Improved recovery of repeat intoxicated drivers using fingernails and blood spots to monitor alcohol and other substance abuse

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\textbf{ABSTRACT}

\textbf{Objectives}. This study reports the results of a pilot program in Kenosha County that used a combination of direct biomarkers extracted from blood spots and nails to monitor repeat intoxicated drivers for their use of alcohol and drugs with a detection window spanning from 3 weeks to several months. The objectives were to test whether the direct biomarkers phosphatidylethanol (PEth), ethylglucuronide (EtG), and 5 drug metabolites would (1) help assessors obtain a more objective evaluation of repeat offenders during the assessment interview, (2) allow for timely identification of relapses and improve classification of drivers into risk categories, and (3) predict recidivism by identifying offenders most likely to obtain a subsequent operating while intoxicated (OWI) offense within 4 years of enrollment in the program.

\textbf{Methods}. All ($N = 261$) repeat offenders were tested using PEth obtained from blood spots and EtG obtained from fingernails; 159 participants were also tested for a 5 drugs of abuse nail panel. Drivers were tested immediately after the assessment interview (baseline) and at 3, 6, 9, and 12 months after baseline. Based on biomarker results and self-reports of abstinence, offenders were classified into different risk categories and required to follow specific testing timelines based on the program’s decision tree.

\textbf{Results}. The baseline analysis shows that 60% of drivers tested positive for alcohol biomarkers (EtG, PEth, or both) at the assessment interview, with lower detection rates (0–11%) for the 5 drug metabolites. The comparison of biomarkers results to self-reports of abstinence identified 28% of all offenders as high risk and assigned them to more frequent testing and more intense monitoring. The longitudinal analysis shows that 56% (completers) of participants completed the program successfully and the remaining 44% (non-compliant) terminated prematurely. Two thirds (68%) of the completers were able to reduce or control their drinking and one third relapsed at least once during their mandated monitoring periods. After a brief intervention by the assessors, 79% of relapsers tested negative for biomarkers in their repeat tests. The rearrest analysis showed that offenders classified in the noncompliant and relapers groups were 7 times more likely to receive a new OWI 4 years after enrollment compared to drivers classified as abstainers or controllers. Refractory drivers were monitored the longest and reported no subsequent rearrests.

\textbf{Conclusion}. These findings demonstrate the benefits of more individualized interventions with repeat OWI offenders and calls for further development of multimodal approaches in traffic medicine including those that use direct alcohol biomarkers as evidence-based practices to reduce recidivism.

\section*{Introduction}

The latest compilations of the NHTSA (2014) regarding fatal alcohol crashes by state show Wisconsin fatalities at 33% of all crashes in the years 2012 and 2013. Another similar report from the Substance Abuse and Mental Health Services Administration (Substance Abuse and Mental Health Services Administration 2008) cites Wisconsin as having the highest rate of drunken driving in the United States, with one of every 4 Wisconsin adults admitting that they had driven under the influence of alcohol in the previous year. Based on these numbers, Wisconsin state administrators have been searching for alternative programs to incarcerate to assist repeat intoxicated drivers because with each additional operating while intoxicated (OWI) conviction, offenders receive harsher penalties, more expensive fines, and increased jail time, costing the state millions of dollars every year without significantly contributing to these offenders’ recovery.

Successful monitoring programs for intoxicated drivers have been implemented in several European countries since the 1980s to help road authorities make informed and objective decisions while regranting drivers’ licenses (Bjerre et al. 2007; Bortolotti et al. 2007; Gjerde et al. 1986; Maenhout et al. 2012). This growing field, called \textit{traffic medicine}, sometimes uses alcohol biomarkers as tools to monitor the drinking behavior of intoxicated drivers and to ascertain drivers’ risk. For instance, in Italy, after an OWI arrest, the driver’s license is confiscated, and the driver must undergo a medical examination, which includes testing with alcohol biomarkers in order to regain their driving privileges (Bortolotti et al. 2007). In Belgium, judges have the authority to order the OWI offender to participate in a driver’s

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\caption{Diagram of the study design.}
\end{figure}
license granting program, and biomarkers are used to monitor adherence to the abstinence program (Maenhout et al. 2012, 2014). Sweden also uses a medical review program that links the reductions in biomarker values to the successful completion of interlock programs (Bjerre et al. 2007).

Similar to the European approach, some counties in the state of Wisconsin have been using alcohol biomarkers since the year 2006 to monitor drinking behavior in repeat OWI offenders. The short-term outcomes show that biomarker information helped the assessors in these counties attain a more accurate evaluation of the offenders’ drinking behavior while participating in the program and this in turn allowed them to assign the proper intensity and duration of treatment to match the needs of each driver (Bean et al. 2009). The biomarker results also assisted the assessor in providing more timely interventions when relapses were detected, therefore providing a more effective resource allocation of their scarce addiction treatment dollars (Bean et al. 2013).

The majority of previous biomarker approaches reported with OWI offenders have used indirect biomarkers, mostly carbohydrate-deficient transferrin (CDT) and gamma glutamyltransferase in Europe and CDT and the Early Detection of Alcohol Consumption test in the United States (Bean et al. 2009, 2013; Bortolotti et al. 2007; Gjerde et al. 1986; Korzec et al. 2001; Maenhout et al. 2012, 2014). Only a handful of studies (Marques et al. 2010, 2011, 2014) have used direct biomarkers to detect alcohol use in intoxicated drivers in Canada with encouraging results. The most widely used direct biomarkers to traffic medicine are phosphatidyl ethanol (PEth) and ethyl glucuronide (EtG; Bergström et al. 2003; Schröck et al. 2016). PEth is an abnormal phospholipid formed in red blood cells following alcohol exposure (Aradottir et al. 2006; Varga et al. 2000); EtG is formed in the liver when ethanol in the bloodstream is conjugated with glucuronic acid (Foti et al. 2005).

