A REVIEW OF SUBSTANCE ABUSE MONITORING IN A SOCIAL SERVICES CONTEXT: A PRIMER FOR CHILD PROTECTION WORKERS

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ABSTRACT

As drug abuse in our society escalates, child protection workers face mounting challenges in accurately assessing parental substance abuse in the interest of effective child protection. The impartial evaluation of substance use and abuse is fundamental, requiring objective and sensitive methods. A variety of biological specimens, some applicable to short-term and some to long-term monitoring, have been successful when applied to a child protection and drug abuse monitoring of caregivers. This article explores the complementary features of drug testing in urine, hair, and meconium, among other alternative matrices and discusses the practicality, basic science, and applicability of each to substance abuse monitoring in the context of child protection.

Keywords: *Drug testing, hair, meconium, prenatal, toxicology, urine screen, infant, child, drug*

The escalation of illicit and prescription drug abuse in North America has imposed inherent difficulties and dangers to many child protection cases.[1] This factor serves as a chief incentive for the development of efficient and effective drug testing techniques. In the past, self-reporting has been a widely used source of information pertaining to drug use in pregnancy, both for pre- and post-natal periods.[2] Due to the social stigma associated with drug abuse and addiction, especially in the circumstance of pregnancy and parenting, self-report is typically elusive and considered an inaccurate mode of substance abuse monitoring when compared to objective measures of drug consumption.[3] For this reason, social workers, researchers and physicians working in the realm of child protection alike have turned to toxicological analysis of body fluids/tissues to provide objective evidence of drug use and/or exposure.

Toxicology is the science of the adverse effects of drugs and poisons. Analytical toxicology is a sub-field that specifically deals with the science of detecting drugs and other toxic compounds in matrices such as urine, saliva, blood, and hair. The employment of these methods can offer a wealth of information pertaining to drug use/exposure however some background knowledge is important to understand what methods are applicable to specific types of situations and for the correct interpretation of results.

Basic Principles of Drug Presence in the Body

The duration of a drug's presence, or how long it persists in the body is dictated by a fundamental set of pharmacokinetic principles (*pharmaco* = "drug", *kinetic* = "movement"), namely; absorption, distribution, metabolism, and excretion. An important guiding canon when attempting to understand drug test results is that every drug (and even different preparations of the same drug) will be unique in each of its pharmacokinetic features. Due to this variability among drugs and the way they are handled by the body, access to toxicological expertise is of the utmost importance when developing a substance abuse monitoring program.

The route of administration or how the drug is taken mainly dictates the absorption of the drug into the body. Drugs taken orally (by mouth and swallowed) tend to be only partially absorbed through the gut and are subjected to significant metabolism by the liver before reaching the brain. Inhaled drugs, such as "crack" cocaine, "crystal meth", cannabis, and nicotine are absorbed into the blood via the lungs and are directed immediately from the lungs to the brain (as the

body is designed to carry oxygen to the brain first) and exhibit an immediate effect and high efficiency of absorption.

Once a drug is absorbed, it is distributed to various tissues and organs around the body and mainly exerts its effect on the brain. It is then subjected to metabolism by a large host of drug-metabolizing enzymes located primarily in the liver but also throughout the body. Genetic variability in the expression of drug-metabolizing enzymes plays a large role in the observed varying responses to the same amount of drug by different individuals; therefore this variability can alter drug intake from person to person while the overall effect achieved by the drug might be equivalent [4-7] A drug may be excreted from the body in a variety of ways; for example, through breath, sweat, urine, stool, and hair. Substance abuse monitoring is essentially the assessment of these matrices for excreted drugs. Detection windows exist that are specific to both drug and matrix. This is the primary information determined through drug testing; due to the fact that drugs will be present in a specific matrix (i.e. urine, hair) for a known amount of time, we can determine if a client or patient used a drug during that specific time period (relative to sample collection).[8] Table 1 may serve as a quick reference for broad detection windows of drugs in these matrices; however, caution should be exerted in solely relying on such information as numerous exceptions apply with respect to different drugs and situations.

