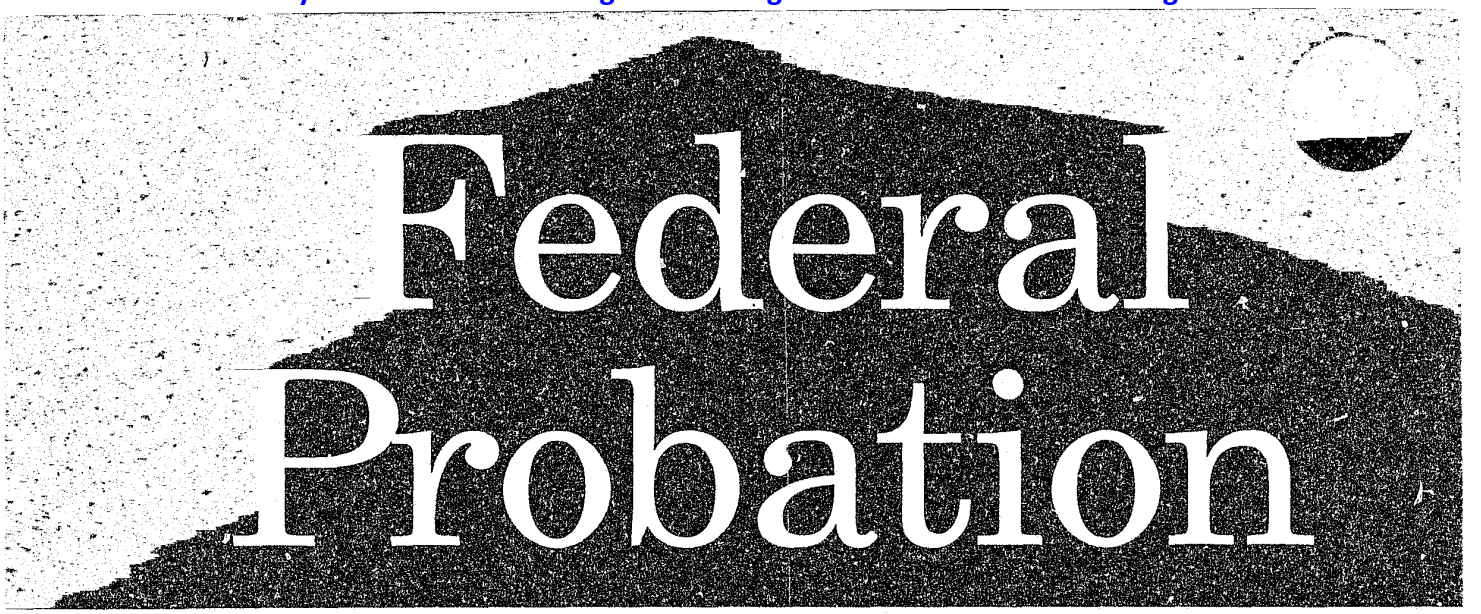

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This Issue in Brief

Bulging Prisons, an Aging U.S. Population, and the Nation's Violent Crime Rate.—Have rapidly rising rates of imprisonment reduced the Nation's violent crime rate? No—according to authors Darrell Steffensmeier and Miles D. Harer—who analyzed data for the years 1980-92 from the two main sources of national statistics on violent crimes—the Uniform Crime Reports and the National Crime Survey. Their findings indicate not only that violence levels have been increasing in recent years but that changes in the population's age structure have had a major impact on violent crime trends. In light of these findings, the authors urge policymakers to rethink whether spending more and more money on incarcerating more and more offenders will solve the crime problem.

Accreditation: Making a Good Process Better.—The accreditation of correctional facilities and programs has led to substantial improvements in the conditions and practices in such facilities and programs across the country. Yet there are a number of ways in which the accreditation process can be improved. Author Lynn S. Branham, a member of the Commission on Accreditation for Corrections, discusses steps that the Commission can and should take to ensure that accredited facilities meet constitutional requirements, that the information provided by auditors to the Commission is accurate and complete, and that the accreditation decisions of the Commission are reliable.

Texas Collects Substantial Revenues From Probation Fees.—With correctional costs skyrocketing, many government officials and legislators have decided that offenders should help pay for the cost of their own supervision and rehabilitation. A recent approach to this strategy is to require employable probationers to pay for at least some of the costs of their supervision. Authors Peter Finn and Dale Parent describe how many probation field offices in Texas—motivated by legislation that provides strong incentives to collect fees—raise substantial amounts of money from assessing probation fees. The authors note that other states and counties may be able to increase revenues from probation fees considerably by adopting some of the statutory incentives and local practices implemented in Texas.

Factors Influencing Probation Outcome: A Review of the Literature.—Past research has provided important insight into what factors influence probation outcome and which offenders are more likely to succeed or fail under probation supervision. Research has pointed to significant relationships between certain variables—such as age, gender, employment, educational attainment, and prior criminal record—and probation success or failure. Author Kathryn D. Morgan reviews some of those studies and their findings. She focuses on studies reporting probation failure

CONTENTS

Comparing Hair and Urine Assays for Cocaine and Marijuana

By Tom Mieczkowski, Ph.D., and Richard Newel*

Introduction

THE USE of drug testing procedures and the determination of the drug status of persons under correctional supervision have been central concerns of criminal justice and correctional practice for more than a decade. Research has consistently shown that drug use aggravates criminality and that the most serious criminal offenders are also the most seriously involved in drug use (Drug Use Forecast, 1990; Bureau of Justice Statistics, 1989). Therefore, the implementation and operation of urine-based drug testing programs have become major responsibilities of correctional departments across the Nation.