There are several distinctive features between direct and indirect tests:

1. Formation: Direct biomarkers are metabolites of alcohol formed in the body only after a person drinks alcohol (Ingall 2012; Winkler et al. 2013); indirect biomarkers form in the body as a reflection of the harmful physiological effects of heavy alcohol consumption (Harasymiw et al. 2004; Substance Abuse and Mental Health Services Administration 2012).

2. Sample matrix and window of detection: Indirect biomarkers are usually measured in samples of whole blood and provide a detection window that spans for 2 to 4 weeks after heavy drinking has stopped (Anton and Youngblood 2006; Harasymiw et al. 2005). Direct biomarkers range from PEth, which is measured in blood and has a half-life of 2 to 3 weeks, to EtG and drugs of abuse, which are deposited in urine, blood, hair, and fingernails to provide a window of detection that ranges from 3 days to 3 months, depending on the sample matrix (Jones et al. 2012; Wurst et al. 2010).

3. Clinical performance: Several sources of false positives have been reported for the indirect biomarkers (Fleming et al. 2004; Harasymiw et al. 2004), whereas no false positives have been reported so far for the direct biomarker PEth or for EtG when measured in hair and nails (Aradottir et al. 2006; Wurst et al. 2003).

Upon conviction for an OWI, drivers across the state of Wisconsin are legally required to contact the approved assessment facility for their county of residence to undergo a mandated assessment within 14 days of their conviction. The assessment consists of a 1-h personal meeting with the offender and an alcohol and other drug abuse counselor to evaluate their substance use habits. As a result of the OWI assessment, a driver safety plan (DSP) is developed with recommendations that are specific for each driver. The DSP is likely to involve either a referral to an educational program in a traffic safety school—usually required of first and second offenders—or to a counseling/treatment program usually required of third offenders and above. The OWI assessor monitors the offenders’ involvement in completing the required DSP and communicates accordingly with the Wisconsin Department of Transportation (DOT). By state statute, drivers must complete all of the requirements of the DSP in order to regain or maintain their driving privileges.

The Hope Council on Alcohol & Other Drug Abuse (Hope Council) is the organization contracted by Kenosha to perform all OWI assessments in that county. In 2014, the Hope Council conducted close to 600 assessments for intoxicated drivers, 40% of which involved repeat offenders. Based on the high rate of repeat offenders in the county and the success reported by previous biomarker programs, in 2011, road administrators in Kenosha County decided to start using biomarkers to monitor repeat offenders with 3 or more OWI offenses. The Hope Council chose to adopt direct (rather than indirect) biomarkers due to several reasons: (1) Direct biomarker tests could now be performed using nails and blood spots as sample matrices, both of which could be collected at their offices (point of care), thus avoiding the additional costs of contracting with a sample collection site as required when using indirect biomarkers. (2) The combination of PEth measured in blood spots and EtG/drug metabolites measured in nails provides a detection window that spans from several weeks to several months, which is broader than the one provided by indirect biomarkers. (3) The use of nails as the sample matrix allowed the Hope Council to test for drugs of abuse in addition to alcohol and evaluate whether licensed drivers were substituting alcohol with other illegal substances.

This study reports the results of a pilot program in Kenosha County that used a combination of direct biomarkers extracted from unique and novel sample matrices—blood spot and nails—to monitor repeat intoxicated drivers for their use of alcohol and drugs with a detection window spanning from 3 weeks to several months. The objectives were to test whether direct biomarkers obtained from these sample matrices would (1) help assessors obtain a more objective evaluation of repeat offenders during the assessment interview, (2) allow for timely identification of relapses and improve classification of drivers into risk categories, and (3) predict recidivism by identifying offenders most likely to obtain a subsequent OWI offense within 4 years of enrollment in the biomarker program.

Subjects and methods

Subjects

Drivers (N = 261) who came to the Hope Council to schedule a mandated assessment between June 2011 and June 2014
and were a 3-time OWI repeat offender or greater were required to enroll in the biomarker program as part of their DSPs. All drivers were required to undergo alcohol treatment in addition to biomarker testing. All 261 repeat offenders were tested for alcohol consumption using both the PEth-blood spot and the EtG-nail tests and 159 of them were also tested for a 5-drug panel: amphetamines, cocaine, opioids, phencyclidine, and cannabinoids in nails. The decision to test for drugs of abuse in addition to alcohol was based on drivers’ reports of another drug of choice during the assessment interview and/or law enforcement reports indicating that another drug was also a factor in the drivers’ lives. Drivers \( (n = 102) \) who admitted to alcohol being their only drug of choice were tested only for alcohol.

Assessments were conducted by licensed alcohol and other drug abuse counselors employed by the Hope Council who used the Wisconsin Assessment of the Impaired Driver (WAID) questionnaire in a one-on-one 60-min interview to determine whether drivers needed education, treatment, or both to reduce the likelihood that they would drive impaired in the future. To collect information on substance use, the Hope Council used one of the questions of the WAID that asked drivers about their last day of alcohol and/or drug use. Drivers also completed the Drinking History Form and the Other Drug Use History Form, both shorter modified versions of the Khavari Alcohol Questionnaire (Khavari and Farber 1978) to gather information on the quantity and frequency of substance use for the 30 days prior to sample collection.

