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ORIGINAL ARTICLE

Long-term blood pressure changes induced by the 2009 L'Aquila earthquake: assessment by 24 h ambulatory monitoring

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An increased rate of cardiovascular and cerebrovascular events has been described during and immediately after earthquakes. In this regard, few data are available on long-term blood pressure control in hypertensive outpatients after an earthquake. We evaluated the long-term effects of the April 2009 L'Aquila earthquake on blood pressure levels, as detected by 24 h ambulatory blood pressure monitoring. Before/after (mean ± s.d. 6.9 ± 4.5/14.2 ± 5.1 months, respectively) the earthquake, the available 24 h ambulatory blood pressure monitoring data for the same patients were extracted from our database. Quake-related daily life discomforts were evaluated through interviews. We enrolled 47 patients (25 female, age 52 ± 14 years), divided into three groups according to antihypertensive therapy changes after versus before the earthquake: unchanged therapy ($n = 24$), increased therapy ($n = 17$) and reduced therapy ($n = 6$). Compared with before the quake, in the unchanged therapy group marked increases in 24 h ($P = 0.004$), daytime ($P = 0.01$) and nighttime ($P = 0.02$) systolic blood pressure were observed after the quake. Corresponding changes in 24 h ($P = 0.005$), daytime ($P = 0.01$) and nighttime ($P = 0.009$) diastolic blood pressure were observed. Daily life discomforts were reported more frequently in the unchanged therapy and increased therapy groups than the reduced therapy group ($P = 0.025$ and $P = 0.018$, respectively). In conclusion, this study shows that patients with unchanged therapy display marked blood pressure increments up to more than 1 year after an earthquake, as well as long-term quake-related discomfort. Our data suggest that particular attention to blood pressure levels and adequate therapy modifications should be considered after an earthquake, not only early after the event but also months later.
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INTRODUCTION

A great number of studies have shown an association between stress and cardiovascular disease.[1] Clearly, natural disasters represent a paradigm of acute physical and psychological stress. In line with this, an increased rate of cardiovascular and cerebrovascular events has been reported during and immediately after an earthquake, probably because of acute sympathetic nervous system activation and its detrimental cardiovascular impact, including marked and sustained blood pressure (BP) increments.[2–4] Hypertension should be considered a major risk factor for an array of cardiovascular and related diseases as well as for diseases leading to a marked increase in cardiovascular risk.[5]

In a previous report,[4] 24-h ambulatory blood pressure monitoring (ABPM) clearly showed that both systolic BP (SBP) and diastolic BP (DBP) levels increased in two hypertensive patients with the first minor earth tremors during the L'Aquila earthquake (6 April 2009). Subsequently, when the major quake occurred (0332h, magnitude 5.8 on the Richter scale (6.3 according to US Geological Survey, National Earthquake Information Center)[6]), SBP and DBP further increased and remained markedly elevated up to the late morning, that is, when ABPM was interrupted.[4] These observations are in line with reports by Parati *et al.*[7] and Chen *et al.*,[8] who described marked increments of BP during the Marche-Umbria and Wenchuan quakes, respectively.

With regard to the duration of these quake-related BP increments, the few data available seem to suggest that BP progressively returns to pre-quake levels within a few weeks.[9–13] In line with these observations, acute coronary events and hemorrhagic stroke rates increased by approximately threefold immediately after the 2007 Noto Peninsula earthquake and were still elevated 7 and 35 days after the mayor quake, respectively.[14] Thus, it is extremely likely that sympathetic nervous system activation with increased BP levels was still present in the Noto Peninsula population more than 1 month after the quake and that these increases led to an increased frequency of coronary and cerebrovascular accidents. Unfortunately, no data are

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available on BP levels in the population of Noto Peninsula or for other populations at more than 2 weeks after an earthquake.

With the aim of addressing this issue in more depth, we retrospectively evaluated the BP effects of the 2009 L'Aquila earthquake by considering available ABPMs performed both before and after this natural disaster in patients who were referred to our Hypertension and Cardiovascular Prevention Outpatient Unit.

