CASE REPORT

Neurological abnormalities associated with CDMA exposure

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Dysaesthesiae of the scalp and neurological abnormality after mobile phone use have been reported previously, but the roles of the phone *per se* or the radiations in causing these findings have been questioned. We report finding a neurological abnormality in a patient after accidental exposure of the left side of the face to mobile phone radiation [code division multiple access (CDMA)] from a down-powered mobile phone base station antenna. He had headaches, unilateral left blurred vision and pupil constriction, unilateral altered sensation on the forehead, and abnormalities of current perception thresholds on testing the left trigeminal ophthalmic nerve. His nerve function recovered during 6 months follow-up. His exposure was 0.015–0.06 mW/cm^2 over 1–2 h. The implications regarding health effects of radiofrequency radiation are discussed.

Key words: Current perception thresholds; dysaesthesiae; mobile phone; neurological; radiofrequency radiation.

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Introduction

Dysaesthesiae of the scalp after mobile phone use have been reported previously [1]. Forty respondents from diverse occupations described unpleasant sensations, such as a burning feeling or a dull ache occurring mainly in the temporal, occipital or auricular areas. The symptoms often started minutes after beginning a call, but could come on later during the day. The symptoms usually ceased within an hour after the call, but could last until evening time. Respondents clearly distinguished these symptoms from ordinary headaches. A community survey in Singapore found a significantly increased prevalence of headaches in mobile phone users compared with non-users [2]. We have also previously reported finding a neurological abnormality in a patient after prolonged use of a mobile phone [3]. He developed permanent unilateral dysaesthesiae of the scalp, slight loss of sensation and abnormalities on current perception threshold testing of the relevant cervical and trigeminal nerves. A neurologist found no other disease. However, the respective roles of the phone itself (e.g. by heat radiated or conducted from the handset or from the posture it is used in) or the radiofrequency radiation (RFR) in causing these findings have been queried. We report a case of accidental exposure to a low-powered mobile phone antenna where there were no such confounders, and where symptoms and nerve changes resulted.

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Case report

Medical aspects

A 31-year-old male rigger was referred 1 day after an accidental exposure to RFR from a low-powered CDMA (code division multiple access) panel antenna. He had been well previously, but during the morning of the exposure he felt 'funny' and had a feeling of warmth over the abdomen. He had been told the system was down, but when he obtained the keys at midday, he checked the control room to make sure and found that the system was on. The system was then shut down. He ate little lunch and resumed work. His palms were sweaty and he felt thirsty. He had the onset of a left-sided headache, felt as a sharp constant pain, that continued into the evening and was relieved by paracetamol. He was able to watch

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television, but had a restless sleep. On the day after his exposure, he noticed that his left eye vision was 'cloudy'; he could see objects clearly but needed time to focus, e.g. to read a magazine. He was also feeling lazy and fatigued and, unusually for him, he slept in. He was well otherwise, with no relevant medical history.

The pulse was 50 and regular; blood pressure was 120/70. The palms were sweaty and there was no tremor of the fingers. The throat, heart, chest and abdomen were normal.

The left pupil was smaller than the right; the left eye was not injected or tender to pressure. The sensation of cotton wool felt firmer over the left ophthalmic distribution than the right ophthalmic or left maxillary divisions. There were also some patchy spots over the left cheek in which he said cotton wool touches felt 'stronger'. The other cranial nerves were intact; limb power, sensation and reflexes, rapid movements, stereognosis, and Mini-Mental State Examination were normal.

An ophthalmological consultant found no abnormality.

Neurophysiological sensory testing was performed using a Neurometer CPT/C® (by R.W.). This device is a variable constant current sine wave stimulator that uses three test frequencies, 2000, 250 and 5 Hz, corresponding preferentially to Aβ, Aδ and C-fibres, respectively [4,5]. The test sites were selected within the affected trigeminal I and C3 dermatomes, and corresponding locations on both normal and symptomatic sides were tested. The stimulus was initially increased until a sensation was reported and then short stimuli (2–5 s) were applied at progressively lower current amplitudes until a minimal threshold for constant detection was determined. The device has a dummy switch to allow the on/off status of the machine to be concealed from the patient during determination of an approximate suprathreshold level. After this, the final current perception threshold (CPT) level for that frequency was determined using a double-blind, forced-choice paradigm to confirm the minimal threshold for perception. CPT testing is included under quantitative sensory nerve testing in the recommendations of the Neurology Consensus Conference [6]. The subject was tested on the day after exposure (Table 1), and 1 month (Table 2) and 6 months later (Table 3). The assertion of significance at the 95% level is based upon our confidence limits for the within-subject variability of the CPT results at these sites in healthy normal controls. The standard deviations of the left/right ratios, as a comparison between corresponding sites bilaterally in healthy normal controls, are ±0.11 mA for 2000 Hz, ±0.09 mA for 250 Hz and ±0.14 mA for 5 Hz. The results for this patient are powerful because they show the progressive trend towards normalization of CPT data with time after CDMA exposure (see Figure 1).

