The electrocardiographic pattern of 164 patients with head injury was studied and compared with two control groups: 100 patients with limb trauma and 164 healthy subjects. In the group with the head injury the electrocardiographic findings were correlated with the level of consciousness.

The possible relationship between head trauma and electrocardiographic changes was first suggested by Bramwell. He described a miner, aged 35 years, who, after a blow on the head that did not cause him to lose consciousness, developed atrial fibrillation that lasted for 4 weeks. On examination of the cardiovascular and central nervous systems, nothing abnormal was found.

Lucke described a 54-year-old man who fell from a ladder and was found to have blocked atrial extrasystoles after a period of concussion. His cardiovascular system was clinically normal.

Doret and Ferrero studied 32 cases of "traumatic encephalopathy" without clinical evidence of cardiovascular disease. They described various changes but did not find a characteristic electrocardiographic tracing. They divided their cases into six "sympathetic tonic" (tachycardia, raised P waves in leads II and III, short P-R interval, increased Q-T interval, and shallow T waves), four "parasympathetic tonic" (bradycardia, depressed P waves, increased P-R interval, short Q-T interval, and tall T waves), and 22 intermediate types. In addition, one case had ventricular extrasystoles and one case had paroxysmal supraventricular tachycardia. Sinus rhythm was present in 23 cases and sinus arrhythmia in nine.

Nadas et al. described a 5-year-old girl who had a normal pulse 4 weeks prior to a head injury. She was unconscious for 5 minutes and after the injury developed paroxysmal ventricular tachycardia, confirmed by electrocardiography. Her central nervous system and cardiovascular systems were clinically normal, and x-ray examination showed a fracture of the base of the skull.

Electrocardiographic changes have also been noted during brain operations, lumbar puncture and pneumoencephalography, in cerebral tumors, poliomyelitis, and in cerebral hemorrhage. Much experimental work has been performed to determine the role played by the central nervous system in the production of cardiac irregularities. Beattie, Brow, and Long produced extrasystoles by stimulation of the posterior hypothalamus in anesthetized cats. A destructive lesion of the posterior hypothalamus or section of the brain behind this level caused these extrasystoles to disappear.

Storm van Leenwen observed nodal and ventricular rhythm, shift of the sinoatrial pacemaker, and multifocal extrasystoles on stimulating the brains of cats between the posterior corpora quadrigemina and the posterior portions of the cerebellum.

Experimental stimulation of subcortical areas in cats by Korteweg et al. yielded the following results: Stimulation of the basal ganglia resulted immediately in occasional extrasystoles. Stimulation of the posterior hypothalamus and the quadrigeminal bodies produced ventricular extrasystoles, wandering pacemaker, and T-wave changes. After stimulation had ceased, ventricular extrasystoles, atrioventricular dissociation, wandering pacemaker, tachycardia, and T-wave changes were noted, all of which were abolished by vagal section.

A study of electrocardiographic changes in head trauma was made by Jacobson and Danufsky in 15 Albino Swiss mice. All the
mice received intraperitoneal thiopeptone prior to the trauma, and six had atropine in addition. Within 20 seconds all nine animals without atropine developed bradycardia, increased amplitude of the T wave, and a variety of arrhythmias—nodal rhythm, sinus arrhythmia, incomplete atrioventricular block, ventricular extrasystoles, and sinoatrial block; in addition, seven of them showed decreased amplitude or inversion of the P wave. In the atropinized group, on the other hand, no bradycardia occurred, one developed T-wave and P-wave changes, and one showed atrial extrasystoles. The authors therefore concluded that the electrocardiographic changes were due to vagal stimulation. At autopsy all the animals had subdural and subarachnoid hemorrhages, a few had cortical lacerations and one had an intracerebral hemorrhage. The brain stems were normal.

In the present paper the effect of cranio-cerebral trauma on the electrocardiogram has been investigated in Bantu subjects.

