Summary
A preliminary study correlating the wrist and gall bladder body areas with their auricular acupuncture points, through recording the somatosensory evoked potentials (SEP) at the corresponding brain localisation, showed that stimulation of the “Wrist” auricular point activates the primary cortical somatosensory area of the upper extremity on the contralateral hemisphere in a similar way to direct median nerve stimulation. A “placebo” point 5 to 8mm from the “Wrist” auricular point was used as a control: no activation in the brain area was observed.

In patients with post-stroke hemiplegia, SEP traces obtained both by direct median nerve stimulation at the wrist, and by stimulation of the “wrist” auricular point, were altered in a similar manner and only on the damaged side. Similarly, “gall bladder” auricular point stimulation activates the corresponding cortical somatosensory area in the same way as direct stimulation of the T7 intercostal nerve. Again, a “placebo” point, 5 to 8mm away from the “Gall bladder” auricular point, was used as a control, and activation in the brain area was not observed. Also, in patients with cholelithiasis, both the SEP traces evoked by T7 direct intercostal nerve stimulation and those evoked by “Gall bladder” auricular point stimulation were altered in the same manner.

These results demonstrate that there is correlation between the activation of specific areas of brain cortex and stimulation of their corresponding auricular acupuncture points, and indicate a convergence into the same cortical somatosensory area of nerve impulses coming from the body organ itself and from the auricular point corresponding to that organ. This might be taken as suggesting neurological support for a functional somatic relationship of auricular points.

Key words
Auricular acupuncture points, Auriculotherapy, Somatosensory evoked potentials (SEP).

Introduction
Auricular acupuncture points are commonly used both for diagnostics and treatment. The specificity of action of an auricular point on its corresponding organ is well recorded (1-3). However, the neurological basis of this correlation between an organ and its corresponding auricular point remains undetermined. Somatosensory evoked potentials (SEP) seemed to be the most straightforward neurophysiological parameter to investigate in this field.

The method was discovered through the work of Dawson, in 1947, which measured the middle cortical electrical response to repetitive electrical stimulation of peripheral nerves. Two main parameters characterise the SEP trace: the amplitude and the latency of its different components. A number of animal and human experiments have shown the effect of acupuncture analgesia on cerebral evoked

### Table 1

<table>
<thead>
<tr>
<th>SEP</th>
<th>L1 Mean Latency (ms)</th>
<th>L2 Mean Latency (ms)</th>
<th>L3 Mean Latency (ms)</th>
<th>L4 Mean Latency (ms)</th>
<th>L5 Mean Latency (ms)</th>
<th>L1-L3 Mean Amplitude (µV)</th>
<th>L2-L3 Mean Amplitude (µV)</th>
<th>L4-L5 Mean Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median N.</td>
<td>19.5±0.4</td>
<td>23.5±1.05</td>
<td>32.5±0.6</td>
<td>40.7±0.7</td>
<td>52.7±2.7</td>
<td>4.98±0.62</td>
<td>2.17±0.39</td>
<td>2.30±0.03</td>
</tr>
<tr>
<td>Wrist point</td>
<td>16.6±1.45</td>
<td>21.6±1.28</td>
<td>30.7±1.68</td>
<td>41.3±4.9</td>
<td>46.2±5.9</td>
<td>1.66±0.12*</td>
<td>1.60±0.09*</td>
<td>1.53±0.18*</td>
</tr>
</tbody>
</table>

* p< 0.01  (n=34)
Figure 1. Recording electrode positions in accordance with the 10-20 system (6).
Cz = vertex (middle of inter-auricular line)
C3 = 1.5cm behind and 7cm to the left of Cz
C4 = 1.5cm behind and 7cm to the right of Cz
Fz = midline on the frontal hairline

potentials (4-6). However I have found no publication concerning auricular point stimulation and SEP. So I was interested to investigate the relationship between auricular acupuncture points, their corresponding body organs and the functional area of brain cortex responding to evoked potentials.

Objectives
i. When stimulation of a peripheral nerve evokes an SEP in its corresponding cortical area, is it possible to record the same SEP trace at the corresponding auricular point?
ii. When stimulation of a peripheral nerve evokes an SEP in its corresponding cortical area, is it possible to record a similar SEP trace at the same cortical area by stimulating the corresponding auricular point?

Method
Recordings using the conventional DANTEC program system were made on volunteers aged 31-65 years: 17 healthy, 4 patients with post-stroke hemiplegia and 4 with cholelithiasis. In each experiment only one active auricular point could be tested.

