nextgen precision™ testing
delivering unprecedented results

a white paper on evolving clinical drug testing cutoff levels to effectively identify drug abuse, misuse, and diversion
executive summary

Financial, societal, and liability costs of prescription drug abuse, misuse, and diversion have grown significantly over the past two decades – along with the number of prescriptions for opioids and benzodiazepines during that similar time period. The utilization of clinical drug testing as a tool that practitioners use to reduce drug abuse, misuse, and diversion has grown significantly in recent years as well. Similarly, so have technologies to accurately assess patient adherence to their prescription drug regimen. This white paper has been created to provide information regarding these trends.

Specifically, this paper provides:

- Statistics and trends on prescription drug abuse, misuse, and diversion

- Information on drug testing methodologies, derivation of drug testing cutoff levels, and the clinical significance these cutoff levels have in uncovering drug misuse

- The results of an internal study performed to determine whether Precision Diagnostics’ standard drug test cutoff levels were optimal for our patient population using normal distribution analysis

- Details of the NextGen Precision™ testing solution and how it can be used to significantly improve clinical drug testing and to reduce false negatives by utilizing statistically-derived drug testing cutoff levels
financial costs of prescription drug misuse and diversion

Health economists from Johns Hopkins University writing in The Journal of Pain reported the annual cost of chronic pain is as high as $635 billion a year, which is more than the yearly costs for cancer, heart disease, and diabetes.¹ Total incremental costs of healthcare due to pain ranged from $261 to $300 billion, and the value of lost productivity ranged from $299 to $334 billion.¹

The Coalition Against Insurance Fraud (CAIF), a national alliance of consumer groups, insurance companies, and government agencies, estimated that opioid analgesic abuse results in over $72 billion in medical costs each year.² Other, more conservative studies estimate the cost of opioid abuse to be $53-$56 billion annually, accounting for medical and substance abuse treatment costs, lost work productivity, and criminal justice costs.³,⁴

In a Journal of Managed Care Pharmacy study, patients “who were opioid abusers had health care costs that were more than eight times higher than those of non-abusers.”⁵ The total average per-patient direct health plan cost for opioid abusers was $15,884, compared with $1,830 for non-abusers, a difference of $14,054 per patient in 2003 dollars.⁶ Assuming an average 3.5% annual increase in medical cost inflation, that difference would be $20,518 per patient in 2014 dollars.

Drug Overdose Deaths Involving Opioid Analgesics
In 2012, of the 41,502 drug overdose deaths in the United States, 22,114 (53%) were related to pharmaceuticals; 16,007 (72%) involved opioid analgesics.⁵

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![Figure 1: The number of deaths due to opioid and benzodiazepine overdose have increased in recent years, whereas there has been a decrease in deaths due to cocaine.](source)

Growth in Opioid Prescriptions

A strong correlation exists between the number of deaths from opioid use/abuse and the number of retail opioid prescriptions from the past decade.\(^5\)

**Opioid Prescriptions\(^5\)**
by retail pharmacies in the United States IN MILLIONS

![Figure 2:](image)
The number of opioid prescriptions filled in the United States has increased dramatically over the past two decades.

- **'91**: 76 million
- **'95**: 150 million
- **'01**: 219 million

\(^5\)OxyContin is introduced in 1995.
Emergency Room Visits

In addition to the concern over increased mortality rates associated with opioid prescriptions, opioid abuse is creating a tremendous economic burden on the healthcare system as a result of escalating emergency room visits. In 2011, approximately 1.4 million ER visits involved the non-medical use of pharmaceuticals. Among those ER visits, 501,207 visits were related to anti-anxiety and insomnia medications, and 420,040 visits were related to opioid analgesics.7

Abusers were 12.2 times more likely to have had at least one hospital inpatient stay, and four times more likely to have had an ER visit. Opioid abusers average 18.7 physician or outpatient visits, compared with seven for non-abusers. Opioid abusers averaged 41.6 prescription drug claims each, compared with 13.8 for non-abusers.6

