THE INTERACTIONS BETWEEN MUNICIPAL SOCIOECONOMIC STATUS AND AGE ON HIP FRACTURE RISK

Carla Maria Oliveira

Rua do Campo Alegre, 823, 4150-180 Porto, INEB, Instituto de Engenharia Biomédica, Portugal

Rua das Taipas 135, 4050-600, Porto, ISPUP, Instituto de Saúde Pública da Universidade do Porto, Portugal

Al. Prof. Hernâni Monteiro, 4200 - 319 Porto, Departamento de Epidemiologia Clínica, Medicina Preditiva e Saúde Pública, Faculdade de Medicina da Universidade do Porto, Portugal

carlaoliveir@gmail.com

Theodoros Economou

College of Engineering, Mathematics and Physical Sciences, University of Exeter, North Park Road, EX4 4QF, Exeter, UK.

t.economou@ex.ac.uk

Trevor Bailey

College of Engineering, Mathematics and Physical Sciences, University of Exeter, North Park Road, EX4 4QF, Exeter, UK.

t.c.bailey@ex.ac.uk

Denisa Mendonça

Rua das Taipas 135, 4050-600, Porto, ISPUP, Instituto de Saúde Pública da Universidade do Porto, Portugal

Rua de Jorge Viterbo Ferreira n.º 228, 4050-313 Porto, ICBAS, Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto

dvmendon@icbas.up.pt

Maria Fátima Pina

Al. Prof. Hernâni Monteiro, 4200 - 319 Porto, Departamento de Epidemiologia Clínica, Medicina Preditiva e Saúde Pública, Faculdade de Medicina da Universidade do Porto, Portugal

Rua do Campo Alegre, 823, 4150-180 Porto, INEB, Instituto de Engenharia Biomédica, Portugal

Rua das Taipas 135, 4050-600, Porto, ISPUP, Instituto de Saúde Pública da Universidade do Porto, Portugal

fpina@med.up.pt

Corresponding author: C Oliveira ; carlaoliveir@gmail.com; phone +351966060193 ; Fax : 351 226094567; Rua do Campo Alegre, 823, 4150-180 Porto, INEB, Instituto de Engenharia Biomédica, Portugal

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Mini-abstract

Age modifies the effect of area-level socioeconomic status (SES) in the risk of fragility hip fractures (HF). For older individuals risk of HF increases as SES increases. For younger, risk of HF increases as SES decreases. Our study may aid decisions makers and medical guidelines for HF prevention.

Background: The effect of socioeconomic status (SES) on hip fracture (HF) incidence remains unclear.

Objective: To evaluate the association between HF incidence and municipality-level SES as well as interactions between age and SES.

Methods: From the Portuguese Hospital Discharge Database we selected hospitalizations (2000-2010) of patients aged 50+, with HF diagnosis (codes 820.x, ICD9.CM), caused by traumas of low/moderate energy, excluding bone cancer cases and readmissions for after-care. Municipalities were classified according to SES (deprived to affluent) using 2001 Census data. A spatial Bayesian hierarchical regression model (controlling for data heterogeneity effect and spatial autocorrelation), using the Poisson distribution, was used to quantify the Relative Risk (RR) of HF, 95% credible interval (95%CrI), and to analyze the interaction between age and SES, after adjusting for rural conditions.

Results: There were 96,905 HF, 77.3% of which were on women who on average were older than men (mean age 81.2±8.5 vs 78.2±10.1 years) at admission ($p<0.001$). In women, there was a lower risk associated with better SES: RR=0.83 (95%CrI 0.65-1.00) for affluent versus deprived. There was an inverse association between SES and HF incidence rate in the youngest and a direct association in the oldest, for both sexes, but significant only between deprived and affluent in older ages (≥75years).

Conclusions: Interaction between SES and age may be due to inequalities in lifestyles, access to health systems and preventive actions. These results may help decision-makers to better understand the epidemiology of hip fractures and to better direct the available funding.

Keywords: osteoporosis, hip fractures, socioeconomic status, spatial epidemiology, interaction

Introduction

Bone fractures in the elderly[1] are mainly caused by a combination of low bone mineral density (BMD) in individuals with osteoporosis, and traumas of low/moderate energy after a fall from standing height or less, and they are more frequent among women [2]. From all such fragility fractures, hip fractures (HF) are the most severe, because of the high costs associated with treatment and recovery [3] and the high physical disability, social dependence and mortality among the elders after a fracture [2, 4].