Electric stimulation of auricular points
Single-use, silver acupuncture needles of 15mm length and 0.18mm diameter were inserted at one of three auricular acupuncture points: Wrist of either right or left ear, or Gall Bladder on the right ear. Auricular points were localised accurately according to their anatomical description, aided with a point detector. The needle penetrated 3-5mm to reach the auricular point and give the specific needling sensation of warmth radiating all over the ear and the blood circulating reaction producing redness of the whole auricle.

The needles were connected to the electrical stimulator, providing a rectangular waveform of variable intensity and frequency, but with fixed duration of 0.2ms. We used a frequency of 6Hz and the intensity of stimulation was set according to each patient’s threshold: the intensity applied was double the level of the first subjective sensation using the apparatus, which was usually between 3 and 5mA; 200 stimuli were given in order to obtain the cortical response (SEP).

Somatosensory stimulation
An electronic DANTEC system stimulator was connected to the standard surface electrode of 2x2cm, commonly used for median nerve stimulation, placed on the middle of the anterior aspect of the left or right wrist for median nerve stimulation, or to an electrode below the right nipple in the 7th intercostal space for 7th intercostal nerve stimulation. Electrodes were held in place with an elastic belt. The intensity of the stimulation was adjusted to obtain light, regular, muscular contractions of the first finger during the whole time of the experiment, demonstrating stimulation of the median nerve, or light intercostal muscular contraction for intercostal nerve stimulation. The intensity varied from 5 to 10mA. Responses to 200 stimuli were recorded.

Detection and recording of SEP traces
The detection electrodes were subcutaneous needles in the scalp, inserted symmetrically to the projection of both primary cortical somatosensory areas (C3 on the left, C4 on the right) 7cm from the inter-hemispheric line and 1.5cm behind the vertex point of the inter-auricular line (Cz). This allowed the detection of SEP contralaterally, through stimulation of the two wrists, via the common reference electrode in the middle of the forehead hair insertion line (Figure 7). The position of this electrode was in accordance with the usual 10-20 system (7).
Practical method

The first experiment involved direct stimulation of the median nerve at the wrist and stimulation of the Wrist auricular acupuncture point, and in both cases recording SEP traces at the projection area of the primary cortical somatosensory centres for the upper extremities.

i. The first stimulating electrode was placed on the classical median nerve point at the centre of the anterior aspect of the wrist.

ii. The second stimulating electrode was placed in the Wrist auricular point on the same side as the median nerve being tested.

iii. The third stimulating electrode, to be used as a control, was inserted in a placebo auricular point on the same side, 5 to 8mm away from the Wrist auricular point.

iv. The recording electrode, as classically used for median nerve SEP recording, was inserted in zone C3-Fz on the opposite side of the scalp for right median nerve stimulation, or C4-Fz contralaterally for the left median nerve.

v. The control recording electrode was placed at Cz-Fz.

The second experiment involved direct stimulation of the T7 intercostal nerve at the 7th intercostal space on the anterior aspect of the trunk at GB.24, the gall bladder Mu point, and stimulation of the Gall bladder auricular point; in both cases recording of SEP traces was made at the projection area corresponding to the gall bladder cortical sensory centres.

i. The first stimulating electrode was placed in the T7 intercostal area at GB.24, directly below the nipple in the 7th intercostal space on the right side of the body.

ii. The second stimulating electrode was to the Gall bladder point on the right ear.

iii. The third stimulating electrode, used as the control, was to a placebo auricular point on the same side, 5 to 8mm away from the Gall bladder auricular point.

iv. The recording cranial electrode was inserted at Cz-Fz.

v. The control recording cranial electrode was at C3-Fz.

Each experiment had six phases:

1. Active sensory nerve stimulation with SEP trace recording.

ii. Preliminary phase: when the active auricular point localisation was checked and the subject's sensitivity was tested to determine the appropriate intensity of stimulation. For this purpose three series of 32 stimuli were registered, so that the needle position could be adjusted if necessary to obtain the correct SEP trace.

iii. Active auricular point stimulation with SEP trace recording.

iv. Placebo auricular point stimulation.

Figure 2. SEP traces for stimulation of the median nerve and the “Wrist” ear point in healthy volunteers.

