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Increased risk of cancer and heart diseases due to the exposure to the radar EMF among the population of Potenza Picena, Italy (1986-91)

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Summary. *Background and aim of the work*: This study investigates the possible association between the prevalence of some chronic and lethal diseases in the population and the exposure to the EMF radiation of the military radar ARGOS 10, that had been located since 1970 until 1998 in the hamlet of Casette Antonelli, Potenza Picena (MC), Italy. *Methods:* Five types of diseases were researched in the hospital admissions between 1986 and 1991: cancer, heart attacks and strokes, miscarriages, congenital malformations and severe behavioral disorders. The search for such diseases was performed among 756 hospital admissions, 355 of which were for cancer and 189 for heart attack and stroke. For each observed case the address of residence was identified and the corresponding level of exposure to the radar EMF radiation was evaluated, in order to collect a large sample of data suitable to a statistical analysis based on risk indices. *Results*: The exposure to the radar radiofrequency emissions can increase the risk of cancer and heart diseases. *Conclusions:* For all the pathologies considered, the observed rate results always higher in exposed groups, since both the indices RR and OR are higher than one. In particular, the risk of cancer results to be highly significant in both patterns of comparison. For the risk of heart attack the comparison between exposed and fully exposed people is highly significant, being consistent with previous studies concluding that chronic RF exposure can bring about increased cardiovascular risk (Bortkiewicz A et al, 1995, 1996; Vangelova K et al, 2006).

Key words: electromagnetic fields, radar, epidemiology, cancer risk, heart attack risk, rate ratio, odds ratio

Introduction

The studies of the adverse effects of the exposure to radars radiation date back to the '50s when various forms of leukaemia and other blood diseases were found among men (30-40 years old) who had worked regularly with radar equipment (Daily 1943, McLaughlin 1953, 1957).

Successively, neurological effects of radar radiation were found in the foreign service and other employees of selected eastern European posts, such as the US embassy in Moscow, where there was a chronic irradiation by a Soviet radar in the years 1958-1988 (Lilienfeld et al. 1978). Hjollund (1997) reported damages on semen of personnel operating military radar equipments. Garaj-Vrhovac (2011) found a cytogenetic damage and oxidative stress on personnel exposed to marine radar equipments.

In the '90s more detailed epidemiological surveys were conducted and possible outcomes of chronic exposure to radar radiation: 1) blood count changes, 2) evidence of somatic mutation, 3) impairment of reproductive outcomes were found, especially increased spontaneous abortion, and 4) increase in cancer incidence and mortality, especially of the hematopoietic system, brain, and breast (Goldsmith 1995, 1997).

Moreover, Szmigielski (1996) and Richter (2000) reported cancer morbidity in radar technicians exposed to radiofrequency/microwave radiation.

The present study is based on the hospitals records of Potenza Picena in the period 1986-91 with a special focus on the diseases potentially related to the exposure to electromagnetic fields. The analysis considered only the records of the residents living in areas exposed to the radar EMF radiation. The results were compared to the hospital admissions regarding Potenza Picena residents not directly exposed to the radar.

Methods

Technical characteristics of the radar

The military base of Potenza Picena was established in April, 12 1956. The radar was placed on top of the hill on the edge of the coastal town in a position that could offer control of most national air space. Then, in 1972 the base was integrated into the chain of NATO Air Defence.

The radar object of our study was "Argos 10" built by Selenia. It was installed at "14th Squadron Aeronautica Militare Potenza Picena" and it had the following characteristics (source: prot. N. SMA/622/1489/t6-3/4 date 13/06/1990):

- Frequency 1000 - 2000 MHz
- Exposure time 43 ms per round
- Impulse 14
- Time of impulse 6 micro sec
- Antenna turn 12 s (5 turns per min)
- High slm 135 m
- High antenna 14,85 m
- Antenna Type ML/G 14
- Dimensions 12,9 x 6,3 m

Other characteristics by DIPIA/ISPESL (DIPIA n. 34 23/01/1991)

- Power density per impulse 20 MW
- Antenna Gain 40 dB
- Horizontal irradiation amplitude at -3dB: 1.16 degrees
- Vertical irradiation amplitude at -3 dB: 2.38 degrees

Collecting patient's data

Five types of diseases were researched in the hospital admissions between 1986 and 1991: cancer, heart attacks and strokes, miscarriages, congenital malformations and severe behavioral disorders. The search for such diseases was performed among 756 hospital admissions, 355 of which were for cancer and 189 for heart attack and stroke, 56 for miscarriage risk,50 for birth defects risks and 97 for severe behavioral disorders. For each observed case the address of residence was identified and the corresponding level of exposure to the radar EMF radiation was evaluated, in order to collect a large sample of data suitable to a statistical analysis based on risk indices.