Exposure aspects

On the day of the accident, the patient was installing a small parabolic antenna on a mobile phone tower. The

Table 1. AC current perception thresholds (mA) by Neurometer CPT/C® (ratio L:R) measured on 31 March 2000

AC frequency/N fibre type	*L. supraorbital, trigeminal I*	*R. supraorbital, trigeminal I*	*L. pre-auricular, trigeminal II*	*R. pre-auricular, trigeminal II*
2000 Hz/Aβ	1.88 (2.29×)[a]	0.82	1.77 (1.11×)	1.60
250 Hz/Aδ	0.20 (1.43×)[a]	0.14	0.29 (1.20×)	0.25
250 Hz NCPT	0.89 (1.07×)	0.83	2.26 (0.86×)	2.63
5 Hz/C-fibres	0.14 (6.67×)[a]	0.021	0.12 (0.67×)	0.18

The left-side 2000, 250 and 5 Hz CPTs were significantly higher than the values on the asymptomatic right side of the forehead. These findings are consistent with the patient's slightly reduced sensory acuity (pinprick hypo-aesthesia) and cotton wool dysaesthesia. By contrast, there was fairly good symmetry of CPT values for both right and left trigeminal II pre-auricular test sites on the cheek.

[a]95% confidence limit.

Table 2. CPT retested on 28 April 2000, 1 month after exposure

AC frequency/N fibre type	*L. supraorbital, trigeminal I*	*R. supraorbital, trigeminal I*	*L. pre-auricular, trigeminal II*	*R. pre-auricular, trigeminal II*
2000 Hz/Aβ	2.46 (1.44×)[a]	1.71	1.67 (1.08×)	1.54
250 Hz/Aδ	0.21 (1.40×)[a]	0.15	0.35 (1.13×)	0.31
250 Hz NCPT	1.70 (1.73×)[a]	0.98	1.52 (1.03×)	1.48
5 Hz/C-fibres	0.086 (5.0×)[a]	0.017	0.11 (1.10×)	0.10

There is still some persistent elevation of the CPT measurements at the left compared with the right forehead (supraorbital) test sites. These asymmetries were consistent with some hypo-algesia for noxious 250 Hz stimuli and slightly reduced sensory acuities for all three frequencies (all sensory fibre types).

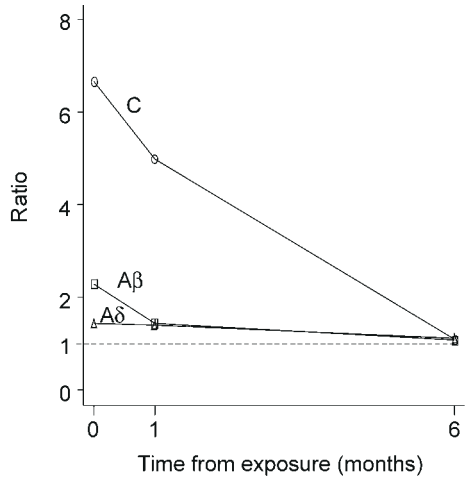
[a]95% confidence limit.

Table 3. On retest 6 months later (15 September 2000), it was found that all CPT values had returned to normal (L:R)

AC frequency/N fibre type	*L. supraorbital, trigeminal I*	*R. supraorbital, trigeminal I*	*L. pre-auricular, trigeminal II*	*R. pre-auricular, trigeminal II*
2000 Hz/Aβ	1.67 (1.08×)	1.54	1.60 (0.94×)	1.70
250 Hz/Aδ	0.35 (1.13×)	0.31	0.32 (1.10×)	0.29
250 Hz NCPT	1.52 (1.03×)	1.48	2.00 (1.06×)	1.88
5 Hz/C-fibres	0.11 (1.10×)	0.10	0.14 (0.88×)	0.16

The abnormalities of the left supraorbital nerve fibre function as shown by the L:R ratio are summarized in Figure 1. The C-fibres (unmyelinated) were most affected. The time to return to normal function of nerve fibres is also shown in the figure; normal values (ratio 1:1) were recorded at 6 months.

