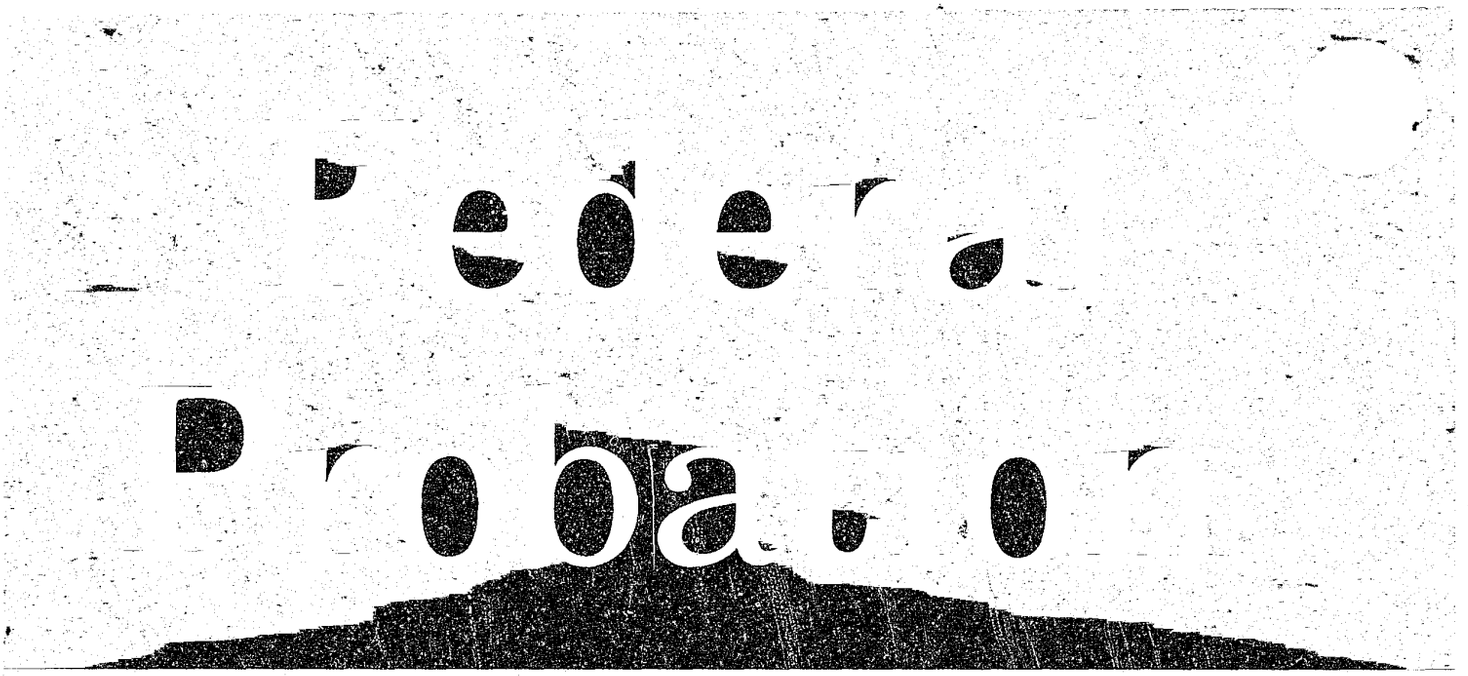

Hair Analysis for the Detection of Drug Use in Pretrial, Probation, and Parole Populations ..... *James D. Baer, Werner A. Baumgartner, Virginia A. Hill, William H. Blahd*

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This Issue in Brief

Hair Analysis for the Detection of Drug Use in Pretrial, Probation, and Parole Populations.—Comparing the results of radioimmunoassay (RIA) hair analysis for drug use with urinalysis results and self-reports of drug use among aftercare clients in the Central District of California, authors James D. Baer, Werner A. Baumgartner, Virginia A. Hill, and William H. Blahd propose that hair analysis offers the criminal justice system a complementary technique for identifying illegal drug use. The study results are timely in light of the recent decision of a U.S. district court judge who accepted a positive RIA hair analysis result as valid forensic proof that a probationer had violated the conditions of probation (EDNY Dkt. No. 87-CR-824-3).