After completion of the assessment interview, the driver was guided to the collection room where samples for alcohol/other drug testing were collected under the supervision of a trained staff member following standard chain of custody procedures.

### Biomarker assays

All testing was done at U.S. Drug Testing Laboratories (Des Plaines, IL). The screening and confirmation methods as well as the limit of detection, limit of quantitation, and the cutoff of the tests used are shown in Table 1. All samples that tested positive by the screening test were tested again using their respective confirmation test and reported positive only if the confirmation test was positive. All of the cutoffs used have been reviewed and accepted by the College of American Pathologists and ISO17025. Tests results were reported back to the Hope Council via e-mail and recorded in a secure master database for analysis and reporting.

#### Phosphatidyl ethanol extraction from blood spots

Dry blood spots were used as the sample matrix for PEth testing; a significant correlation between whole blood and dried blood spot PEth levels among binge drinkers was recently reported (Piano et al. 2015).

Sample collection procedures required the driver to position his or her hand below the heart and wipe his or her (chosen) finger with an isopropyl alcohol pad. After air drying the finger, the driver punctured the finger with a sterile lancet and the first drop of blood was wiped away; the second and subsequent drops were used to fill in the circles of the specimen collection card provided by the laboratory. The specimen card was then placed in the blood spot drying box and shipped to the laboratory for analysis.

At the laboratory, 3 standard blood spot punches (3.1 mm) were prepared for each dried blood spot specimen, calibrator, and control as previously described (Jones et al. 2011). The punches were extracted with methanol and separation was achieved using an Agilent 6460 liquid chromatography–tandem mass spectrometry (LC-MS/MS; Agilent Technologies, Santa Clara, CA) as the detector. The method monitored a single isomer of PEth (palmitoyl/oleoyl), which is the most prevalent PEth species. The limit of detection was 2 ng/mL, the limit of quantitation was 8 ng/mL, and the assay was linear up to 800 ng/mL (Table 1). The cutoffs chosen for the screening and confirmatory methods were adapted from previous reports (Marques et al. 2011; Piano et al. 2015).

#### Ethyl glucuronide extraction from nails

Fingernails were used as the sample matrix for EtG testing. Sample collection procedures requested the drivers to remove all cosmetic treatments and wash hands before clipping their own nails. A clipping of 2- to 3-mm-long from all 10 fingernails was recommended to provide the 100 mg (alcohol only) to 150 mg (alcohol plus drugs) of sample required for the analysis. Nail clippings were weighed on a jeweler’s scale and placed in the specimen collection kit before shipping to the laboratory.

At the laboratory, weighed portions (10–50 mg) of distal fingernail clippings were powderd in a Mini-Beadbeater 24 Homogenizer (Biospec Products, Bartlesville, OK) and the EtG was extracted from the powdered specimens using a solid phase extraction procedure described previously (Jones et al. 2012). The detector was an Agilent 6460 LC-MS/MS using electrospray in the negative mode. The limit of detection was 2 pg/mg, the limit of quantitation was 8 pg/mg, and the assay was linear up to 2,000 ng/mL (Table 1). The cutoffs chosen for the screening and confirmatory tests were adapted from previous reports (Berger et al. 2014; Kharbouche et al. 2012).

### Table 1. Screening and confirmation methods used to test for alcohol and other drugs of abuse.a

| Analyte               | Sample type | Screening method | Screening cutoff | Confirmation method | Confirmation cutoff | Limit of quantitation | Limit of detection | Upper limit of linearity |
|-----------------------|-------------|------------------|------------------|---------------------|---------------------|----------------------|---------------------|------------------------|
| PEth (ng/mg)          | Blood spot  | LC-MS/MS         | 20               | LC-MS/MS            | 8                   | 8                    | 2                   | 800                    |
| EtG (pg/mg)           | Nails       | LC-MS/MS         | 20               | LC-MS/MS            | 8                   | 8                    | 2                   | 2,000                  |
| Amphetamines (pg/mg)  | Nails       | ELISA            | 500              | LC-MS/MS            | 100                 | 40                   | 20                  | 1,000                  |
| Opiates (pg/mg)       | Nails       | ELISA            | 500              | LC-MS/MS            | 100                 | 40                   | 20                  | 1,000                  |
| Cocaine (pg/mg)       | Nails       | ELISA            | 200              | LC-MS/MS            | 100                 | 40                   | 20                  | 1,000                  |
| Phencyclidine (pg/mg) | Nails       | ELISA            | 300              | LC-MS/MS            | 100                 | 40                   | 20                  | 1,000                  |
| Cannabinoids (pg/mg)  | Nails       | ELISA            | 1                | GC/GC-MS/MS         | 0.05                | 0.02                 | 0.01                | 10                     |

aMethods used to detect for alcohol and other drugs are shown for the screening and confirmation tests along with their respective cutoff points.
Drugs of abuse extraction from nails
Sample collection followed the same procedure described for EtG nails above. In general, drugs are detected in nails for up to 8 months after use, depending on the substance used, the amount used, and personal metabolism (Baumgartner 2014; Krumbiegel et al. 2014; Palmeri et al. 2000).

Drugs in nails were tested using an enzyme-linked immunosorbent assay (ELISA) as the screening method; all presumptive positives were confirmed using either LC-MS/MS or 2-dimensional gas chromatography–tandem mass spectrometry (GC/GC-MS/MS). The analytic components detected for each class of drugs were as follows: (1) Amphetamines: amphetamine, 3,4-methylenedioxyamphetamine, 3,4-methylenedioxymethamphetamine, and 3,4-methylenedioxyethylamphetamine; (2) cannabinoids: carboxy-tetrahydrocannabinol (THC) and native-THC; (3) cocaine: benzoylecgonine, cocaethylene, cocaine, and norcocaine; (4) opiates: 6-monoacetylmorphine, codeine, hydrocodone, hydromorphone, morphine, oxymorphone, and oxycodone; and (5) phencyclidine.

