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Evaluation of Dräger DrugTest 5000 in a Naturalistic Setting

Hallvard Gjerde[1,*], Grethe Brennhovd Clausen[2], Espen Andreassen[2], and Håvard Furuhaugen[1]

[1]Department of Forensic Sciences, Oslo University Hospital, P.O. Box 4950 Nydalen, NO-0424 Oslo, Norway, and [2]Mobile Police Service, P.O. Box 100, NO-3291 Stavern, Norway

*Author to whom correspondence should be addressed. Email: hallvard.gjerde@ous-hf.no

Abstract

Reliable field testing devices for psychoactive drugs would be useful tools for the police for detecting drug-impaired drivers. The Norwegian Mobile Police Service (NMPS) started using Dräger DrugTest 5000 (DDT5000) in 2015 as an on-site screening instrument for drugs in samples of oral fluid. The aim of this study was to compare the results of field testing of DDT5000 with drug findings in blood and oral fluid samples taken from drivers suspected for driving under the influence of drugs (DUID). In total, 369 drivers were included in this field testing; blood samples were obtained from all of them, while oral fluid samples were collected with the Intercept device from 301 of them. The median time from field testing with DDT5000 and collection of blood and oral fluid samples was 50 min. The proportions of false positive results with DDT5000 compared to findings in blood samples above the Norwegian legal per se limits were for cannabis 14.5%, amphetamine 23.2%, methamphetamine 38.4%, cocaine 87.1%, opiates 65.9% and benzodiazepines 36.4%. The proportions of false negatives were for cannabis 13.4%, amphetamine 4.9%, methamphetamine 6.1%, cocaine 0.0%, opiates 0.0% and benzodiazepines 18.8%. Among drivers who had drug concentrations above the legal limits in blood, the proportion who tested positive using DDT5000 was 82.9% for THC, 90.8% for amphetamine, 75.7% for methamphetamine, 100.0% for cocaine, 100.0% for opiates and 37.2% for benzodiazepines. In cases with false-positive DDT5000 results compared to blood, traces of drugs were most often found in oral fluid. The DDT5000 did not absolutely correctly identify DUID offenders due to fairly large proportions of false-positive or false-negative results compared to drug concentrations in blood. The police reported that DDT5000 was still a valuable tool in identifying possible DUID offenders, resulting in more than doubling the number of apprehended DUID offenders.

Introduction

Reliable field testing devices for illicit drugs and psychoactive medicinal drugs would be important tools for the police in the investigation of suspected cases of driving under the influence of drugs (DUID). For alcohol, hand-held breathalyzer equipment has been in use for decades and evidential breath testing instruments are also in use. For drugs, the accurate detection of drug impairment is more difficult. Some countries have implemented zero tolerance legislation or per se limits on the use of illicit drugs by drivers, whereas other countries have impairment based legislation.

Norway implemented an impairment law on DUID in 1959, requiring documentations of clinical impairment in addition to positive drug test result. In most cases an expert report was required as well, assessing whether impairment according to the Road Traffic Act was likely. As the legal blood alcohol concentration (BAC) was reduced from 0.5 to 0.2 g/kg in 2001, a debate on revising the Road Traffic Act regarding DUID commenced: the police and politicians wanted to harmonize the law regarding driving under the influence of drugs and alcohol. Therefore, Norway implemented legal concentration limits in blood for 20 drugs corresponding to BAC of 0.2 g/kg

in 2012, and limits for graded sanctions corresponding to BACs of 0.5 and 1.2 g/kg for most of the substances (1). Eight more substances were assigned with legal limits in 2016 (2). The implementation of legal limits has also simplified the legal process in DUID cases and reduced the need for expert reports.