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**ER Visits Caused by Abuse of Narcotic Painkillers**

![Graph showing ER visits caused by abuse of narcotic painkillers from 2004 to 2008.](image)

**ER Visits Caused by Abuse of Certain Painkillers, 2004 - 2008**

![Bar chart showing ER visits for specific painkillers from 2004 to 2008.](image)

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**Emergency Room Visits Caused by Drug Misuse and Abuse in 2007, by Combination**

- Nonmedical use of pharmaceuticals only (30.9%)
- Illicit drugs only (27.8%)
- Illicit drugs; alcohol (12.6%)
- Alcohol; nonmedical use of pharmaceuticals (10.1%)
- Illicit drugs; pharmaceuticals (7.6%)
- (Underage) Alcohol only (7.3%)
- Illicit drugs; alcohol; pharmaceuticals (3.7%)

1,883,272 total emergency visits for drug misuse and abuse in 2007
history of drug testing

Drug screening in the USA began in the 1970s as an attempt to mitigate the spread of drug abuse in the US military forces stationed in Vietnam. The Navy started screening after an accident on the carrier Nimitz revealed that a number of sailors and airmen were taking mind altering drugs. Before the start of drug screening in the U.S. military, surveys showed a prevalence of drug use at 47%. When random testing was begun, the positive rate was 22%, a figure which steadily declined every year to 2.5% after six years of testing and to less than 1% today. Although these numbers were specific to military drug testing, the efficacy of random drug testing illustrates the impact that implementing a drug testing solution can have in preventing drug misuse.

immunoassay

Immunoassay testing has inherent technological shortcomings, creating a level of uncertainty in drug test results. Although it was invented in the 1940s, immunoassay technology wasn’t really introduced on a broad scale until 1973. Immunoassay uses light-emitting chemicals bound to antibodies that are intended to bind to the drug of interest. This technology employs an indirect measurement of the drugs or drug classes by utilizing the chemical properties of the drugs of interest and their innate ability to bind to the light-emitting labeled antibodies. Since this measurement and technique is indirect, its specificity is less than optimal and raises a rather high level of scrutiny and its reliability has been questioned.

False positives results can occur when similar structural characteristics of dissimilar compounds bind to the light-emitting antibodies and emit a positive response. False positives can be confirmed and thus pose less of a threat than false negatives.

False Negatives and Cutoffs

False negative results occur when the concentration of the analyte being tested is lower than the laboratory’s ability to detect it. The time since drug usage, the amount and frequency of use, fluid intake, body fat level, and metabolic factors can affect the urine drug concentration.

False Positives and Cutoffs

The administrative concentration cutoff ranges depend on the technology available, as well as what is clinically important for the application. The performance traits of the reagents are very important when considering assay cutoff levels. Cross reactivity is when the binding site of dissimilar compounds are similar and thus binding to the labeled antibody. This causes a reading that is translated to a result, thus causing a positive result. Whether or not it is a similar compound to the target or completely different is undiscernible by reviewing the immunoassay data. This inherent, and well researched, issue is responsible for guiding cutoff levels to prevent too many false positives.

For example, the cross reactivity of target compounds including but not limited to codeine, morphine, amphetamine, and methamphetamine may cause the assays’ cutoff level to range higher than the confirmatory cutoff because, in many cases, these thresholds are set to minimize the potential error that is exacerbated by poor result interpretation. For instance, the initial cutoff which was established for opiates in these programs was set up to 300 ng/mL, which was revised to 2000 ng/ml in the year 1994 to lower the number of positive results that had lower morphine concentration due to ingestion of poppy seeds in certain foodstuff. SAMHSA has attempted to set cutoff levels high enough to minimize false positive results. However, drug use patterns follow all types of trends, and do not necessarily reach ultra-high levels before drug use is considered a serious threat to one’s health and to society as a whole.
gas chromatography-mass spectrometry (GC-MS)
In 1966, as the immunoassay test was being developed, Manfred Donike pioneered the use of gas chromatography-mass spectrometry (GC-MS) to detect anabolic steroids and other prohibited substances in athletes’ urine. Donike began the first full-scale testing of athletes at the 1972 Summer Olympics, in Munich, using a GC-MS linked to a Hewlett Packard computer. At the 1983, Pan American Games, Donike’s laboratory disqualified 19 athletes and caused numerous others to withdraw before they were due to be tested. During the 1988 Summer Olympics, his testimony led to the suspension of Canadian sprinter Ben Johnson even though there were claims that drugs were spiked in sports drinks.11