Tools for the Trade: Neuro-Linguistic Programming and the Art of Communication.—Whether viewed as a rehabilitative modality or a sanction, probation remains a person-to-person profession in that probation officers still deal with individuals. According to author Richard Gray, some recent developments in psychology may provide tools for investigation, assessment, helping, and, sometimes, healing. His article describes neuro-linguistic programming and how probation officers may use the technique to develop rapport and communicate effectively and consciously with clients.

Social-Psychological Effects of the Status of Probationer.—Authors Charles Bahn and James R. Davis report on a non-random sample of 43 probationers who were tested and interviewed in order to assess the social-psychological effects of probation in four areas: emotions; family, peer, and work relations; self-concept; and stigma. The authors administered an open-ended questionnaire, a scalogram, and a self-concept inventory and found, among other things, that probationers had the support of family, friends, and even some employers. The authors conclude that probation is more than a "slap on the wrist" but that it does not overwhelm all aspects of a probationer's life.

Electronic Monitoring in Federal Pretrial Release.—Author Timothy P. Cadigan focuses on current use of electronic monitoring in Federal pretrial release programs, first discussing, in general, how to establish such programs and what to consider in doing so. Then, based on demographic data about Federal defendants on electronic monitoring, the article assesses whether

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Hair Analysis for the Detection of Drug Use in Pretrial, Probation, and Parole Populations

BY JAMES D. BAER, WERNER A. BAUMGARTNER, VIRGINIA A. HILL, AND WILLIAM H. BLAHD*

Introduction

HAIR ANALYSIS for drugs of abuse is an effective means of identifying drug users for purposes of medical diagnosis and workplace testing (1-9).

The present study is the first systematic exploration of the use of hair analysis for drugs of abuse in an operational criminal justice context. Its primary purposes were to explore the abilities of hair analysis to detect drug use violations in criminal justice clients, to resolve any problems in obtaining and handling hair samples in these situations, and to establish procedures for potential routine hair testing.

Primarily, the study compared the results of hair analysis by radioimmunoassay with those of urinalysis by enzyme immunoassay (EMIT) and thin-layer chromatography (TLC) for major illicit drugs (opiates, marijuana, cocaine, and PCP) against data from self-reports of clients in pretrial release, probation, and parole.

The testing protocol in effect for urine specimens considered in this study (September 1986 to May 1988) commenced in February 1984. Although immunoassay cut-off levels for opiates and cannabinoids were the same as currently recommended, cut-off levels for drugs analyzed solely by TLC (cocaine and PCP) were relatively insensitive compared to the guidelines set forth in April 1988 by the Department of Health and Human Services. Therefore, the results of this exploratory study do not reflect the optimal performance of urinalysis tests employing more sensitive cut-off levels or other analytical techniques.

Background

Hair analysis complements urine and blood analysis in several respects (table 1). In contrast to short-term and qualitative information from urinalysis, hair analysis provides long-term, semiquantitative data concerning the duration, pattern, and severity of an individual's drug use. Most abused drugs are present in urine for only a few days following use. Thus, the presence or absence of a drug in urine indicates use or no-use within those few days. This is the period inaccessible to hair analysis. With hair, the period of past drug use that can be accessed begins about 3 days prior to hair collection and is limited only by the length and type of hair. Since hair grows at a rate of approximately ½ inch per month, information on drug use ranging over months to years can be obtained from hair analysis (figure 1). The amount of drug found in hair increases approximately in proportion to the amount of drug used. Therefore, cutting hair into small segments and assaying these can establish both the temporal and the intensity pattern of use over relatively long periods of time.