Trace 1: SEP for right median nerve, control recording Cz-Fz
Trace 2: SEP for right median nerve, recording C3-Fz
Trace 3: SEP for right Wrist ear point, control recording Cz-Fz
Trace 4: SEP for right Wrist ear point, recording C3-Fz
Trace 5: SEP for left median nerve, control recording Cz-Fz
Trace 6: SEP for left median nerve, recording C4-Fz
Trace 7: SEP for left Wrist ear point, control recording Cz-Fz
Trace 8: SEP for left Wrist ear point, recording C4-Fz
v. The subject was allowed to relax for 25 min while active auricular acupuncture point stimulation was performed with the same parameters of stimulation.

vi. Repeat of the active sensory nerve stimulation with SEP traces in order to find any changes in the trace following the auricular point stimulation.

**Figure 3.** SEP traces for stimulation of the median nerve and the "Wrist" ear point in healthy volunteers, using different equipment from that used in Figure 2.

- Trace 1: SEP for median nerve, control recording Cz-Fz
- Trace 2: SEP for median nerve, recording C3-Fz
- Trace 3: SEP for Wrist ear point, control recording Cr-Fz
- Trace 4: SEP for Wrist ear point, recording C3-Fz

This work has been carried out intermittently over a period of 10 years in different circumstances, in different premises and with different equipment. As a result the methods have varied slightly over time, sometimes intentionally, sometimes not so, and some of the practical details have been lost or forgotten. However, despite minor inconsistencies in technique (some of which may be detected in this paper) the individual SEP traces have consistently shown the same results; examples of traces taken at different times and using different equipment are included in the figures to demonstrate this.

**Results**

For analysis, peak to peak measurements of latencies and amplitudes were made (Figures 2-8). In normal subjects it is usually easy to make these measurements on the SEP trace. In pathological cases, however, it may sometimes be difficult to do this, since the normal characteristics of the trace may have changed due to the pathological process. So the SEP traces were scored according to waveform configuration in addition to the latency and amplitude measurements of peaks (L1,3 and 5) and troughs (L2 and 4). A similar method was used as by Holmagren *et al* (8) and Rappoport *et al* (9). Statistical analysis, when it was possible (because of the small number of cases), was performed using Wilcoxon's non-parametric test, and *p* = 0.05 was considered an acceptable level of significance.

An SEP trace in the scalp projection areas of cortical somatosensory centres of the upper extremities (C3-Fz cranial area with right side stimulation, and C4-Fz cranial area with the left side stimulation, but never in Cz-Fz cranial area) was evoked by direct stimulation of the median nerve at the wrist and also by stimulation of the Wrist auricular point (Figure 2). However, while stimulation of the median nerve at the wrist evoked an SEP in its cortical area no similar SEP trace could be recorded at the auricular Wrist point.

The waveform configuration of the SEP trace of the Wrist auricular point was similar to the classic median nerve SEP trace (Figure 3). There was no significant difference between peak latencies in the two traces, but the amplitudes of peaks were lower in SEP traces of the Wrist auricular point compared to those of classic median nerve traces which corresponded to normal data. **Table 1** shows the mean data of latency and amplitude characteristics (left and right sides combined) of the SEP traces of median nerve direct stimulation and of the Wrist auricular point stimulation in healthy volunteers.

The placebo auricular point stimulation did not induce any trace similar to the SEP trace. Moreover, in preparing for the experiment we had to resite the auricular electrode several times within the locality of the Wrist auricular point before finding the exact Wrist point and obtaining...
Figure 4. SEP traces for stimulation of the median nerve and the “Wrist” ear point in a patient with right hemiplegia.
Trace 1: SEP for right median nerve, control recording Cr-Fz
Trace 2: SEP for right median nerve, recording C3-Fz
Trace 3: SEP for right Wrist ear point, control recording Cz-Fz
Trace 4: SEP for right Wrist ear point, recording C3-Fz
Trace 5: SEP for left median nerve, control recording Cz-Fz
Trace 6: SEP for left median nerve, recording C4-Fz
Trace 7: SEP for left Wrist ear point, control recording Cz-Fz
Trace 8: SEP for left Wrist ear point, recording C4-Fz

Figure 5. SEP for stimulation of the 7th intercostal nerve and the “Gall bladder” ear point in healthy volunteers.
Trace 1: SEP for intercostal nerve, recording Cz-Fz
Trace 2: SEP for intercostal nerve, control recording C3-Fz
Trace 3: SEP for Gall bladder ear point, control recording Cz-Fz
Trace 4: SEP for Gall bladder ear point, control recording C3-Fz