In Europe, incidence rates of HF are seven times higher in the northern countries when compared to the southern countries [5], although when analyzing the incidence of HF at municipality level, there are strong geographical differences within the countries - in Portugal incidence rates of HF in the northeast and south of the country are similar to those reported in Finland [6]. The reasons for such geographical differences are not well understood but a plausible explanation is that such differences are associated with socioeconomic and environmental contexts [7]: geographical variations in diet, body height and weight, smoking, alcohol intake, physical activity and uptake of anti-osteoporosis medication [2] can be associated with HF incidence and may explain the geographical differences in the incidence rates. Heterogeneity in the policy framework, service provision and service uptake for osteoporotic fractures may be also a reason for the difference in HF risk between regions[8]. In addition, unhealthy lifestyles and exposure to environmental risk factors tend to be higher in deprived areas [9].

Unfortunately, relatively little work has been published regarding the association between HF risks and socioeconomic status (SES), or some proxy:

Studies consistently showed a significant association with marital status (a decrease in those married or living with someone) [10-12], occupational category (reduced risk for employed vs unemployed and for tradespeople vs laborers) [13, 14] and residence type (living in large vs small homes decreases the risk) [11]. A study in Stockholm [10, 11, 15] indicated reduced risk for those with medium or high incomes compared to low incomes. For Australia [16], there was reduced risk for those with private health insurance compared to ones without. In the Trend region (UK) study, an increased risk of falls in areas of lower SES (for adults aged 75 years or over) was described but without significant association with HF [7]. Nevertheless, some inconsistencies do exists, for example the role of income or education in the risk of HF: there were different associations in different age groups, which might suggest an age interaction with SES [17].

The age modifiable effect on the association between SES and HF is not well studied in the current literature. A nationwide case-control study in Denmark described a reduction in the risk of any type of fracture in younger age groups (<40 years old) among those with higher education levels, while the opposite was observed among subjects aged 60 years or more: higher risk in the higher education levels [18]. In Wales, those over 74 years-old living in affluent neighborhoods have greater risk compared with those living in more deprived areas, while individuals below 74 living in more deprived areas, had an increased risk of HF when compared with those living in more affluent areas [15, 19]. In the Stockolm metropolitan area, a higher risk of HF was found in the elderly living in more affluent areas, corroborating these findings. [18]

Better understanding of the relationship between HF and socioeconomic and environmental factors, and their interactions with age, can help in better targeting prevention measures of HF [7]. However, there is a gap in the scientific literature regarding this issue. Our objective here is to investigate and quantify the relationship between HF and SES as well as the relevance of the interaction between age and SES on HF incidence, in Portugal using data in the period 2000-2010. To this end, we propose a flexible statistical model, which accounts for spatial heterogeneity in the data while also allowing for unobserved but also observed factors in the form of predictors.

Materials and Methods:

Study area

The study area is Continental Portugal, which had 10,057,999 inhabitants in 2010, distributed heterogeneously throughout 278 municipalities, with a median of 15,741 inhabitants per municipality. The least populated municipality has 1,836 inhabitants and the most populated is the capital, Lisbon, with 548,422 inhabitants. The population over the age of 50 rose from 3,298,900 (in 2000) to 3,789,091 (in 2010)[20]. In Portugal, although it is a developed country, inequality of wealth distribution, measured through the GINI index, is among the highest in the European region [21].

Data

We used data from the National Hospital Discharge Register (NHDR), which has been mandatory for all Portuguese public hospitals since 1997 and whose quality is assessed regularly by internal (hospitals) and external (ACSS – Central Administration of the National System) auditors [22]. Each record in the NHDR corresponds to one discharge and contains information such as: sex; age; first cause of admission and main diagnosis (and up to 19 secondary causes and 19 secondary diagnoses), coded according to the International Classification of Diseases, version 9, Clinical Modification (ICD9-CM); municipality of patient’s residence; date of admission and discharge, hospital to and hospital from whenever there is a transfer between hospitals, among others [23]. In Portugal, access to the national health-care system is universal and tendentiously free-of-charge: contributions are based upon citizens’ social and economic conditions [22]. All the patients with a HF are hospitalized for treatment and due to the high costs involved, HF are primarily treated in public hospitals. Therefore, the admissions by HF registered in the NHDR represent almost the totality nationwide and can be seen as a proxy of incidence. For reasons of confidentiality we did not have access to patient´s code and therefore recurrent fractures in the same patient could not be identified.