The evasive measures successful against urinalysis are ineffective against hair analysis. For example, hair specimens can be collected under close supervision without embarrassment, and "flushing" with excessive fluids does not affect the result. Moreover, drug users cannot avoid detection merely by abstaining from drug use for a few days prior to a scheduled probationary meeting. If the original result or authenticity of the hair specimen is challenged, the analysis can be repeated with a newly collected hair specimen. Also, hair analysis is not subject to evidential

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The authors thank Dr. Bernard Gropper, research program director of the National Institute of Justice, for his valuable contributions at a critical stage in the development of hair analysis. They also thank Dr. Irving Lyon, Beverly Starks, Chris Berka, Susan Gross, and James Dunn for their research assistance. For work on mass spectrometry problems, the authors acknowledge the collaboration of Dr. James Peterson and Gordon Hisayasu of the Pacific Toxicology Laboratory, Drs. David Kidwell and David Blank of the Naval Research Laboratories, and Roger Martz of the FBI Laboratories.

TABLE 1. COMPLEMENTARY FEATURES OF DRUG TESTING TECHNIQUES

Urine Analysis	Hair Analysis
1. Narrow window of detection (days)	1. Wide window of detection (months to years)
2. Temporary retention of drug information	2. Permanent retention of drug information
3. Rapid onset of detection (hours)	3. Delayed onset of detection (days)
4. Single sample does not reflect pattern or severity of use	4. Single sample reflects pattern and severity of use
5. Sample collection can be intrusive and demeaning	5. Sample collection without embarrassment
6. Single sample source	6. Multiple sample sources (head hair, body hair)
7. High drug concentrations do not require highly sensitive screening techniques	7. Low drug concentrations require highly sensitive (RIA) screening techniques
8. Confirmation by conventional GC/MS instrumentation	8. Confirmation by advanced GC/MS (or MS/MS) instrumentation
9. Probative value reduced by:	9. Probative value enhanced by:
a. evasion by short-term abstension	a. inability to evade through short-term abstention
b. evasion by substitution, adulteration, or dilution of sample	b. inability to evade by substitution, adulteration, or dilution of sample
c. chemical instability of sample	c. chemical stability of sample
d. inability to identify sample by physical or microscopic means	d. physical and microscopic identification of sample
e. inability to collect an identical repeat sample	e. ability to collect an identical repeat sample
f. urine tests not helpful to probative value of hair test	f. hair analysis helpful to probative value of urine test

false positive claims, i.e., false positives which cannot be identified by gas chromatography/mass spectrometry (GC/MS) confirmation, e.g., those due to the inadvertent ingestion of drugs such as in spiked foods or poppy seed. These advantages of hair analysis have been demonstrated in several medical, employment, and military field studies and have been confirmed by independent laboratories in 28 scientific studies (10-37), including those from the Federal Bureau of Investigation and Naval Research Laboratories.

