

## ALCOHOL BREATH TESTING: IS THERE REASONABLE DOUBT?

### Introduction

The Alcohol breath test (ABT), commonly known by its commercial name as the “Breathalyzer,” is a device made popular in the United States and used by law enforcement agencies throughout the world to assess and determine the blood alcohol concentration (BAC) of individuals suspected of driving under the influence (DUI).<sup>1,2,3</sup> With increased popularity of the automobile in the late 19<sup>th</sup> century, traffic accidents caused by individuals driving while intoxicated became a serious problem.<sup>4</sup> While legislation was created making it illegal to operate a vehicle under the influence, no quantitative method existed which could assess the intoxication level of an individual. Instead, subjective field tests were used to assess drunkenness relying on identifying certain behaviors in the suspected individual. Blood tests eventually became available to determine BAC, but since drawing blood roadside from a suspected individual is not a viable option for law enforcement officials, another method was needed which could determine intoxication or BAC indirectly and in a non-invasive manner.<sup>8</sup>

### History of the Breathalyzer<sup>5</sup>

Early research in the late 20<sup>th</sup> century showed alcohol was present in the breath of individuals who were intoxicated.<sup>6</sup> This seminal observation has led to over a century of work aimed at demonstrating the correlation between breath alcohol concentration (BrAC) and BAC that could be used for non-invasive alcohol testing. Correlating BrAC and BAC was not as straightforward as originally anticipated, but eventually in the 1950s, the ABT was created to quantify the BrAC of an individual. However, this instrument was based on a very simple understanding of the relationship between BAC to BrAC, and there would be disagreement about this correlation for years to come.

In 1927, Emil Bogen published a seminal report in the Journal of Medical Association,<sup>7</sup> documenting one of the earliest attempts to measure BrAC in the scientific literature. Bogen designed an experiment to quantify the BrAC by using the redox reaction of potassium dichromate and ethanol found in the breath. He collected breath samples in a football-shaped balloon apparatus for analysis. He then bubbled this air through a hot solution of acidic potassium dichromate. Alcohol-positive samples produced a color change in the dichromate solution from orange to green. By comparing the color change to a series of standard solutions, Bogen was able to determine a crude BAC using breath analysis. His findings found that BAC and BrAC were related by a rough 1 to 2000<sup>7</sup> these ideas were improved and developed further shortly thereafter and published by Liljestrand and Linde.<sup>8</sup>

The next progress in the development of the an actual breath testing device, all of which are referred to as “Breathalyzers” for purposes of this paper and ease of reference, came in 1938, when Rolla N. Harger<sup>9</sup> *et al.* developed a procedure he believed could allow breath testing shortly after a DUI suspect was arrested, making it easier for law enforcement to gather evidence for DUI prosecutions. For this testing protocol, Harger *et al.* purported that the absorption of alcohol was always rapid in individuals, and almost immediately led to the ethanol in the body being at equilibrium. Based on his research, Harger developed a device called the “Drunkometer” to allow for non-invasive testing of potentially intoxicated individuals. The device determined BAC by having the suspect fill up a balloon with air from the lungs. The balloon was then expelled into

the instrument containing an acidic solution of potassium permanganate, an oxidant, like that used by Bogen. The ethanol present in the breath would undergo an oxidation reaction with the permanganate, yielding acetic acid and manganese byproducts. This reaction was accompanied by a color change in the solution from purple to brown. Depending on the extent of this color change, the level of intoxication of an individual could be approximated via breath analysis. Though the device was not quantitative, and required the operator to subjectively judge a color change in the instrument, Harger's invention was implemented in the state of Indiana, where it was used to convict DUI suspects for many years.