METHODS

Study participants

We searched in our database for ABPMs performed in the same hypertensive patients before and after the L'Aquila earthquake. Hypertension was defined as a clinic systolic/diastolic BP >140/90 mm Hg and/or a 24-h BP >130/80mm Hg.[5]

Arbitrarily, we decided to search only for hypertensive patients who had the first ABPM recorded no more than 18 months before the quake and who had been kept on constant antihypertensive treatment until earthquake occurrence We excluded all ABPMs from patients with medical history of renal impairment (that is, glomerular filtration rate $<60\,ml\,min^{-1}$ per $1.73\,m^2$ or urinary albumin-to-creatinine ratio $>30\,mg\,g^{-1}$),[15] diabetes mellitus (that is, known diabetes or hemoglobin A1c ⩾6.5%, fasting plasma glucose $\geqslant 126\,mg\,dl^{-1}$, 2 h plasma glucose $\geqslant 200\,mg\,dl^{-1}$ during an oral glucose tolerance test or random plasma glucose $\geqslant 200\,mg\,dl^{-1}$ associated with classic symptoms of hyperglycemia),[16] heart failure (that is, known heart failure or patients with typical symptoms and signs resulting from any abnormality of cardiac structure or function),[17] malignant disease and excess alcohol intake.

In all patients, short but exhaustive interviews were performed after the quake. In particular, we used a questionnaire with yes/no answers to evaluate the presence of quake-related housing discomfort, changes in physical activity, diet and work activities after the quake. The interviews assessed also perceived quality of life (QoL) after the earthquake. Each patient was asked to quantify QoL on an arbitrary scale from a minimum of 1 to a maximum of 10, considering that his/her perceived QoL was at the highest level (that is, 10) before the quake. In all cases, interviews were carried out *post hoc* by the same trained physicians, who were unaware of the study purpose and result.

From a cohort of 79 patients, we selected 47 patients (25 female, age 52 ± 14 years), according to the inclusion/exclusion criteria. These patients had a 24-h ABPM performed both before (mean 6.9 ± 4.5 months) and after (mean 14.2 ± 5.1 months) the earthquake. The modest number of available ABPMs is because of the partial destruction of our Division at the San Salvatore Hospital with the quake, and the consequent loss of a consistent amount of clinical data stored in our server as well as the temporary interruption in the activity of our Outpatient Unit.

Patients were divided into three groups according to the occurrence of modifications in their antihypertensive drug regimens after as compared with before the earthquake (Table 1): group 1, with unchanged therapy (UT; $n=24$, 15 female, mean age 54 ± 13 years); group 2, with increased therapy (IT; $n=17$, 8 female, mean age 53 ± 13 years); and group 3, with reduced therapy (RT; $n=6$, 2 female, mean age 42 ± 13 years).

Data were also compared with those obtained in a control group of Italian hypertensive outpatients, having 24 h ABPM performed twice over a comparable time period, but living far from any natural disaster.

The study was performed according to the good clinical practice and the ethical principles, enunciated in the Declaration of Helsinki.

Clinic and ABP measurement

Ambulatory BP measurements (carried out by using only validated oscillometric non-invasive Spacelabs 90207 devices (Spacelabs Healthcare, Issaquah, WA, USA)), were scheduled at 15 min intervals during daytime and at 20 min intervals during nighttime. During the recordings, the subjects were asked to attend their usual daily schedule, refraining from unusual activities and from excessive physical exercise. They were also instructed to keep their arm still at the time of each automated measurement, according to usual procedures.[18] Conventional BP measurements were performed twice in our clinic in all subjects, in the sitting position, before application of the ABPM device, using a mercury manometer and the auscultatory technique, according to the recommendations of the European Society of Hypertension (ESH).[18]

Table 1 Hypertensive therapy before and after the L'Aquila quake.

