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The 2003 heat wave in France: hydration status changes in older inpatients

Adrien Kettaneh · Laurence Fardet · Nathalie Mario · Aurelia Retbi · Namik Taright · Kiet Tiev · Ingrid Reinhard · Bertrand Guidet · Jean Cabane

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Abstract Little is known about the impact of behavioral changes after the 2003 heat wave on hydration status of elderly citizens in France. We used an administrative data file provided information about 23,022 inpatients aged ≥ 70 years admitted between 2000 and 2006, including vital status at discharge and Charlson comorbidity index and matched it with the result of five blood tests (sodium, potassium, glucose, urea nitrogen, creatinine) within the first 24 h after admission and with daily temperatures before admission. We then measured the prevalence of plasma tonicity (PT) < 275 mOsm/l or > 300 mOsm/l,

blood urea nitrogen/creatinine ratio (BUNC) > 100 and in-hospital mortality. In 2000–2002, 2003, 2004–2006, prevalence (%) was, respectively 7.5, 8.0, 9.5 ($P < 0.0001$) for PT < 275 mOsm/l, 8.4, 10.4, 7.2 ($P < 0.0001$) for PT > 300 mOsm/l, and 35.4, 30.7, 26.7 ($P < 0.0001$) for BUNC > 100 . In-hospital mortality rate was 10.8, 10.8 and 9.0%, respectively ($P < 0.0001$). After adjustment for covariates, OR (95% CI) in 2004–2006 with reference to 2000–2002 was 1.26 (1.13–1.39) for PT < 275 mOsm/l, 0.85 (0.76–0.94) for PT > 300 mOsm/l, and 0.65 (0.61–0.69) for BUNC > 100 . In-hospital mortality risk associated with hydration disorders did not vary significantly over periods for PT < 275 mOsm/l (HR 1.06 to 1.40) and PT > 300 mOsm/l (HR 1.76 to 1.96) but was lower for BUNC > 100 in 2003 (HR 1.27) than in 2000–2002 (HR 1.64) or 2004–2006 (HR 1.77) ($P = 0.04$). So, since the 2003 heat wave, significant shifts in prevalence of intra-cellular hydration disorders indicate behavioral changes with positive impact on hydration status.

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Introduction

During the first weeks of August 2003, a heat wave of uncommon duration and intensity occurred in Europe. With reference to 2000–2002, an excess mortality of 55% was reported in France from August 1st to 20th and 11,731 of the 14,729 excess deaths involved subjects aged 75 years and over, a majority being women [1]. About one-third of deaths in excess occurred in Ile-de-France, the region surrounding Paris [2]. From 4 to 18 August 2003, our hospital recorded a 66% increase in hospitalization through the emergency department and a 30.1% increase in the

number of electrolyte determinations compared to the corresponding period in 2002 [3].

Following the heat wave, the French government introduced a 3 level “National heat wave response plan” to monitor and face periods with extreme temperatures. The level 1 was activated every year since 2004, from June 1 to August 31. It consists in a daily monitoring of temperatures and data from an information network involving the National Meteorological Office, the National Health Monitoring Institute, and the National Agency for the Improvement of Working Conditions. All citizens and particularly those at high risk such as elderly, infants’ parents, manual workers and sportsmen are advised through an extensive media campaign to protect against heat and drink regularly still water at least 1.5 l per day. Whenever a heat wave is forecast, the level 2, an “alert and action” protocol, mobilizes local and national public services in order to prevent public health consequences. The level 3 involves exceptional measures with maximal mobilization as soon as the heat wave began. Since 2003, level 3 has been activated during the July 2006 heat wave.

Little is known about the impact of behavioral changes related to the French 2003 heat wave experience, on hydration status of elderly citizens. We examined the changes in hydration profiles and inhospital mortality in elderly patients admitted in a tertiary center in Paris through the emergency department, after the 2003 heat wave, by comparison.