The Norwegian police was allowed to perform preliminary tests for drug use in cases of suspected DUID in 2012. Field testing of drugs by the police using blood samples is not feasible, whereas drug concentrations in urine samples do not reflect drug impairment or recent drug use (3). Samples of sweat have been tested for drug screening (4–7), but oral fluid testing seems to be the best alternative (6–9). The collection of oral fluid is regarded as less intrusive than the collection of urine or blood, and it can be done within a few minutes. The detection of a drug in oral fluid confirms recent intake, but does not confirm impairment or intoxication (10, 11). Therefore, the Road Traffic Acts requires that drug concentrations are determined in blood samples.

After reviewing available equipment and performing an initial evaluation, the Norwegian Mobile Police Service (NMPS) started using Dräger DrugTest 5000 (DDT5000) as a field test device for drugs of abuse in 2015. This device can be used to determine drug concentrations in samples of oral fluid by using immunological technology.

When the police detect a suspected drunk or drugged driver, a breath test for alcohol is taken. The police officers may also check for clinical signs of drug use or impairment. If the breath test shows an alcohol concentration above the legal limit, either evidential breath testing equipment is used to confirm and quantify the breath alcohol level, or the driver is brought to a physician for collection of a blood sample for alcohol analysis. If the police suspect impairment by drugs, a blood sample is taken for testing of drugs and alcohol at the national forensic toxicology laboratory. In addition, a standardized field sobriety test (SFST) is also performed.

There are three main difficulties with using oral fluid for on-site screening: first, the drug concentration in oral fluid does not reflect the drug concentration in blood accurately (10–13). There are large inter-individual variations in the oral fluid to blood concentration ratios; and in addition, there may be high concentrations of drugs in the oral cavity after eating a tablet or powder, drinking a drug solution, or smoking a drug (such as cannabis, crack-cocaine, methamphetamine or heroin). Therefore, the drug concentration in blood cannot be estimated based on analysis of oral fluid. Second, the immunological methodology is unable to distinguish between active drug and inactive metabolite, or between different drugs within each drug class (9, 14, 15). Third, the time lapse between field testing and collection of blood sample may cause a significant elimination of drugs from blood, particularly for THC and cocaine (16–18), causing drug concentrations in the collected blood sample that are much lower than at the time of police apprehension.

The primary aim of this study was to compare the results of field analysis of oral fluid performed by NMPS officers using DDT5000 with drug findings in blood samples from suspected DUID offenders. An additional aim was to analyse for traces of drugs in samples of oral fluid to investigate cases where DDT5000 gave a positive drug finding while the blood sample had drug concentrations below the legal limits.

Methods

The NMPS purchased 25 Dräger DrugTest 5000 instruments (Drägerwerk AG & Co., Lübeck, Germany) during 2015–16 for use in the different police districts. All NMPS districts were asked to participate in the study. We prepared a questionnaire for recording DDT5000 test results; no information about the driver or the vehicle was recorded. The questionnaire was labeled with the same barcode as the blood and oral fluid sample vials taken at a later stage. Suspected DUID offenders were included from November 2015 to March 2016.

The field drug testing of oral fluid with DDT5000 was performed for amphetamine, methamphetamine, cannabinoids, cocaine, benzodiazepines and opiates. Suspected DUID offenders were brought to a physician for collection of blood and oral fluid samples. Whole blood was collected in 5 mL Vacutainer® tubes containing 20 mg sodium fluoride and 143 I.U. heparin (BD Vacutainer Systems, Belliver Industrial Estate, Plymouth, UK), whereas oral fluid samples were collected at the same time using the Intercept® Oral Fluid Collection Device (OraSure Technologies, Bethlehem, PA, USA). All samples of oral fluid and blood were sent by mail or transported on road to the Norwegian national forensic toxicology laboratory in Oslo, which at that time was organized as part of the Division of Forensic Sciences of the Norwegian Institute of Public Health (after a re-organization, the Division is now a part of Oslo University Hospital). The samples were stored at 2–8°C until analyzed, normally within a few days.

