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Accuracy and reliability of breath alcohol testing by handheld electrochemical analysers

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Abstract

Usefulness of portable, handheld breath analysers equipped with electrochemical sensor was assessed. Breath- and blood-alcohol concentrations in drunken drivers were taken from 370 expert opinions elaborated at the Institute of Forensic Research between January 1st 2002 and February 28th 2007. The results of second and subsequent measurements were re-calculated using mean elimination rates. The readings of portable instruments were in very good agreement with the results of confirmatory analyses performed by stationary devices ($r = 0.978$, $p < 0.001$, $y = 0.969x - 0.0002$). The correlation with the results of blood analysis was weaker ($r = 0.940$, $p < 0.001$, $y = 1.722x + 0.214$), but comparable with the correlation between the readings of stationary devices and the results of blood analyses ($r = 0.936$, $p < 0.001$, $y = 1.790x + 0.091$). The readings of portable and stationary breath analysers were also compared by the Bland–Altman plots. The differences in results were independent of alcohol concentration (absolute difference (mg/L): $r = 0.054$, $p > 0.1$, $y = 0.011x + 0.013$; relative difference (%): $r = 0.020$, $p > 0.1$, $y = 0.90x + 2.36$).

Keywords: Alcohol; Accuracy; Breath

1. Introduction

Breath alcohol analysis is the most frequently performed and the most widely employed forensic science procedure. It has been practiced for more than 75 years and has been used in connection with traffic law enforcement for about 65 years [1]. Technology of breath analysers has changed in time. The first instrument, the Drunkometer, was developed by Harger at the University of Indiana in 1938 [2]. The alcohol content was measured by an oxidimetric reaction with potassium permanganate. The next, the Alcometer, measured alcohol in end-expired air by oxidation with iodine pentoxide [3]. The closing of 1960s marked in the introduction of breath analysers based on gas chromatographic analysis. The early 1970s saw the introduction of infrared absorption as a measurement principle followed by electrochemical sensors [4]. At present, these two technologies are applied in breath analysers used for forensic purposes.

Electrochemical cell (EC) technology utilises a fuel-cell sensor, which is characterised by high sensitivity, longevity, stable performance and reduced selectivity to interfering substances. Accuracy meets specifications of the National Highway Traffic Safety Administration (NHTSA) for evidential instruments and remains stable more than 6 months. Measurements are not biased or influenced by endogenous substances such as acetone, benzene or CO, however the sensor is cross-sensitive to methanol or isopropanol. EC device does not monitor breath alcohol concentration (BrAC) during exhalation and thus detect mouth alcohol. EC devices are commonly used for screening purposes. Infrared (IR) technology has been the primary means of evidentiary breath alcohol testing. A major advantage of this technology is its ability to make real-time, continuous measurements during the course of sample delivery [5]. This allows to assure that breath sample was of alveolar nature and no residual or mouth alcohol was present. The recorded absorption curve can be presented in court if the case is challenged. The major disadvantages are the high cost of achieving specificity and accuracy at low BrAC and the numerous mechanical component that increase the maintenance costs. The infrared detector output is non-linear

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with respect to the alcohol concentration and must be corrected by measurement circuits. Furthermore, IR sensors tend to be unstable [5].

Breath testing for alcohol is predicated on an assumption that it provides an estimate of the blood alcohol concentration (BAC) that in turn is related to the concentration of alcohol in the brain. Unfortunately, many factors that affect the blood to breath ratio, from the time of initial diffusion into the airways until the final changes that occur in the mouth, vary from person to person. Thus, most European Union countries now operate with breath alcohol limits defined by statute [6]. The limit in Poland is prescribed in the Act of October 26, 1982 on upbringing in Sobriety and Counteracting Alcoholism at 0.1 mg/L for ''the state after use of alcohol'', with more severe penalties for levels exceeding 0.25 mg/L for ''intoxication state''. The specifications, against which the instruments are tested in Poland by the State Central Office of Measures, are based on the OIML (Organisation Internationale Métrologie Légale) R 126 Recommendation. The OIML is a worldwide intergovernmental organisation of legal metrology, which has tried to harmonise the metrological characteristic required of evidential breath analysers (EBAs). However, there is no consensus between the member countries on the recommendation and each country operates their own individual type approval and compliance testing for EBAs for their own jurisdiction [7]. In Poland, three EC portable devices – Alcotest 7410, AlcoSensor IV and AlcoQuant 3020 – were approved beside several models of IR instruments. On the other hand, a police procedure requires that in many circumstances, e.g. when a person was injured or killed in a traffic accident, a positive result (BrAC >0.10 mg/L) determined by handheld device must be confirmed using stationary instrument or blood analysis. This seems to be in contradiction with the regulations on legal metrology, where there is no distinction between stationary (IR) instruments and handheld (EC) devices. It is suggested that the evidential value of the results obtained by both types of instruments is identical and, therefore, the readings of handheld device should be confirmed only in exceptional cases. Practical use of handheld devices was verified by the Orange Country Sheriff-Coroner Forensic Science Services Laboratory, California [8,9]. Two systems were chosen for full evaluation, the Draeger 7410+ EPAS and the Intoximeters AlcoSensor IV-XL@Point of Arrest system and the second was chosen for implementation. It was revealed that the automated design of the portable evidential breath testers insures accuracy and quick distribution of results to the prosecutor's office and to the Department of Motor Vehicles. The performance of the Alcotest 7410 GLC in the field was assessed by Wilkie et al. [10]. The authors concluded that this device has a low false positive screening rate when operated under field conditions by the police and therefore it is a robust and reliable instrument for screening drivers who are suspected of having elevated BACs while operating a motor vehicle.