Patients and methods

Study population

All patients aged 70 years and over, admitted in our hospital after an evaluation in the emergency department from 1 January, 2000 through 31 December, 2006, were eligible for this study. These patients were identified from an administrative data file, providing information about age, gender, date and hour of admission, vital status at discharge and International Classification of Diseases version 10 (ICD-10) [4] codes for hospital diagnoses. A matching procedure searched the biochemistry laboratory file for the first result within 24 h after admission of five blood tests (sodium, potassium, glucose, urea nitrogen and creatinine).

The administrative and the biochemistry data files have been declared to the Commission Nationale Informatique et Liberté. After the matching procedure performed on these files, all records were anonymised.

The study population finally included all patients with a match for the five tests and did not include other patients for whom at least one of these tests was not available within 24 h after admission.

Hydration status measurements

Plasma tonicity, defined as the effective osmolality, equals the sum of the concentrations of the solutes which determine the transcellular distribution of water. Plasma tonicity (mOsm/l) was estimated by calculation as glucose (mMol/l) plus twice the sum of sodium (mMol/l) and potassium (mMol/l) [5]. Normal range was defined as 275–300 mOsm/l. We hypothesized that a tonicity value below 275 mOsm/l reflects an excess of body water, either absolute or relative to total body sodium, and that a tonicity value over 300 mOsm/l reflects absolute body water deficit.

BUNC ratio was calculated as the ratio between blood urea nitrogen (BUN) (mMol/l) and creatinine (C) (mMol/l). We hypothesized that a BUNC ratio ≤ 100 reflects normal systemic perfusion whereas a BUNC ratio > 100 reflects reduced systemic perfusion [6].

Temperature measurements

Daily minimum temperatures measured in the meteorological station Paris-14^{ème} Parc Montsouris, were obtained from the website of the European Climate Assessment & Dataset (ECA&D) project [7, 8].

Comorbidity variable

The Charlson index (CI) takes into account 19 comorbid conditions, each with an associated weight ranging from 1 to 6 [9, 10]. The relative risk of death from an increase of one in the comorbidity score has been estimated approximately equal to that from an additional decade of age [9, 10]. Charlson comorbidity scores based on three digits ICD-10 administrative data for hospital diagnoses were calculated with the STATA[®] Charlson procedure adapted by V. Stagg from a SAS[®] procedure [11].

Statistical analysis

Three distinct time periods were compared: the 3 years prior to heat wave year (2000 to 2002) used as the reference period, the heat wave year (2003) and the three next years (2004–2006), in which the “National heat wave response plan” was operational.

Study and excluded patients characteristics were compared, in each time period separately, with the Student t test (unequal variances in independent samples) for continuous variables and the Chi-square test for categorical variables. Patients characteristics were compared between groups defined by tonicity thresholds (3 groups: < 275 , 275–300, and > 300 mOsm/l) and BUNC ratio threshold (2 groups: ≤ 100 and > 100) with the Student t test (unequal variances in independent samples) or a one way

analysis of variance, respectively, for continuous variables, and the Chi-square test for categorical variables. Bartlett test checked equality of variances among groups in one way analyses of variance. If this test was significant, *p* values comparing groups were alternately estimated by the Kruskal-Wallis non parametric test.

Logistic models estimated adjusted risks for each hydration disorder index separately (tonicity < 275, tonicity > 300 and BUNC ratio > 100) as odds-ratios and 95% confidence intervals in the periods 2003 and 2004–2006 with reference to 2000–2002. For high and low tonicity indexes the reference was the group of patients in the range 275–300 mOsm/L.

In each time period separately, hazard ratios with 95% confidence intervals for in-hospital mortality associated with any index of hydration disorder were estimated simultaneously in a Cox proportional hazard model and compared between time periods. The time variable was defined as days from admission to death or discharge, whichever came first. The proportional-hazard assumption was checked by analyzing Schoenfeld residuals and Kaplan–Meier survival graphs.