We selected all hospital admissions, from 1 January 2000 to 31 December 2010, of patients aged 50 years and over, with a discharge diagnosis of HF (ICD9-CM codes 820.x) caused by traumas of low/moderate energy (ICD9-CM codes E849.0, E849.7 and E880-E888). We excluded readmissions for after care (ICD9-CM codes 996.4 and V54.x) and pathological fractures (ICD9-CM codes 170.x and 171.x). No such data was available for the two autonomous regions, the archipelagos of the Azores or Madeira (representing 5% of the Portuguese population), and therefore they were not included in the study. Counts of HF were stratified by municipality of patient's residence, admission year, sex and 5-year age groups (50-54… 80-84, 85+).

To calculate the population at-risk or person-years we aggregated population per municipality, sex and 5-year age groups using data from the 2001 Census and from the annual official estimates for all the other years (INE - Statistics Portugal [20]).

The socioeconomic characterization of municipalities was based on data from the last available Census - 2001 (INE - Statistics Portugal [20]). In Portugal there were no significant changes in SES during the study period and therefore the relative position in the SES rank of municipalities between 2000 and 2010 remains stable (results not shown); each municipality was characterized by a set of variables related to buildings, households, families and individuals. The variables included were: proportion of population by age groups and sex; proportion of retired individuals (by sex); proportion of widows; proportion of individuals receiving social support; proportion of illiteracy; ageing and youth dependency indexes; proportion of individuals living alone; mean number of rooms per household; mean number of individuals per household; unemployment rate; proportion of subjects with higher and basic education; proportion of subjects by category of occupation (managers/professionals/technicians; services/sales workers; skilled agricultural/plant & machine operators); income; proportion of residences and buildings with/without public water supply, mains or otherwise; and proportion of households with heating, by type of heating. To create the SES index, we performed a principal component analysis to reduce the set of variables described above to four components, which explained 75.8% of the total variability. Afterwards, we used the four components to develop a hierarchical cluster analysis [24], using the Ward´s method. We used three clusters of SES to analyze the association with HP incidence: affluent, medium and deprived (Figure 1). The affluent SES category aggregates municipalities with younger population, higher educational level, higher percentage of employed individuals and good housing conditions (plumbing, heating and bathroom facilities and shower). The medium SES category aggregates municipalities with population older than in affluent group, higher illiteracy rate, low indices per capita, higher percentage of individuals employed in agriculture, forestry and industry. The deprived SES category aggregates municipalities with the highest percentage of elderly, the highest illiteracy rate, the highest rate of people living alone, the lowest level of education, the lowest indices per capita, higher percentage of individuals with rural activities, the highest percentage of house with no running water and no bathroom facilities and shower and the highest percentage of individuals receiving unemployment benefits.

The distribution of the population in Continental Portugal significantly differ per SES group ($p<0.001$). The median population per municipality increases with SES: 1,607 inhabitants (interquartile rage (IQR)

1,207 – 2,402) in the deprived SES cluster; 3,473 inhabitants (IQR 2,386 – 6,285) in the medium SES cluster and 7,426 inhabitants (IQR 3,453 – 12,706) in the affluent SES cluster. [20].

We considered rural conditions as a possible confounder of the association between SES and HF incidence rate, since rural areas can be associated with a lower risk of HF[25] and some rural regions may have lower SES. Therefore we classified the municipalities as rural, urban and semi-urban (Figure 1) based on the official information available [20].

Statistical analysis

For individual's characteristics, differences in mean age by sex and SES were analyzed using ANOVA and the Tukey HSD test for multiple comparisons; statistical significance level (two-sided) was set at 5%.

To assess the relationship between mean HF rates and SES, a spatial Bayesian hierarchical regression model was implemented. Age and rural conditions were included in the model as predictors to allow for the (possible) different behavior of HF rate between various categories of age and rural conditions. An interaction term between age and SES was also included to capture the possible modifiable effect of age in the relation between SES and HF incidence. The interaction term in our model is essentially another categorical variable with N levels, where N is the number of age groups times the number of SES groups. All analyses were performed separately for each sex.