**Table 1**

<table>
<thead>
<tr>
<th>Changes in Individual Components of Electrocardiogram</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave 2.5 mm or more in S&lt;sub&gt;n&lt;/sub&gt;</td>
<td>24%</td>
<td>14%</td>
<td>2%</td>
</tr>
<tr>
<td>P-R interval more than .22 second</td>
<td>0</td>
<td>0</td>
<td>.6%</td>
</tr>
<tr>
<td>QRST complex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Incomplete right bundle-branch block</td>
<td>4%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Complete right bundle-branch block</td>
<td>0</td>
<td>1%</td>
<td>0</td>
</tr>
<tr>
<td>3. Voltage S in V&lt;sub&gt;1&lt;/sub&gt; + R in V&lt;sub&gt;s&lt;/sub&gt;&lt;sup&gt;*&lt;/sup&gt;</td>
<td>65% increased</td>
<td>64% increased</td>
<td>48% increased</td>
</tr>
<tr>
<td>Average R + S = 44 mm.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-T&lt;sub&gt;s&lt;/sub&gt; in seconds&lt;sup&gt;†&lt;/sup&gt;</td>
<td>15% increased</td>
<td>1% increased</td>
<td>All normal</td>
</tr>
<tr>
<td>.24—.54 (normal .24—.44)</td>
<td>.29—.44 (normal .29—.43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-T segment raised more than 2.5 mm. in V leads</td>
<td>14%</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>Inverted T waves in V&lt;sub&gt;4&lt;/sub&gt;—V&lt;sub&gt;6&lt;/sub&gt;</td>
<td>10%</td>
<td>6%</td>
<td>0</td>
</tr>
<tr>
<td>U wave more than 1 mm.</td>
<td>21%</td>
<td>21%</td>
<td>.6%</td>
</tr>
<tr>
<td>(range 1.2—4 mm.)</td>
<td>(range 1.2—2.5 mm.)</td>
<td>(1.5 mm.)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>*</sup>Increased voltage: \(-8V<sub>s</sub> + RV<sub>s</sub> = >35 mm.

<sup>†</sup>Q-T<sub>s</sub> measured by the method of Ashman and Hull.

*HERSCH*
ELECTROCARDIOGRAM IN HEAD INJURIES

Figure 2

A first shows an increase in the Q-Tc interval. Later the Q-T interval was normal. In tracings from two other patients (B and C) large U waves are present, best seen in V6.

Table 2

<table>
<thead>
<tr>
<th>Arrhythmias</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus Arrhythmia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) fixed pacemaker</td>
<td>10%</td>
<td>13%</td>
<td>3%</td>
</tr>
<tr>
<td>(b) wandering pacemaker in sinoatrial node</td>
<td>7%</td>
<td>13%</td>
<td>0%</td>
</tr>
<tr>
<td>(c) wandering pacemaker to atrioventricular node</td>
<td>3%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Extrasystoles</td>
<td>6%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Nodal rhythm</td>
<td>4%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>Atrioventricular block</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>Heart Rates</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>between 55 and 70 per minute</td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Heart rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>between 70 and 90 per minute</td>
<td>18</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Heart rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>above 90 per minute</td>
<td>36</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

Subjects and Methods

Three groups of patients were studied. Group A consisted of 164 Bantu patients (158 male and 6 female) with head injury, who were admitted to Baragwanath Hospital over the period March 1957 to March 1958.

There were two control groups: Group B consisted of 100 consecutive Bantu patients who sustained trauma confined to either the upper or lower limbs. These cases comprised fractures, dislocations, traumatic amputations, and bullet wounds. No patients were unconscious or required blood transfusion. Group C was made up of 164 healthy Bantu subjects of age and sex distribution similar to group A.

All the patients in group A were under 40 years of age and all had a history of impaired consciousness. In no case was there clinical evidence of cardiovascular disease. Electrocardiograms were performed within 18 hours of admission to the hospital. The cases were classified into groups according to level of consciousness at the time of the electrocardiograms: group 1 was mentally normal (103 cases), group 2 was drowsy
The significant findings may be classified as follows:

**Changes Occurring More Commonly in the Head Injury Group Than in the Control Groups**

*P* waves of increased amplitude (fig. 1) were found much more commonly in the patients with head injury than in those with limb trauma (*p* = <0.05). In turn, the incidence of tall *P* waves in the latter group was much higher than that in the healthy controls (*p* = <0.05).

In the head injury group the tall *P* waves were associated with heart rates above 90 per minute in 61 per cent of cases (table 3). It is possible that these *P* waves were due to sympathetic stimulation, since similar *P* waves have been noted during exercise, anxiety, hypoxia, and following the administration of epinephrine. In the remaining cases tall *P* waves were found with heart rates from 55 to 90 per minute, which suggests that factors other than sympathetic stimulation were operative.

An increased Q-T interval was virtually confined to the head injury group, occurring in 15 per cent of the cases (fig. 2A).

The increased Q-T interval, like some of the tall *P* waves, may be due to sympathetic stimulation. In man the injection of epinephrine results in an increase of the Q-T interval.

Of the patients with an increased Q-T interval, only 36 per cent were accompanied by heart rates of over 90 per minute and 32 per cent also had tall *P* waves.