To take into account the correlations between variables measured repeatedly in patients admitted several times, confidence intervals of odds-ratios and hazard ratios were based on the robust estimator of variance with the subject as clustering unit. All models were adjusted for age, gender, Charlson comorbidity index, and mean of the lowest temperature during the 3 days prior to admission. The choice of combining temperatures over the 3 days prior to admission was empirical in an intend to fit the recommendations of the 2004 National heat wave response plan which recommends Meteo France to alert INVS when minimal or maximal temperatures reach the alert threshold over 3 consecutive days. Additional analyses conducted with the mean of minimal, maximal and mean daily temperatures, over 3 days showed similar results (results not shown).

Analyses were conducted in all patients then stratified for patients admitted in June–August and September–May.

All tests were two-sided with a significance level of 5%. All analyses were performed with STATA® Statistical Software: Release 8.2 (Stata Corporation, College Station, TX).

Results

Study population

Table 1 shows characteristics of the 23,022 study patients and excluded 3,490 patients for whom we could not establish hydration status within 24 h after admission. In

all periods, study patients had higher mean age, higher mean stay duration, higher Charlson comorbidity scores, and a higher proportion was admitted in intensive care unit, than non participants. Proportion of men was lower in excluded patients admitted in 2003 than in study patients admitted in 2003 and study or excluded patients admitted before or after 2003. In 2003 a higher proportion of excluded than study patients had been admitted in autumn.

Characteristics of patients associated with hydration status

Table 2 shows characteristics of patients associated with hydration status on admission. Proportion of men was lower in patients with tonicity <275 mOsm/l or BUNC ratio >100 than in others. Compared to others, patients with any hydration disorder had higher mean stay duration, a higher mean value for Charlson comorbidity index, a higher proportion with stay in intensive care unit, and a higher in-hospital mortality rate. A higher proportion of patients with tonicity < 275 mOsm/l were admitted during hot periods whereas tendency was inverse for patients with BUNC ratio > 100 or tonicity > 300 mOsm/l.

Hydration status profile over periods

Figure 1 shows unadjusted prevalence of hydration disorders and in-hospital mortality rates in the periods 2000–2002, 2003, and 2004–2006.

With reference to 2000–2002, the proportion of patients with plasma tonicity <275 mOsm/l has increased in 2003, and further increased in 2004–2006, whereas the proportion of patients with plasma tonicity >300 mOsm/l has increased in 2003, and further decreased in 2004–2006 to a level lower than in 2000–2002. The proportion of patients with BUNC ratio >100 has decreased in 2003 and further decreased in 2004–2006.

In hospital mortality rate was similar in 2003 and in 2000–2002 and further decreased in 2004–2006. Figure 2 shows the same features limited to the subgroup of patients admitted between June 1 and August 31, the period during which level 1 of the “National heatwave response plan” has been activated every year since 2004. In this subgroup tendency was similar than in the whole study population except for a marked peak for in-hospital mortality rate and a higher proportion of patients with tonicity > 300 mOsm/l or <275 mOsm/l during the 2003 summer compared to other periods.

Hydration status over periods adjusted for covariates

Table 3 shows odds-ratios of hydration disorders in 2003 and 2004–2006 with reference to 2000–2002, adjusted for