Widespread use of breath testing came from the Robert F. Borkenstein, a student-collaborator of Harger. The majority of Robert F. Borkenstein's contributions to the area of alcohol and law enforcement took place while he was employed by the Indiana State Police from 1936 to 1958 and was based on the findings of Harger.<sup>10</sup> In 1958, although Borkenstein completed a bachelor's degree through an extension program, he had no formal education in science, and no graduate level education. Regardless, Borkenstein was named chairman of Indiana University's department of police administration. In 1954, he produced the first device to be called a Breathalyzer, a device used to determine the intoxication and/or blood ethanol levels of individuals suspected of driving under the influence.<sup>9</sup> Borkenstein explained that the Breathalyzer conducts the "analysis of breath [and] will reflect the concentration of alcohol in the blood going to the brain. In this respect, the concentration of alcohol in the breath will more closely reflect the condition of the subject than will the concentration in arm (venous) blood."<sup>11</sup> The theories used by Harger and Borkenstein to form the bases of the Drunkometer and the Breathalyzer, respectively, are the same theories that are used to support the use of the ABT in modern instruments. Although not found in the history of breath-alcohol testing, Borkenstein, after whom "The Borkenstein Institute" at [www.BorkensteinInstitute.org](http://www.BorkensteinInstitute.org) is named, was universally regarded as a businessman peddling a device and not a scientist. The U.S. Department of Transportation (DOT) and/or the National Highway Traffic Safety Administration (NHTSA) were very vocal about this, as well as other scientists in the community. See Appendix A, attachments obtained via months of research and archival searches, library science and research expert, Matthew Strandmark, a graduate student at the University of Indiana.

### **Modern Science Applied to the Breathalyzer**

Many of the theories that were used for the development of the original ABT in the early to mid-1900s are still thought to apply to modern ABT devices. In reality, as science and medicine have progressed, many of the theories used to engineer the Breathalyzer have undergone revolutionary changes and should reflect contemporary science. As a result, some of the assumptions made in engineering the original ABT device have scientifically flawed premises when analyzed by modern science. An understanding of the pulmonary system, gas exchange, and lung physiology is important and must be thoroughly considered to engineer a reliable ABT device. The pharmacokinetics (absorption, distribution, and excretion) of ethanol is no longer understood the same way as it was by the founders of the Breathalyzer and must likewise be considered. Along the lines of the aforementioned points, the correlation of BAC to the BrAC has higher variability among individuals than original assumed, particularly when race, age, gender, and health are considered. Additionally, the conditions under which the test is administered and the conditions of the subjects are all factors that can significantly affect the measurement of BAC. Finally, interference by endogenous organic compounds,<sup>12131415</sup> which can register a reading on the ABT, must be accounted for when engineering an ABT. The margin of error based on the points mentioned make the ABT an unreliable method for determining impairment, and its widespread use in court and by law enforcement should be reconsidered.

### **Foundations of the Breathalyzer**

Early attempts to understand the relationship between the quantities of alcohol consumed, BAC, and BrAC made liberal assumptions that led to an erroneous understanding of the underlying principles needed to develop the ABT. For instance, Harger's seminal publication on the Drunkometer assumed that alcohol absorption was rapid and almost immediately led to the ethanol in the body being at equilibrium<sup>16</sup> (*vide infra*). In support of this theory, Harger cited a laboratory study in fasting dogs were given three grams of alcohol per kilogram via a stomach tube delivering alcohol into the dogs' stomachs directly.<sup>7a</sup> Absorption of 50% of the alcohol took only fifteen minutes on average, at which point most the dogs were killed due to alcohol poisoning. Harger's experiments, as described, led to a device made available to law enforcement in the State of Indiana in 1938. Harger's assumptions were improperly derived from experiments with canines and bolus dosing of alcohol, and these results were extrapolated to human models without any studies on human subjects.

Further, Harger *et. al.* supported the feasibility of breath testing incorrectly based on research on drug absorption conducted by Cushny.<sup>17</sup> Cushny was interested in using alveolar air, the last air expelled reflecting the contents of the alveoli, to quantify the exhalation of volatile organic compounds via the lungs. He intended to assay alveolar air and correlate the value to how much of the compound was initially administered intravenously. For quantifying ethanol, Cushny used a cat as an animal model and only performed studies on a single animal subject. No follow-up studies employing a larger sample size or

other animal subjects were performed. Based on Cushny's publication, Harger purported:

"Breath may be employed for predicting the concentration of alcohol in the body. In 1910 Cushny pointed out that the distribution between the alveolar air and the blood of such volatile substances as acetone, ether and alcohol obeys Henry's law, which means that the concentration of alcohol in the blood may be predicted from the concentration in the alveolar air."<sup>7</sup>

This assertion by Harger *et al.*, which was made thirty years after the actual paper on the issue was published, would later become the lynchpin of the operation of the Breathalyzer and the cornerstone of breath testing and theory upon which all Breathalyzers were based.