Decision tree and testing schedule
All drivers \((n = 260)\) enrolled in this program were expected to participate in biomarker testing using both the PEth and EtG tests at baseline and the 4 standard established timelines (3, 6, 9, and 12 months) according to the testing guidelines and decision tree developed specifically for this program (Appendix 1, see online supplement). A subgroup of drivers \((n = 159)\) was also tested for 5 other drugs of abuse.

The first testing timeline occurred immediately after the assessment interview to establish a baseline. Depending on the tests results, the assessors at the Hope Council did the following:

1. If both PEth and EtG results were negative the assessor conducted a brief intervention (BI) with the driver by phone within 1 week of receiving the tests results to encourage sustained abstinence. The driver was tested again every 4 months and if all biomarker tests continued to be negative the DSP was completed within 12 months of enrollment and the driver was able to maintain/regain driving privileges.

2. If either PEth or EtG were positive and the driver reported any drinking for the 30 days prior to the assessment interview the assessor did a BI with the driver by phone to report the positive test result(s) and made recommendations regarding the proper course of alcohol treatment. Testing resumed every 4 months as described above.

3. If either PEth or EtG was positive at baseline and the driver reported no drinking for the 30 days prior to the assessment interview the driver was considered high risk. The assessor again conducted a BI by phone to report the positive test result(s) to the driver and to plan the proper course of alcohol treatment. In addition, the assessor requested a repeat test within a month; all repeat tests were done using PEth-blood spot only because a shorter window of detection allowed for closer and more frequent monitoring of their drinking behaviors. The PEth test was repeated monthly until the results turned negative or until 3 positive tests were produced and the client went into noncompliance. Once the repeated PEth tests normalized, the driver resumed the standard testing schedule.

For the last follow-up test—conducted 12 months after baseline—if either PEth or EtG was positive then the DSP was extended for 4 more months and additional testing was done at 15 months; that is, one month before the driver’s release from the extended program. Any positive results at the 15-month follow-up triggered a new assessment and a new DSP with driving privileges suspended indefinitely until the new assessment was completed and the new DSP was established, allowing the assessor an additional 12 to 16 months of biomarker monitoring. By state statute, the only way to keep an offender who relapses enrolled in the biomarker program for more than 16 months is to request a second DSP.

For drivers tested also for drugs, those who were negative for all drugs of abuse at baseline were tested again at 6 and 11 months after enrollment. If tests results continued to be negative, the DSP was successfully completed within 12 months and the drivers maintained their driving privileges. If any test was positive at the 6-month follow-up the DSP was extended for 4 months and the testing was repeated at 11 and 15 months. Drivers who tested positive for other drugs at the 11- or 15-month follow-up ended the DSP in noncompliance and were requested to undergo a new assessment and DSP until all tests were negative.

Outcomes measures and data analysis
The evaluation of results was divided into 3 main areas: (1) baseline, (2) follow-up, and (3) recidivism analyses to address the 3 hypotheses mentioned previously.

The baseline analysis consisted of 3 parts: (1) defining the demographic profile of the drivers enrolled in the program, (2) determining the biomarker positive rates for EtG and PEth (when used combined and separate from each other) as well as the other 5 drugs of abuse tested, and (3) comparing biomarker results to self-reports of abstinence; the latter were calculated from the drivers’ recollections of their last day of use as reported in the WAID questionnaire. The comparisons between biomarkers and self-reports were made to help the assessors at the Hope Council determine a specific course of action for each driver based on their preestablished decision tree.

The follow-up analysis consisted of 2 parts: (1) determining program completion rates and (2) monitoring the longitudinal changes of the biomarker results for each driver during the DSP.

Completion rates were determined by classifying drivers as completers (those who complied with all of the program requirements stipulated in their DSP) or noncompliant (those who did not complete the biomarker program and abandoned the program prematurely).

The changes in biomarker results were monitored by further classifying those drivers who completed the program into 4 subgroups based on definitions established previously by Maenhout et al. (2014). The 4 subgroups were (1) abstainers/moderate drivers: Drivers with negative biomarker results at baseline, as well as the entire 12-month monitoring period; (2) controlled drivers: Drivers with one or more positive biomarker results at
baseline only, followed by negative biomarker results for the rest of the 12-month follow-up period; (3) relapers: Drivers with any biomarker test exceeding the cutoff at least once during the follow-up period; and (4) refractory drivers: Drivers who ended the first 12–16 months of follow-up with one or more biomarker-positive test for alcohol and/or other drugs. This group was required to undergo a new assessment and complete a new DSP before regaining diving privileges as described above.

The recidivism analysis consisted of evaluating whether a positive biomarker test could predict subsequent rearrests within 4 years of enrollment in the biomarker program. Kaplan-Meier survival estimates were used based on previous reports (Maenhout et al. 2014) that measured the probability of intoxicated drivers’ recidivism plotted over time at different biomarker levels. The drivers’ rearrest data were obtained at the Wisconsin State DOT by looking at the driving records for all 261 subjects in June 2015.

The overall follow-up period was 36 months, ranging from June 2011 (first driver enrolled in program) to June 2014 (last driver to complete 12 months of monitoring by June 2015, the time when the DOT reviewed all rearrest records). Those who enrolled in 2011 were followed for 4 years and those who enrolled in 2014 were followed for 1 year at the time the DOT reviewed their files in 2015.