Table 1 Characteristics of patients

N	2000–2002			2003			2004–2006		
	Study patients 9,484	Patients excluded 1,409	P value	Study patients 3,115	Patients excluded 458	P value	Study patients 10,423	Patients excluded 1,623	P value
Men (%)	35.3	33.4	0.15	35.9	29.3	0.006	35.8	34.3	0.24
Age (years)	83.1 ± 7.3	82.0 ± 7.3	<0.0001	83.1 ± 7.4	82.2 ± 7.4	0.009	83.3 ± 7.3	82.5 ± 7.4	<0.0001
Stay duration (d)*	13.5 ± 15.2	11.1 ± 11.3	<0.0001	12.2 ± 14.7	10.7 ± 13.9	0.04	11.0 ± 13.0	9.0 ± 11.4	<0.0001
Death during stay (%)	10.9	11.6	0.97	10.8	8.7	0.19	9.0	7.5	0.04
Mean day lowest T° (°C)**	9.0 ± 4.9	8.9 ± 4.9	0.41	9.4 ± 6.8	9.0 ± 6.0	0.26	9.1 ± 5.8	8.7 ± 5.7	0.01
Season of stay (%)									
Winter	27.8	26.7	0.48	27.3	16.8	<0.0001	26.6	30.3	0.009
Spring	24.5	26.3		23.4	17.0		24.9	24.7	
Summer	22.8	22.9		25.9	20.5		23.2	20.8	
Autumn	24.9	24.1		23.4	45.6		25.4	24.2	
Charlson comorbidity index	1.24 ± 1.5	0.99 ± 1.4	<0.0001	1.26 ± 1.6	1.04 ± 1.6	0.009	1.36 ± 1.6	1.02 ± 1.5	<0.0001
Index = 0	37.0	49.2	<0.0001	38.0	52.6	<0.0001	35.7	49.1	<0.0001
Index = 1	34.2	27.4		33.0	24.7		31.7	26.6	
Index ≥ 2	28.9	23.4		29.1	22.7		32.6	24.3	
Intensive care stay (%)	7.1	4.1	<0.0001	6.4	3.9	0.04	7.0	2.7	<0.0001

Results are given as mean value ± standard deviation or %

* In survivors at discharge

** Mean of lowest temperature in the 3 days prior to admission, recorded at the weather station Paris-Montsouris

gender, age, Charlson comorbidity index, and the mean day lowest temperature of the 3 previous days. Independently from these covariates and with reference to the period 2000–2002, the risk of having a plasma tonicity higher than 300 mOsm/l had increased significantly in 2003 (OR 1.28; 95% CI: 1.11–1.47), and decreased in 2004–2006 (OR 0.85; 95% CI: 0.76–0.95) whereas the risk of having a BUNC ratio higher than 100 had decreased in 2003 (OR 0.81; 95% CI: 0.74–0.88) and was even lower in 2004–2006 (OR 0.65 95% CI: 0.61–0.70).

With reference to 2000–2002, the risk of having a plasma tonicity lower than 275 mOsm/l was unchanged in 2003 (OR 1.08; 95% CI: 0.92–1.27) but increased significantly in 2004–2006 (OR 1.26; 95% CI: 1.11–1.41). Tendencies were similar in the subgroups of patients admitted between June and August, or September and May.

Inhospital mortality associated with hydration disorders

Table 4 shows inhospital mortality in 2000–2002, 2003 and 2004–2006 according to hydration status. Mortality risk associated with plasma tonicity <275 or >300 mOsm/l did not vary significantly between these periods, whereas mortality risk associated with BUNC ratio higher than 100,

was lower in 2003 (HR 1.27; 95% CI: 1.01–1.60) than in other periods.

Discussion

In this study we have identified significant shifts in intracellular hydration profiles of patients through and after the 2003 heat wave. These shifts observed in an elderly population are consistent with the impact from the incitation to drink regularly still water through level 1 of the National Heatwave Plan since 2004. Furthermore these results suggest that the effect of incitation have been maintained beyond the June to August periods of level 1 activation. The changes in plasma tonicity indexes, after taking into account potential confounding effects, suggest that since 2004 mean body water content had increased resulting in a lower relative risk for intracellular dehydration and a higher risk for intracellular water inflation.