	UT group	*IT group*		*RT group*	
	Before and after	*Before*	*After*	*Before*	*After*
ACE inhibitors	8%	17%	41%	50%	50%
AT-1 receptor antagonist (%)	21%	35%	47%	50%	16%
Ca antagonist (%)	54%	23%	59%	100%	33%
β-Blocker (%)	8%	23%	41%	50%	33%
α-Blocker (%)	0%	6%	6%	0%	0%
Diuretic (%)	25%	0%	35%	16%	16%

Abbreviations: ACE, angiotensin-converting enzyme; AT-1, angiotensin II receptor, type 1; IT, increased therapy; RT, reduced therapy; UT, unchanged therapy.
Some patients were treated with more than one antihypertensive drug.

Statistical methods

ABPMs were then processed by computing the average 24 h, daytime and nighttime BP values. Day and night periods were defined based on subjects' diaries. Comparisons of BP and interview-derived data obtained after versus before the earthquake were made through appropriate statistical tests, in relation to the variables being consider (paired *t*-test, Wilcoxon test, χ^2 test and Fisher's exact test). A *P*-value of <0.05 was considered as significant. Unless otherwise stated, all data are shown as means ± s.d. and median (25–75%).

RESULTS

In comparison with the values before the quake, marked increases in 24 h ($P=0.004$), daytime ($P=0.01$) and nighttime ($P=0.02$) SBP, as well as in 24 h ($P=0.005$), daytime ($P=0.01$) and nighttime ($P=0.009$) DBP were observed in the UT group (first ABPM: 7 ± 4 months before; second ABPM: 15 ± 5 months after the earthquake). The corresponding changes in clinic BP in the same group showed a significant increment in SBP ($P=0.008$) and in DBP ($P=0.009$) after the quake. No differences were found in heart rate during the 24 h ($P=0.53$), daytime ($P=0.98$) or nighttime ($P=0.53$) periods, and during the clinic evaluation ($P=0.69$) in the UT group. In a group of control patients who did not experience a natural disaster ($n=25$, 15 female, mean age 53 ± 9.6 years), the 24 h ($P=0.53$), daytime ($P=0.30$) and nighttime ($P=0.66$) SBP, as well as the 24 h ($P=0.99$), daytime ($P=0.68$) and nighttime ($P=0.77$) DBP did not change after 12 months of follow-up. In the same group, similar findings were observed for both clinic SBP ($P=0.99$) and clinic DBP ($P=0.268$) (Figure 1; Table 2).

No differences in BP levels were observed in both the IT and RT groups (IT; first ABPM: 7 ± 5 months before, second ABPM: 15 ± 5 months after the earthquake. RT; first ABPM: 7 ± 3 months before, second ABPM: 11 ± 5 months after the earthquake; Table 2).

Data collected through interviews of the UT group showed housing discomfort (temporary small housing unit and/or housing solutions offered far from L'Aquila) in 45.8% of the patients, reduction in daily physical activity in 37.5%, worsened daily diet in 29.2%, working problems (firing or layoff) in 8.3% and reduction in perceived QoL in 70.8% of the patients. Similar worsening of self-reported QoL was also observed in the IT group but not in the RT group (Table 3).

DISCUSSION

The present report firstly demonstrates long-term marked increments in both clinic and ambulatory 24-h, daytime and nighttime BP levels after a natural disaster in hypertensive patients who experienced no quake-related changes in antihypertensive treatment but not in those who had their therapy increased (IT group). Although we do not have precise data with which to explain this finding, it is likely that most patients missed their family doctors in the early months after this natural disaster. Moreover, most of the patient clinical rec ords were destroyed or lost during the quake, making the proper management of their BP condition more difficult. Third, after the quake, the few open pharmacies had a reduced supply of drugs after the disaster. Finally, the worsening of perceived QoL demonstrated by interviews suggests that psychosocial stress significantly contributed to the persistent increase in BP more than 1 year from the seismic event. Clearly, data on sympathetic nervous system activation and specific psychometric tests would reinforce such a hypothesis but, because of the quake, we were unable to evaluate adrenergic activity and/or to perform a more in-depth analysis of the behavioral response to the quake. Thus, we have no data with which to speculate on this matter.