Methodology

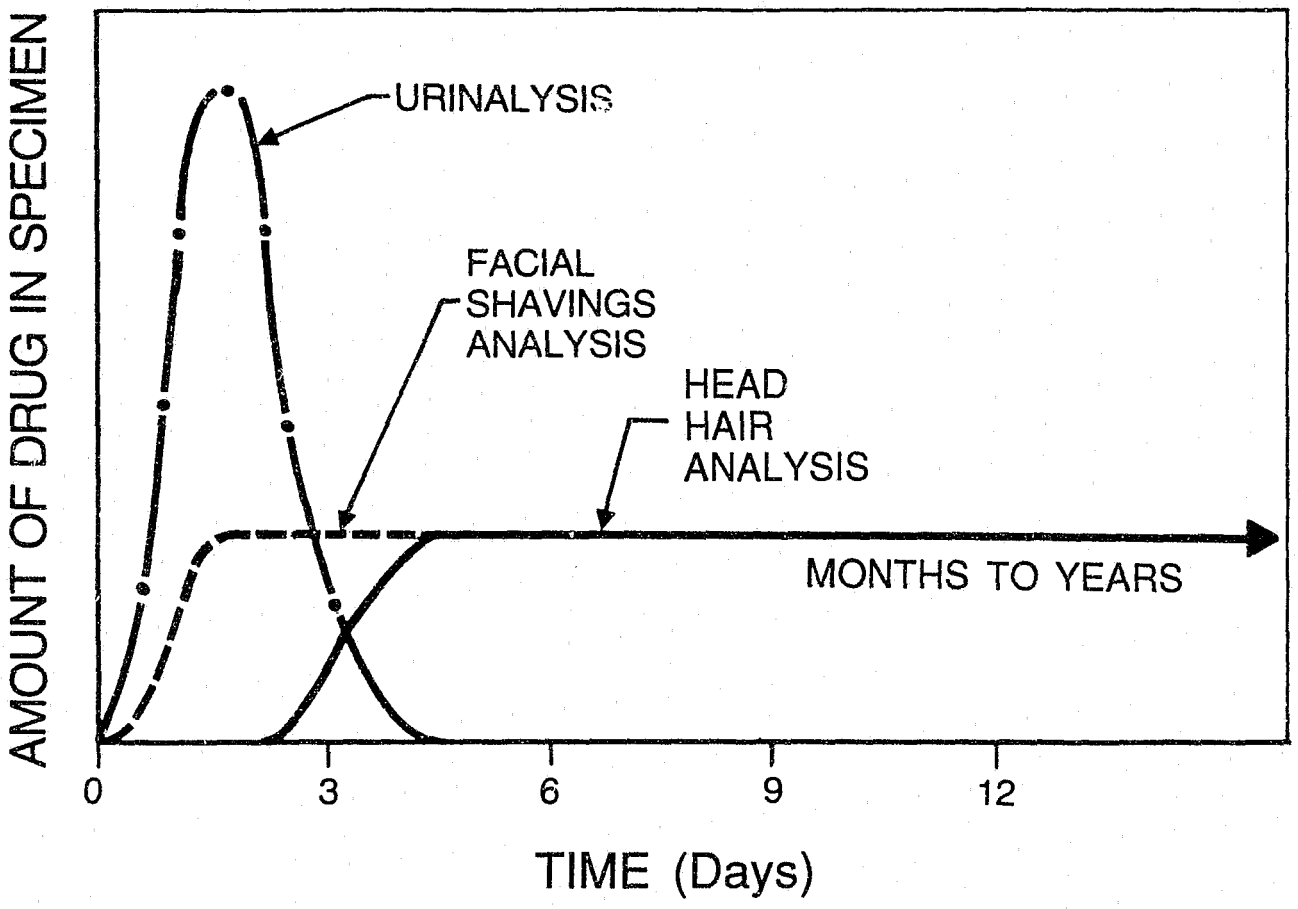
Hair analysis and urinalysis were compared by both a retrospective and prospective approach. In the retrospective study, the results of hair analysis were compared to those of urinalysis and confidential self-reports from individuals who had been identified as drug users or nonusers prior to entry into the study. This phase of the study also included an investigation of the correlation between drug content of hair and amount of drug used. Also investigated was whether hair analysis results of the retrospective study could be used for predicting drug use violations in the prospective phase of the investigation.

The prospective study compared the relative effectiveness of urine and hair analysis for detecting drug use violations during a regular criminal justice surveillance program, i.e., under conditions where drug users were not in part preselected on the basis of a positive urine result as in the retrospective study.

In the course of the study, 315 clients were asked to participate. Of these, 201 (64 percent) volunteered for the retrospective study and 112 of the latter for the prospective study. Clients continued with their usual urinalysis program in current use by the Federal probation office. Except for marijuana testing, urinalysis following intake was performed at a rate of about five times per month on a partly random basis. Marijuana urinalysis was done only under certain circumstances and then with a maximum frequency of twice per month. If no special circumstances prevailed, marijuana testing occurred once per month or less. Specimens were screened for marijuana by EMIT and confirmed by high-performance thin-layer chromatography (HPTLC), with a cut-off of 100 nanograms/milliliter (ng/ml) of delta-9-carboxy-THC. PCP and cocaine were screened for using TLC with respective cut-offs of 500 ng/ml and 2000 ng/ml. Opiates were screened for using EMIT at 300 ng/ml cut-off and TLC at 500 ng/ml cut-off. Presumptive positives for PCP, cocaine, and opiates were confirmed by gas liquid chromatography. At the time of collections, urine samples were checked for concentration/dilution by use of clinical refractometers (38).