Our results also show a higher risk for inhospital mortality with the 3 indexes of hydration disorders in patients aged 70 years and over, with a wide spectrum of diseases, in the same range as previously reported with indexes based on plasma sodium concentration [12–14] and BUN

Table 2 Patients characteristics according to plasma tonicity and blood urea nitrogen/creatinine ratio on admission

N	Tonicity (mOsm/l)				BUNC*** ratio		
	<275 1,945	275–300 19,208	>300 1,869	P value	≤100 15,926	>100 7,096	P value
Men (%)	27.5	36.0	39.4	<0.0001	39.1	27.6	<0.0001
Age (years)	83.4 ± 7.1	83.1 ± 7.3	84.3 ± 7.5	<0.0001	82.7 ± 7.2	84.4 ± 7.3	<0.0001
Stay duration (d)*	13.1 ± 14.3	12.0 ± 14.2	13.6 ± 14.9	<0.0001	11.8 ± 14.0	13.1 ± 14.6	<0.0001
Death during stay (%)	12.2	8.7	21.1	<0.0001	7.8	14.7	<0.0001
Mean day lowest T° (°C)**	10.2 ± 5.8	9.0 ± 5.6	9.0 ± 6.0	<0.0001	9.2 ± 5.6	9.0 ± 5.6	0.01
Season distribution (%)							
Winter	21.4	27.6	29.0	<0.0001	26.4	28.9	0.001
Spring	26.1	24.5	23.7		24.7	24.1	
Summer	31.0	22.7	22.8		23.9	22.3	
Autumn	21.5	25.3	24.6		25.0	24.7	
Period distribution (%)							
2000–2002	36.4	41.5	42.6	<0.0001	38.5	47.3	<0.0001
2003	12.8	13.2	17.4		13.5	13.5	
2004–2006	50.8	45.2	40.0		48.0	39.2	
Charlson comorbidity index	1.50 ± 1.8	1.26 ± 1.6	1.47 ± 1.5	<0.0001	1.29 ± 1.6	1.32 ± 1.6	0.11
Index = 0	36.5	37.7	24.6	<0.0001	36.9	35.7	0.20
Index = 1	28.0	32.8	38.7		32.6	33.5	
Index ≥2	35.5	29.5	36.7		30.5	30.8	
Intensive care stay (%)	8.8	6.2	12.0	<0.0001	6.8	7.3	0.14

Results are given as mean value ± standard deviation or %

* In survivors at discharge

** Mean of lowest temperature in 3 days prior to admission., recorded at the weather station Paris-Montsouris

*** BUNC Blood urea nitrogen/creatinine

Fig. 1 Prevalence of hydration disorders on admission, and in-hospital mortality. P values are for global comparison between the 3 periods

Fig. 2 Prevalence of hydration disorders and in-hospital mortality limited to admissions between June 1 and August 31. P values are for global comparison between the 3 periods

concentration [6, 15, 16] mainly in hospital patients with heart failure or coronary disease.

In patients admitted between June and August, as only the risk for tonicity >300 mOsm/l has increased in 2003 with reference to 2000–2002, intracellular dehydration may have been, among hydration disorders, the main contributor to the excess in mortality observed during the heat wave.

During the 2003 heat wave, records of medical causes of death suggested a 20-fold increase for causes directly related to the heat wave (heatstroke, hyperthermia and dehydration), and a major impact of circulatory, respiratory and nervous systems diseases as well as ill-defined morbid conditions [1]. However, accuracy of these declarative data about mortality causes may be questioned and the harvesting hypothesis suggests that death may have favored

Table 3 Multiple logistic regression. Adjusted odds-ratios for hydration disorders before and after the 2003 heat wave