The present study was conducted to assess the reliability and performance of two handheld devices, the Alcotest 7410 and the AlcoSensor IV, in view of their use for evidential purposes.

2. Material and methods

The paper presents a five-year retrospective study. Data were achieved from 370 expert opinions elaborated at the Institute of Forensic Research, Krakow, Poland, between January 1st 2002 and February 28th 2007.

Results obtained by four models of breath analysers were presented. The Alcotest 7410 (Dräger Safety AG & Co. KGaA, Lübeck, Germany) and the AlcoSensor IV (Intoximeters, Inc., St. Louis, MO) are the portable devices, which measure BrAC using a fuel-cell detector. Both devices automatically sample deep lung breath. They can be connected to a microprocessor or printer, and are capable of storing more than 1000 test results and calibration checks. These devices are used by the police in Poland at roadside. The standard procedure requires duplicate measurements of BrAC within 15-min period. When a portable device is used at roadside, the positive results are usually confirmed by use of stationary instrument at police station or blood analysis. The Alcomat (Siemens, Karlsruhe, Germany) and the Alkometr A2.0 (AWAT, Warsaw, Poland) are the stationary instruments introduced in 1980s, which measure infrared absorption by alcohol vapour in a chamber that contains end-expired air. Both analysers operate at a single wavelength of 3.39 μm in the IR region. The BrACs are reported in this study as milligrams of alcohol in 1 L of breath (mg/L), as used in the OIML recommendation. Results obtained by the Alcomat, expressed in grams of alcohol per 1 L of blood, were recalculated using a factor of 2100 to 1 (it is the forensically acceptable blood to breath ratio).

Blood alcohol analyses were performed in the Institute of Forensic Research, police laboratories or Departments of Forensic Toxicology of Medical Universities. Standard procedure of BAC determination is composed of two analyses by means of (headspace) gas chromatography followed by two analyses by means of ADH enzymatic (spectrophotometric) method. The BACs are reported in this study as grams of alcohol per 1 L of blood (g/L).

3. Results

In Poland, breath alcohol analysis is a primary method of testing drivers who are suspected of driving under the influence of alcohol. In most of the examined cases (339 of 370; 91.4%) the first measurement of alcohol concentration was performed using a breath analyser. The police procedure requires that if a result is positive (BrAC >0.1 mg/L), the second measurement is carried out immediately (IR instruments) or after 15 min (EC devices). Such examinations were performed in 313 cases (84.7%). If the results were inconsistent, the third measurement was carried out. The results obtained by handheld devices were usually confirmed by blood analysis (178 cases, 52.5%) or using IR instruments (58 cases, 17.1%). If a tested person refused a breath test (31 of 370, 8.4%), he or she was taken to a nearest hospital and two or three blood samples were taken in 1 h intervals. Multiple measure of BrAC using different models of breath analyser and collection of blood samples allow to assess the accuracy of handheld breath analysers. The analytical database contained 326 BrACs determined by handheld devices (237 by the Alcotest 7410 and 89 by the AlcoSensor IV, respectively), 440 results measured by IR instruments (241 by the Alkometr A2.0 and 199 by the Alcomat, respectively) and 434 results of blood analysis.

Because the second and subsequent measurements of BrAC were performed after a certain period of time, ranging from several minutes to more than 2 h, elimination of alcohol was taken into account. It concerns also blood samples, which were collected in 1 h intervals. The results were re-calculated using mean elimination rates from breath and blood. These values were estimated on the basis of differences in alcohol