A major limitation of urinalysis is the relatively short retrospective time period or "window" for detecting drug exposure. For cocaine, opiates, and amphetamines, for example, the limit is about 48 hours. Furthermore, urine is problematic to handle, can be septic, requires refrigeration or freezing for long-term storage, and must often be collected under observation.

The most salient feature of hair analysis for illegal drugs is its greatly expanded time window for the detection of exposure to an illicit drug. Hair analysis can reveal exposure weeks prior to the testing period. Also, hair is quite resistant to evasive manipulation. Hair has other advantages relative to urine; it is inert, easy to handle, and requires no special storage facilities or conditions. Collecting comparable samples for repeating assays is easily done with hair specimens, making retest procedures quite simple.

This article reports the outcomes of hair assay, urinalysis, and self-reported cocaine and marijuana exposure for a sample of arrestees in the southeastern United States. It demonstrates the effectiveness of hair specimens in identifying cocaine exposure and the comparative ineffectiveness of hair specimens to reliably identify marijuana exposure. Overall, the results indicate that relative to urinalysis:

1. Hair analysis was effective in identifying cocaine use and was not effective in identifying marijuana use in this sample.

2. Arrestees appear to underreport their use of cocaine substantially. This is true whether one uses urine or hair assays as validators, but the underreporting is more pronounced when using hair as the indicator.

3. Subjects appear to literally "overreport" their marijuana use—more people report marijuana use than are detected by either hair or urine tests. Thus, cocaine and marijuana have "reversed relationships" relative to their validators.

4. In examining nonconcordant assay outcomes, arrestees are most likely to have a negative urinalysis for cocaine but a positive hair analysis. Regarding self-reported cocaine use, 50 percent to 70 percent of those who are cocaine positive will deny *any* cocaine use within the last 2 months. The cocaine pattern, however, is *reversed* for marijuana. We find that more people test *urine* positive for marijuana than test hair positive for marijuana, and more arrestees report marijuana use than can be accounted for by *either* hair or urine assay.

The Historical Development of Hair Assays for Psychoactive Drugs

Hair assays for psychoactive drugs were first reported in the 1950's (Goldblum, Goldbaum, & Piper, 1954). Since then further research has demonstrated the deposition of various drugs in hair (Valente, Cassini, Pigliapochi, & Vansetti, 1981; Forrest, Otis, & Serra, 1972; Harrison, Gray, & Solomon, 1974). Since the late 1970's a growing body of work has focused on human hair analysis using immunoassay screens (Baumgartner, Jones, Baumgartner, & Black, 1979; Smith & Pomposini, 1981; Smith & Liu, 1986). This work has demonstrated the ability to detect cocaine opiates, and other illicit drugs in hair (Puschel, Thomasch, & Arnold, 1983; Baumgartner, Jones, Baumgartner, & Black, 1979). A number of researchers have reported techniques for distinguishing external from endogenous deposition and the capability to quantify the amount of drug found in the hair specimen (Baumgartner, Jones, & Black, 1981; Sramek et al., 1985; Martz, 1988).

In addition to the ability to detect and quantify the concentration in single specimens, research results from sectioning the hair into small lengths for segmental assay indicated that the assay values for individual segments of the hair shaft generally corresponded to the subject's reported use rates (although this has not

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been reported invariantly). Thus, hair potentially could act as a drug dosimeter or "recording tape" over a relatively long retrospective time period. Hair specimens could be analyzed to coordinate "spikes" in the segments to known consumption or exposure events (Martz et al., 1991; Staub, 1992; Uematsu, 1992). Cone (1990) reported data on the time profiles of morphine and codeine in plasma, urine, saliva, and beard hair using radioimmunoassay (RIA). His data suggested that "segmental analysis could provide approximate time windows of drug exposure." Cone (1990), however, has stated that these findings are preliminary and much work has yet to be done to standardize the hair assay protocol in order to make it reliable. Among other things, this includes establishing widely accepted cutoff levels, quality control standards, and standardized washing and assay procedures.

European researchers, using a variety of analytic techniques, have reported findings similar to those of American researchers (Valente et al., 1981; Staub, 1992; Möller, 1992; Arnold, 1986; Sachs, 1992; Mangin & Kintz, 1992; Balbanova & Wolf, 1982). The Japanese also have reported work confirming the efficacy of hair assay techniques for drug detection and segmental analysis. The Japanese have done a lot of work on amphetamine detection and several other substances including halperidol and the nicotine metabolite cotinine (Niwaguchi, Suzuki, & Inoue, 1983; Suzuki, Hattori, & Asano, 1984; Nagata, 1983; Ishiyama, Nagai, & Toshida, 1983; Nakahara, Shimamine, & Takahashi, 1992; Uematsu, 1992).

Problems and Controversies

There are criticisms of hair assay technology (Kidwell, 1989, 1990; Henderson, Harkey, Zhou, & Jones, 1992). While the *detection* of the compounds in the hair, and to some degree their quantification, is not controversial, the *interpretation* of these measures is. These concerns are translated into criticisms mainly directed at the issue of passive or environmental contamination and the ability to quantify an individual's consumed dose or exposure based on the values found by the hair assay.

We have noted that the preparation of the hair sample, its washing, and the methodology for extracting the material for the purposes of analysis is not standardized. Assay values may be affected by preparatory techniques, including washing procedures and extraction procedures. Cone and his colleagues (see Goldberger, Caplan, Maguire, & Cone, 1991; Cone, Yousenejad, Darwin, & Maguire, 1991), for example, created various laboratory contamination scenarios with opiates and cocaine and detected contaminants after their washing procedures. Blank and Kidwell (1992) have also recently reported failure to successfully wash cocaine contamination from hair soaked in strong aqueous concentrations of cocaine. Recently, however, assay washes have been reported as effectively removing externally acquired cocaine from the hair of known cocaine users (Koren, Klein, Forman, & Graham, 1992).