### Statistical analysis

The baseline and follow-up analysis used a z test of equality of proportions to determine whether the differences between the percentages shown were statistically significant (P < .05). Pearson’s correlation was used to evaluate the relationship between the length of the monitoring (LOM) period and the numbers of times the drivers were tested with biomarkers.

In the Kaplan-Meier curves, each subject was characterized by 3 variables: (1) their serial time defined as the number of days from the driver’s enrollment in the program until the time of his or her next rearrest or, if not rearrested until June 2015, the time when the DOT reviewed his or her driving record; (2) the offender’s rearrest status at the end of his or her serial time (rearrested = 1 or censored = 0). Censored observations were drivers who did not experience a subsequent rearrest before the end of the observation period; and (3) the classification group they were in: abstainers, controllers, relapers, refractory, or noncompliant.

All analyses were done using the software package SPSS version 20.

### Results

#### Baseline analysis

**Demographics**

The demographic profile of the drivers enrolled in this program showed a population of adults mostly males (84%), with a mean age of 43 years, Caucasian (73%), and either single, divorced, or widowed (79%). More than one third (36%) had attended some college, and over one half (55%) were employed either full or part time at the time of enrollment in the biomarker program (Table 2). The vast majority of them (79%) had findings of alcohol and/or drug dependence at the start of the program, and only a small fraction (15%) had no previous history of addiction treatment. The z test of proportions showed that those required to test for alcohol and drugs were younger (41 years of age) and more severely dependent (83%) than those tested for alcohol only (45 years and 73% dependent, respectively; P < .05).

#### Positive biomarker rates at baseline

The detection rate for the combination EtG and PEth shows that 60% (157/261) of all repeat offenders enrolled in the biomarker program tested positive for one or both of these alcohol tests at the time of the assessment interview (baseline) and 40% (104/261) tested negative by both tests. There were no statistically significant differences between the detection rates reported for those offenders who were tested for alcohol only (56.8%) versus those tested for alcohol and other drugs (62.2%).

When these 2 alcohol biomarkers were analyzed separately, the positive rate for EtG alone was 49% (127/259) and the positive rate for PEth alone was 48.7% (128/262). Ten percent of all drivers (25/261) tested PEth positive and EtG negative; 11% (28/261) tested EtG positive and PEth negative at baseline.

A test of proportions show that the 60% detection rate achieved by using both biomarkers combined is significantly greater than the 50% detection rates found when using them separately.

The drug profile for the entire population shows that approximately one in 10 repeat offenders tested positive for marijuana (11.1%) and cocaine (8.4%). Lower detection rates were found for opiates (6.9%) and amphetamines (1.5%) with no positives for phencyclidine (0%).

### Cross-tabulation of biomarkers versus self-reports at baseline

The comparison of the biomarker results to self-reports of abstinence for the 30 days prior to the assessment interview was determined for PEth and EtG used combined and separately from one another (Table 3). When using both alcohol biomarkers combined, the results showed that 40% (101/251) of all drivers tested negative for both the PEth and EtG tests
and, of these, 91% (92/101) claimed abstinence for 30 days or more before the assessment interview. The remaining 60% of all drivers (n = 150/251) tested positive by either PEth, EtG, or both at baseline and, of these, 52% (78/150) reported alcohol use and 48% (72/150) reported full abstinence for 30 days or more before their assessment interviews. Using this information and the guidelines specified in the decision the high-risk population was identified and their testing timelines were adjusted.

For the PEth test used alone, the analysis shows that half (n = 130) of the drivers tested PEth negative at baseline and, of these, 88% (114/130) claimed abstinence for 30 days or more before their assessments. The remaining half (n = 127) tested positive for the PEth test at baseline and, of these, 58% (74/127) reported alcohol use and 42% (53/127) claimed 30 days or more of full abstinence.

For the EtG test used alone, the percentages were similar, with half (n = 126) of the drivers testing negative for EtG at baseline and, of these, 88% (111/126) claiming abstinence; the other half (n = 128) tested EtG positive and, of these, 42% (54/128) reported abstinence (Table 3).

Overall, the statistical analysis using z tests on equality of proportions showed no differences between the percentages of drinkers in these different categories (P > .05). This means that when using self-reports in addition to biomarker results to make the recommendations for the DSP the percentage of drivers classified in each quadrant in Table 3 is the same whether using both biomarkers combined or separately. These findings may have relevant cost-saving implications for these programs as discussed below.

Follow-up analysis

Monitoring substance use behavior during the DSP

The follow-up results show that 56% (146/260) of all repeat offenders enrolled completed the program successfully (completers), and 44% (114/260) abandoned the program prematurely (noncompliant). The subgroup tested for alcohol and other drugs had a higher noncompliance rate (50%) compared to those tested for alcohol only (35%; P < .05).

