and statistical support, contribution to the writing and final validation.

### **Use of Artificial Intelligence**

The authors did not use any form of artificial intelligence for data extraction and processing.

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## Figure Legends

Figure 1: Principal Component Analysis, after factorization. The seven dimensions were spread out from each other. The psychiatric and neurological diseases were gathered in the same dimension, as well as the comorbidities.

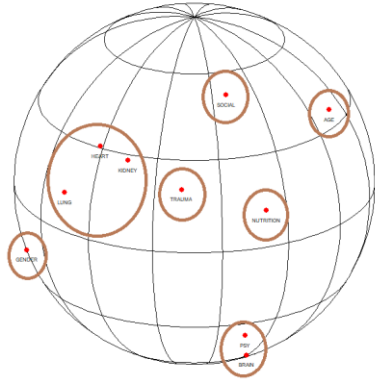


Figure 2: Calibration plots for 90-day mortality. The AUCs were all around 0.7 except the one in the middle right. The highest figures tended to be the more labile, either too high or too low. A lack of power is suspected.

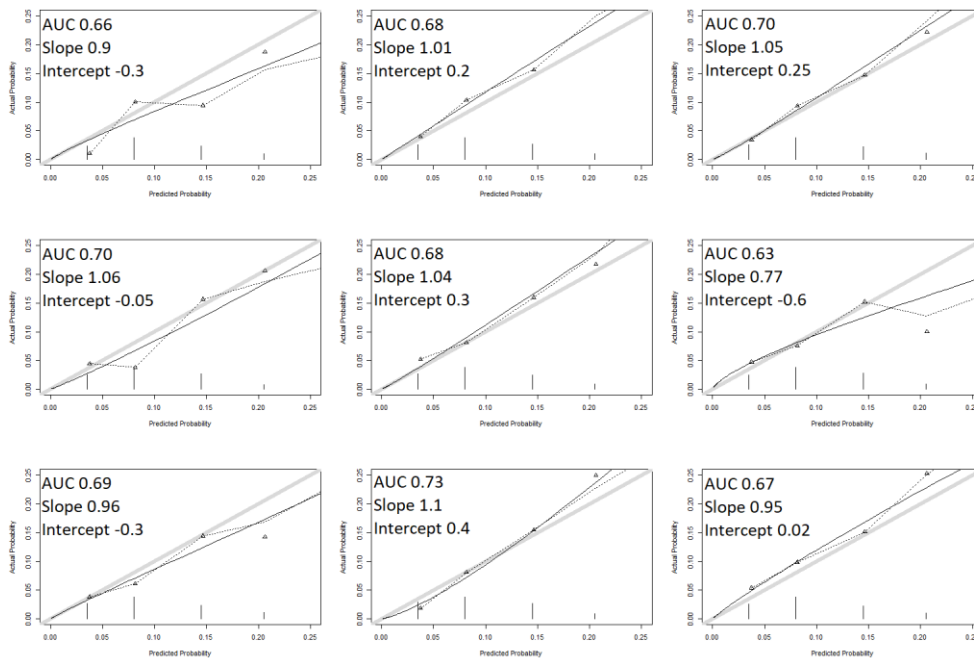


Figure 3: Calibration plots for complications.