Although Cushny's work on drug absorption was up to par for the scientific standards of the time, the conclusions drawn in his publication cannot be applied to contemporary scientific standards. Several issues arise when implementing the work of Cushny as it applies to using the Breathalyzer as a predictor of BAC. Despite Cushny's correlation of the administered intravenous dose of an organic compound with its breath ratio, the study failed to examine the blood concentration with breath alcohol. While the values may have some correlation, it is very unlikely that the two will be identical. Furthermore, Cushny limited his sample size to a single cat as an animal model. As a result, no statistical analysis could be applied to his studies, and no correlations could be drawn from the results.

Based on Cushny's research, a ratio was established that could correlate BrAC to BAC. Developers of the Breathalyzer have assumed that BAC could be determined from this ratio by using a simple equation,  $\text{BrAC} \times 2100 = \text{Assumed Blood Alcohol Concentration (ABAC)}$ . The ABAC is the value displayed by the Breathalyzer and is considered to be synonymous with BAC. This calculation operates under the assumption that the alcohol in the alveolar air is at equilibrium with the blood in the venous capillary blood supplied by the pulmonary vein. The ethanol level of the breath is then measured by the Breathalyzer and presents the result, the ABAC, by software that multiplies the BrAC by 2100.<sup>14</sup> In other words, the Breathalyzer reading, or ABAC in the United States, is actually showing you 2100 times the BrAC, the origin of which will be discussed in further detail later in this paper.

## The Partition Ratio

The laws in the United States purported to define the correlation between BAC and BrAC by employing the advice of the Committee on Alcohol and Other Drugs, first known as the Committee on Tests for Intoxication.<sup>18</sup> The committee was given the task of determining the blood-to-breath ratio to be applied on all U.S. Breathalyzers without regard to variations in human biology and numerous other factors (*vide infra*). In 1976, the committee agreed on a 2100 to 1 ratio of blood-to-breath, meaning any result read out by the Breathalyzer would be multiplied by 2100 by the software in the Breathalyzer before the results are given. This ratio of 2100 to 1 has now become known and widely referred to as the "Partition Ratio."<sup>19</sup>

The term "Partition Ratio"<sup>12</sup> is a misnomer used in the forensic community referring to the alcohol content of a person's breath compared to the alcohol content of their blood. This is presumed to be 2100 to 1, meaning the BrAC result is converted to a BAC by multiplying it by 2100. The variability between the BAC and BrAC ratio in individual subjects is large, with values ranging from 900:1 to 3700:1.<sup>20</sup> More recent evaluations using modern technology still demonstrate large variability in this ratio.

From a scientific perspective, "partition" is an inappropriate term since equilibrium conditions are required to apply the term. This would occur if the alcohol exchanged within the alveolus remained unchanged, however, the fact that alcohol exchanges within the airways in a dynamic sense means that equilibrium conditions do not exist. Hence "partition" does not apply to the alcohol breath test. The only appropriate term, and one that should replace "partition ratio" would be blood-to-breath ratio (BBR), meaning the ratio of the person's BAC compared to their BrAC at a given time. Regardless of the names given, the use of a standard 2100 to 1 ratio is not scientifically sound, as ratios vary from 900 to 3700 and it is impossible to determine where this ratio truly lies at the time the Breathalyzer is used.<sup>21</sup>

Additionally, the term "partition ratio" has been given some erroneous interpretations by State Supreme Court Judges. For example, the California Supreme Court stated: "The conversion from breath alcohol to blood alcohol is based on the chemistry principle of 'Henry's law,' which holds that there is a constant ratio between the concentration of alcohol in the blood and the concentration of alcohol in the alveolar air of the lungs."<sup>22</sup> The California Supreme Court may not have realized that Henry was a scientist in the early 1800s and never knew what an alveolus was, as the word did not appear in the scientific literature until the early 1900s.<sup>23</sup>

A variability of significant consequence is the differences between individuals and their hematocrit content. The hematocrit is the component of blood that is made up of red blood cells. Having a high hematocrit means that the water portion of the blood is lower. Men and women have different average hematocrit compositions, with women having lower hematocrit content. This variability is not accounted for by the Breathalyzer, which leads to inaccuracy across the two genders.<sup>24</sup> As a result, a woman and man that have equal BACs for their body weight would have a different reading on an ABT due to their variance in hematocrit.