We assumed that the number of HF, $NFrat_{ij}$, in a specific age group i ($i = 1, \dots, 8$) and in a specific municipality j ($j = 1, \dots, 278$) is distributed as a Poisson random variable with mean $\lambda_{ij} = NPop_{ij}\varrho_{ij}$ where $NPop_{ij}$ is the population in age group i and municipality j, and ϱ_{ij} is the incidence rate of HF per unit population in age group i and municipality j; so that, for instance, the quantity $\varrho_{ij}/\varrho_{kj}$ is the relative risk (RR) of age group i to reference age group k ($k = 1, \dots, 8$). For each sex, the parameters of interest were estimate by the following model:

$$NFrat_{ij}|(\psi_j, \phi_j) \sim Pois(\lambda_{ij})$$

$$log(\lambda_{ij}) = log(NPop_{ij}) + log(\varrho_{ij}) = log(NPop_{ij}) + \beta_0 + \beta_1 AgGr_i + \beta_2 SES_j + \beta_3 RurUrb_j$$

$$+\beta_{12} AgGr_i * SES_j + \psi_j + \phi_j$$

$$\psi_j \sim N(0, \sigma_\psi^2)$$

$$\phi_j|\phi_{(-j)} \sim N(\bar{\phi}_j, \sigma_\phi^2/m_j); \;\; \phi_{(-j)} = \{\phi_k : \mathrm{k} \neq \mathrm{j} \wedge \mathrm{k} \in A_j\}$$

where A_j is the set of neighbors of municipality j; the $AgGr_i$ is the age group i; the SES (SES_j) and the rural condition $(RurUrb_j)$ are characteristics of the municipality j; ψ_j is the non-spatial random effect and ϕ_j is the spatially structured random effect ($\bar{\phi}_j$ is the average of the ϕ_k that are adjacent to ϕ_j and m_j is the number of these adjacencies). The joint model for the ϕ_j's is the so called conditional autoregressive (CAR) normal prior [26]. With this model we attempt to modeling the effect of AGE, SES and the interaction AGE*SES (adjusting for rurality) on the risk of hip fracture incidence rates where β_1, β_2 and β_{12} are the age, sex and interaction term coefficients, respectively.

The model included two random effects (or latent variables) at the municipality level. One of the random effects (ψ_j) accounted for the unexplained heterogeneity in HF rate due to unobserved municipality-level factors while the other (ϕ_j) allowed for spatially structured dependence in measurements of HF in municipalities that were spatially close. The latter relates to the fact that HF incidence in two nearby municipalities tends to be more similar (in terms of risk) than two areas chosen randomly.

The model described above was implemented in a Bayesian framework and estimated using Markov Chain Monte Carlo (MCMC). In this framework, parameters are treated as random variables whose "prior" distribution expresses the uncertainty about their value before any data is observed. After data is obtained though, prior distributions (or simply priors), are combined with the data through Bayes theorem to produce the posterior distributions (or simply the posteriors) of each parameter. The posteriors express the uncertainty about model parameters after data is observed and all statistical inference is based solely on the posteriors. MCMC is a numerical technique which produces samples of values that eventually converge (after a certain "burn-in" number) to samples of values from the posterior (distribution) of each parameter.

Uninformative prior distributions were assumed for the model parameters. Parameters $\beta_0, \beta_1, \beta_2, \beta_3, \beta_{12}$ were given Gaussian priors with zero mean and large variance (1000) whereas σ_{ψ}^2 and σ_{ϕ}^2 priors were assumed to be gamma distributed: gamma (0.5, 0.0005).

All the analyses were performed with the Statistical software R version 2.14.1 (Project for Statistical Computing)[27] and WinBUGS14 (WinBUGS14, Cambridge, UK)[28] using R2WinBUGS package to connect both tools. WinBUGS uses Gibbs sampling, a particular MCMC technique, to produce samples from the posterior distribution of each parameter (or simply posterior samples).

The RR and its 95% credible interval (95% CrI) were estimated using the sample mean and the 2.5% and 97.5% empirical quantiles of the posterior samples from each parameter of interest. These samples are based on two MCMC chains with 100,000 iterations each and a burn-in period of 10,000.