It has been suggested that the problems of distinguishing external contamination from endogenous drug can be accomplished by reliance upon analyte-to-wash value ratios rather than single measures of either target (Allgood, Sniegoski, & Welch, 1991). Another approach has been to measure unique metabolites of the drugs found in hair (Harkey, Henderson, & Zhou, 1991; Henderson et al., 1992). Several specific and unique cocaine metabolites, for example, have been identified in hair and in Cone's term "convincingly demonstrate" that cocaine is excreted via hair. The presence of unique metabolites cannot be explained by environmental contamination (Cone et al., 1991).

The Utility of Screening Assays

For hair analysis to be a practical tool it must be based upon a technology which is both rapid and cost-effective. Radioimmunoassay (RIA) is a particularly sensitive technology for screening hair specimens (Franceschin, Morosin, & Dell'Anna, 1987). RIA has been shown to be effective for detecting benzoylecgonine (BE), the primary excretory metabolite of cocaine, as well as cocaine itself in a variety of research settings (Mule, Jukofsky, & Kogan, 1977; Baumgartner, Black, Jones, and Blahd, 1982; Valente et al., 1981; Michalodimitrakis, 1987; Graham, Koren, Klein, Schneidermann, & Greenwald, 1989; Welch, Martier, Ager, Ostrea, & Sokol, 1990).

Baumgartner, Hill, and Blahd (1989) have reported on testing hair samples from Federal probationers and comparing the outcomes to the probationers self-reported drug use, and urinalysis testing for drug use. Their work showed that the rates of discovery of drug use compared to either self-report or urine tests were much higher for hair assays. Baer, Baumgartner, Hill, and Blahd (1991) conducted a retrospective study comparing self-reported drug use, urinalysis outcomes, and RIA of hair outcomes in a probation and parole population of approximately 200 subjects. Based on their data they concluded that hair assays were a better measure of long-term drug use than urinalysis or self-report.

Work with other criminal justice system subjects has generally supported these same conclusions. For example, Mieczkowski, Barzelay, Wish, and Gropper (1991) have reported data on the use of hair samples to assay self-reported cocaine use among arrestees. They reported substantially more cocaine positive hair

samples than urine samples. The most common outcome between urinalysis, hair assay, and self-report was agreement between assays. But in cases where assays disagreed, it was very likely that the hair assay was cocaine positive and urinalysis negative. When persons in treatment programs (who are more likely to be truthful about their drug use) are tested, the opiates and cocaine results for hair and urine assays are highly concordant (Magura, Freeman, Siddiqi, & Lipton, 1991).

Thus, we conclude that while some have questioned the efficacy of hair analysis for drugs of abuse [see the Society of Forensic Toxicology (SOFT) "Consensus Opinion", 1990], we believe that there is a diverse literature supporting the reliability, sensitivity, and clinical utility of hair testing. We believe that when used in conjunction with other indicators such as urinalysis, interview data, and third-party verification this technique can add valuable, reliable information to analyzing particular cases. Hair assays are especially useful in aggregate data analysis and epidemiological research, where their collection and assays are anonymous, confidential, or both.

Methods

The specimens and survey data were collected from volunteers at the Pinellas County (Florida) Jail. Twice a year the research group interviews 250-300 male and female arrestees and collects hair and urine specimens at the booking stage of arrest. This article reports on four collection "waves," comprising a total of 1,245 cases. At each data collection period trained staff members administer a questionnaire during a private, face-to-face interview with each volunteer arrestee. The interview and all other participation is structured to guarantee client privacy, confidentiality, and anonymity.

The urine specimens are analyzed for metabolites of cocaine, cannabinoids, opiates, and amphetamines using FPIA technology (Abbott Laboratory TDX system) and employing cutoff values as recommended by the reagent manufacturer (300 μg/mL for cocaine metabolite and 25 μg/mL for cannabinoids).[1]

The hair samples are analyzed by RIA at a commercial laboratory (Psychemedics Corporation, Santa Monica, California) for cocaine, opiates, amphetamines, PCP, and marijuana. The laboratory uses segments which permitted approximately 60-day retrospective intervals—length permitting—from the time of sample acquisition. Segmental interpretation is contingent on the length and condition of the hair sample received. The dating sequence on the hair specimens is based on the conventional estimation that scalp hair grows at an average rate of ½ inch every 30 days. When hair assay data are reported in this article, they apply to a maximum estimated 60-day retrospective period.

The Data

The description of the sample and the compliance rates by gender and ethnicity are presented in table 1.

TABLE 1. HAIR AND URINE DONATION BY ETHNICITY AND SEX WAVES 1-4

	Sex			
	male		female	
	Count	Count Percent	Count	Count Percent
Ethnicity				
black	288	23.1%	47	3.8%
white	806	64.7%	84	6.7%
Hispanic	13	1.0%	1	.1%
other	6	.5%		
total	1113	89.4%	132	10.6%
Provided Hair Sample				
provided sample	814	65.6%	106	8.5%
refused	87	7.0%	18	1.5%
too short	208	16.8%	8	.6%
Urine Sample				
provided sample	1057	85.1%	123	9.9%
refused	12	1.0%	3	.2%
tried/no urine	41	3.3%	6	.5%

The sample is 71.5 percent white, 26.9 percent black, with the balance being Hispanic and "other" ethnicity; 73.9 percent of the sample provided a hair specimen. By gender, 73.4 percent of the males provided hair samples, while 80.4 percent of the females did so. Of those not providing hair, 32.7 percent refused, while 67.3 percent did not have sufficient head hair from which a sample could be harvested. Very few interviewees failed to provide a urine specimen. Only 1.1 percent of the males refused to provide a urine specimen, while approximately .2 percent of the females refused. Approximately 4 percent of the arrestees tried but were unable to provide a urine sample.