Recidivism analysis

The recidivism rate for the entire group shows that 7.7% (20/260) of the repeat offenders had a subsequent OWI offense within 4 years of enrolling in the biomarker program. The recidivism rates for the follow-up groups are shown in Figure 1:  

| Table 3. Cross-tabulation of the results of alcohol biomarker testing versus self-reports of abstinence. |
|---------------------------------------------------------------|
| **Biomarker positive (EtG and/or PEth)** | **Biomarker negative (EtG and PEth)** | **Biomarker positive (PEth only)** | **Biomarker negative (PEth only)** | **Biomarker positive (EtG only)** | **Biomarker negative (EtG only)** |
|---------------------------------------------------------------|
| Drinkers (reported any alcohol use), % (n) | Abstainers (reported no alcohol use), % (n) | Total number of drivers |
|---------------------------------------------------------------|
| Biomarker positive (EtG and/or PEth) | 52 (78/150) | 48 (72/150) | 150 |
| Biomarker negative (EtG and PEth) | 9 (9/101) | 91 (92/101) | 101 |
| Biomarker positive (PEth only) | 58 (74/127) | 42 (53/127) | 127 |
| Biomarker negative (PEth only) | 12 (16/130) | 88 (114/130) | 130 |
| Biomarker positive (EtG only) | 58 (74/128) | 42 (54/128) | 128 |
| Biomarker negative (EtG only) | 12 (15/126) | 88 (111/126) | 126 |

Note. The number of abstinent days was determined by asking repeat offenders about their last day of substance use at the time of the assessment interview. Drinkers were drivers reporting any drinking for 29 days prior to assessment and abstainers were drivers reporting full abstinence for 30 days or more prior to assessment. Each quadrant represents the percentages of drivers in the different categories and in parenthesis are the numbers of drivers in each analysis.

The 146 drivers who completed the biomarker program included 32% (46/146) abstainers, 36% (53/146) controllers, 25% (37/146) relapsers, and 7% (10/146) refractories (Table 4). Overall, two thirds (abstainers plus controllers) of drivers tested negative for all biomarkers at the 3-, 6-, 9-, and 12-month follow-ups and one third (relapsers plus refractory) tested positive at least once during the first 12 months of monitoring. The majority (79%, 37/47) of those who tested biomarker positive at follow-up responded favorably to the brief intervention they received from their assessors by showing a negative PEth result in their repeat tests. The relapsers who did not respond to the brief intervention and ended the first DSP with a positive test became the refractory group (21%, 10/47) and had to undergo a new round of 12 months of monitoring. Seven of these 10 refractory drivers were able to finish the second DSP successfully and the remaining 3 consistently failed the biomarker program.

There was a strong positive correlation (r = 0.86; P < .05) between the LOM period and the number of times a repeat offender was tested during follow-up (Table 4). Thus, the drivers in the noncompliant group were monitored for an average of 158 days before abandoning the program and during this time they were tested 3 different times on average. The completers group as a whole was monitored for 450 days and tested 6 different times on average. For the completers subgroups, the abstainers and controllers finished the program in approximately 12 months (mean = 350 days) and underwent the 4 mandatory sets of tests required in the testing schedule guidelines. Relapsers completed the program in 13 months (mean = 390 days) and underwent testing 6 different times on average. Drivers in the refractory group stayed in the program for 24 months (mean = 716 days) and were tested 9 different times on average. The longer time frames in the relapser and refractory groups were consistent with the frequent rounds of repeat testing required for those drivers who tested biomarker positive and had to extend their DSPs.

| Table 4. Classification of repeat offenders into different drinking categories based on follow-up results. |
|---------------------------------------------------------------|
| **All drivers (n = 260)** | **Noncompliant** | **Total** |
|---------------------------------------------------------------|
| **Completers** | 146 | 65% | 450 | 5.9 |
| **Controller** | 114 | 44% | 158 | 3.2 |
| **Total** | 260 | 100% | 280 | 4.2 |

Note. The number of drivers in each of the subgroups (abstainer, controller, relapser, and refractory) as well as the mean LOM period and the average number of times the drivers went to the Hope Council for biomarker testing.

The 146 drivers who completed the biomarker program included 32% (46/146) abstainers, 36% (53/146) controllers, 25% (37/146) relapsers, and 7% (10/146) refractories (Table 4). Overall, two thirds (abstainers plus controllers) of drivers tested negative for all biomarkers at the 3-, 6-, 9-, and 12-month follow-ups and one third (relapsers plus refractory) tested positive at least once during the first 12 months of monitoring. The majority (79%, 37/47) of those who tested biomarker positive at follow-up responded favorably to the brief intervention they received from their assessors by showing a negative PEth result in their repeat tests. The relapsers who did not respond to the brief intervention and ended the first DSP with a positive test became the refractory group (21%, 10/47) and had to undergo a new round of 12 months of monitoring. Seven of these 10 refractory drivers were able to finish the second DSP successfully and the remaining 3 consistently failed the biomarker program.

There was a strong positive correlation (r = 0.86; P < .05) between the LOM period and the number of times a repeat offender was tested during follow-up (Table 4). Thus, the drivers in the noncompliant group were monitored for an average of 158 days before abandoning the program and during this time they were tested 3 different times on average. The completers group as a whole was monitored for 450 days and tested 6 different times on average. For the completers subgroups, the abstainers and controllers finished the program in approximately 12 months (mean = 350 days) and underwent the 4 mandatory sets of tests required in the testing schedule guidelines. Relapsers completed the program in 13 months (mean = 390 days) and underwent testing 6 different times on average. Drivers in the refractory group stayed in the program for 24 months (mean = 716 days) and were tested 9 different times on average. The longer time frames in the relapser and refractory groups were consistent with the frequent rounds of repeat testing required for those drivers who tested biomarker positive and had to extend their DSPs.

Recidivism analysis

The recidivism rate for the entire group shows that 7.7% (20/260) of the repeat offenders had a subsequent OWI offense within 4 years of enrolling in the biomarker program. The recidivism rates for the follow-up groups are shown in Figure 1:
there was a 2% (1/46) rearrest rate for both abstainers and controllers (1/53) compared to 14% (5/37) for the relapsers and 11% (13/114) for the noncompliant group. An analysis of proportions showed that there were statistically significant differences \( (P < .05) \) in the probability of recidivism between these follow-up groups. Repeat offenders who relapsed during the DSP or became noncompliant with the program were at least 5 times more likely to be rearrested within the 4-year observation period compared to drivers who completed the program as abstainers or controllers. An exception was found with drivers in the refractory group, none of whom were rearrested after being asked to enroll in a second DSP and completing an additional 12 months of monitoring.