liquid chromatography-mass spectrometry/mass spectrometry (LC-MS/MS)
Since GC-MS was the first mass spectrometry testing methodology and the cost of a GC-MS was one-fifth of the cost of liquid chromatography tandem mass spectrometry (LC-MS/MS) technology at the time, GC-MS became the industry standard. During the early 2000s, LC-MS/MS technology greatly improved in sensitivity, robustness, and reproducibility. By 2005, as clinical and toxicology testing was becoming widely adopted, LC-MS/MS manufacturers were selling instrumentation that gained equivalency to GC-MS’s sensitivity levels.

**Figure 3:**
Historical research into laboratory testing technology.
questioning usual and customary cutoff levels

With the increase in information available to the general public on how to create uncertainty in drug test results, the tools used to identify drug misuse and diversion must evolve as well, to remain technically relevant and applicable. Medical imaging technology has continually evolved to improve diagnostic sensitivity and accuracy. In a similar way, clinical drug testing monitoring technology (and methodologies) should continually improve to deliver the best possible results and outcomes.

In a letter titled “What Congress and the Next Administration Must Do to Save Drug Testing”, written by the chairman of the American Association of Medical Review Officers (AAMRO), Theodore F. Shults, JD, MS brought this to the attention of the Substance Abuse and Mental Health Association (SAMHSA), an agency that determines appropriate drug test cutoff levels for the industry. In this letter he stated “...there is an astounding number of false-negative results caused by the failure of SAMHSA to adopt lower cutoff values for cocaine, amphetamine and THC (not including the unknown number of specimens that are really substituted).” Additionally, in this letter, it suggests that sources indicate that SAMHSA has not improved their technology since the 1980s — and yet the drug testing industry is still using these technologies as the basis to address the drug epidemic in the United States.

Upon recognizing that the GC-MS and standard LC-MS/MS cutoff levels were potentially resulting in a large number of false negative test results, Precision Diagnostics investigated various research grade LC-MS/MS instrumentation to properly address the drug testing offerings that have been dogma for many years. Precision Diagnostics’ goal was to identify what drug cutoffs should be if sensitivity was not limited by technology.

methods

A retrospective analysis of 54,830 human urine samples was performed to determine the appropriate clinical cutoff concentration for common over the counter, prescription, and illicit drugs in the patient population currently served by Precision Diagnostics. All concentrations were determined by LC-MS/MS analysis. A histogram of patient results was created on a logarithmic x-axis of concentrations in nanograms of analyte per milliliter of urine (ng/mL). The frequency of results found in each grouping were plotted on the y-axis and a trend line was applied to drugs with greater than 200 positive patient results, which formed a normal distribution, at the intersection of the x-axis intersection to determine the appropriate cutoff for future clinical testing.

“... there is an astounding number of false-negative results caused by the failure of SAMHSA to adopt lower cutoff values for cocaine, amphetamine and THC ...

– Theodore F. Shults, JD, MS
results

Precision Diagnostics determined that our current cutoff levels were suboptimal for 34 of the 39 drugs in our current test panel that occurred often enough to form a normal distribution. Twelve drugs were present in insufficient numbers for analysis. For EDDP, the metabolite of methadone, we actually determined that our current cutoff level was lower than necessary to achieve 99% coverage on the normal distribution curve. In the vast majority of drugs for which we test, however, we determined that our current cutoff levels were higher than necessary to achieve satisfactory coverage on the low end of the normal distribution curve and that we needed to significantly lower our cutoff level in order to achieve adequate coverage.