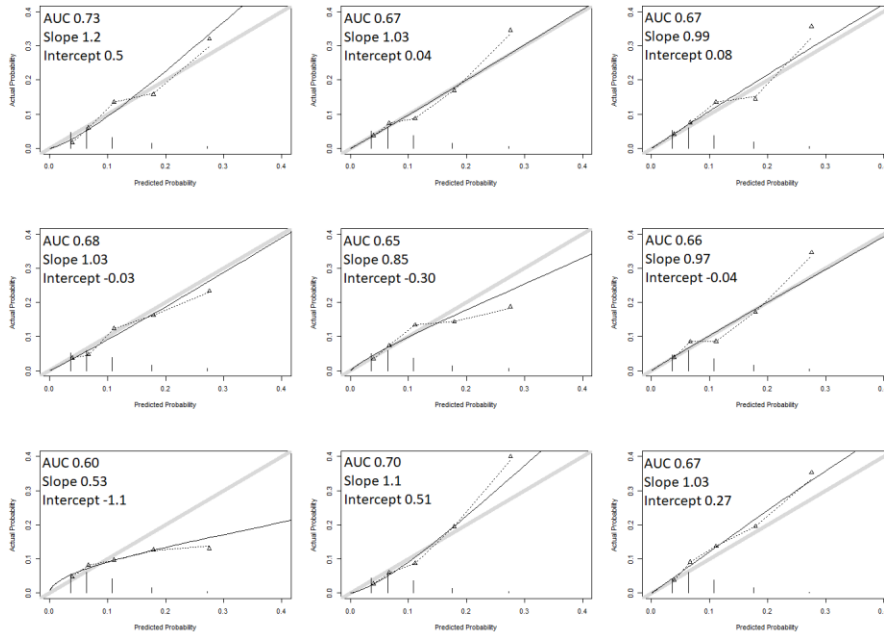


Figure 4: Kaplan Meier curves representing the 90-day mortality for each figure of AtoG. The mortality increased by 5% per point, roughly.

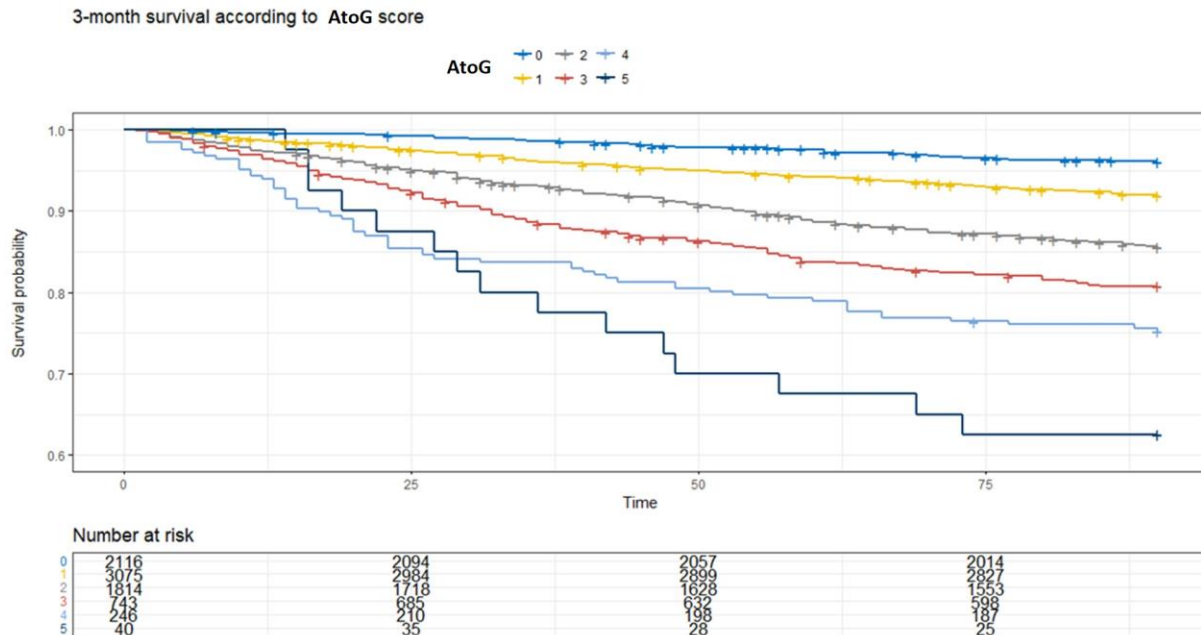
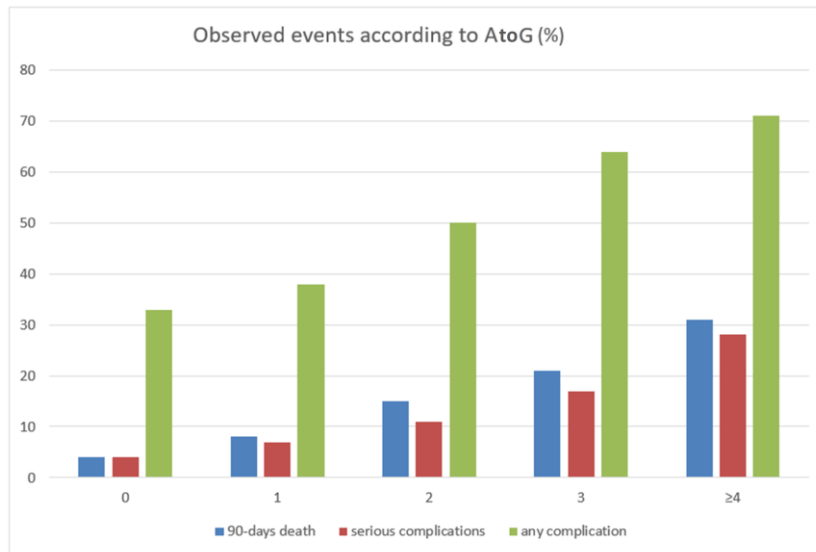