Comparing Hair and Urine Assays for Cocaine

For a drug such as cocaine, rapidly excreted from the body, urine is not a desirable medium for assaying long-term exposure. Under most circumstances, 48 hours prior to obtaining the sample is the limit generally accepted for detecting cocaine in urine. If drug users are evading detection by urinalysis and hair analysis provides a longer time window for detection,

then hair should detect greater prevalence. Significant spontaneous loss of cocaine from hair appears to be negligible (Cartmell, Aufderheide, Springfield, Weems, & Arriaza, 1991).

Table 2 presents the outcome of urine screens and the RIA of hair for the cocaine metabolite BE.

TABLE 2. COCAINE: HAIR ASSAYS & URINALYSIS COMPARED WAVES 1-4

	Cocaine/Urine		Row Total
	negative	positive	
Cocaine/Hair			
negative	495	10	505
positive	208	147	355
Column Total	703	157	860

Table 2 shows that the most frequent outcome is *both* urine and hair will be negative for BE, the major cocaine metabolite. Overall, 57.5 percent of all cases were BE negative on both hair and urine specimens. The second most frequent category is the hair assay (+) and the urinalysis (-) for BE. There are 208 such cases representing 24.2 percent of the total. This category represents those cases which would pass urine screens as "drug negative."

Cases on which both urine and hair assays are positive are the third most numerous group, with 147 cases and constituting about 17.1 percent of the total table. There are only 10 cases (1.2 percent) which are negative for the hair assay and positive for the urine assay. Thus, approximately 75 percent of all cases in the table are consistent in their urine and hair assay outcomes (i.e., either both positive or both negative). There are few urine (+), hair (-) cocaine cases. We believe this pattern is likely due to the increased detection of cocaine by hair assays. The data indicate that there are approximately *twice as many hair positive cocaine cases as urine positive cocaine cases.*

To what degree are the hair and urine assays concordant with each other and with self-reported cocaine use? In recent years the literature has argued that cocaine use self-reports are, in essence, underreports (see Mieczkowski, 1990; Wish, Johnson, Strug, Chedekel, & Lipton, 1983; Harrison, 1989). If one examines table 3, there is substantial underreporting of cocaine use, but the degree of underreporting varies for different concentration values of the hair assays. We believe this is a particularly interesting finding.

The laboratory reports for BE assays are a quantitative number; the analyte concentration in nanograms per 10 milligrams of hair (μng/mg). The higher this number, the more cocaine metabolite present in the hair. The values of individual assays are grouped together into "levels" based on concentration. Across the top of table 3 the six "levels" of cocaine metabolite represent concentrations of hair assay values. As the level's number increases, the concentration of BE detected in the sample is greater. Level 0 assays were measured at less than 2 μg/10 mg and are consid-

TABLE 3. LEVELS OF COCAINE IN HAIR WAVES 1-4

	Cocaine/Hair Concentration Level					
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Cocaine/Urine						
negative	495	50	88	32	25	13
positive	10	4	19	37	36	51
used any type of cocaine/48 hrs						
no	500	54	97	52	44	42
yes	5	0	10	17	17	22
used any type of cocaine/30 days						
no	487	52	88	42	43	40
yes	18	2	19	27	18	24
used any type of cocaine/60 days						
no	484	48	86	46	45	42
yes	21	6	21	23	16	22
ever used any type of cocaine						
no	291	23	42	15	16	27
yes	214	31	65	54	45	37

ered a "hair negative." Table 3 indicates that there were 505 such Level 0 or "hair negative" cases. Ten of these cases were urine (+) for BE. Of these Level 0 cases, 5 subjects (<1 percent) reported cocaine use within the preceding 48 hours, 18 (3.6 percent) reported use within 30 days, and 214 (42 percent) admitted to having used cocaine at some time in their life.

The second column, "Level 1" includes hair assayed at concentrations of 2 - 5 μg/10 mg. Table 3 shows 54 such cases. Of these 54 hair (+) Level 1 cases, only 4 tested urine (+) for BE. Of these 54 cases none admitted to cocaine use within the last 2 days, and 2 admitted to use within the last month. Approximately 60 percent of the cases in this column admitted to using cocaine at some time in their life. This same pattern occurs at Level 2 (cases with 5 - 30 μg/10 mg). One hundred and seven cases are reported as Level 2. Nineteen of these 107 cases tested urine (+) for BE, only 10 admitted to use within the preceding 48 hours, and 19 admitted to use within the last month. Slightly more than half of all Level 2 positive cases admitted to using cocaine at some time in their life. At Level 3 (30 - 100 μg/10 mg), one finds again a similar pattern. Sixty-nine are hair (+) at Level 3, of which 37 are urine (+) for BE. Seventeen of the cases admitted to cocaine use within the last 48 hours, and 27 admitted to use within the last month. Fifty-four Level 3 cases admitted to using cocaine at some time in their life.