Laboratory analysis

Ultra high-performance liquid chromatography tandem mass spectrometry (UHPLC–MS-MS) methods were used for quantification of drugs in oral fluid (19) and for screening of drugs in blood (20). In blood samples, UHPLC–MS-MS was also used for quantification of benzodiazepines (21), opiates and cocaine using a method originally developed for urine (22) but with a modified sample preparation suitable for blood. Amphetamines and MDMA were quantified using UHPLC–MS-MS (23), whereas THC was quantified using GC-MS (24). The laboratory is accredited for drug testing in accordance with ISO 17025.

Cut-off concentrations using DDT5000 and UHPLC–MS-MS methodology for oral fluid and blood are presented in Table I. For blood samples, the legal per se limits were used as cut-off, if assigned.

Data analysis

A research database was generated using SPSS version 23 (IBM Corporation, Armonk, NY). The ID-number on the questionnaire was coupled with results of blood and oral fluid testing. Thereafter the ID-number was deleted, generating an anonymous database without any link to the actual samples.

The numbers of true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN) were used to calculate the sensitivity (SE = TP/[TP + FN] × 100%), specificity (SP = TN/[TN + FP] × 100%), diagnostic accuracy (AC = [TP + TN]/[TP + TN + FP + FN] × 100%). A TP was defined as a positive finding with DDT5000 for an individual with a drug concentration in blood equal to or above the per se limits; whereas, a FN was defined as a negative finding with DDT5000 for an individual with a blood drug concentration equal to or above the per se limits. TN and FP were defined similarly.

Ethics

This study was performed in accordance with the data processing agreement with the Norwegian Higher Prosecuting Authority, which is the legal owner of forensic materials in Norway. In accordance

with this agreement, only anonymous data were used. Studies handling only anonymous data do not need approval from the Regional Committee for Medical Research Ethics, according to the Norwegian Research Ethics Act of June 2006 and the Act on Medical and Health Research of June 2008.

Results and Discussion

Blood samples and results of field DDT5000 analysis were received from 369 drivers suspected for DUID; oral fluid samples were submitted from 301 of those drivers. The average time lapse between field testing with DDT5000 and collection of blood and oral fluid samples was 50 min; the time lapse was 1–4 h in 25% of the cases and less than 30 min in 25%.

Results of field testing with DDT5000 and confirmatory analyses of blood samples taken by a physician after apprehension are presented in Table II. The data show that there were some false-positive and false-negative results with DDT5000 compared with confirmation in blood for all drug classes. The largest proportions of false positive findings were observed for cocaine (87.1%), opiates (65.5%) and methamphetamine (38.4%). The proportion of false positives for benzodiazepines was also unexpectedly high (36.4%). The Norwegian legal per se limits are fairly low, selected to be in accordance with the low legal limit for alcohol (0.2 g/kg blood).

The median oral fluid to blood concentration ratios have been found to be fairly high for opiates (about 3–10), amphetamine/methamphetamine (about 5–22) and cocaine (about 17–22) (12, 13), therefore the drug concentrations in oral fluid are relatively high

Table I. Cut-off concentrations for Dräger DrugTest 5000 and for confirmatory methods using UHPLC–MS-MS

Compound	Cut-off in oral fluid by DDT5000[a] (ng/mL)	Cut-off in oral fluid buffer mixture[b] by UHPLC–MS-MS (ng/mL)	Cut-off in blood[c] by UHPLC–MS-MS (ng/mL)
Amphetamines			
Amphetamine	50	2.7	41
Methamphetamine	35	3.0	45
3,4-Methylenedioxymethamphetamine (MDMA)	75	3.9	97
Benzodiazepines			
Alprazolam	10	0.31	3
Clonazepam	15	0.32	1.3
7-Aminoclonazepam		0.29	
Diazepam	15	0.28	57
Phenazepam		0.35	1.8
Flunitrazepam	20	0.31	1.6
7-Aminoflunitrazepam	50	0.28	
Nordiazepam		0.27	108
Nitrazepam	30	0.28	17
7-Aminonitrazepam		0.25	
Oxazepam	40	0.29	172
Cannabinoids			
Delta-9-tetrahydrocannabinol (THC)	5	0.94	1.3
Cocaine	20	0.91	24
Opiates			
Codeine	25	0.90	100[d]
Morphine	20	0.86	9
6-acetylmorphine	35	0.98	

[a]According to the manufacturer's cross-reactivity table dated 31 October 2013.
[b]Expected dilution 0.4 mL oral fluid + 0.8 mL buffer.
[c]Legal limits, except for codeine.
[d]Legal limit not assigned.