TABLE 1 Quick reference guide to applicability and detection windows for drug testing methods suited to Social Services casework

Specimen (matrix)	Duration of Detectability	Social Service Applications
Adult Scalp Hair	Hair growth ~1 cm / month As many cm of hair present on scalp equated in months	Suspicion of drug abuse or exposure (i.e. handling of drug); **constant** drug monitoring over long periods of time
Children's Hair	Hair growth ~1 cm / month As many cm of hair present on scalp equated in months	Suspicion of drug abusing caregiver; suspected contaminated environments; suspected administration of drug; **constant** drug exposure monitoring over long periods of time
Neonatal Hair	Last trimester of pregnancy	*In utero* drug exposure (maternal drug use) in the last trimester
Meconium	Second and/or third trimester of pregnancy	*In utero* drug exposure (maternal drug use) sometime after the 12th week of pregnancy
Adult Urine	Few hours–days–weeks (depending on drug, see ***Table 2***)	Rapid and convenient point of care testing. determines drug use in the recent past (last 2-4 days); drug monitoring over short periods of time; verify suspicions of drug use prior to child access visits
Child Urine	Few hours – days	Post-apprehension from very high-risk environments (e.g. 'crack houses', 'meth labs' or suspected drug administration) to determine risk of systemic drug exposure
Saliva	Few hours–days (depending on drug)	Point of care testing to determine drug use in very recent past (i.e. to screen high-risk individuals prior to child access visits)

Dose Estimation

The most commonly asked question by social workers when assessing drug test results is, "*how much drug did this person use?*" This question is essentially unanswerable by any existing toxicological method. Due to inherent variability in the absorption, distribution, metabolism, and elimination of drugs, subject not only to the unique characteristics of the drugs themselves, but also the user (physiological and genetic status)[9], it is impossible to ascertain exact doses taken. Co-administration of other substances may further alter the distribution and metabolism of the drug in question.

Beyond the physiological variability involved, even accurately obtaining dose information or self-reports from willing patients can be highly problematic. The definition of 'a single use' or 'one relapse' may vary considerably from person to person; on one hand, it may indicate one pill/line/hit of the substance in question, while on the other hand it could indicate a single binge episode or series of binge episodes over several hours, days, or weeks. In addition to differing definitions of "one-time" use, the lack of regulation in illicit substance production and distribution means that the purity and content of the drug in question varies from dealer to dealer and from batch to batch. In fact, it was discovered that the primary cause of heroin overdose was due to increases in drug purity that were unknown to the users.[10-12] Moreover, studies conducted on seized drugs have shown that when purchasing, for example, MDMA (i.e."Ecstasy") on the street, one may actually be receiving a pill composed of amphetamine, methamphetamine, MDA, or a variable combination of these amphetamine derivatives and other substances.[13,14]

Ultimately, depending on which toxicological methodology is used, the primary questions that <u>*can*</u> be answered through drug testing are:

1. what drugs did this person use;
2. approximately when did this person use those drugs; and,
3. what is this person's average level of drug use/exposure.

This report addresses some of the most commonly asked questions regarding blood, urine, hair and meconium analysis, and provides an overview of various other specimens used for toxicological assessment. Reviewed is the applicability of different drug testing methods in assessing parental drug abuse, determining passive exposure to drugs in the children of drug users, and the assessment of prenatal drug exposure.

Methods of Drug Use Monitoring

Blood Analysis

Testing blood levels for a drug and/or its metabolites may be applicable in acute toxicity cases (i.e. medical emergencies), primarily because blood drug levels are detectable for only a short period of time after intake. The detection of illicit substances in blood heavily relies on the time elapsed post-ingestion and the detection of drugs in blood generally does not confer quantitative information pertaining to dosage. Drugs are eliminated quite rapidly (within minutes to hours) to undetectable levels after administration[15], making blood analysis of drugs relatively useless in a substance abuse monitoring situation. Moreover, the invasive nature of blood sampling makes this method of testing undesirable. Testing umbilical cord blood to determine prenatal exposures possesses similar drawbacks with respect to the narrow window of detection of most drugs, thereby limiting its use.[16]

Sweat Analysis

Sweat analysis involves the adhesion of a sweat-patch to the skin of the monitored individual and has been employed to constantly monitor drug abuse behaviour. A critical drawback to sweat testing is the difficulty behind determining the volume of sweat produced in a given period of time. This volume can vary inter-individually as well as intra-individually due to environmental cues, as well as the mental and health status of the patient.[17] Moreover, issues with the site of patch placement as well as patient cooperation have been shown to compromise the reliability of sweat testing.[18,19]