At the higher concentration levels (3, 4, and 5) more hair positive subjects are testing urine positive than urine negative, the opposite of the first two levels. Level 4, for example, consists of 61 hair samples assayed at 100 - 400 μg/10 mg concentration. Thirty-six of these cases tested urine (+) for BE. However, only 17 cases admitted to cocaine use within 48 hours, and only 18 admitted to any use within 30 days. Forty-five admitted to using cocaine some time in their life. An identical pattern is revealed for Level 5 (>400 μg/10 mg), which consists of 64 cases hair (+) at the highest concentration values reported. Of these 64 cases, 51 tested urine (+) for BE. Twenty-two admitted to cocaine use within 48 hours, and 24 admitted to using any cocaine within the last 30 days. Thirty-seven admitted to using cocaine at some time in their life.

Figure 1 demonstrates this distinction in concordance on hair and urine outcomes as hair concentration increases. In Figure 1, the cases, all of which are hair (+), are arrayed by concentration level along the horizontal axis. The total number of hair (+) cases for each level is represented by a plain bar column in the background. The textured bar in the foreground represents the number of cases at that level which had (+) urinalysis.

Figure 1 illustrates the convergence of hair and urine assays at Levels 4 and 5 and the relative divergence of those outcomes for Levels 1, 2, and 3. Cases at Levels 1, 2, and 3 indicate that RIA of hair appears to be most effective in identifying individuals who are likely to pass a one-time urine screen done at currently accepted cutoff levels. Cases at Levels 4 and 5 show that those with high levels of BE in their hair appear to be much more likely also to fail a urine test. Note the substantial increase in urine (+) cases at level 3 and beyond. At Levels 1 and 2 only a small fraction of these cases are urine (+), whereas approximately one-half or greater of the cases are urine (+) at Levels 3, 4, and 5. We believe this outcome is because persons testing at Levels 4 and 5 are individuals who are exposed to or use relatively large amounts of cocaine. These "high concentration" cases are very likely to be identified by urinalysis, since they are chronically cocaine exposed and continuously excreting BE in their urine. Individuals at low concentrations (Levels 1, 2, and 3) are likely to evade detection by urine, since they use either small amounts of cocaine or avoid daily or near daily use.

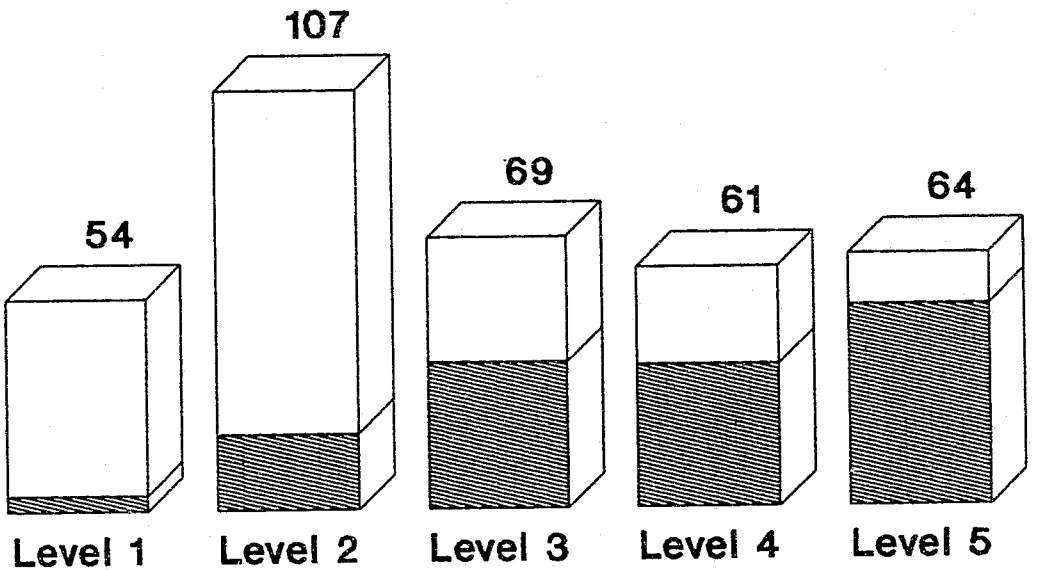
Comparing Hair and Urine Assays for Marijuana

In addition to testing for cocaine metabolites, the urine and hair samples were also screened for the principle psychoactive in marijuana (THC metabolites). Screening hair specimens for THC is more difficult than screening for cocaine because marijuana apparently accumulates at low levels in the hair. Hair specimens intended for marijuana assay ideally require large mass and very sensitive assays. In comparing hair and urine assay time windows it must be noted that marijuana has a slow clearance rate for the urine, so urinalysis will normally detect marijuana for a longer time period than cocaine.

The laboratory reports marijuana assays as (+) or (-) without a corresponding concentration value. We contrast the outcomes of dichotomous hair and urine marijuana assays in table 4. Because of poor specimen mass, no marijuana assays were done on the hair samples from wave 1. Table 4 shows all cases from waves 2 through 4 which had urine and hair specimens of sufficient quantity to permit assays.

Table 4 shows the outcome for marijuana differs markedly in its pattern from the outcome for the cocaine assays. The relatively high number of paradoxical cases (62) which tested hair (-) and urine (+) for cannabinoids is indicative of the assays' failure to detect marijuana in the hair. The smallest cell count in the table is the urine (-), hair (+) cell at 43 cases. We do not believe it likely that a large number of arrestees consumed marijuana for the first time just prior to their arrest (thus having "clean" hair but "dirty" urine). It is a more plausible explanation that the hair assay proce-

Figure One. Comparing Assay Outcomes
Urine and Hair, Waves 1 - 4



	Level 1	Level 2	Level 3	Level 4	Level 5
Urine (-) Cocaine	50	88	32	25	13
Urine (+) Cocaine	4	19	37	36	51
Hair (+) Cocaine	54	107	69	61	64

Urine (+) Cocaine Urine (-) Cocaine

Grouped by Cocaine Hair Assay Level

TABLE 4. MARIJUANA: HAIR ASSAYS & URINALYSIS COMPARED WAVES 2, 3, & 4 COMBINED

	Marijuana/Urine		Row Total
	negative	positive	
Marijuana/Hair			
negative	300	62	362
positive	43	167	210
Column Total	**343**	**229**	**572**

dure has failed to consistently identify marijuana positive hair specimens from negative specimens.