Table II. Results of field testing of oral fluid using Dräger DrugTest 5000 and confirmation analysis of blood samples using UHPLC–MS-MS

	Cannabis/THC	Amphetamine	Methamphetamine	Opiates	Benzodiazepines	Cocaine
Positive DDT5000 (*n*)	159	142	86	29	55	31
Negative DDT5000 (*n*)	208	226	279	340	313	338
Invalid DDT5000 (*n*)	2	1	4	0	1	0
Positive in blood (*n*)	164	120	70	10	94	4
Negative in blood (*n*)	203	248	295	359	274	365
True positive (%)	85.5	76.8	61.6	34.5	63.6	12.9
True negative (%)	86.5	95.1	93.9	100.0	81.2	100.0
False positive (%)	14.5	23.2	38.4	65.5	36.4	87.1
False negative (%)	13.5	4.9	6.1	0.0	18.8	0.0
Sensitivity (%)	82.9	90.8	75.7	100.0	37.2	100.0
Specificity (%)	88.7	86.7	88.8	94.7	92.7	92.6
Accuracy (%)	86.1	88.0	86.3	94.9	78.5	92.7

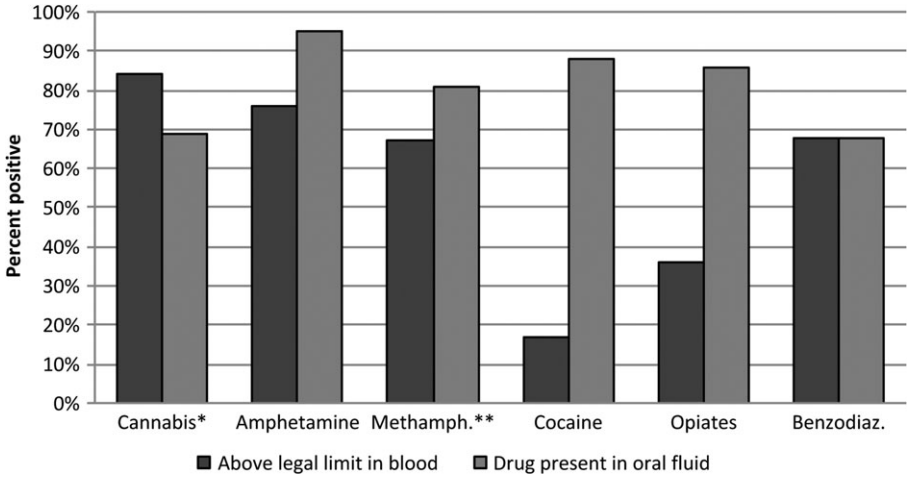

Figure 1. Proportion of positive drug findings in samples of blood and oral fluid analyzed by UHPLC–MS-MS in drivers found positive by field analysis of oral fluid using Dräger DrugTest 5000. Cut-off concentrations are presented in Table I. *The documented recovery of THC from the Intercept Oral Fluid Collection Device is low. **Including MDMA.

compared to the concentrations in blood; this may partly explain the high rate of false positive findings in oral fluid compared to blood. For cocaine, the time lapse between field testing and blood sampling may also have caused a significant elimination of the drug from the blood stream (18), ending with drug concentrations below the legal limit at time of blood sampling for most cases.

The oral fluid to blood concentration ratios are fairly low for benzodiazepines (about 0.02–0.3) (12, 13). Therefore, the proportion of false negatives was fairly high for those substances.