Methadone Analysis

Methadone is an example of a drug for which our current cutoff level was set appropriately to avoid false negatives within our patient population. The histogram of patient results shows a normal distribution or “bell curve.” The trend line applied to the data crosses the x-axis at approximately 75 ng/mL. Excluding all patient results below that level would remove 1% of likely positive results.

![Methadone Distribution]

Figure 4:
The excretion profile of methadone follows a normal distribution with a trend line applied to find the cutoff level which would result in approximately 99% coverage of likely positive samples.
Alprazolam Analysis
In the analysis of alprazolam on a normal distribution plot, the left side of the curve is truncated, indicating an inappropriately set cutoff level. The current cutoff of 50 ng/mL causes likely positive patient results to be reported as negative. The trend line crosses the x-axis at approximately 5 ng/mL, indicating a more appropriate clinical drug test cutoff level. In this case, the industry standard cutoff level was woefully inadequate in identifying a large number of positive test results for alprazolam, resulting in a significant number of false negative test results.

Amitriptyline Analysis
Amitriptyline is a widely prescribed tricyclic antidepressant and is intended to be taken every day to manage symptoms of depression. Long term adherence to the regimen is vital to the patient’s health and must be monitored during treatment. The industry standard cutoff level of 100 ng/mL is insufficient for about half of patients who are taking amitriptyline. A myriad of issues are caused by the false negative results, including decreased doctor-patient trust and ascribing depressive symptoms to medication non-adherence rather than other causes.
Cyclobenzaprine Analysis
For the analytes cyclobenzaprine, amitriptyline, clonazepam, nordiazepam, nortriptyline, and zolpidem, half or fewer of the expected positive patient samples were identified with our current cutoff levels. This was a very alarming finding of this retrospective analysis. Based on our statistical analysis, these compounds have the greatest need for higher sensitivity analysis so that positive results are not missed.

Zolpidem Analysis
Zolpidem is prescribed to treat insomnia, but can also be used recreationally for its ability to induce euphoria and vivid visual effects. Its usage is contraindicated by opioids, alcohol, benzodiazepines and other medications. The distribution of positive results shows a truncated left side of the bell curve indicating a lower cutoff level should be used.
**Cutoff level comparison summary**

The table below illustrates drugs within the analysis that routinely tested positive as well as a cutoff level comparison from the evolved NextGen Precision™ cutoff levels. This table also illustrates the estimated percentage of false negatives using current cutoff levels versus the newly recommended NextGen Precision™ cutoff levels.

**NextGen Precision™ Testing Analysis**

<table>
<thead>
<tr>
<th>Drug Name</th>
<th>Old Precision Cutoff Levels</th>
<th>New NextGen Precision Cutoff Levels</th>
<th>% Increase in Sensitivity</th>
<th>Est % False Negatives Old Cutoff vs. NextGen Cutoff Levels</th>
<th>Est % NextGen False Negatives</th>
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<tr>
<td>Alphahydroxyalprazolam</td>
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</tbody>
</table>

*Projected false negatives based on the data extrapolated from our pooled patient population in this study. **For clinics that treat with transdermal buprenorphine at μg/day doses, this data does not apply. *** Codeine and Morphine were not adjusted due to potential environmental exposures such as poppy seeds.