Table 4 shows that 10.8 percent overall of marijuana cases fall in this category for aggregated marijuana test data. This is a tenfold greater rate than occurs for the cocaine data. There are also a relatively small number of hair (+), urine (-) cases for marijuana (43). About 7.5 percent overall of the marijuana cases are in this category (the smallest cell value for marijuana cases), while 24.1 percent of cocaine cases are in this category. This is somewhat less surprising, since marijuana remains for a relatively long time in the urine, one would expect to see this particular category as relatively smaller. We suspect several factors are operating simultaneously which reduce the efficacy of the hair marijuana assay. First, the hair does not absorb significant quantities of THC metabolites relative to cocaine. Second, we are employing a very low cutoff level for urinalysis (thus maximizing the urine (+) cases). Third, since THC "lingers" in the urine, this reduces the measurable effect of the time factor.

It is also interesting that the marijuana self-report data are the reverse pattern of the cocaine self-report data. If we consider the hair or urine assays as tests which "validate" the self-report, the data show that cocaine users underreport their cocaine use and marijuana users overreport their marijuana use. According to the urine assays, about 55 percent of respondents misreport their cocaine use, and nearly 70 percent misreport their cocaine use if hair assay outcomes are the standard. But for marijuana self-reported use, the number of admitted users is greater than either the hair or urine assay outcomes. For example, while 210 individuals test hair positive for marijuana, and 229 individuals test urine positive for marijuana, *265 admit to marijuana use within the previous 30 days.* Why this is so is not well understood, but this pattern has been reported previously (Mieczkowski, 1990).

Discussion and Summary

Hair assays for drugs of abuse will continue to be of interest to criminal justice and treatment professionals because the technique offers several features not available with urinalysis. The primarily advantage is the longer timeframe for detection of exposure. Hair also has potential to act like a dosimeter, accumulating the substances of interest in a relatively inert matrix, perhaps in manner allowing for retrospective reconstruction of consumption over long timeframes. One may not only be able to determine if a person has been exposed to a drug, but also to *how much* of the drug. And we have noted other advantages as well.

Since hair can "look back" longer, individuals in treatment or under court control could be effectively monitored without high-frequency urine testing. Hair screens could also be useful as the first "general screening" device in examining drug use among probation and parole populations at intake. Those who fail a hair screen then could be monitored in a more intense fashion, while those who pass a hair screen could be exempt from multiple, frequent testing. Correctional officers and treatment providers may find it useful to be able to determine past drug usage and degrees of past use for diagnostic and compliance purposes (Ostrea, Parks, & Brady, 1989; Callahan et al., 1992). Hair assays can also be used to evaluate the accuracy of claims by persons who have failed a urine screen but deny drug use or challenge the accuracy of the test, the chain of custody, or similar issues.

The data presented in this article are consistent with the hypothesis that RIA of hair effectively identifies exposure to cocaine. In contrast, the ability to detect marijuana by hair assay does not appear effective. Urinalysis identifies marijuana exposure as readily as does hair assay.

Focusing specifically on cocaine, the very low number of "least likely" cocaine cases [that is urine (+), hair (-)] and the high degree of concordance or plausibility of remaining outcomes support the hair assay's ability to detect cocaine. Furthermore, the convergence of urine and hair values, demonstrated by figure 1, for cases which are at the higher Levels 4 and 5 is noteworthy, indicating that compulsive daily users are highly likely to be identified regardless of the assay medium. Sporadic, or moderate, users are more likely to pass a urine screen and fail a hair screen.

A major finding of this research is that hair assays appear to identify cocaine exposure effectively. Another major finding of this research is that hair assays for marijuana appear no more effective than urinalysis in detecting marijuana exposure. The findings also indicate that it is extremely unlikely for a person to turn up urine (+) for cocaine but hair (-). However, if a marijuana user is going to test (+) for an assay, the user is more likely to turn up as *urine* (+) than *hair* (+). Furthermore, it appears that the marijuana hair assay does not produce large numbers of hair "false positives," but rather that hair assays miss a substantial number of people who test urine (+), i.e., hair

assays for marijuana produce "false negatives." Recall, as well, that we have deliberately used a very low cutoff value for marijuana urinalysis, so that we are "driving" this outcome to some degree. Using higher marijuana cutoff values would undoubtedly dampen this effect.

To reiterate our basic conclusions:

1. Hair analysis appears notably effective in identifying cocaine use and not very effective in identifying marijuana use.

2. Arrestees appear to underreport their use of cocaine quite substantially, whether one considers urine or hair assays as the validation marker. The underreporting of cocaine is more dramatic when using hair as the indicator; about 50 percent of the arrestees underreport cocaine use when measured by their urine assay outcomes, and about 70 percent do when measured by their hair assay outcomes.

3. In contrast to cocaine, subjects appear to "overreport" their marijuana use—more people report recent marijuana use than are detected by either hair or urine tests.