Classification of the radar exposure according to orientation and altitude above sea level

The observed cases were classified according the exposure level to the radar radiation, following a criterion based on the home position of the patients.

In order to do so, the following data were considered:

- incidence and location of different diseases, street by street, in the years 1986-91;
- identification of the morbidity to each street and square in the town related to the level of exposure to the radar, identifying four different levels.
- Municipal census of the citizens of streets or squares (annual). The number of the exposed population was estimated as the half-sum of the starting data and the data at end of the observed period.
- The data records, including address information, come from the hospital database of Potenza Picena.

In particular, all the streets and squares of Potenza Picena have been classified, with the aid of a working group of the Tribunale della Salute of Potenza Picena, into four categories, depending on the level of exposure to the EMFs emitted by the radar. Since the altitude of the radar is 140 m a.s.l., the vertical amplitude of the signal is 2°38' (at -3 dB), and the distance from the town center is 4 km, the sector which receives the radar emission corresponds to the range of altitude from 80 to 200 m a.s.l.; therefore, four categories of exposure were classified:

- A. unexposed (control population);
- B. slightly exposed, living near the radar (<4.5 km), at an altitude at which the level of exposure is reduced (less than 80 m or above 200m);
- C. markedly exposed, facing the radar at a distance <4.5 km, at an altitude at which the level of exposure increases (80-120 or 160-200 m);
- D. fully exposed to the radar EMF because of their altitude and orientation (120-60 m).

People living in some streets were classified in two categories (for example: 50% A and 50% C). People classified in the category D were considered to be the most exposed because the highest intensity of electromagnetic field was measured in the houses placed at the same altitude of the radar. See Table 1 which represents the pattern of people classification into categories:

The total population under study was composed by 6878 people, classified this way: 4712 (68.5%) resulted to be “not exposed” (cat. A), 856 (12.4%) resulted to be “partially exposed” (cat. B and C) and finally, 1310 (19.0%) were “fully exposed” (cat. D)

Statistical analysis of health risks

The statistical comparisons were performed according to two criteria: A vs. B, C, D (comparison between the non-exposed and exposed population) and A vs. D (comparison between non-exposed and fully exposed population). The most evident results came out from the second type of comparison.

For each type of comparison and for each one of the diseases analyzed, a contingency table was made,

Table 1. Categories of people exposure.

	Facing the radar	
Residence altitude	YES	NO
Less than 80 m	B	A
80 - 120 m	C	A
120 - 160 m	D	A
160 - 200 m	C	A
More than 200 m	B	A

Classification of the exposure to the radar signal, depending on the position of the residence of the patients

Table 2. Exposure/affection

	affected	unaffected	Total
exposed to the risk	n_a	n_b	$= n_a + n_b$
not exposed	n_c	n_d	$= n_c + n_d$
Total	$n_a + n_c$	$n_b + n_d$	$= n$

Contingency table

(see Table 2) ranking each sample data in four categories: exposed and affected by the disease (n_a), exposed and unaffected (n_b), unexposed and affected (n_c) unexposed and unaffected (n_d). Denoting by n the total number of the data, the table can be represented as in Table 2.

If there is a causal relationship between the exposure to the risk and the considered disease, (see Table 2) the values n_a and n_d (exposed patients and non-exposed healthy cases) will tend to be higher than the values n_b and n_c (exposed healthy cases and non-exposed patients). Among the most used risk indicators for data classified in this way, there are the risk ratio (Rate Ratio, RR) and the relationship of inequality (odds ratio, OR), defined as follows.

$$RR = \frac{\frac{a}{a+b}}{\frac{c}{c+d}}, \qquad OR = \frac{a/b}{c/d} = \frac{a\,d}{b\,c}$$

Using the risk ratio RR it is possible to compare directly the fraction of affected individuals among the exposed and the non-exposed population, while using the odds ratio it possible to compare the prevalence of the main diagonal values (n_a and n_d), that shows the causal link between the exposure to the risk and the disease, compared to those of the secondary diagonal (n_b and n_c), which goes to the opposite direction. If there is no causal relationship between the exposure factor and the pathology, both the indices take a value equal or close to 1, while if there is a strong causal link the two indexes tend to assume values sensibly greater than 1.