Furthermore, the variability among the male and female population themselves is also significant. If an individual has high hematocrit, their blood water content is low. As a consequence, the alcohol content in their blood will be diluted to a lesser extent, and this will result in a higher ABT reading. In this circumstance, the partition ratio will change depending on the percent hematocrit an individual possesses. For the previously mentioned reasons, the partition ratio is inaccurate as a static figure and must be modified on a case-to-case basis to accommodate for the many variables that can influence it. Hence, a ratio of 2100:1 is not an accurate basis for estimating BAC, and hematocrit content must also be accounted for.

### External and Physiological Variations

The physiology of gas exchange in the lungs precludes the accurate assay of BAC based on BrAC. The lungs are responsible for processing the transfer of oxygen, carbon dioxide, and other gases to and from the blood. This is accomplished by a series of divided tubes that maximize the surface area of the lungs. When air is inhaled, it enters the body via the mouth and/or nose, travels through the trachea, and is then split between the two lungs into the left and right bronchi. The bronchi then divide over twenty times into smaller tubes called bronchioles. The bronchioles are connected to over 300 million small, sub-millimeter-sized air sacs called alveoli. These sacs contain small capillaries which facilitate the exchange of gases with the bloodstream.<sup>252627</sup>

The function of the ABT is dependent on the premise that alcohol in the bloodstream exchanges into the alveoli with a predictable rate and ratio.<sup>28</sup> This air must then travel through over twenty dividing branches of airways before it can reach the mouth and be assayed by the ABT. The theory of ABT starts to become questionable when one asks if this ratio and rate are highly dependent on the conditions under which breath testing is conducted. If testing is conducted on a hot summer day with high humidity, does the ratio remain the same as it would if the test were conducted on a dry, cold winter night? Furthermore, does the exchange rate and ratio depend on the breathing pattern of the individual prior to administration of the ABT?

Research has shown external factors like temperature and humidity do indeed change the outcome of the ABT.<sup>29</sup> As air travels from the alveoli, through the many branches of airways in the lungs, alcohol can interact with the many levels of lung tissue.<sup>30</sup> Alcohol is extremely soluble in biological media. As a result, breath alcohol will become absorbed and released by the lung tissue as it travels from the alveoli to the mouth and into the Breathalyzer for analysis. Accounting for this exchange is not simple. The rate of ethanol exchange and partition coefficient with the lung tissue will be highly dependent on the outside air temperature, humidity, and other external conditions.<sup>31</sup> Breathing in cold air will cause ethanol condensation which will decrease the amount of alcohol in the gas phase and lower the measured BrAC. In contrast, breathing in warm air will encourage evaporation of alcohol and will increase the measured BrAC. Variations in humidity have a similar effect on measured BrAC.<sup>23</sup> Alcohol is rapidly absorbed into the humid environment of the lungs. When a subject is placed into an overly moist environment or an overly arid one, the exchange rate changes, and can change the amount of ethanol that is expelled in the breath. The change in breath alcohol will undoubtedly affect the readout of the ABT and add an additional layer of uncertainty.

Like temperature, breathing pattern also impacts the BrAC of a given individual.<sup>3233</sup> When the ABT test is administered, the individual is always asked to inhale a large breath of air and expel it as forcefully as possible into the Breathalyzer. Studies have shown that hyperventilation shortly before breath testing can cause ABT test results to drop by 11%. Likewise, taking several deep breaths prior to testing has been shown to give an erroneously high BrAC reading by 16%. Both these phenomena are attributed to changes in the air temperature, which influence the rate of ethanol exchange and partition coefficient.<sup>1</sup>

Variations amongst individuals can also impact the outcome of breath analysis and can create an additional level of uncertainty when employing ABT to assay intoxication. Factors like lung function, lung capacity, age, race and overall health are important variables in ABT. Other issues arise when one considers variations in BrAC as a function of the volume of exhaled air. All major ABTs are designed to measure the alcohol content after the subject has expelled a threshold volume of air called dead air. However, the BrAC as a function of exhaled volume is not static for a given individual. This can lead to

significant variations and lack of reproducibility in replicated measurements for a given individual when the volume of air exhaled is changed over several consecutive trials.