The hazards plot in Figure 2 shows that 400 days (1 year) after the start of this pilot no drivers had been rearrested from the abstainers and controllers groups, one driver was rearrested from the relapers group, and 7 drivers were rearrests from the noncompliant group. Similarly, 2 years (730 days) after the start of the program one driver had been rearrested from each of the abstainers and controllers groups, 2 more drivers were rearrested in the relapers group, and 10 additional drivers were rearrested in the noncompliant group. Thus, relapsers and noncompliant drivers showed similarly high rearrest rates but differed in the number of days to a subsequent rearrest. The relapers were rearrested 547 days after enrollment in the program and were monitored for 390 days on average, whereas the offenders in the noncompliant group were rearrested 331 days after baseline and were monitored for 158 days on average. This means that relapers were rearrested an average of 216 days later in the study period compared to drivers in the noncompliant group.

**Discussion**

In 2005, the Wisconsin Department of Health and Family Services determined that the use of biomarkers is permissible in the state under Intoxicated Driver Program rules (HFS 62.03) and in treatment-oriented driver safety plans. Since then, 8 counties (Waukesha, Dane, Taylor, Kenosha, Oneida, Forest, Vilas, and Washington) in the state of Wisconsin have implemented biomarker programs, with more than 3,000 repeat offenders tested so far. Most of these programs have used indirect biomarkers similar to the programs widely used in Europe. The pilot described in this report evaluates the use of 2 direct biomarkers (EtG and PETH) extracted from 2 novel sample matrices (nails and dried blood spots) in a cross-sectional analysis to determine demographics and biomarker detection rates as well as a longitudinal analysis to classify offenders in different risk categories, evaluate program compliance, and review subsequent OWI rearrests.

The cross-sectional analysis at the time of the assessment interview revealed the average offender as an adult Caucasian male, mostly employed, not married, and with an extensive history of addiction treatment. This profile is consistent with previous findings portraying similar demographic parameters in intoxicated drivers in the United States, Europe, and Canada (Bean et al. 2009; Marques et al. 2010; Portman et al. 2013). The subgroup tested for alcohol and other drugs had a larger proportion of drivers who were single and with more severe findings of dependence, which may be in turn contributing to the higher rate (50%) of program failure found in this subgroup. This pilot also helped Kenosha County administrators obtain information about the drug profile of these offenders, with cannabis and cocaine being the most widely used substances after alcohol. This is similar to a recent study with intoxicated drivers in Europe (Snenghi et al. 2015) where cocaine was also the most widely used substance, followed by cannabis and opiates. Even though heroin is the most widely used drug of abuse in Wisconsin at present, the percentage of repeat intoxicated drivers who tested positive for this type of drugs in this pilot was low.

The biomarker detection rates show that 60% of repeat offenders tested positive for heavy drinking at the baseline test when PETH and EtG were used together compared to 50% when they were used separately, and these differences were statistically significant \( (P < .05) \). Overall these detection rates are higher than previous reports using indirect alcohol biomarkers in Waukesha County (20%; Bean et al. 2009) and Dane County (28%; Bean et al. 2013), most likely a reflection of the longer window of detection described for the direct biomarkers (Nanau and Neuman 2015; Substance Abuse and Mental Health Services Administration 2012). These high detection rates are also an indication that the majority of repeat offenders continue to drink and drive after their OWI arrest until the time of their assessment interviews. The comparisons of biomarker profiles to self-reports of abstinence show that almost half (48%) of repeat offenders who tested positive for biomarker(s) at baseline...
reported full abstinence for 30 days or more prior to their assessment interviews. Because there are no false positives reported for PETH and EtG when extracted from the sample matrices used in this pilot, these results indicate that half of the offenders had accurate recollections of their substance use when they reported abstinence immediately preceding the baseline test and the other half were using alcohol/drugs above the thresholds required to elevate these tests and were seemingly in denial. Assessors used this information to classify offenders in different risk categories and to make more objective recommendations based on their decision tree; the higher the risk category, the stricter the monitoring requirements of their DSPs. Using these guidelines, one of every 4 (72/260) repeat offenders enrolled in this pilot received more intense treatment and longer monitoring periods based on biomarkers and self-report data.

The longitudinal analysis showed that 56% of the repeat offenders enrolled in biomarker testing finished the program successfully and the remaining 44% abandoned the program prematurely. This is similar to the 56% completion rate reported for the treatment courts funded by the state of Wisconsin’s Treatment Alternative and Diversion programs (Van Stelle et al. 2014). However, the noncompliance rate in Kenosha is slightly higher than the 30–35% noncompliance reported previously in the Dane and Waukesha programs. This difference appears to be related at least in part to the inclusion of the group tested for drugs because the alcohol group alone shows a 35% noncompliance rate. Another reason for the high noncompliance rate may be related to the cost of the testing, which in Kenosha is fully transferred to the drivers; in most other counties biomarker testing is subsidized by federal and county funds, with drivers paying only a fraction of the tests costs. In fact, noncompliant drivers are one of the most challenging aspects of these biomarker programs because they continue to drink and drive and are rearrested shortly after abandoning the program. Counselors at the Hope Council have been looking for several ways to reduce the noncompliance rate in this type of program, but using more staff resources to monitor the noncompliant group more closely leads to higher program costs. If these costs are transferred to the drivers, officials believe that it could feed and perpetuate the noncompliance cycle. It is very likely that multimodal programs with more intense interventions—such as the new OWI and drug courts being implemented in several of these counties—may be better suited for repeat offenders who fail the biomarker program.