In addition to measuring the values of the indices, it is useful to apply a simple statistic test for the OR, using the normal distribution approximated by the

LOR statistic = ln OR (ln = logarithm in base e). The statistics, for the logarithms properties, can be written in the form:

$$LOR = \ln (n_a \times n_d / n_b \times n_c) = \ln n_a + \ln n_d - \ln n_b - \ln n_c.$$

Suppose that the probability of having a certain disease is P_E for exposed people, and P_N for not exposed people. The null hypothesis of the test is H_0: $P_E = P_N$. If the number of observations is not too reduced, and this condition always holds in the present study, the statistic:

$$z = \frac{LOR}{\sqrt{\frac{1}{n_a} + \frac{1}{n_b} + \frac{1}{n_c} + \frac{1}{n_d}}}$$

follows, under the null hypothesis H_0, a standard normal distribution N(0,1). Therefore, if the observed value of z is a tail value of the standardized normal variable, the null hypothesis is rejected and, indeed, an effect of the risk factors on the probability of occurrence of the considered disease becomes plausible. The p-value corresponds to the probability of obtaining, only due to random effects, a result equivalent or more extreme than the one effectively observed.

If the p-value is less than 5% (1/20), the result is considered significant. If it is less than 1% (1/100), it is considered highly significant. The Tables 3 to 12 represent the main results obtained in this study; the p-value is displayed for each comparison, and Statistical Significance it is specified with the initials S. for Significant and N.S. for not Significant Also a 95% confidence interval for the parameter is given, i.e. a range of values that contains, with a probability of 0.95, the “true” value of the index in the population.

Results

For all the pathologies considered, the observed rate is always higher in exposed groups, since both the indices RR and OR are higher than one. In particular, the risk of cancer results (Tables 3 and 4) to be highly significant in both patterns of comparison (exposed/

Table 3 - Risk of Cancer: Comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	139	2027	2166
Not exposed	216	4496	4712
Total	355	6523	6878
RR =	1,400		
OR =	1,427	(1.208 - 1.647)	
z =	3,177		
p value	0,074%	(1/3144) S.	

S.= Statistically Significant
Rate ratio and odds ratio calculation for the cancer risk between exposed and not exposed patients.

Table 4 - Risk of Cancer: Comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	139	2027	2166
Not exposed	216	4496	4712
Total	355	6523	6878
RR =	1,400		
OR =	1,427	(1.208 - 1.647)	
z =	3,177		
p value	0,074%	(1/3144) S.	

S.= Statistically Significant
Rate ratio and odds ratio calculation for the cancer risk between exposed and not exposed patients.

Table 5 - Risk of heart attacks and strokes: Comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	69	2097	2166
Not exposed	120	4592	4712
Total	189	6689	6878
RR =	1,251		
OR =	1,259	(0.959 - 1.560)	
z =	1,502		
p value	6,65	(1/15) N.S.	

N.S. = Not Significant
Rate ratio and odds ratio calculation for the heart attack and stroke risk between exposed and not exposed patients.

Table 6 - Risk of heart attacks and strokes: Comparison A (not exposed) vs. D (fully exposed)

	Affected	Not affected	Total
Exposed	54	1256	1310
Not exposed	120	4592	4712
Total	174	5848	6022
RR =	1,619		
OR =	1,645	(0.959 - 1.560)	
z =	2,984		
p value	0,142%	(1/15) N.S.	

S.= Statistically Significant
Rate ratio and odds ratio calculation for the heart attack and stroke risk between fully-exposed and not exposed patients

Table 7 - Risk of miscarriages: comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	21	2145	2166
Not exposed	44	4668	4712
Total	65	6813	6878
RR =	1,038	(0.515 - 1.561)	
OR =	1,039		
z =	0,142		
p value	44,35%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for miscarriage risk between fully-exposed and not exposed patients

Table 8 - Risk of miscarriages: comparison A (not exposed) vs. D (fully exposed)

	Affected	Not affected	Total
Fully exposed	16	1294	1310
Not exposed	44	4668	4712
Total	60	5962	6022
RR =	1,308	(0.736 - 1.887)	
OR =	1,312		
z =	0,923		
p value	17,80%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for miscarriage risk between fully-exposed and not exposed patients

Table 9 - Risk of birth defects: comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	18	2148	2166
Not exposed	32	4680	4712
Total	50	6828	6878
RR =	1,244	(0.649 - 1.805)	
OR =	1,226		
z =	0,688		
p value	24,57%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for birth defects risk between exposed and not exposed patients.