Additionally, the threshold volume of exhaled air for a given instrument is a constant value, and therefore, this volume will constitute drastically different ratios of total lung volume among subjects of varying lung sizes. The ABT will register a result as long as the volume of air expelled is between 1.1 liters to 1.5 liters, depending on the jurisdiction and the total lung capacity. The exhaled volume of air also varies based on the limitation of the individual's lungs and the effort of the person being tested, which will always vary drastically. Hence, individuals with smaller lung capacities will need to expel a larger percentage of their total lung volume to register a reading on the ABT. These variations in lung capacities are not insignificant, and can be shown to differ among age groups, race, body size, and overall health of the individual. This is problematic when considering the previously mentioned point that BrAC is not static when considered as a function of exhaled volume of air. In fact, the measured BrAC decreases as a large volume of air is expelled. Individuals with smaller lung capacities will give unusually high BrAC readings simply because they have expelled a large percentage of their total lung capacity.<sup>34</sup> This point alone renders the BAC an unreliable method for quantifying intoxication as it cannot account for lung size and is biased against individuals with smaller lung capacities. The variables discussed result in a margin of error in ABT testing of 50% or higher, which does not meet the required 95% to 99% level of confidence needed for criminal cases.

### Pharmacokinetic Factors

An issue of particular importance with the ABT deals with the pharmacokinetics of alcohol metabolism and how it affects the BAC when compared to the BrAC as a function of time. There are typically two pharmacokinetic phases that directly impact the ABT, absorption and elimination. If there is a non-linear relationship between BAC and BrAC it is dependent on which of these two pharmacokinetic stages a subject may be in at the point of testing. This adds an additional variable to breath testing which must be accounted for. In order for ABT to be a useful field test for intoxication, it is necessary that the relationship between BAC and BrAC be known and accounted for, regardless of the metabolic stage of the subject. Furthermore, if this relationship varies between individuals amongst the population, then the ABT cannot serve as a just means of assaying intoxication.

A study conducted by Martin *et al.* focused on establishing a correlation between venous blood alcohol concentration (vBAC), arterial blood concentration (aBAC) and BrAC among individuals given the same dose of ethanol and amongst individuals given different doses, specifically, in the absorptive phase of alcohol metabolism.<sup>35</sup> The absorptive phase is defined as the phase after the last drink is consumed in which BAC is rising prior to reaching the peak level ( $C_{max}$ ). Martin *et al.* wanted to determine if the time it took to reach  $C_{max}$  varied within a given dosage group and amongst different dosage groups. Martin *et al.* studied over 40 male and female subjects by administering various doses of ethanol and looked at the concentration-time profiles of three types of measurements.

The vBAC, aBAC and BrAC were then assayed simultaneously at different times after alcohol was consumed, and the two values were compared as a profile for each individual tested. Additionally, these profiles were compared to other individuals tested to determine if a standard model could be applied. The results of this study demonstrated that vBAC, aBAC and BrAC had variable relationships in the absorptive phase of alcohol metabolism such that a linear relationship could not be established. In other words, a simple relationship like the partition ratio could not be used to relate the three values during the absorptive phase. Hence it would be difficult, if not impossible, to relate BrAC to BAC in the absorptive phase of alcohol metabolism across all individuals. Furthermore, Martin *et al.* found that the time to reach  $C_{max}$  varied from half an hour to several hours for each individual, even in the same dosage group. Therefore, it would be difficult to determine if an individual has reached  $C_{max}$ , prior to which reliable breath testing cannot be conducted. The study concluded that the ABT could not be used reliably in the absorptive phase. While one could potentially obtain more accurate results when measuring the BrAC in the elimination phase, this phase can take up to several hours to be reached, and is not predictable. Furthermore, the process of waiting for an individual to reach a metabolic point is not practical in use as a field test.

Another issue addressed by Martin *et al.* as well as several other studies is that vBAC and aBAC are not equal and vary with the metabolic stage of the individual.<sup>36</sup> In particular, the ABT can deliver unusually high readings during the absorptive phase of alcohol metabolism. Since vBAC is associated with impairment, the ABT is believed to reflect the vBAC of an individual. However in the study conducted by Martin *et al.* during the absorptive phase, aBAC was a better indicator of impairment since during this phase, arterial blood delivers alcohol to the brain. As a result, during the absorptive phase, the ABT does not reflect alcohol that is delivered to the brain and is a poor indicator of impairment. aBAC was found to exceed vBAC by more than 50% during absorption; however, vBAC was greater than aBAC during the elimination phase of metabolism. While there existed an equilibrium phase during which aBAC and vBAC were statistically equal, this study showed that this phase was short-lived and difficult to predict. During the elimination phase, this situation is reversed, such