**Changes That Appeared to Be a Nonspecific Reaction to Trauma**

These changes occurred with similar frequency in both the groups with trauma (A and B). At the same time the incidence of the changes in these groups was greater than in the healthy control group C. The *p* values given below designate the level at which the difference between the traumatic groups and the healthy controls was significant.

1. *Increased* QRS *voltage* in the precordial leads (*p* = 0.02).
2. *Raised* S-T segments (fig. 5) in pre-

---

**Figure 3**

Left. The *T* waves were inverted in the three standard leads, aV1, and V1 to V6. Four days later, right, *T* waves became upright except in lead III. The S-T's were elevated in the standard and precordial leads, more marked in the later tracing.

(12 cases), group 3 was stuporous (29 cases), and group 4 was comatose (20 cases). Eleven patients died, and necropsies were performed in all cases.

**Results and Comment**

The electrocardiographic findings were divided into the two categories of changes in complexes (table 1) and changes in rhythm (table 2).
ELECTROCARDIOGRAM IN HEAD INJURIES

A. Ventricular ectopic beats were present (upper) and later (center) the ventricular ectopic beats constituted trigeminal rhythm. Note also the tall P waves. B. Shows sinus arrhythmia with a fixed pacemaker and an atrial ectopic beat.

cordial leads ($p = 0.01$). It is of interest that 48 per cent of the healthy Bantu controls had increased QRS voltage by standards established for white subjects (Sokolow and Lyon). Also, raised S-T segments were found in 3 per cent of such controls. Both increased QRS voltage and raised S-T segments have previously been described by Grusin in normal Bantu.

3. Inverted T waves in precordial leads $V_4$.

Table 4

Changes in Individual Electrocardiographic Components

<table>
<thead>
<tr>
<th>Type of change</th>
<th>Group 1 103 Cases</th>
<th>Group 2 32 Cases</th>
<th>Group 3 29 Cases</th>
<th>Group 4 20 Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>P waves 2.5 mm. or more</td>
<td>23 (22.3%)</td>
<td>3 (25%)</td>
<td>9 (31%)</td>
<td>5 (25%)</td>
</tr>
<tr>
<td>Incomplete right bundle-branch block</td>
<td>5 (4.8%)</td>
<td>0</td>
<td>1 (3%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Prolonged Q-T</td>
<td>16 (15.5%)</td>
<td>0</td>
<td>6 (21%)</td>
<td>4 (20%)</td>
</tr>
<tr>
<td>S-T segment raised more than 2.5 mm.</td>
<td>11 (10.7%)</td>
<td>3 (25%)</td>
<td>4 (14%)</td>
<td>4 (25%)</td>
</tr>
<tr>
<td>in $V$ leads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverted T waves $V_{4-6}$</td>
<td>7 (6.8%)</td>
<td>2 (17%)</td>
<td>3 (10%)</td>
<td>4 (20%)</td>
</tr>
<tr>
<td>U waves taller than 1 mm.</td>
<td>11 (10.7%)</td>
<td>1 (17%)</td>
<td>10 (34%)</td>
<td>13 (65%)</td>
</tr>
</tbody>
</table>

4. Type of arrhythmia

Sinus Arrhythmia

(a) fixed pacemaker                  | 7 (6.8%)          | 3 (25%)          | 5 (21%)          | 2 (10%)         |
(b) pacemaker wandering in sinoatrial node | 3 (2.9%)          | 2 (17%)          | 3 (10%)          | 4 (20%)         |
(c) pacemaker wandering to atrioventricular node | 1 (9%)            | 1 (8%)           | 1 (3%)           | 2 (10%)         |
Extrasystoles                          | 2 (1.9%)          | 2 (17%)          | 1 (3%)           | 4 (20%)         |
Nodal rhythm                           | 1 (0.9%)          | 1 (8%)           | 0                | 4 (20%)         |
Atrioventricular block                 | 0                 | 0                | 0                | 1 (5%)          |

Total number of changes: 87           | 18                | 44               | 48               |

Total average number of changes per case: 0.84 | 1.50 | 1.52 | 2.40 |

Circulation, Volume XXIII, June 1961
A shows wandering of the pacemaker in the sinoatrial node. In B the pacemaker wanders to the atrioventricular node. A Valsalva maneuver (z) results in sinus rhythm (C). After the Valsalva maneuver, D shows wandering of the pacemaker to the atrioventricular node and E shows nodal rhythm. Four days later, F and G show wandering of the pacemaker in the atrioventricular node. Sinus rhythm is restored 3 days later (H and I).