Table 10 - Risk of birth defects: comparison A (not exposed) vs. D (fully exposed)

	Affected	Not affected	Total
Fully exposed	13	1297	1310
Not exposed	32	4680	4712
Total	45	5977	6022
RR =	1,461	(0.818 - 2.113)	
OR =	1,466		
z =	1,160		
p value	12,30%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for birth defects risk between fully-exposed and not exposed patients.

Table 11 - Risk of severe behavioral disorders: comparison A (not exposed) vs. B, C, D (exposed)

	Affected	Not affected	Total
Exposed	36	2130	2166
Not exposed	61	4651	4712
Total	97	6781	6878
RR =	1,284	(0.874 - 1.704)	
OR =	1,289		
z =	1,055		
p value	14,57%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for behavioral disorders risk between exposed and not exposed patients.

Table 12 - Risk of severe behavioral disorders: comparison A (not exposed) vs. D (fully exposed)

	Affected	Not affected	Total
Fully exposed	22	1288	1310
Not exposed	61	4651	4712
Total	83	5939	6022
RR =	1,297	(0.811 - 1.794)	
OR =	1,302		
z =	1,198		
p value	11,55%	(>5%) N.S.	

N.S. = not significant
Rate ratio and odds ratio calculation for behavioral disorders risk between fully-exposed and not exposed patients.

not exposed and fully exposed/not exposed), as shown in Table 3, 4. Regarding the risk of heart attack (Tables 5 and 6), the comparison between fully exposed and not exposed is highly significant, as shown in Table 4.while the comparison between exposed and not exposed people is not significant but near to the statistical limit. For the other pathologies considered (miscarriages, birth defects and severe behavioral disorders) the results are not significant, but the indices of risk are always higher in the second kind of comparison (fully exposed/not exposed), as can be seen in Tables from 7 to 12.

Discussion

According to the results obtained for the different pathologies, it has been found that the comparison between exposed and unexposed (A vs. B C D) is highly significant for cancers (with a frequency higher than 40% among the exposed) and very close to the threshold of significance for heart attacks and strokes (frequency higher than 25% of the exposed). The comparison between the unexposed and the highest level of exposure (A vs. D) is significant both for the tumors (+ 50% among the exposed) and for heart attacks and strokes (+ 61% among the exposed). Taking into account multiple comparisons, the significant comparisons remain valid also when applying Bonferroni correction, which is very conservative for the null hypothesis, consisting in multiplying the p value for the number of tests carried out (in this case 5, one for each pathology).

Therefore, the higher exposure areas, and in particular the zone D (the fully exposed town zone) show significantly higher incidences of tumors and heart attacks, when compared to the less exposed areas. The percentage increases observed in zone D (most exposed category) than non-exposed are 61% for heart attacks and stroke and 50% for tumors. If we compare the unexposed group with the three groups exposed, the increments are 40% for cancers and 25% for heart attacks and strokes.

For the other pathologies the found differences resulted to be far from significance limit, even if the inhabitants of the exposed areas are in any case more affected than others, and the difference is systematically more relevant when comparing fully exposed with not exposed. The lack of significance for the last three pathologies could possibly be due not only to lower values of the risk levels, but also to the very small number of cases observed. In fact, it is well known that, at equal levels of RR and OR, the pathologies most frequently observed are the most significant.

The results obtained can give a preliminary answer to the problem of determining the effect of electromagnetic radiation on human health. Actually, the findings suggest a correlation between the radar emissions and some major diseases such as heart attacks, strokes and cancers. The analysis, carried out on the basis of information that was available to the authors, should be updated and conducted more in-depth, for example, by focusing the various types of cancer, identifying the locations where the diseases are localized and eventually causing an increase in mortality. It would be very important to make an overall meta-analysis, comparing and integrating the results considering various areas exposed to strong electromagnetic emissions.

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