NOTE

[1]The cocaine cutoff level for urine conforms to the NIDA recommendations, but the marijuana cutoff is *lower* than the NIDA value (100 ng/ml recommended). We use this lower value in order to minimize the number of evidentiary "false negatives" for marijuana and to reduce the likelihood that hair will *appear* to be more effective because it falsely identifies apparent "hair (+), urine (-)" cases for marijuana.

REFERENCES

Allgood, C.C., Sniegoski, L., & Welch, M. (1991, May). *The analysis of human hair for drugs of abuse.* Proceedings of the 39th ASMS Conference on Mass Spectrometry and Allied Topics, Nashville, TN.

Arnold, W. (1986). RIA analysis of head hair for narcotics and substitutes. *Journal of Chemistry and Clinical Biochemistry, 24*(10), 797-798.

Baer, J., Baumgartner, W., Hill, V., & Blahd, W. (1991). Hair analysis for the detection of drug use in pretrial, probation, and parole populations. *Federal Probation, 55*(1), 3-10.

Balbanova, S., & Wolf, H. (1982). Determination of methadone in human hair by radioimmunoassay. *Zeitschrift für Rechtsmedizin, 102,* 1-4.

Baumgartner, W., Black, C., Jones, P., & Blahd, W. (1982). Radioimmunoassay of cocaine in hair: A concise communication. *Journal of Nuclear Medicine, 23,* 790-792.

Baumgartner, W., Hill, V., & Blahd, W. (1989). Hair analysis for drugs of abuse. *Journal of Forensic Sciences, 34*(6), 1433-1453.

Baumgartner, A., Jones, P., Baumgartner, W., & Black, C. (1979). Radioimmunoassay of hair for determining opiate-abuse histories. *Journal of Nuclear Medicine, 20,* 748-752.

Baumgartner, A., Jones, P., & Black, C. (1981). Detection of phencyclidine in hair. *Journal of Forensic Sciences, 26*(3), 576-581.

Blank, D., & Kidwell, D. (1992, December). *External contamination of hair by drugs of abuse: A problem looming for forensic analysis.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Bureau of Justice Statistics. (1989). *Drug use and crime.* Washington, DC: U.S. Department of Justice.

Callahan, C., Grant, T., Phipps, P., Clark, G., Novack, A., Streissguth, A., & Raisys, V. (1992). Measurement of gestational cocaine exposure: Sensitivity of infant's hair, meconium, and urine. *The Journal of Pediatrics, 120*(5), 763-768.

Cartmell, L., Aufderheide, A., Springfield, A., Weems, C., & Arriaza, B. (1991, September). The frequency and antiquity of prehistoric coca leaf chewing practices in northern Chile: A radioimmunoassay study of a cocaine metabolite in human mummy hair. *Latin American Antiquity.*

Cone, E. (1990). Testing human hair for drugs of abuse. I. Individual dose and time profiles of morphine and codeine in plasma, saliva, urine, and beard compared to drug-induced effects on pupils and behavior. *Journal of Analytic Toxicology, 14,* 1-7.

Cone, E., Yousenejad, D., Darwin, W., & Maguire, T. (1991). Testing human hair for drugs of abuse. II. Identification of unique cocaine metabolites in hair of drug abusers and evaluation of decontamination procedures. *Journal of Analytical Toxicology, 15*(5), 250-255.

Drug Use Forecast. (1990). *DUF 1989 annual report.* Washington, DC: National Institute of Justice.

Forrest, I., Otis, L., & Serra, M. (1972). Passage of ^{3}H-chloropromazine and ^{3}H-▲-tetrahydrocannibinol into the hair (fur) of various mammals. *Proceedings of the Western Pharmacological Society, 15,* 83-86.

Franceschin, A., Morosin, L., & Dell'Anna, L. (1987). Detection of morphine in hair with the Abbot TDX. *Clinical Chemistry, 31,* 21-25.

Goldblum, R.W., Goldbaum, L., & Piper, W. (1954). Barbiturate concentrations in the skin and hair of guinea pigs. *Journal of Investigative Dermatology, 22,* 121-128.

Goldberger, B., Caplan, Y., Maguire, T., & Cone, E. (1991). Testing human hair for drugs of abuse. III. Identification of heroin and 6-acetylmorphine as indicators of heroin use. *Journal of Analytical Toxicology, 15*(5), 226-232.

Graham, K., Koren, G., Klein, J., Schneiderman, J., & Greenwald, M. (1989). Determination of gestational cocaine exposure by hair analysis. *Journal of the American Medical Association, 262*(23), 3328-3330.

Harkey M., & Henderson, G. (1989). Hair analysis for drugs of abuse. In R. Baselt (Ed.), *Advances in analytical toxicology.* Chicago, IL: Year Book Medical Publishers.

Harkey, M., Henderson, G., & Zhou, C. (1991). Simultaneous quantitation of cocaine and its major metabolites in human hair by gas chromotography/chemical ionization mass spectrometry. *Journal of Analytical Toxicology, 15*(5), 260-266.

Harrison, L. (1989, November). *The validity of self-reported drug use among arrestees.* Paper presented at the American Society of Criminology, Reno, Nevada.

Harrison, W., Gray, R., & Solomon, L. (1974). Incorporation of d-amphetamine into pigmented guinea pig hair. *British Journal of Dermatology, 91,* 415-418.

Henderson, G., Harkey, M., Zhou, C., & Jones, R. (1992). Cocaine and metabolite concentrations in the hair of South American coca chewers. *Journal of Analytical Toxicology, 16,* 199-201.

Ishiyama, I., Nagai, T., & Toshida, S. (1983). Detection of basic drugs (methamphetamine, antidepressants, and nicotine) from human hair. *Journal of Forensic Sciences, 28*(2), 380-385.