Figure 5: The observed rates of any complications, serious complications (Clavien Dindo >2), and mortality increased with AtoG score.



type of complications	rates	Risks				
		AtoG score*		Charlson score*		
		OR 95%CI[-]	p value	OR 95%CI[-]	p value	
inpatient medical complications	thromboembolic complications	180/7756 (2.3%)	1.002 [0.99-1.005]	0.08	1 [0.99-1]	0.20
	postoperative anaemia	1674/7756 (21.5%)	1.04 [1.03-1.05]	<0.0001	1.01 [1-1.01]	<0.0001
	urine retention	433/7756 (5.6%)	1.02 [1.01-1.03]	<0.0001	1 [0.99-1]	0.23
	cystitis and other urine infections	676/7756 (8.7%)	1.01 [1.007-1.02]	<0.0001	1.005 [1.002-1.008]	0.001
	Pneumonia/bronchiectasis	219/7756 (2.8%)	1.02 [1.02-1.02]	<0.0001	1.01 [1-1.01]	<0.0001
	acute kidney failure	102/7756 (1.3%)	1.01 [1.007-1.01]	<0.0001	1.003 [1.002-1.005]	<0.0001
	acute heart conditions (ischemic or rhythmic)	103/7756 (1.3%)	1.01 [1.01-1.01]	<0.0001	1.004 [1.003-1.005]	<0.0001
inpatient implant related complications		All cohort				
	mechanical complications (including dislocations)	149/7756 (1.9%)	1 [1-1]	0.21	1 [1-1]	0.24
	infection/haematoma	289/7756 (3.7%)	1.01 [1.01-1.02]	<0.0001	1.003 [1.001-1.005]	0.001
			Osteosyntheses, n=3953°			
	mechanical complications	50/3953 (1.2%)	1 [1-1]	0.48	1 [1-1]	0.50
	infection/haematoma	152/3953 (3.8%)	1.01 [1.01-1.02]	<0.0001	1.005 [1.002-1.008]	0.0001
		Arthroplasties, n=2820°				

	mechanical complications (including dislocations)	54/2820 (1.9%)	1 [1-1]	0.88	1 [1-1]	0.40
	infection/haematoma	116/2820 (4.1%)	1.01 [1.01-1.02]	<0.0001	1 [1-1]	0.56
inpatient mortality	mortality	266/7756 (3.4%)	1.02 [1.02-1.03]	<0.0001	1.007 [1.005-1.009]	<0.0001
			HR 95%CI[-]	p value	HR 95%CI[-]	p value
	90-day mortality	822/7756 (10.6%)	1.70 [1.60-1.80]	<0.0001	1.09 [1.07-1.1]	<0.0001
	1-year mortality	1629/7756 (21%)	1.60 [1.50-1.65]	<0.0001	1.09 [1.07-1.1]	<0.0001
post-discharge mortality	5-year mortality	3855/7756 (49.7%)	1.51 [1.46-1.55]	<0.0001	1.08 [1.07-1.09]	<0.0001