Results:

There were 98,186 admissions for HF in Continental Portugal between 2000 and 2010. From those we excluded 585 because of missing data for municipality of residence and 696 because of readmissions for after care; our final sample includes 96,905 fractures of which 74,928 (77.3%) were in women. On average, women were older than men at admission (p<0.001), with a mean age (Standard Deviation – SD) of 81.2 (8.5) versus 78.2 (10.1) years old, and the same pattern was observed in all the SES; the highest age difference (3.3 years 95% CI: 3.0-3.5) between sexes was in the affluent municipalities and the lowest (2.5 years 95% CI: 2.0-3.1) was in the deprived municipalities (Table 1).

Age differences between all SES were observed in both sexes, except between affluent and medium SES in women. Men and women were older at admission in the deprived SES and younger in the affluent SES; such differences in the mean age of admission between SES were higher in men (1.8 years 95% CI: 1.2-2.3) than in women (1.0 years (95% CI: 0.7-1.3) (Table 1).

Figure 1 – Geographical distribution of socioeconomic status (SES) and rural conditions, by municipality

The annual average of age-standardized incidence rates (per 100,000 inhabitants, 95% confidence intervals) of HF were 210 (207 - 212) for women and 102 (100 – 105 for men (direct method, 2006 European standard population). There is an accentuated geographic pattern, with the highest incidence rates in the northeast, and south of Portugal[6]. Table 2 shows the annual average of age-specific incidence rates of HF per SES and Sex. In general, youngest adults living in areas with higher SES had a lower risk of HF compared to those living in lower SES areas and the reverse occurs for the oldest individuals.

Initially, a main effect model was considered (not including interaction term: $\beta_{12} = 0$) and adjusting for age and rural conditions, the highest risk of HF was in the deprived SES areas in both sexes. Among women, there was a trend in HF incidence and SES: the risk decreased as the SES increased. Among men, such a trend was not observed (Table 1).

Table 1 – Mean age (95% Confidence Intervals) at admission, absolute incidence (%) and Relative Risk of hip fracture (95%Credible Intervals) by sex and socioeconomic status (SES)

Table 2 – Age-specific incidence rates of hip fracture by sex and socioeconomic status (SES)

Considering the model described above, an interaction between age and SES in HF incidence was observed for both sexes: in medium and affluent areas the incidence rates were lower in younger age-groups, and higher in older age-groups, when compared with the most deprived areas (Figure 2 and Table 3). The relative risks (RR) were statistically significant in age groups of 75-79, 80-84 and 85+ in affluent municipalities (using deprived municipalities as reference) in both sexes and in the borderline of the significance in other age groups, such as in women with ages between 50-54 years (Table 3).

Figure 2 – Relative risk of hip fractures, by sex, age group and three classes of socioeconomic status, using the most deprived as reference

Table 3 – Relative risk of hip fractures (95%CrI) by sex, age group and three classes of socioeconomic status, using the most deprived as reference

Figure 3 shows the significant higher and lower RR of HF attributed to unobserved spatial effect. It seems that there are two areas of municipalities with particularly higher risk of HF (Northeast and the very South). This may be related with unobserved variables and future investigation needs to be performed.

Figure 3 – Significant higher and lower municipality-specific unobserved effect of hip fractures

Discussion

Our study suggests that, at an ecological level, the main effect of the risk of HF is related with the SES of patients' municipality of residence. In both sexes, a higher risk was observed in deprived municipalities and a trend was identified in women: more affluent areas, lower risk; however some of our results are in the borderline of significance or are not statistically significant.

The inverse relation between HF risk and SES observed in our study is in accordance with a set of studies that explored this issue. In Oslo (Norway) [29] a study including population aged 50 years and over found an higher risk of HF in deprived areas compared with more affluent ones; in Geneva (Switzerland) [30] a study also including population aged 50 years and over found an higher risk in low-income regions compared with medium/higher income regions and their results were similar to a study in Sweden [13] including population in all ages. The same direction of this association was found in an Australian study [16], using a private health insurance as a proxy of higher SES and including population aged 65 years and over. In the Trend region (north of England) [7] a study using the Townsend deprivation index as a proxy of SES, found a significant inverse association in the risk of falls; although, no association between HF and deprivation was found [7] and this may be due to the low statistical power of the study [15] or because only individuals aged >74 years were included in the study (the association between SES and HF can be dependent of the age group). In the United States [31], in a community-dwelling of people aged ≥70 years and over there was a non-significant inverse association between HF and income.