For the 60% of offenders who completed this pilot program, the majority (68%) tested negative for biomarkers during the entire monitoring period, an indication that most of those who participate and engage in biomarker testing are capable of controlling their intake for the entire duration of their DSPs. This is similar to the results reported in the ROAD and Waukesha studies, where the majority of those enrolled were able to abstain or control their drinking during a one-year follow-up (Bean et al. 2013; Maenhout et al. 2014).

One of the most relevant contributions of biomarker testing in these programs is the ability to detect relapses and provide timely interventions during follow-up. In this pilot, one third of those who completed the biomarker program had one or more relapses during their DSPs and 79% (37/47) of those who suffered a relapse reduced their drinking after a BI was conducted by the assessors at the Hope Council. This is consistent with findings in Waukesha and Dane, where 80 and 68% of those who relapsed decreased their drinking after the biomarker information was used to increase the frequency of testing and extend the duration and/or intensity of addiction treatment (Bean et al. 2009, 2013). It is also similar to the brief motivational interviewing sessions documented as useful interventions to prevent OWI recidivism in remedial programs in Canada (Ouimet et al. 2013). However, one fifth of the relapsers did not respond to these interventions the first 12 months of monitoring and eventually became part of the refractory group, required to undergo a second DSP. The fact that 70% of those in the refractory group successfully completed a second round of monitoring supports the notion that a longer follow-up period may be needed in these high-risk offenders to achieve long-term sobriety. The 30% of refractory drivers who continued to test biomarker positive and therefore failed their second DSPs may need additional, more stringent interventions similar to the noncompliant group.

The recidivism analysis show a 7.7% rearrest rate, which is lower than the 12% rate previously reported with third OWI offenders in Waukesha County (Bean et al. 2014). However, Kenosha used 4 years of DOT data compared to 6 years in Waukesha; when recidivism rates are adjusted annually, the mean rearrest rate was 2% per year in both counties. The rearrest rate in Kenosha is also lower than the 21% recidivism rate found in the ROAD study (Maenhout et al. 2014) and the 17% conviction rate reported for the Wisconsin’s Treatment Alternatives and Diversion Programs (Van Stelle et al. 2014). The reasons for the variations in these recidivism rates are not clear at present and may be related to the low number of rearrested drivers in this pilot, which is another weakness of this report. Arrests and convictions are rare events; additional measurements of these occurrences gathered over time would improve the power and stability of this analysis.

Amidst the low numbers, the test of proportions comparing rearrest rates between the follow-up groups showed that relapsers were 7 times more likely to be rearrested within 4 years of enrolling in the program compared to abstainers or controllers. This is similar to findings in Belgium and Finland where high levels of the indirect biomarker CDT and gamma-CDT were capable of distinguishing drunk drivers with a high risk of recidivism (Maenhout et al. 2014; Portman et al. 2010). Interestingly, drivers in both the relapsers and noncompliant groups recidivated at a similar rate but the relapsers stayed engaged in the biomarker program for an additional 232 days and delayed their subsequent rearrest for an average of 216 days compared to the noncompliant group. Drivers in the refractory group were monitored the longest and none of them received a subsequent OWI after enrolling in their second DSPs, supporting the use of extended mandatory follow-up periods.

The penalties for a repeat OWI offender in Wisconsin are harsh and include $1,000 to $2,500 in fines, the installation of an ignition interlock device, and 60 days to one year in jail time. Each repeat offender costs taxpayers in this state $90 per day in jail expenses alone (Brown 2011), which translates into an annual cost of almost $33,000 per year per driver. For comparison, the cost of biomarker testing in the United States—direct or indirect—ranges around $100 to $150 per test.
Therefore, monitoring a single repeat offender for 12 months with 4 biomarker tests costs these counties $400–$600 per year, almost 2 orders of magnitude less than the costs of one year of jail. Despite the lower costs of the biomarker programs, most counties are still reluctant to pass on the testing costs to the drivers thinking the noncompliance rates would increase even more. In fact, Kenosha County is now evaluating whether to continue to use both the EtG and PEth tests to maximize detection rates every time an offender is tested or to choose just one of the 2 in an attempt to lower testing costs. The results of this pilot (Table 3) seem to indicate that the outcomes are the same whether using them combined or separately.

Overall, the cross-sectional analysis proved the hypothesis that direct biomarkers obtained from blood spots and nails provide Kenosha County with a convenient and more objective evaluation of repeat offenders during the assessment interview resulting in better recommendations for addiction treatment. The longitudinal data showed that direct biomarkers behave similar to indirect tests in that their results can assist the assessor in providing timely intervention during relapses and can help identify those offenders who are most likely to reoffend. Kenosha has now extended biomarker testing to all intoxicated drivers in the county using different decision trees based on the number of OWI offenses; it has also expanded the nail panel to test for up to 12 drugs of abuse. Washington County has added direct biomarker testing to its OWI diversion program; Oneida, Forest, and Vilas counties have expanded nail testing to include not only EtG but also 5 drugs of abuse; and Dane County has recently switched from indirect to direct biomarkers and is testing all repeat offenders with 3 or more OWI convictions.

OWI offenders represent a clinical population with high levels of complex and competing treatment needs that are not currently being met (Mullen et al. 2015). The findings in this pilot demonstrate the benefit of more individualized interventions and calls for further development of multimodal approaches including biomarker testing in efforts to use evidence based practices to reduce recidivism.

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