With the exception of methadone, EDDP, meprobamate, codeine, morphine and norbuprenorphine, there is an average estimated improvement of 90% that results from shifting from the standard cutoff levels to our new NextGen Precision™ statistically derived cutoff levels. In order to achieve this 90% improvement, we had to increase the sensitivity by 900% in many cases. For those drugs where decreasing the cutoff levels did not appear to impact our estimated improvement, the cutoff levels remained the same. In fact, EDDP cutoff levels were actually increased as current cutoff level of 50 ng/mL does not appear to improve clinical data more than 100ng/mL.
NextGen Precision vs. Standard LC-MS/MS and Immunoassay Cutoff Levels

A secondary goal of the analysis was to evaluate the new NextGen Precision™ cutoff levels compared to the standard LC-MS/MS cutoff levels, as well as how they compare to typical immunoassay cutoff levels. This was done to determine what the theoretical false negative percentage is across the three different assays for a given drug analyte. We looked at alprazolam, as it is a commonly prescribed drug to treat anxiety disorders and also has a high abuse potential.

The following charts show the normal distribution curve for our patient population and where the cutoff level for each testing methodology lands on the normal distribution curve.

**Figure 9:** The results histogram for alprazolam contrast three methods to test for its presence. The blue bars represent positive patient results that can be expected using immunoassay (300 ng/mL cutoff level), standard LC-MS/MS (50 ng/mL cutoff level) and NextGen Precision™ (5 ng/mL cutoff level). The grey bars represent false negative patient results.
Clinical drug testing, as a tool, is only useful if the data received from the laboratory can be trusted as being accurate and at a high inclusiveness for the patient population for every drug being tested. It is just as important for prescribers to have complete visibility into their patients’ drug use tendencies when prescribed controlled substances as it is to have visibility into their patients who are not prescribed any medications.

Our retrospective analysis of existing patient test result data concluded that industry standard cutoff levels were not appropriately set, when it comes to patient inclusiveness, to identify a significant number of positive test results that were otherwise being reported as negative. As we have illustrated, false negatives can occur as a result of using inappropriately set drug cutoff levels for either immunoassay or LC-MS/MS. This can ultimately cause prescribers to doubt their patients’ adherence to a prescribed regimen, or result in a missed opportunity to intervene in the case of a missed unexpected positive drug test result.

This analysis was the impetus in launching the NextGen Precision™ Testing solution. This solution was developed to improve clinical data through statistically-derived cutoff levels that optimize technological advances in LC-MS/MS, giving healthcare providers the best possible information to improve outcomes, minimize waste, and implement early patient intervention.

Medical imaging technology has evolved rapidly since Wilhelm Röntgen took the first X-ray of his wife’s hand back in 1895. Today, physicians can image the human body in intricate detail — choosing from many advanced imaging options, including X-ray technology to ultrasound, computerized tomography, magnetic resonance imaging, positron emission tomography, and more. In the same way that innovation in medical imaging has progressed, the technology used for clinical drug testing monitoring technology should also evolve to address the needs of providers, payers, and patients. Patients are finding new ways to create uncertainty in drug testing; new drugs are constantly being introduced; and the costs and health risks associated with drug misuse, abuse, and diversion continue to grow. The results of our statistical analysis of 54,830 human urine samples indicate that NextGen Precision™ Testing will represent the next important step forward in delivering the comprehensive insights physicians need to improve outcomes for all of their patients.
References


8 CDC/NCHS National Vital Statistics, CDC Wonder. Updated with 2010 mortality. (moved from chart, per client's note on pg. ‘3”)


transforming healthcare through clinical laboratory science

Precision Diagnostics is a clinical laboratory unlike any other. Our NextGen Precision™ Testing platform employs ultra-sensitive LC-MS/MS technology in a fully automated, robotic facility.

We are committed to transforming healthcare by delivering accurate, comprehensive, actionable clinical data needed to enhance population health and improve outcomes throughout the continuum of care.

INNOVATION
We relentlessly pursue research, technology, and quality – providing unparalleled, cutting-edge clinical laboratory science and delivery.

INTEGRITY
We accept and incorporate only ethical business solutions representing the highest quality standards, rooted in honesty, fairness, and transparency.

INSIGHTS
We integrate and deliver intelligent analytics that power objective, actionable clinical data – fulfilling our commitment to an evolved healthcare delivery system.

OUTCOMES
With a focus on the end goal, we continually explore new advances in delivering informed, coordinated, efficient patient care.

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