Socioeconomic status seem to be also related with bone mineral density - individuals with higher income [32] and higher education [33] had higher BMD when compared with individuals with lower income and education.

The higher risk of HF in individuals living in deprived areas may result from a combination of lifestyle, environmental and social factors: unhealthy lifestyles can lead to higher risk of osteoporosis[2]; inappropriate built environment can lead to higher risk of falls [34]; and lower access to health services can lead to lower access to actions for osteoporosis prevention [35]. Even though in Portugal access to the national health-care system is universal and tendentiously free-of-charge, regions with lower SES can be more isolated, with lower street connections and lack of public transports which may difficult the access to health centers.

The observed increasing trend, at individual level, of the mean age at admission with the decrease in SES can be due to the age structure of the population since the regions with lower SES have the highest proportion of elderly.

An interaction between SES and age was observed, more accentuated among men: youngest adults living in areas with higher SES had a lower risk of HF compared to those living in lower SES areas and the reverse occurs for the oldest individuals. Few studies have evaluated the age interaction between HF and SES, but results similar to ours were found in Wales and Denmark [15, 18]. The lower risk in the youngest living in more affluent areas may be a result of a cohort effect: higher education in the younger may influence risk behaviors [18]. In Wales, among individuals aged < 75 years an inverse association was observed between HF incidence and deprivation of the region of residence, although the relationship disappears in older age groups (≥75 years) [15]. In Denmark, the association between HF risk and income was not significant and a possible reason can be the reduced social inequalities [18]. In Spain, an interaction between age and income was found in the relation between BMD and income: youngest adults (20-39 years-old) had a higher BMD in the more affluent areas compared to the more deprived areas and a reverse relation was observed in the older ages [32]. A U-shape relation between BMD and SES was also found in Australia (women, over 18 years) - individuals living in the extreme categories of SES had lower Bone Mineral Density (BMD) [36]

For women, the age interaction with SES was not so clear: older women from areas in the medium SES had lower risk compared to women from lower SES areas and we need further studies to understand if this pattern is related to risk factors such as obesity, physical activity, occupational work, etc; risk for women in the age group 70-74 years was similar in the three SES areas and this may be due to the fact that in Portugal the health guidelines for osteoporosis prevention are mainly focusing in women between 65-74 ages[37].

A limitation of our study is the absence of individual data for SES and for previous places of patient´s residence; therefore conclusions need to be taken with caution. The age interaction on the relative risk between HF and SES could be a consequence of changes in place of residence of the elderly. Older and frail individuals, living in more isolated and deprived municipalities, may have moved to more affluent municipalities to live with or close to caregivers. However, other studies tested this hypothesis and non-significant differences were found in the mean change of SES on moving to another place [15]. Our study refers to a period of eleven years at nationwide level and it is unlikely that the eventual migration within the country would affect a high percentage of the elders. Because of confidentiality issues we could not identify recurrent fractures and this might be seen as a limitation since the risk of a new fragility fracture increases after the primary hip fracture. However, in our perspective, such limitation does not bias our results since there is no reason to believe that recurrent fractures would be differential among geographic areas or SES groups.

The strength of our study is that we used longitudinal data from nationwide registers and a rigorous study design that minimize the risk of selection and information bias. Besides, we used powerful statistical analysis to measure the association between socioeconomic status and hip fractures. The use of socioeconomic status per municipality was helpful in recognizing areas of higher risk of HF and can help in the design of public health intervention programs.

Conclusion:

Ecological studies can help in the identification of areas/population groups at higher risk of hip fractures. This area-level study suggests a general pattern, the more deprived municipalities presented a higher risk of hip fracture, and an interaction between age group and socioeconomic status of the municipality of residence in the risk of hip fracture; the association between hip fractures incidence and socioeconomic status was inverse in younger ages (lower risk in more affluent areas) and direct in older ages (higher risk in more affluent areas). These results may help decision-makers to better understand the epidemiology of hip fractures and better direct the implementation of political decisions.

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