The proportions of positive findings in blood and oral fluid samples for drivers found positive using DDT5000 are presented in Figure 1. In most cases where DDT5000 was positive while confirmatory analysis of blood samples were negative, traces of drugs were found in samples of oral fluid. For cocaine, the vast majority of the samples found positive by DDT5000 still contained traces of cocaine at time of oral fluid sampling, suggesting that the field testing gave correct positive finding, whereas the time lapse before the blood sample was collected was in most cases long enough to eliminate most of the drug present in blood. Cocaine may also degrade during storage of blood samples; therefore, sodium fluoride is commonly added to the blood sample vials in order to reduce this degradation (25, 26). Some degradation may thus also have contributed to the low number of blood samples that tested positive for cocaine.

For opiates, the high concentration ratio between oral fluid and blood may explain why a large proportion of the oral fluid samples were positive while the concentration in blood was below the cut-off in blood.

The proportion of oral fluid samples found positive for THC was lower than for blood samples. This was most likely due to adsorption of THC to the Intercept collection device, which is a known problem with that device (27).

The proportion of positive test results for DDT5000 among drivers with blood drug concentration above the Norwegian legal per se limit was 82.9% for THC, 90.8% for amphetamine, 75.7% for methamphetamine, 100.0% for cocaine, 100.0% for opiates and 37.2% for benzodiazepines.

The detection of benzodiazepines using DDT5000 was expected to be a challenge because of the low concentration ratio between oral fluid and blood and because some benzodiazepines are much more potent than others. The proportions of positive DDT5000 findings among drivers with benzodiazepines above the legal limits are presented in Table III. Surprisingly, the proportions of positive DDT5000 tests were similarly low for all the different benzodiazepines.

Table III. Results for field testing using Dräger DrugTest 5000 for drivers with one or more benzodiazepines in blood at or above the legal per se limits

Substance	No. at or above the per se limit in blood	Positive with Dräger DrugTest 5000 (%)
Alprazolam	3	0.0
Diazepam/nordiazepam	32	37.5
Flunitrazepam	1	100.0
Clonazepam	34	38.2
Nitrazepam	1	100.0
Oxazepam	2	50.0
More benzodiazepines	22	31.8
In total	95	36.8

A few similar studies have been published previously (see Table IV). In addition, some studies have compared DDT5000 findings with actual drug concentrations in oral fluid samples taken at the same time (28–32). In general, studies comparing the results of DDT5000 with laboratory confirmations in oral fluid may find better correlation than when comparing with findings in blood if appropriate cut-off concentrations are used. In our study, the average time lapse between testing of oral fluid with DDT5000 and collection of oral fluid samples for confirmation and quantification using UHPLC–MS-MS was very long: 50 min. We have therefore not calculated the TP, TN, FP, FN, etc. for DDT5000 compared to actual concentrations in oral fluid, because the findings would not reflect the actual performance of the instrument.

Different cut-off concentrations were used in other studies presented in Table IV; therefore, it is somewhat difficult to compare the results of the studies. The most significant difference between our study and the previous ones is the result for cocaine. The antibody used in DDT5000 also cross-reacts with the cocaine metabolite benzoylecgonine; therefore, drivers found to be positive on the DDT5000 test for cocaine may have had cocaine or benzoylecgonine in oral fluid. We did not analyse for benzoylecgonine, but some other studies did so, and included benzoylecgonine together with cocaine when

Table IV. Results from similar field testing of Dräger DrugTest 5000 compared with confirmatory analysis of blood samples