	All patients	Patients admitted between June and August	Patients admitted between September and May
Tonicity < 275 mOsm/l*			
2000–2002	1 (Ref)	1 (Ref)	1 (Ref)
2003	1.08 (0.92–1.27)	1.08 (0.81–1.45)	0.94 (0.77–1.14)
2004–2006	1.26 (1.11–1.41)	1.23 (1.00–1.52)	1.24 (1.09–1.42)
Tonicity > 300 mOsm/l*			
2000–2002	1 (Ref)	1 (Ref)	1 (Ref)
2003	1.28 (1.11–1.47)	1.43 (1.06–1.92)	1.13 (0.96–1.33)
2004–2006	0.85 (0.76–0.95)	0.83 (0.65–1.05)	0.84 (0.74–0.95)
BUNC** ratio > 100			
2000–2002	1 (Ref)	1 (Ref)	1 (Ref)
2003	0.81 (0.74–0.88)	0.72 (0.59–0.89)	0.82 (0.74–0.91)
2004–2006	0.65 (0.61–0.70)	0.54 (0.47–0.62)	0.69 (0.64–0.74)

Results are given as odds-ratio (95% confidence interval)

All models are adjusted for age, gender, mean day lowest temperature during the 3 days prior to admission, and Charlson comorbidity index
Confidence intervals were based on the robust estimator with the subject as cluster

* Reference is patients in the tonicity range 275–300 mOsm/l

** BUNC Blood urea nitrogen/creatinine

Table 4 Cox proportional hazard model. Independent hazard ratios for in-hospital mortality according to patient characteristics, and hydration status

	2000–2002	2003	2004–2006	P value
Plasma tonicity (mOsm/l)				
275–300	1 (ref)	1 (ref)	1 (ref)	
<275	1.40 (1.12–1.74)	1.06 (0.70–1.61)	1.26 (1.03–1.53)	0.50
>300	1.96 (1.64–2.34)	1.76 (1.31–2.35)	1.95 (1.60–2.38)	0.80
BUNC* ratio				
≤100	1 (ref)	1 (ref)	1 (ref)	
>100	1.64 (1.45–1.86)	1.27 (1.01–1.60)	1.77 (1.55–2.02)	0.04

Results are given as hazard ratios (95% confidence interval)

All models are adjusted for age, gender, mean day lowest temperature during the 3 days prior to admission and Charlson comorbidity index.
All hydration status indexes are adjusted on each other

Confidence intervals were based on the robust estimator with the subject as cluster

* BUNC Blood urea nitrogen/creatinine

Time variable in days (median [range])/total events: in 2000–2002: 10 [1–481]/1021, in 2003: 8 [1–332]/335, in 2004–2006: 7[1–337]/938

people that were at any rate doomed to die soon, during the following winter [17]. A cohort study carried out in Ile-de-France in 31603 dependent subjects ≥60 years of age, has identified dependency as a risk factor associated with mortality during the 2003 heat wave [18]. Conversely a retrospective observational study conducted in the nursing

homes of the Assistance Publique-Hôpitaux de Paris has reported higher mortality rates in the less frail patients suggesting beneficial effect of medical care focused on more fragile patients [19]. A questionnaire-based study identified risk factors for death among 345 patients admitted for heatstroke, to 80 intensive care units in France during the 2003 heatwave [20]. Risk factors included a higher temperature, pre-existing cardiac disease, diuretic use, and serum creatinine over 120 μmol/l. Davido et al. [21] have identified risk factors for heat related death among the 841 patients evaluated in the emergency department of a teaching hospital in Paris during the 2003 heat wave. Risk factors included a greater degree of dependent living, more severe clinical condition at admission, higher values of blood glucose, troponin and white blood cell count, lower values of serum protein and prothrombin levels, pre-existing ischaemic cardiomyopathy, pneumonia as associated infection, and previous psychotropic treatment. Diuretics, angiotensin converting enzyme inhibitors and psychotropic treatments may contribute to hydration disorders and mortality during heat waves. A study from the French Network of Pharmacovigilance Database has reported no significant excess in records for serious adverse drug reactions during the 2003 summer with reference to 2002 [22]. Indeed common side effects of widely prescribed drugs are seldomly declared and may then be scarce in this database.