Approximately 100 hair strands, cut as close to

Figure 1. Accumulation of Drug in Urine and Hair as a Function of Time



the scalp as possible, were collected at 3-month intervals. These were analyzed by radioimmunoassay (RIA) procedures. One milligram of hair was required for each cocaine, PCP, or heroin RIA analysis, and 2.5 milligrams for the marijuana assay. Currently, a five-drug panel screening test (cocaine, PCP, heroin, amphetamines, and marijuana) on a single sample can be accomplished at a price of $40 to $55, depending on the volume of samples.

To guard against false positive problems due to antibody cross-reactivity of the screening assay, gas chromatography/mass spectrometry procedures were developed for confirmation of positive hair analysis results from the initial RIA screen. Five milligrams of hair were required for these confirmations. Extensive studies failed to provide any evidence of technical false positive hair analysis results. False positives due to external contamination of hair by drugs were avoided by repeated washings of the hair sample until the drug content (if any) was 1/10 or less than that found in the hair.

In a separate study in which people ingested poppy seeds over a 1-month period, it was shown that hair analysis did not generate any evidential false positives due to such ingestion. Urinalysis, on the other hand, generated evidential false positives as high as 500 ng/ml of morphine in the urine.

Hair analysis was extended to methadone, methamphetamine, and benzodiazepines as part of this study. These new methods were field tested on patients from Wadsworth V.A. Medical Center and the criminal justice population (4).

The Retrospective Study

The retrospective studies were of two types. The first included individuals who had been subjected to extensive urinalysis testing prior to entering the study. This group was further subdivided into those who admitted drug use during the period being tested (table 2) and those who reported no use (table 3). Urinalysis records and self-reports were compared to the results of hair analysis. (Marijuana results are not included in the retrospective data presentations because marijuana urinalysis was done on an infrequent and variable basis and because there was no preselection on the basis of marijuana urinalysis or self-re-

ports. For these reasons the marijuana results from both the retrospective and prospective studies are included in table 6, prospective study results.) In recruiting the study participants, the emphasis was on inclusion of volunteers with a record of positive urine tests in order to compensate for a suspected tendency toward attracting volunteers who were not engaged in drug use. Urinalysis records of this group covered a period of at least 2 months and frequently extended beyond this period. The impression was that these "preselected" positive clients provided more truthful self-reports on their past drug use than those who had remained undetected, perhaps because the former had nothing to lose and consequently were generally highly cooperative.

TABLE 2. RESULTS OF HAIR AND URINE ANALYSIS ON CRIMINAL JUSTICE POPULATIONS—POSITIVE SELF-REPORT

Study Phase	Substance	N	H+U+	H-U-	H-U+	H+U-
Retrospective Study[1]	Cocaine	22	14	0	1	7
	Morphine	6	2	1	0	3
	PCP	2	1	0	0	1

[1]Urine and hair surveillance windows: 2 months; average urine collections: 5.9/month.

TABLE 3. RESULTS OF HAIR AND URINE ANALYSIS ON CRIMINAL JUSTICE POPULATIONS—NEGATIVE SELF-REPORT

Study Phase	Substance	N	H+U+	H-U-	H-U+	H+U-
Retrospective Study[1]	Cocaine	64	3	48	0	13
	Morphine	75	4	69	1	1
	PCP	81	0	80	0	1

[1]Urine and hair surveillance windows: 2 months; average urine collections: 5.9/month.

The second group in the retrospective study, the limited retrospective study, consisted of individuals who had only recently entered the urinalysis drug surveillance program and for whom no extensive urinalysis background was available. These clients were also divided into those with positive (table 4) and negative (table 5) self-reports. In contrast to the first group, their urinalysis data covered only a 1-3 week period prior to the hair collection. Urinalysis and self-report data from this limited retrospective group were therefore of less value in confirming the results of retrospective hair analysis and self-reports. The main reason for assembling this group was to have these clients participate in the prospective study where the relative efficiencies of urine and hair analysis for identifying drug use violations were to be compared (see below). Also, retrospective hair analysis on this group (extending into the previous 3-month period, i.e., beyond the urinalysis data) was carried out to answer the question whether or not individuals with positive hair analysis results are more likely to resume or continue their drug use than those who provided a negative 3-month hair specimen prior to entering the surveillance program of the prospective study.