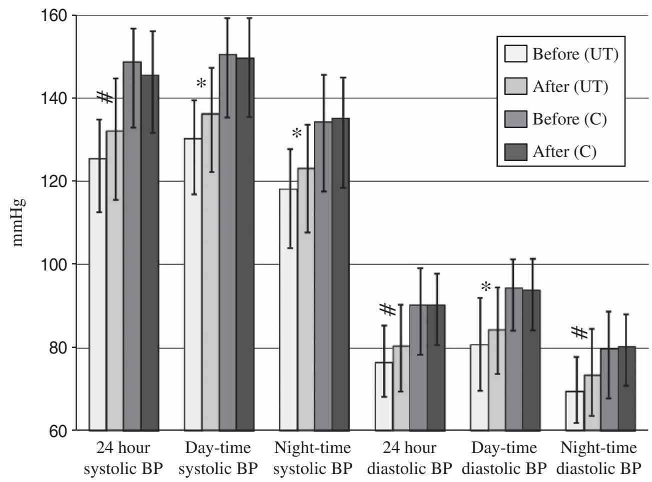

Figure 1 The 24 h ambulatory blood pressure monitoring (ABPM) data (mean + s.d.) in patients who continued the same antihypertensive therapy (unchanged therapy (UT) group) before as well as after the L'Aquila earthquake. Data obtained from a control group of Italian hypertensive patients, living far from the earthquake region, by repeating 24 h ABPM twice over a follow-up period of similar duration (C group) are also shown. BP, blood pressure. *$P<0.05$; #$P<0.01$.

Therefore, our data suggest that an appropriate modulation of the antihypertensive regimen should always be taken into consideration after natural disasters such as earthquakes. In keeping with this, data obtained in a control group of North Italian hypertensive outpatients, living in geographical regions where the quake was not perceived, who were followed over a comparable period of time in the absence of any kind of natural disaster, showed no BP increments. In a recent study, Ito *et al.*[19] demonstrated a transient rise in BP in a group of hypertensive patients living in Tokyo, far from the Great East Japan Earthquake. We did not observe such changes in our control subjects, probably because the second ABPM was performed months after the quake and subjects lived very far from the seismic event. Clearly, we cannot exclude the possibility that such blood pressure changes occurred in subjects living near the L'Aquila region, but we have no data to support this hypothesis. Furthermore, patients in the IT group did not show any change in BP levels despite having a comparable housing discomfort and worsened QoL. Thus, it seems extremely likely that patients in the IT group had unchanged BP levels because they received the appropriate modifications in individual antihypertensive treatments.

Surprisingly, antihypertensive therapy was reduced in a few patients ($n=6$), who reported no increments in either SBP or DBP levels. Of note, our interviews indicated the highest QoL scores and the lowest

Table 2 Blood pressure levels (mean ± s.d.) before and after the L'Aquila quake

	Unchanged therapy group (n = *24*)[a]			*Control group* (n = *25*)[a]		
	Before the quake (mm Hg)	*After the quake (mm Hg)*	P	*Before the quake (mm Hg)*	*After the quake (mm Hg)*	P
24 h SBP	125.6 ± 10.7	132.1 ± 13.5	0.004	148.8 ± 11.8	145.6 ± 12.3	0.53
Daytime SBP	130.3 ± 11.6	136.4 ± 13.5	0.01	150.5 ± 10.8	149.7 ± 11.8	0.30
Nighttime SBP	118.3 ± 11.9	123.3 ± 14.3	0.02	134.4 ± 16.4	135.2 ± 15.5	0.66
24 h DBP	76.5 ± 7.7	80.6 ± 9.8	0.005	90.2 ± 8.4	90.2 ± 7.8	0.99
Daytime DBP	80.7 ± 9.2	84.5 ± 10.1	0.01	94.4 ± 8.5	93.9 ± 8.3	0.68
Nighttime DBP	69.4 ± 6.6	73.8 ± 9.7	0.009	79.8 ± 10.0	80.3 ± 8.6	0.77
Clinic SBP	142.7 ± 10.9	148.9 ± 11.3	0.008	164.9 ± 18.1	161.1 ± 14.8	0.99
Clinic DBP	86.4 ± 7.8	90 ± 8.8	0.009	103.8 ± 4.9	102.4 ± 7.3	0.27
	Increased therapy group (n = *17*)[a]			*Reduced therapy group* (n = *6*)[b]		
	Before the quake (mm Hg)	*After the quake (mm Hg)*	P	*Before the quake (mm Hg)*	*After the quake (mm Hg)*	P
24 h SBP	127.5 ± 14.1	127.2 ± 13.5	0.93	128.5 ± 12	129 ± 14	0.88
Daytime SBP	132.9 ± 15.5	131.9 ± 15.3	0.77	134 ± 8	137 ± 23	0.94
Nighttime SBP	119.1 ± 12.9	119.2 ± 11.7	0.96	120.5 ± 17	114.5 ± 13	1
24 h DBP	79 ± 11.3	79.2 ± 11.3	0.93	85.5 ± 13	84 ± 13	0.5
Daytime DBP	84 ± 11.8	83.5 ± 12.7	0.85	90 ± 12	91.5 ± 14	1
Nighttime DBP	71.3 ± 11.2	72 ± 9.8	0.69	78 ± 15	73.5 ± 17	0.5
Clinic SBP	137.6 ± 14.0	135.3 ± 11.8	0.44	137.5 ± 10	135 ± 15	0.88
Clinic DBP	84.1 ± 10.9	84.4 ± 11.0	0.89	90 ± 10	92.5 ± 10	0.78

Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a]All data are expressed as mean ± s.d. and Student's *t*-test.
[b]All data are expressed as median (25–75%) and Wilcoxon test.

Table 3 Quality of life and score of discomfort observed after the L'Aquila earthquake

	UT group n = *24*	*IT group* n = *17*	*RT group* n = *6*	*UT versus IT group*	*UT versus RT group*	*IT versus RT group*
Housing discomfort (%)	45.8%	52.9%	33.3%	NS	NS	NS
Reduced physical activity (%)	37.5%	29.4%	16.6%	NS	NS	NS
Diet problems (%)	29.2%	29.4%	16.6%	NS	NS	NS
Work problems (%)	8.3%	17.6%	0%	NS	NS	NS
Quality of life[a](% of worsening)/ score[b]	70.8%/ 3.7	76.5%/ 3.9	16.6%/ 8.6	NS	$P = 0.025$	$P = 0.018$

Abbreviations: IT, increased therapy; NS, not significant; RT, reduced therapy; UT, unchanged therapy.
[a]In the case of quality of life, each patient was asked to quantify it on an arbitrary scale (1 = worst, 10 = no change), always assuming that his/her quality of life was at the highest level (that is, 10) before the quake.
[b]All data were collected by asking each patient if one or more of the above problems appeared after the quake, always assuming that no problems were present before the quake.

incidence of quake-related daily life discomfort in these patients (Table 3). Thus, it is intriguing to speculate that no BP increments occurred in these patients because of reduced stress, but the very small number of patients in the RT group does not allow us to support any definitive conclusion on this matter.

We acknowledge several limitations of our study, largely because of the difficult environmental conditions in which it was carried out and the loss of clinical data that occurred as a result of the massive building destructions caused by this quake. First, we have been able to evaluate only a relatively small number of patients. Second, for obvious reasons, given that an earthquake is not an event that can be forecast, our data analysis could only be of a retrospective nature. Third, because of the disaster we were unable to obtain any data on clinic and/or home BP in the acute and subacute phases. Finally, only limited clinical information could be obtained *post hoc* through our interviews.

In spite of these limitations, our study clearly shows that marked 24 h BP increments occurred more than 1 year after the L'Aquila earthquake in hypertensive patients who had their antihypertensive therapy unchanged. In contrast, no BP changes were observed in patients who underwent appropriate modifications of individual antihypertensive regimens.

In summary, our data indicate that the consequences on health of natural disasters should always be monitored not only over the short term but also over the long term. In particular, given the greater reproducibility and the stronger prognostic value of ambulatory BP than clinic BP,[20–22] attention should be given to ambulatory BP levels over 24 h under these conditions, and appropriate changes in prescribed antihypertensive medications should be considered.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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