OR: Odd Ratio from logistic regression, HR: Hazard Ratio from Cox'PH model, 95%IC: Confident intervals; \*: scores entered as a continuous variable. °: the analysis in subgroups arthroplasties/osteosyntheses was responsible for a loss of patients, total n=6773

**Table 1.** Inpatient complications, mortality, and their association with AtoG. OR: Odd Ratio from logistic regression, HR: Hazard Ratio from Cox'PH model, 95%IC: Confident intervals; \*: scores entered as a continuous variable. °: the analysis in subgroups arthroplasties/osteosyntheses was responsible for a loss of patients, total n=6773.



Table 2. AtoG's dimensions and their association with the risk of any complication.

Items	OR 95%IC[-] for complications	HR 95%IC[-] for 90-day mortality	points in AtoG score
Age > median age of the cohort	1.24 [1.2-1.35]	2.0 [1.8-2.3]	1
Brain			
Any of <ul style="list-style-type: none"> <li>· Dementia</li> <li>· Psychiatric issues</li> <li>· Parkinson disease or other neurological disorder</li> </ul>	1.82 [1.6-2]	1.4 [1.2-1.7]	1
Comorbidities			
Any of these chronic serious comorbidities <ul style="list-style-type: none"> <li>· Heart failure (whatever the cause)</li> <li>· Kidney failure</li> <li>· COPD or other lung chronic failure</li> <li>· Tumour</li> </ul>	2.64 [2.25-3]	2.2 [1.9-2.7]	1
unDernutrition			
Any of <ul style="list-style-type: none"> <li>· Pressure ulcers</li> <li>· Cachexia</li> <li>· Malnutrition syndromes</li> <li>· Vitamin deficiency</li> </ul>	2.4 [2.3-3]	1.24 [1.07-1.4]	1
Environment			
Any of <ul style="list-style-type: none"> <li>· Housing issues</li> <li>· Difficulties with social environment</li> </ul>	1.58 [1.3-1.8]	0.62 [0.45-0.81]	1 for complication, -1 for 90-day mortality

· Trouble with justice			
Fractures			
· Any associated trauma	1.78 [1.5-2]	1.23 [1.02-1.51]	1
Gender			
· Male	1.06 [1.04-1.08]	2.1 [1.76-2.46]	1

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## STROBE Guidelines for authors of OTSR

	Item No	Recommendation	Please insert check where included or N/A where not applicable
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre specified hypotheses	3
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, treatment, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of treated and untreated	
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls	

		per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-5-6
Bias	9	Describe any efforts to address potential sources of bias	6 (cross validation in statistics)
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6
		(b) Describe any methods used to examine subgroups and interactions	6
		(c) Explain how missing data were addressed	-
		(d) If applicable, explain how loss to follow-up was addressed	-
		(e) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	7
		(b) Give reasons for nonparticipation at each stage	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg, demographic, clinical, social) and information on other treatments and potential confounders	7 + tables
		(b) Indicate number of participants with missing data for each variable of interest	7+ tables
		(c) <i>Cohort study</i> —Summarize follow-up time (eg, average and total amount)	-

Outcome data	15*	Report numbers of outcome events or summary measures over time	8
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8
		(b) Report category boundaries when continuous variables were categorized	6-7-8+ tables
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8-9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

\*Give information separately for cases and controls.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.