TABLE 4. RESULTS OF HAIR AND URINE ANALYSIS ON CRIMINAL JUSTICE POPULATIONS—POSITIVE SELF-REPORT

Study Phase	Substance	N	H+U+	H-U-	H-U+	H+U-
Limited Retrospective Study[1]	Cocaine	26	6	2	0	18
	Morphine	10	6	2	0	2
	PCP	2	2	0	0	0

[1]Urine surveillance window: 1-4 weeks at 5 collections per month; hair surveillance window: 2 months.

TABLE 5. RESULTS OF HAIR AND URINE ANALYSIS ON CRIMINAL JUSTICE POPULATIONS—NEGATIVE SELF-REPORT

Study Phase	Substance	N	H+U+	H-U-	H-U+	H+U-
Limited Retrospective Study[1]	Cocaine	53	0	38	0	13
	Morphine	84	0	76	1	3
	PCP	93	0	95	0	1

[1]Urine surveillance window: 1-4 weeks at 5 collections per month; hair surveillance window: 2 months.

The results of urinalysis were scored such that a 3-month (or shorter) surveillance period was designated as positive (U+) if one or more of the 15 (or fewer) urine tests were positive. If all urines over a particular surveillance period were negative then a (U-) score was assigned for this period. Only one hair analysis was performed for a 3-month-wide surveillance window. The results of hair analysis were scored either as positive (H+) or negative (H-) depending on the outcome of the hair analysis.

In some cases, hair analysis was performed to investigate problem cases not easily studied by urinalysis. The example in figure 2 shows a case where an individual had absconded from custody for a period of several months. Upon surrendering to authorities, the individual was reinstated in an outpatient program and subsequently identified by urinalysis (after extensive testing and considerable expense) as a PCP user. In this case, a more restrictive program (residential, custody) might have been more appropriate. Hair analysis

could have revealed the individual's drug status immediately upon readmission. Hair analysis showed escalation of the client's PCP use during the time that the client was without supervision.

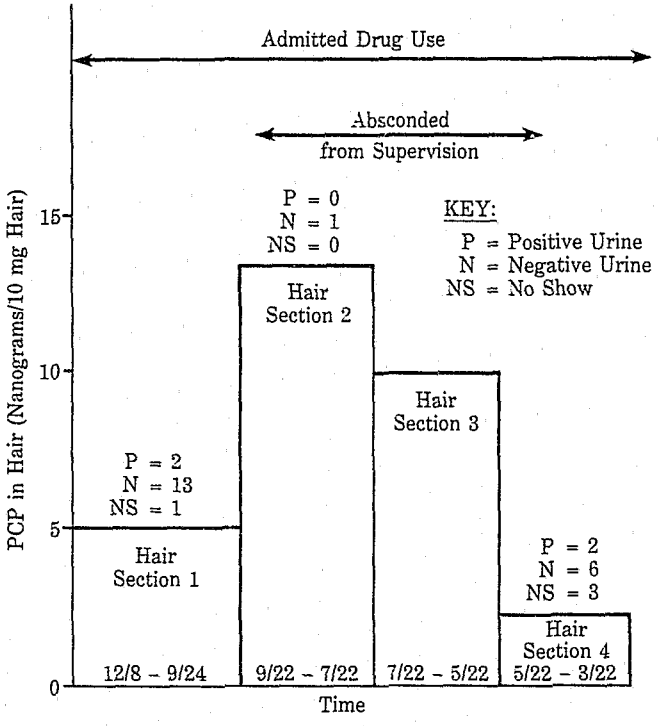


FIGURE 2. RESULTS OF SECTIONAL HAIR ANALYSIS COMPARED TO URINALYSIS AND CONFIDENTIAL SELF REPORT.

Although a detailed comparison between self-reports, urinalysis, and hair analysis as shown in figure 2 could have been constructed for each client in the retrospective and prospective studies, this was not found to be necessary for meeting the main objectives. The correlations of interest are those given in abbreviated, i.e., tabular, form (tables 2-6).