During one heat wave in July 2006, the whole National Heatwave Plan has been activated effectively and INSEE, the national polling organization, reported “only” 2000

additional deaths whereas 6400 had been expected [23]. The specific effect of hydration shifts on in-hospital mortality cannot be precisely evaluated from our data. However, overall in-hospital mortality has significantly decreased in 2004–2006, with reference to 2000–2002, as well as the relative risk for intracellular dehydration. Moreover, in-hospital mortality risks associated with the intracellular dehydration index were higher than the risk associated with intracellular water inflation, in all study periods. As in 2004–2006, with reference to 2000–2002, the proportion of patients with intracellular water inflation has significantly increased and the proportion of patients with intracellular dehydration has significantly decreased, it seems reasonable to hypothesize that the shift in intracellular hydration disorders was beneficial on mortality.

Our study has several potential limitations. Independently of extracellular water content, the BUNC ratio may be influenced by several morbid processes unrelated to extracellular water content, such as cardiovascular failure, digestive bleeding, and infection which are also potential risks factors for mortality. Finding a lower risk for $BUNC > 100$, and a lower corresponding mortality rate in 2003 compared to 2000–2002 was unexpected and confirms low specificity of BUNC as a marker for extracellular dehydration. The Charlson index was not originally designed for the prediction of hydration disorders risks. However, it is a valid and reliable method for assessing comorbidity in a variety of clinical research situations [24]. It predicted significant increase in the risks for the 3 hydration disorders and mortality in all the multivariate analyses we have conducted (data not shown). Data about hydration status were not available in about 15% of our eligible population. Patients who were not included in our analyses were younger and with a lower Charlson comorbidity index, thus they may represent a group at lower risk for hydration disorders. Excluding these patients may have resulted in overestimating the magnitude of risks for hydration disorders and mortality in all study periods. However, the proportion of excluded patients was similar in each period and analyses were adjusted for age and Charlson index. Therefore, it seems reasonable to expect minimal effect of selection bias on estimates. The proportion of male patients was similar among periods in study patients, and was similar in study and excluded patients except for the 2003 subgroup (35.9 vs. 29.3%). However, we did not find significant difference among periods for the odds-ratios between gender and hydration status, and no significant difference among periods in hazard ratios for gender related survival. Therefore, it seems unlikely that the gender difference in excluded patients in the 2003 subgroup may impact substantially our results. Referral patterns into this tertiary centre could have varied over time resulting in a lack of a defined

denominator population. Also, many diseases are seasonal which would create biases when using all admitted patients as the denominator. To limit the effect of potential biases in the denominator population we restrained the population study to patients admitted through the emergency department, most of whom live in the neighbourhood, adjusted analyses for the Charlson index and atmospheric conditions and performed and performed subgroup analyses for periods with distinct climatic conditions.

Since the 2003 heat wave, significant shifts in prevalence of intracellular hydration disorders indicate behavioral changes with positive impact on hydration status in elderly patients admitted to tertiary a center. These behavioral changes instigated by the deep psychological impact of the 2003 heat wave are in accordance with the repercussions expected from a prevention policy activated yearly between June and August.

References

1. Fouillet A, Rey G, Laurent F, et al. Excess mortality related to the August 2003 heat wave in France. *Int Arch Occup Environ Health*. 2006;80(1):16–24.
2. Gremy I, Lefranc A, Pepin P. Conséquences sanitaires de la canicule d'août 2003 en Ile-de-France. *Rev Epidemiol Sante Publique*. 2004;52(1):93–8.
3. Mario N, Pernet P, Lasnier E, Hermand C, Vaubourdolle M. Effect of August 2003 heat wave in France on a hospital biochemistry laboratory activity in Paris. *Ann Biol Clin (Paris)*. 2004;62(3):356–60.
4. World Health Organization. *ICD-10 : international statistical classification of diseases and related health problems*. 10th revision. ed. Geneva: World Health Organization; 1992.
5. Stookey JD. High prevalence of plasma hypertonicity among community-dwelling older adults: results from NHANES III. *J Am Diet Assoc*. 2005;105(8):1231–9.
6. Aronson D, Mittleman MA, Burger AJ. Elevated blood urea nitrogen level as a predictor of mortality in patients admitted for decompensated heart failure. *Am J Med*. 2004;116(7):466–73.
7. Climate Assessment & Dataset (ECA&D) project. <http://eca.knmi.nl>. Accessed 12 Feb 2007.
8. Klein Tank A, Wijngaard J, Können G, et al. Daily dataset of 20th-century surface air temperature and precipitation series for the European climate assessment. *Int J Climatol*. 2002;22(12):1441–53.
9. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. *J Clin Epidemiol*. 1994;47(11):1245–51.
10. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373–83.
11. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43(11):1130–9.
12. Klein L, O'Connor CM, Leimberger JD, et al. Lower serum sodium is associated with increased short-term mortality in hospitalized patients with worsening heart failure: results from the Outcomes of a Prospective Trial of Intravenous Milrinone for