that venous blood becomes a better indicator of impairment, since this blood is delivered to the brain. The disparity between vBAC and aBAC can be attributed to several physiological factors. During absorption, arterial blood is distributed in the organs such that it is delivered to the brain more quickly than the venous blood. It was clearly shown in the Martin study that the  $C_{max}$  was directly dependent upon the initial dosage, where those individuals who were administered a higher dosage of alcohol had a much longer absorptive phase. For this reason, determining intoxication is further complicated, and the conditions of measurement must be even more precisely defined for when relating BAC to BrAC.

Finally, an important point to consider along the lines of pharmacokinetics is a problem often referred to as retrograde extrapolation.<sup>37</sup> When an individual is pulled over for a potential DUI offense, there is a time span on the lines of twenty minutes to several hours between when the suspect was driving and when the actual ABT is administered. Since absorption is not instantaneous, there is a high likelihood that the individual's BAC has changed or has not reached a maximum and is still rising between the time they are pulled over and the ABT is administered. This would mean that an individual that had a BAC below the legal limit could be convicted of a DUI offense due to the lag time in measuring the BrAC. Additionally, it is difficult to account for when the last drink was consumed in order to determine the rate of absorption of an individual.

### **Interference Aspects**

When measuring any compound using an analytical method, information about the method's specificity and susceptibility to interference is necessary. Likewise, it is necessary to quantify any background effects that may affect the measurement. The ABT, like any other analytical method, is susceptible to a variety of interferences that may skew the results obtained. A group of breathalyzers utilizes infrared spectroscopy to determine the alcohol content present in the breath. In particular, the instrument detects the methyl groups present in ethanol. Since many other organic compounds are present in the environment, and metabolites in the body contain this functional group,<sup>38</sup> this type of Breathalyzer is susceptible to error whenever other organic compounds are present. One such compound is acetone, which is a metabolite found in humans. While the device can be calibrated to account for the average amount of ethanol found in the breath, diabetics have been shown to possess an elevated level of acetone in the breath.<sup>39</sup> Hence, diabetics would be at an unfair disadvantage when breath is tested using an infrared-based instrument and would show a BrAC that is higher than the true measurement.

### **Conclusion**

DUI is a major, worldwide issue that can lead to property damage, injury or death. As a result, a method to assay the state of intoxication of a suspected individual is needed. However, it is still necessary that the tools used for gathering evidence for the arrest, prosecution, and conviction of suspects be accurate, just, and scientifically sound. Although the ABT has seen an evolution of over a century with many changes to its design and instrumentation, the underlying principles that form the basis of its design remain outdated and the same as the original instrument. This is problematic considering our modern understanding of the physiological processes involved in pulmonary function and the transport of alcohol in the blood to the breath. Cushny's outdated but still widely accepted assertion that partition ratio relates a constant conversion factor for BrAC to BAC has been shown to be a liberal and inaccurate assumption. It has been demonstrated that the ratio of BAC to BrAC can be influenced by a variety of factors including, age, race, gender, physical condition, and basic genetic traits with significant variability from person-to-person.<sup>40</sup> Although the concept of "alveolar air" has formed the basis for relating BAC to BrAC in breathalyzers, modern understanding of the pulmonary system now reveals this concept is highly simplified, and it can be demonstrated that a variety of environmental factors can alter the efficiency of transporting alcohol from the lungs to the breath. Additionally, pharmacokinetic factors play a non-trivial role in determining how well a Breathalyzer will relate BAC to BrAC. This relationship has been demonstrated to be highly variable and particularly influenced on the pharmacokinetic stage (absorption versus elimination) of the subject.<sup>41</sup> Finally, interference by exogenous substances has been demonstrated to elevate ABT readings based both on metabolites found in individuals and environmental compounds.<sup>42</sup>

Ultimately, the ABT does not provide reliable evidence as to the state of impairment of an individual suspected of driving under the influence of alcohol, and therefore its use as evidence in a DWI court case should be reconsidered. For the same reasons, probable cause for a blood test cannot be established by an ABT due to the variety of factors that cannot be corrected for by an officer in the field. It is the duty of those involved in the forensic sciences and the legal system to acknowledge these limitations to avoid unjustified arrests, prosecution, and conviction of innocent citizens.