The results of the retrospective study with clients with positive self-reports (table 2) show that hair analysis results are in excellent agreement with self-reports. In spite of the fact that many of the clients listed in table 2 were preselected on the basis of positive self-reports, and in some cases positive urinalysis results, hair analysis—because of its wide window of detection—identified more drug users than did urinalysis.

The usefulness of hair analysis is further confirmed by the results in table 3, listing data of clients whose self-reports indicated no illicit drug use. A good correlation was shown between the large number of self-reported nonusers and negative urinalysis and negative hair results (H-U-). However, a relatively small number of individuals (who concealed their drug use with false self-reports of nonuse) were identified as users by both urinalysis and hair analysis (H+U+). Once again, hair analysis identified more false negative self-reports than did urinalysis (H+U-).

Essentially similar results were obtained in the limited retrospective studies. A good correlation was observed between positive self-reports and positive hair analysis results (table 4). Because of the fewer urinalysis tests, fewer drug users were identified by urinalysis than in table 2.

With the negative self-reporting group (table 5), hair analysis was more effective than urinalysis at identifying false self-reports of nonuse. Because of the fewer urine tests, the superiority of hair analysis is greater than under the conditions of frequent, repeated urine tests shown in table 3.

Concerning the identification of false negative self-reports by hair analysis, it must be remembered that the alternative explanation, i.e., false positive hair analysis results, has been essentially excluded by the GC/MS confirmation studies and by work with hair from guaranteed-negative populations. The majority of negative self-reports in table 5 are corroborated by negative hair and negative urinalysis results.

The Prospective Study

The prospective study compared the effectiveness of hair analysis for identifying drug use violations to that of the routine urinalysis program used at the time of the study by the Probation Office of the Central District of California. In order to compare two dissimilar tests such as hair and urine analysis, a protocol was devised. Volunteers were monitored for drug use for a period of 12 months. In the case of hair analysis, the volunteers provided specimens after 3, 6, 9, and 12 months. During each 3-month "surveillance window," volunteers provided approximately 15 urine specimens as part of their regular drug monitoring program (except in the case of marijuana where testing was more variable and infrequent).

Of the 201 volunteers, 112 proceeded into the prospective study. Although all individuals had some prior history of drug use which had caused them to be referred to the drug aftercare program, only 48 percent were positive by a 3-month retrospective hair analysis at the beginning of the study (tables 4 and 5).

The prospective study was affected by a significant drop-out rate: 112 clients provided a 3-month specimen; 63, a 6-month specimen; 26, a 9-month specimen; and 11, a 12-month specimen. The main reasons for this attrition were (a)

transfers to other rehabilitation programs; (b) completion of aftercare program; (c) absconding; or (d) warrants for no-shows or re-arrests for drug violations that occurred during the time monitored by both urine and hair analysis.

We see from the comparison in table 6 that approximately one-tenth of the number of cocaine hair tests identified 3.5 times as many positive surveillance windows as the urine test, thereby giving hair analysis a 36-fold superiority on a per-test basis over the TLC urinalysis test. For morphine, the relative greater effectiveness is 12.9, and for PCP, 38. These results are attributed to the wider surveillance window provided by hair analysis, its resistance to evasion, and in the cases of cocaine and PCP, also in part to the relative insensitivity of the TLC urinalysis screen. Only in the case of marijuana is random urinalysis more effective than non-random hair analysis, and this by only a factor of 1.3 under the test conditions used during this study. This was attributed to the wider detection window for marijuana urinalysis relative to the other drugs, to the greater sensitivity of the EMIT marijuana urinalysis screen, and to the lower sensitivity of the marijuana hair assay used in this study as compared to the hair assays for the other drugs.