Kidwell, D. (1989). Analysis of drugs of abuse in hair by tandem mass spectrometry. *Proceedings, 36th American Society of Mass Spectrometry Conference on Mass Spectrometry and Allied Topics,* San Francisco, pp. 1364-65.

Kidwell, D. (1990). *Caveats in testing for drugs of abuse.* Paper presented to the National Institute on Drug Abuse, Technical Review.

Kidwell, D. (1990a). *Analysis of cocaine, heroin, and their metabolites in saliva.* (NRL Memorandum Report 6678). Washington, DC: Naval Research Laboratory.

Koren, G., Klein, J., Forman, R., & Graham, K. (1992). Hair analysis of cocaine: Differentiation between systemic exposure and exter-

nal contamination. *Journal of Clinical Pharmacology, 32,* 671-675.

Magura, S., Freemen, R., Siddiqi, Q., & Lipton, D. (1991). The validity of hair analysis for detecting cocaine and heroin use among addicts. *International Journal of the Addictions.*

Mangin P., & Kintz, P. (1992, December). *Evidence of gestational heroin or nicotine exposure by analysis of fetal hair.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Martz, R. (1988). The identification of cocaine in hair by GC/MS and MS/MS. *Crime Lab Digest, 15,* 67-73.

Martz, R., Donnelly, B., Fetteroff, D., Lasswell, L., Hime, G., & Hearn, W. (1991). The use of hair analysis to document a cocaine overdose following a sustained survival period before death. *Journal of Analytical Toxicology, 15,* 279-281.

Michalodimitrakis, M. (1987). Detection of cocaine on rats from analysis of hair. *Medical Science Law, 27,* 13-15.

Mieczkowski, T. (1990). The accuracy of self-reported drug use: An analysis of new data. In R. Weisheit (Ed.), *Drugs, Crime and the Criminal Justice System* (pp. 275-302). Cincinnati: Anderson.

Mieczkowski, T., Barzelay, D., Gropper, B., Wish, E. (1991). Concordance of 3 measures of cocaine use in an arrestee population: Hair, urine and self-report. *The Journal of Psychoactive Drugs, 23*(3), 241-249.

Möller, M. (1992). Drug detection in hair by chromatographic procedures. *Journal of Chromatography, 580,* 125-134.

Mule, S., Jukofsky, D., & Kogan, M. (1977). Evaluation of the radioimmunoassay for benzoylecgonine (a cocaine metabolite) in human urine. *Clinical Chemistry, 23,* 796-801.

Nagata, T. (1983). Significance of methamphetamine levels in blood and tissues. *Abstracts of the 67th Conference of the Medico-legal Society of Japan,* Osaka, Japan, pp. 11-12.

Nakahara, Y., Shimamine, M., & Takahashi K. (1992, December). *Methamphetamine and related compounds in hair: Incorporation and movement of drugs in hair.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Niwaguchi, T., Suzuki, S., & Inoue, T. (1983). Determination of methamphetamine in hair after single and repeated administration to rat. *Archives of Toxicology, 52*(2), 157-164.

Ostrea, E., Parks, P., & Brady, M. (1989). The detection of heroin, cocaine, and cannabinoid metabolites in meconium of infants of drug dependent mothers. *Pediatric Research, 25,* 225a.

Puschel, K., Thomasch, P., & Arnold, W. (1983). Opiate levels in hair. *Forensic Science International, 21,* 181-186.

Sachs, H. (1992, December). *Confirmation of immunological results of drugs in human hair by GC/MS.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Smith, F., & Liu, R. (1986). Detection of cocaine metabolites in perspiration stain, menstrual bloodstain, and hair. *Journal of Forensic Sciences, 31*(4), 1269-1273.

Smith, F., & Pomposini, D. (1981). Detection of phenobarbital in bloodstains, semen, seminal stains, saliva stains, perspiration stains, and hair. *Journal of Forensic Science, 26,* 582-586.

Society of Forensic Toxicology (1990). Consensus opinion summarizing the current applicability of hair analysis to testing for drugs of abuse. *ToxTalk, 14*(3).

Sramek, J., Baumgartner, W., Tallos, J., Aherns, T., Heiser, J., & Blahd, W. (1985). Hair analysis for detection of phencyclidine in newly admitted psychiatric patients. *American Journal of Psychiatry, 142*(8), 950-953.

Staub, C. (1992, December). *Is hair analysis a useful tool in forensic toxicology? The situation in Switzerland.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Suzuki, O., Hattori, H., & Asano, M. (1984). Detection of amphetamine and methamphetamine in a single human hair by gas chromatography/chemical ionization mass spectrometry. *Journal of Forensic Science, 29,* 611-617.

Uematsu, T. (1992, December). *Utilization of hair analysis for therapeutic drug monitoring with a special reference to nicotine determined in hair as an index of smoking habit.* Paper presented at the First International Conference on Hair Analysis for Drugs of Abuse, Genoa, Italy.

Valente, D., Cassini, M., Pigliapochi, M., & Vansetti, G. (1981). Hair as a sample in assessing morphine and cocaine addiction. *Clinical Chemistry, 27*(11), 1952-1953.

Welch, R., Martier, S., Ager, J., Ostrea, E., & Sokol, R. (1990). Radioimmunassay of hair: A valid technique for determining maternal cocaine abuse. *Substance Abuse, 11*(4), 214-217.

Wish, E., Johnson, B.D., Strug, D., Chedekel, M., & Lipton, D. (1983). *Are urine tests good indicators of the validity of self-reports of drug use? It depends on the test.* New York: Narcotics and Drug Research, Inc.