- Exacerbations of Chronic Heart Failure (OPTIME-CHF) study. *Circulation*. 2005;111(19):2454–60.
13. Tierney WM, Martin DK, Greenlee MC, Zerbe RL, McDonald CJ. The prognosis of hyponatremia at hospital admission. *J Gen Intern Med*. 1986;1(6):380–5.
 14. Brunsvig PF, Os I, Frederichsen P. Hyponatremi. En retrospektiv studie med henblikk på forekomst, årsak og mortalitet. *Tidsskr Nor Lægeforen*. 1990;110(18):2367–9.
 15. Hartz AJ, Kuhn EM, Kayser KL, Johnson WD. BUN as a risk factor for mortality after coronary artery bypass grafting. *Ann Thorac Surg*. 1995;60(2):398–404.
 16. Kirtane AJ, Leder DM, Waikar SS, et al. Serum blood urea nitrogen as an independent marker of subsequent mortality among patients with acute coronary syndromes and normal to mildly reduced glomerular filtration rates. *J Am Coll Cardiol*. 2005;45(11):1781–6.
 17. Valleron AJ, Boumendil A. Epidemiologie et canicules : analyses de la vague de chaleur 2003 en France. *C R Biol*. 2004;327(12):1125–41.
 18. Belmin J, Auffray JC, Berbezier C, et al. Level of dependency: a simple marker associated with mortality during the 2003 heat wave among French dependent elderly people living in the community or in institutions. *Age Ageing*. 2007;36(3):298–303.
 19. Holstein J, Canoui-Poitaine F, Neumann A, Lepage E, Spira A. Were less disabled patients the most affected by 2003 heat wave in nursing homes in Paris, France? *J Public Health (Oxf)*. 2005;27(4):359–65.
 20. Misset B, De Jonghe B, Bastuji-Garin S, et al. Mortality of patients with heatstroke admitted to intensive care units during the 2003 heat wave in France: a national multiple-center risk-factor study. *Crit Care Med*. 2006;34(4):1087–92.
 21. Davido A, Patzak A, Dart T, et al. Risk factors for heat related death during the August 2003 heat wave in Paris, France, in patients evaluated at the emergency department of the Hopital Europeen Georges Pompidou. *Emerg Med J*. 2006;23(7):515–8.
 22. Michenot F, Sommet A, Bagheri H, Lapeyre-Mestre M, Montastruc JL. Adverse drug reactions in patients older than 70 years during the heat wave occurred in France in summer 2003: a study from the French Pharmacovigilance Database. *Pharmacoepidemiol Drug Saf*. 2006;15(10):735–40.
 23. Fouillet A, Rey G, Jouglé E, Hémon D. Estimation de la surmortalité observée et attendue au cours de la vague de chaleur du mois de Juillet 2006. *BEH*. 2007;2007:192–4.
 24. de Groot V, Beckerman H, Lankhorst GJ, Bouter LM. How to measure comorbidity. A critical review of available methods. *J Clin Epidemiol*. 2003;56(3):221–9.