TABLE 6. COMPARISON OF URINALYSIS AND HAIR ANALYSIS FOR IDENTIFYING DRUG USE

Drug	Urinalysis			Hair Analysis		
	Total Number of Tests	Total Number Positive	Percent Positive	Total Number of Tests	Total Number Positive	Percent Positive
Cocaine	1697	11	0.65	176	41	23.3
Morphine	1783	11	0.62	187	15	8.0
PCP	1515	2	0.13	158	8	5.1
Marijuana	295	16	5.4	295	12	4.1

The superiority of the hair test is not greatly diminished if the urine test efficiency is scored on the basis of positive individual urine results; the efficiencies on this basis are, for cocaine, 24; for morphine, 6.5; for PCP, 38; and marijuana, 0.8. These data suggest a cooperative use of hair and urine analysis, one in which an initial application of hair analysis identifies a high-risk population which subsequently is monitored by random urinalysis testing for maximum immediate deterrent effect. It was shown by Miike that the testing of such "undiluted" populations leads to a pronounced effect on the cost effectiveness of urinalysis (40).

Quantitative and Prognostic Aspects

The study supports the concept that hair analysis can provide a semi-quantitative measure of the severity of an individual's drug use. For example, a correlation can be seen between self-reported amounts of cocaine used and cocaine metabolite levels found in hair (figure 3). The small number of positives for the other drugs precluded performing similar analyses for these. With this information on the severity of cocaine use, it was shown that urinalysis by TLC identified mainly heavy and intermediate cocaine users, but with only about 50 percent and 33 percent efficiency, respectively. Light users, on the other hand, were detected with only 4 percent efficiency.

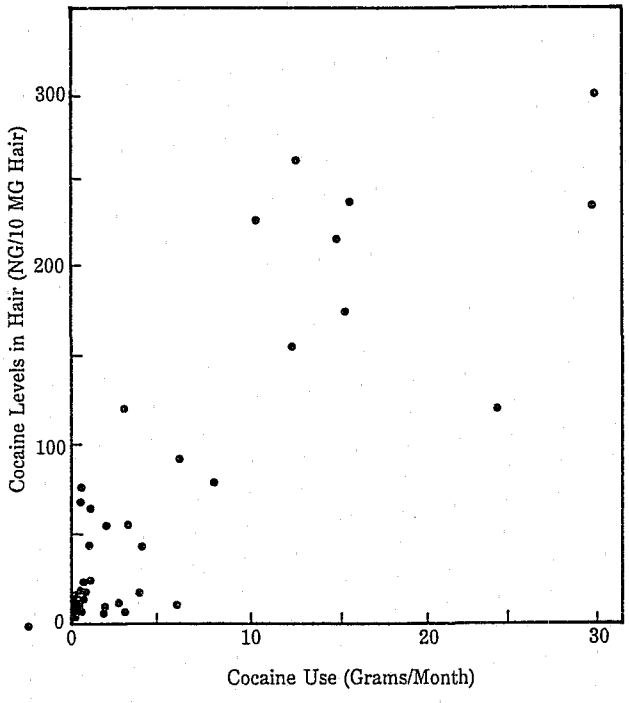


FIGURE 3. CORRELATION BETWEEN SELF-REPORTED COCAINE USE AND COCAINE LEVELS IN HAIR

The study also demonstrated that retrospective hair analysis can serve as a predictor of drug use during criminal justice supervision. It was found that 25 percent of clients with negative retrospective hair analysis results prior to entering the program returned to drug use during surveillance. In contrast to this, 53 percent of those who were positive by retrospective hair analysis resumed or continued their drug use while in supervision.

This capability to forecast drug use by retrospective hair analysis could be applied when individuals first enter the criminal justice system. The results of the Drug Use Forecasting studies have shown that up to 80 percent of arrestees for mostly non-drug-related crimes provide a positive urine specimen at the time of arrest (39). This percentage of drug abusers exceeds to a consider-

able extent the custody capacity of most criminal justice systems. Consequently, the possibility of distinguishing between heavy, medium, light, or no drug use by retrospective hair analysis and the potential of linking such findings to other risk factors is a promising approach for referring individuals to appropriate supervision programs. Hair analysis also may be useful as an adjunct to urinalysis testing (particularly when this is manipulated by various evasive maneuvers and false positive claims) and as a means of evaluating the efficacy of various drug treatment approaches.

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