Drug class	References	Cut-off in blood (ng/mL)	No. of positive on DDT5000	True positive (%)	False positive (%)	No. of negative on DDT5000	True negative (%)	False negative (%)
Cannabis	Brackemeyer (35)[a]	1	319	87.8	12.2	201	80.1	19.9
	Musshoff et al. (36)	1[b]	255	92.5	7.5	52	32.7	67.3
	Wille et al. (37)[c]	2	40	95.0	5.0	8	62.5	37.5
	Houwing et al. (38)	1	9	88.9	11.1	55	72.7	27.3
Amphetamine	Brackemeyer (35)	n.s.	114	85.1	14.9	406	96.1	3.9
	Musshoff et al. (36)	25[b]	97	97.9	2.1	37	51.4	48.6
	Wille et al. (37)	50	5	100.0	0.0	6	100.0	0.0
	Houwing et al. (38)	20	1	100.0	0.0	63	98.4	1.6
Methamphetamine	Brackemeyer (35)	n.s.	7	57.1	42.9	513	98.8	1.2
	Musshoff et al. (36)	25[b]	2	50.0	50.0	21	95.2	4.8
	Houwing et al. (38)	20	0	–	–	63[d]	100.0	0.0
Cocaine	Brackemeyer (35)	n.s.	37	73.0	27.0	483	96.1	3.9
	Musshoff et al. (36)	10[b,e]	22	72.7	27.3	22	77.3	22.7
	Wille et al. (37)	50[f]	10	70.0	30.0	14	71.4	28.6
	Houwing et al. (38)	10	2	50.0	50.0	62	100.0	0.0
Opiates	Brackemeyer (35)	n.s.	36	80.6	19.4	484	99.8	0.2
	Musshoff et al. (36)	M 10[b]	23	91.3	8.7	22	95.5	4.5
	Houwing et al. (38)	10	1	100.0	0.0	63	100.0	0.0
Benzodiazepines	Brackemeyer (35)	n.s.	0	–	–	519	100.0	0.0
	Musshoff et al. (36)	10	2	100.0	0.0	20	80.0	20.0
	Houwing et al. (38)	2–50 (39)	2	50.0	50.0	62	98.4	1.6

n.s., not specified; M, morphine.
[a]Using the "5 ng/mL cut-off version".
[b]In serum.
[c]Using the "improved test cassette".
[d]One invalid test.
[e]Or benzoylecgonine 75 ng/mL.
[f]Or benzoylecgonine 50 ng/mL.

reporting the findings. That may have contributed to a lower proportion of false positives. Other factors that affects the proportion of false positives is the time between testing with DDT5000 and collection of blood sample and, as previously mentioned, a possible degradation of cocaine before the blood sample is analyzed.

When comparing test results for DDT5000 with drug findings in oral fluid samples taken at the same time, criteria for maximum proportions of FP and FN may be decided to determine whether the drug test is acceptable. However, when comparing positive test results for drugs in oral fluid with drug concentrations in blood samples taken some time later, it may not be relevant to decide exact criteria for a maximum proportion of FP and FN in oral fluid compared to blood, as this depends on the time between oral fluid and blood testing, the type of drugs, as well as the legal limits in blood that are used (zero tolerance or per se limits). A requirement for drug screening devices for roadside testing of suspected DUID offenders by the police, specified when revising the Norwegian Road Traffic Act, was that the proportion of false positive test results should not be "unreasonably large" (33). It is important that police officers understand that a positive test result for a drug in oral fluid should not be the only reason for suspending a driver's license; there should also be other indications of drug impairment.

In spite of the many false positive and false negative findings with DDT5000, the NMPS have found that the DDT5000 is a helpful tool in the selection of suspected DUID offenders. This is partly due to the fact that a large proportion of drug-impaired drivers are multidrug users, increasing the probability of getting a positive result with DDT5000. According to news media, the number of DUID suspects detected by the NMPS has therefore doubled from 2015 to 2016 (34).

Limitations

The presented data are from drivers suspected of drug-impaired driving. Therefore, the prevalence of drugs was high. The proportion of false-positive and false-negative findings may be different in a population with low prevalence of drug use.

Conclusions

The DDT5000 did not absolutely correctly identify DUID offenders due to fairly large proportions of false-positive or false-negative results compared to drug concentrations in blood. However, the police reported that DDT5000 was still a valuable tool in identifying possible DUID offenders, helping them to more than double the number of drivers suspected for DUI.

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