Figure 5

Nodal rhythm reverting to sinus rhythm on the sixth day in lead II.

to $V_6$ ($p = 0.05$). T-wave inversion in precordial leads $V_1$ to $V_3$ may occur normally, therefore only inverted T waves from $V_4$ to $V_6$ were considered (fig. 3).

4. $U$ waves of increased amplitude ($p = 0.05$). In normal white subjects $U$ waves may be seen in precordial leads in 100 per cent of cases and are usually highest in $V_3$. Values exceeding 1 mm. are found in only 2 per cent of cases, although values of 2 to 3 mm. may be seen normally. Such waves (fig. 2B and C) are a well-known feature of hypokalemia, but this was found in only one of four cases in which the serum potassium was estimated.

5. Sinus arrhythmia with fixed pacemaker ($p = 0.01$). The criteria$^{22}$ for this arrhythmia were (1) P-P interval varying by more than 0.16 second, (2) P-R interval of 0.12 second or more, and (3) P waves not varying in shape or direction (fig. 4B).

6. Sinus arrhythmia with pacemaker wan-
dering in the sinoatrial node ($p = <0.05$).
The criteria for this are similar to those for sinus arrhythmia alone except that the
configuration of the P wave varies, depending on whether the pacemaker is in the head,
body, or tail of the sinoatrial node$^{22}$ (fig. 5A).

All varieties of sinus arrhythmia are generally attributed to vagal stimulation.

Miscellaneous Changes

The remaining electrocardiographic abnormalities were few in number, and detailed
statistical analysis was not undertaken. It did appear, however, that ectopic beats (fig.
4A and B) occurred more commonly in the traumatic groups than in the healthy
controls. As regards sinus arrhythmia with the pacemaker wandering to the atrioventricular
node (fig. 5B, D, F, and G) and nodal rhythm (figs. 5E and 6), there was a suggestion
of a decreasing incidence in the three groups—head injury, limb trauma, and
normal subjects respectively.

Correlation of the Electrocardiographic Changes with the Level of Consciousness in the Head Injury Group (Table 4)

The number of electrocardiographic abnormalities increased as the level of consciousness
deteriorated and all the 11 patients dying from head injuries had marked changes. There
was, however, no correlation between the type of electrocardiographic change and the level of consciousness.

Postmortem Findings

In cases that died from head injury it was thought that no useful purpose would be
served in attempting to correlate the electrocardiographic changes with the anatomic
lesions, since damage to cerebral tissue was invariably gross and extensive. This consisted
of combinations of extradural, subdural, subarachnoid, and intracerebral bleeding, edema,
and laceration of the brain.

Summary

Electrocardiograms of 164 Bantu patients with head trauma were recorded and studied
with reference to two control groups, 100 Bantu patients with trauma to limbs and 164
healthy Bantu subjects.

The electrocardiographic abnormalities that occurred more commonly in the head injury
group than in either of the control groups were an increased Q-Tc interval and an in-
creased voltage of the P wave.

Both traumatic groups differed from the healthy controls in showing a higher inci-
dence of increased QRS voltage and raised S-T segments in precordial leads, inverted
T waves in precordial leads V4 to V6, U waves of more than 1 mm. in height, sinus arrhyth-
mia with fixed pacemaker, and sinus arrhythmia with pacemaker wandering in the sino-
atrial node.

The number of electrocardiographic abnormalities increased as the level of consciousness
deteriorated.

Acknowledgment

My sincerest thanks are due to Dr. H. C. Seftel, for his advice and help with the manuscript, to Mr.
A. M. Shevitz, for the photographs, and to Mr. W. Lutz, for the statistical analyses.

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Circulation, Volume XXIII, June 1961


Harvey’s contemporary, Francis Bacon, sagaciously guessed that heat is an expansive motion of particles; but he regarded heat and cold as two contrary principles. Almost in the same generation the brilliant John Mayow perceived a substance in the air “allied to saltpetre,” which passed in and out of the blood by the way of the lungs or placenta. “Innate heat” then gave way to phlogiston; but it was not till the discovery of oxygen and of the conservation of energy that we attained a theory of energy, and finally got rid of “matter and form,” and of all the thicket of metaphysics, relating thereto; through which in the day of Harvey no mind, however mighty, could have made its way.—Thomas Clifford Albott, M.A., M.D. Science and Medieval Thought, London, C. J. Clay and Sons, 1901, p. 50.
Electrocardiographic Changes in Head Injuries
COLIN HERSCH

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