Table 2

<table>
<thead>
<tr>
<th>SEP</th>
<th>Mean Latency (ms)</th>
<th>Mean Amplitude (uV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1</td>
<td>L2</td>
</tr>
<tr>
<td>Intercostal N.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(healthy)</td>
<td>23.1±1.3</td>
<td>31.2±1.3</td>
</tr>
<tr>
<td>(cholelithiasis before)</td>
<td>19.8±1.5</td>
<td>25.7±2.0</td>
</tr>
<tr>
<td>(cholelithiasis after)</td>
<td>22.1</td>
<td>22.0</td>
</tr>
</tbody>
</table>

before/after = before/after stimulation of the Gall bladder auricular point.
the correct SEP trace. This demonstrates the importance of precision in localising auricular acupuncture points.

These results show that both direct median nerve stimulation at the wrist and stimulation of the Wrist auricular point evoke SEP traces in the same cortical somatosensory area.

In patients with post-stroke hemiplegia, the traces of both the SEP of direct median nerve stimulation and that of Wrist auricular point stimulation were so altered that it was impossible to measure any latency correctly. This alteration of SEP traces (Figure 4) was seen mostly on the same side as the neurological damage.

In the second experiment, both direct stimulation of the T7 intercostal nerve at the 7th intercostal space and stimulation of the Gall bladder auricular point, but not of the placebo auricular point, produced SEP traces in the same Cz-Fz cranial area, but never in the C3-Fz cranial area (Figure 5). The waveform configuration of the SEP trace from the Gall bladder auricular point was similar to the SEP trace from the 7th intercostal nerve (Figure 6). There was a non-significant tendency to have slightly lower latencies and moderately lower amplitudes of peaks in SEP traces of the Gall bladder auricular point compared to those of the 7th intercostal nerve traces (Table 2).

Both of these SEP traces were altered in patients with gall-stones (Figure 7). The results suggest that stimulation of the Gall bladder auricular point increases the latency and amplitude of peaks seen on the 7th intercostal nerve SEP traces in patients with cholelithiasis (Figure 8 and Table 2), but this shows only a tendency and the experiment must be repeated with a larger number of cases: with only four patients, it was not possible to perform
meaningful statistical analysis.

Table 2 shows the mean data of latency and amplitude characteristics of the SEP traces of Gall bladder auricular point stimulation and direct 7th intercostal nerve stimulation in healthy volunteers and in patients with cholelithiasis both before and after stimulation of the Gall bladder auricular point.

Discussion
Several studies have shown the correlation of acupuncture points and brain structures, suggesting a neurophysiological basis for the mechanism of acupuncture. In human experiments Cho et al, using a functional MRI method, found a correlation between acupuncture points on the foot (BL.60,65-67), traditionally used for treatment of eye disorders, and the corresponding occipital area of the brain involved in vision (10). In animals, Rohner and Planche (5) showed that electrical stimulation of the GB.30 and ST.36 acupuncture points modify the SEP trace received from an electrode implanted in the thalamic central node in experimental cat’s brain, and Kerr et al (11) described reduction in evoked potential of the trigeminal nerve recorded in the brain trunk during stimulation of the LI.4 acupuncture point. Oleson (12) has recently confirmed that the stimulation of auricular acupuncture points is associated with release of endorphins.

Our results are in concordance with previous research and now demonstrate a relationship between the auricular acupuncture point, its corresponding body site and the functional area of brain cortex. In our experiments stimulation of the auricular point is seen by SEP trace to activate
the cortical somatosensory area in the same way as direct peripheral nerve stimulation does, while a non-active placebo auricular point had no such action. In addition, traces from both the auricular and body sites show similar changes in patients with pathology of the corresponding organ.

**Conclusion**

It is not possible to make any definitive claim with this small number of cases, so these results can only indicate a pattern. The experiments therefore need to be repeated and confirmed, and further information obtained using other stimulation sites, nonetheless the results suggest that there is a convergence of nerve impulses coming from a body organ itself and from the auricular point corresponding to this organ in the same cortical area. This can be taken as suggesting neurological support for the functional somatic relationship of auricular points, but, while raising expectation of therapeutic possibilities, no clinical significance can be attributed to these findings. The clinical effectiveness of auricular acupuncture must rely upon appropriate randomised controlled clinical trials.

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**References**

Somatosensory evoked potentials in the investigation of auricular acupuncture points

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