Figure 1. Ratio of CPT values L:R of supraorbital nerve fibres over 6 months from exposure (normal ratio = 1).



tower transceives CDMA at 800–900 MHz from three panel antennae arranged in a triangle. He tried to site the parabolic antenna just below and between the panels. He stood on a 3 m ladder with his head and shoulders level with a panel that was 10–40 cm away from him, and he was ~0–45° to the left side of it (i.e. his left side was nearest the panel). The adjacent panel was at 120° to his right side and its rear produced negligible exposure. He was in this exposed position for ~2 h, broken by going down the ladder to get tools. He was wearing plastic safety glasses, a sun hat and a safety harness.

The patient's exposure was reproduced in the laboratory with his cooperation. The antenna panel supplied for the laboratory measurement was an ACE Technology ACS-15-65B. Normal operation with maximum telephone traffic creates a radiofrequency (RF) power level of ~10 W at the input to the antenna. When there is no telephone traffic, the RF power level falls to ~4 W as the radio signal only has the control channel. As the base station was not fully operational, the laboratory tests were conducted with a worst case, no telephone traffic antenna power of 4 W. Other information from the telephone carrier indicated lower transmitting power, but the worst case level of 4 W was used for the laboratory measurements. The effective isotropic radiated power (EIRP) for the antenna being surveyed was 205 W.

The CDMA antenna (Ace Technology ACS-15-65B) was mounted in an anechoic chamber, the patient modelled his positions about the antenna and the distances to his body were measured. The antenna was then activated with a CW signal at the operating power of 4 W at 878.49 MHz (Sierra High Power Signal generator Model 470A). The exposure levels around the antenna were measured using a Narda meter model 8718 and probe model 8761. His maximum exposures were between 0.015 (left shoulder) and 0.06 mW/cm^2 (head).

Discussion

This rigger had temporary ocular and neurological changes after exposure to a low-powered mobile phone base station antenna. These findings of neurological changes after exposure to mobile phone RFR, but independently of a phone, are evidence that the previously reported unpleasant sensations after phone use and permanent neurological changes have arisen from the RFR itself, although other mechanisms, such as heating of the head by the warmth of the phone or the plastics in the case causing a neuropathy, cannot be excluded. Frey [7] has previously reported that exposure of the heads of volunteers to low levels of radar from a radar horn resulted in 'headaches', which also confirms that low levels of RFR can interact with nerve tissue to cause dysaesthesiae.

The patient in this case had begun to recover nerve function after 1 month and had virtually fully recovered by 6 months (see Figure 1). This shows that recovery is possible after such an exposure and is probably the course followed in most of the cases reporting transient symptoms after mobile phone use [1], although prolonged injury may sometimes occur, as with one case we reported previously [3].

The maximum exposure of 0.06 mW/cm^2 at 870 MHz in this case is below the whole body and partial body occupational and public exposure limits. For the public, the permitted exposure to the whole body is 0.2 mW/cm^2

and to the head only 1.0 mW/cm^2. Thus, the patient's exposure was well below current safety levels.

This observation of nerve injury on the scalp at these low exposure levels questions the current view that all health effects of RFR (>10 MHz) are due to thermal (heating) effects. The scalp has a good blood supply to keep the head cool from any resultant heating, which further discounts the plausibility of this mechanism. Therefore, the case is further evidence for non-thermal mechanisms of injury in humans from RFR and its modulations.

These observations of a subtle neurological abnormality after RFR exposure may also be helpful in understanding recent reports of sleep disturbance [8], raised blood pressure [9] and cognitive effects [10] after mobile phone field exposure, although other mechanisms cannot be excluded by this report. This neurological abnormality also provides a possible explanatory mechanism regarding case reports of prolonged fatigue, malaise, dysaesthesiae and other non-specific symptoms in workers who have been overexposed to RFR, a condition sometimes termed 'microwave sickness' [11–14].

We consider that exposure to the head from mobile phones should be minimized by short call times and the use of hands-free or other devices. These observations give support to the Stewart enquiry's view that the use of phones by children should be limited and caution be used in the application of the safety standards (IEGMP [15]) until a fuller understanding is achieved.

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