Instead of utilizing an unreliable device based on outdated theory as a solution to a pressing problem, efforts should be focused on developing a non-invasive field test that can better assess the relevant signs of intoxication and provide a quantitative assessment with minimal error. This way, countless government dollars are not wasted on prosecutors that are given the burden of upholding the validity of an invalid means of measuring intoxication. Furthermore, development of better

field tests would avoid the wrongful conviction of innocent individuals. Until such a device is available, prosecution should limit their reliance on the ABT as evidence for the conviction of individuals accused of drunk driving.

| Footnotes |  |
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| 1         | <b>Okorie Okorocho</b> is an expert in Forensic Intoxication Testing and Analysis who is appointed on a regular basis by Courts throughout California. He is also a 9 year licensed attorney, with a Doctorate in Law and will obtain his Master's degree in Forensic Science in December 2012.  |
| 2         | Matthew Strandmark is a Library Science Graduate student at the University of Indiana who has done extensive research on the role of Robert Borkenstein while at the University of Indiana and provided invaluable information for this paper. He expects to receive his Masters of Arts in Library Science in 2013.   |
| 1         | Hlastala, M. P., 55 J FORENSIC SCI. 451 (2010); Hlastala, M. P., 93 J. APPL. PHYSIOL. 405 (2002); Hlastala, M. P., 84 J. APPL. PHYSIOL. 401 (1998).  |
| 2         | Dubowski, K. M., <i>Breath Analysis as a Technique in Clinical Chemistry</i> , 20.8 CLINICAL CHEM. 966 (1974).   |
| 3         | Kurt M. Dubowski, <i>Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects</i> , 10 J. STUD. ALCOHOL SUPPLEMENT 98 (1985).   |
| 4         | Linda J. Rosen & Catherine L. Lee, <i>Acute and Chronic Effects of Alcohol Use on Organizational Processes in Memory</i> , 85 J. ABNORMAL PSYCHOL. 309 (1976); N.G. Flanagan, P.W. Strike, C.J. Rigby & G.K. Lochridge, <i>The Effects of Low Doses of Alcohol on Driving Performance</i> , 23 MED. SCI. LAW 203 (1983).   |
| 5         | The word "Breathalyzer" is a trademarked term for the breath-testing instrument developed by Robert Borkenstein in 1954. It was not a generic term for all breath-alcohol analyzers at the time, but for purposes of modern day terminology and this paper, it is used as a generic term.  |
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| 7         | Emil Bogen, <i>Drunkenness: A Quantitative Study of Acute Alcoholic Intoxication</i> , 89 J. AM. MED. ASS'N 18, 1508 (1927).   |
| 8         | Dubowski, <i>supra</i> note 3.   |
| 9         | R.N. Harger, E.B. Lamb, and H.R. Hulpieu, <i>A Rapid Chemical Test for Intoxication Employing Breath: A New Reagent for Alcohol and a Procedure for Estimating the Concentration of Alcohol in the Body from the Ratio of Alcohol to Carbon Dioxide in the Breath</i> , 110 J. AM. MED. ASS'N. 11, 799 (1938); R.N. Harger, R.B. Forney, and H.B. Barnes, <i>Estimation of the Level of Blood Alcohol from Analysis of Breath</i> , 36 J. LAB. & CLINICAL MED. 306 (1950). |
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| 11        | Robert F. Borkenstein & H. W. Smith, <i>The Breathalyzer and Its Application</i> , 1 MED. SCI. LAW, 13, 13 (1961).   |
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| 13        | Miekisch W. Schubert, Schubert JK, Noeldge-Schomburg GF, <i>Diagnostic Potential of Breath Analysis--Focus on Volatile Organic Compounds</i> , Clinica Chimica Acta; International Journal of Clinical Chemistry, 347(1-2); 25-29 (2004).  |
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| 15 | CM Bell & SJ Gutowski, <i>Diethyl Ether Interference with Infrared Breath Analysis</i> , 16 Journal of Analytical Toxicology 166 -- 68 (May-June 1992).  |
| 16 | <b>Okorie Okorochoa</b> , <i>Commentary on: Sterling K. The rate of dissipation of mouth alcohol in alcohol positive subjects</i> , 57 J Forensic Sci. 1140 (2012).  |
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