Saliva/Oral Fluid Analysis

Oral fluid has been regarded as more desirable than blood due to a less invasive collection procedure and somewhat prolonged window of detection. Saliva is a filtrate of blood: drugs present in the blood are filtered by the salivary glands and passed into the saliva. As a result, saliva portrays the toxicological profile of blood. Therefore, the detectable presence of many (but

not all) drugs in this specimen is longer than that of plasma, with windows of detection approximated at around 5 days in chronic users.[20-22] However, if drug administration occurs via the oral cavity (the mouth), the concentrations of drug detected in the saliva may be unrepresentatively increased.[17] The transient nature of drugs present in saliva implies that this methodology is not optimal for long-term substance abuse monitoring due to the inconvenience and the high cost related to collecting samples every few days. A valid potential application for oral fluid analysis, which is particularly sensitive and useful for the assessment of recent drug use, is in screening of high-risk individuals prior to child access visits. Point-of-care, easy-to-use, rapid-result testing kits for oral fluid have been developed, primarily in the interest of road-side testing to address drug-impaired driving.[23-24] While the results obtained by these kits themselves generally do not meet requirements for admission into trial evidence, a positive result can prompt an on-site urine sample collection which can confirm the initial findings and be submitted as evidence of recent drug use. It is prudent to note that this type of access-visit screening would primarily be useful and reliable for drugs such as cocaine, methamphetamine, and methadone.[25] The detection of cannabis in saliva can be very elusive with extensive report of false positives and negatives alike, therefore this method of evaluation is recommended to be confirmed with urine analysis.[26]

Urine Analysis

Urine toxicology is useful for detection of recent exposures to numerous illicit substances due to its rapidity and convenience. Like saliva, urine is also a filtrate of blood: drugs present in the blood are filtered by the kidneys and concentrated in the urine. Due to this concentration of drugs in a relatively small volume of urine, drugs that are undetectable in the blood several days after use will still be detectable in a urine sample. Moreover, the relatively short detection window for most drugs of abuse in urine (generally 1-5 days post-use) requires that twice weekly testing should be employed- with samples collected no more than three days apart- to be effectively reliable. Some drugs may even require sample collections up to three times weekly or even daily testing for adequate reliability.[27,28] Table 2 summarizes commonly abused drugs (street drugs and prescription medications) and their detection windows in urine.

In summary, urine analysis is highly sensitive at detecting drug use that has occurred within a few days prior to sample collection. Due to the availability of rapid testing, urine is particularly useful in high-risk situations that demand constant monitoring over relatively short periods of time (e.g. post-intake with a high-risk individual to assist in determining custody decisions in the short-term). If diligently testing two to three samples per week, monitoring through urine analysis is quite feasible over a condensed term (e.g. 2-4 weeks). However when monitoring individuals over periods of months and/or years, as is quite common in child protection cases, twice weekly urine analysis becomes very costly and unsustainable as evasive actions by patients is a common issue. Any missed sample collection provides a "blind spot" in the monitoring record during which undetected drug use could have occurred. Supervised urine sample collection is highly recommended as monitored individuals frequently dilute or provide adulterated samples (e.g. masking or interfering agents added to urine samples), or provide false samples (e.g. stored urine from a child, friend, or pet).[29] Overall, urine testing certainly plays a large role in substance abuse monitoring, but child protection workers and authorities must be mindful of the inherent drawbacks urine analysis possesses.

Hair Strand Analysis

Hair strand analysis has proven to be particularly effective and economical as a method of substance abuse monitoring in a child protection context. Drugs present in the blood stream are incorporated into the growing hair shaft through the capillary blood supply to the follicle. Compounds trapped inside the hair shaft are protected from degradation by the external environment, and since hair grows at a semi-uniform rate across the population, hair analysis enables the determination of a retrospective timeline of drug exposure.[30] The degree to which a drug is incorporated into the hair shaft depends on the physiochemical properties of that drug, how it interacts with certain proteins in the hair, and the structural integrity of the hair strand itself.

TABLE 2 Duration of Detectability of commonly abused drugs (and their metabolites) in urine

Drug	Commonly Used Street Names / Prescription Medications‡	Duration of Detectability
Cocaine **Crack Cocaine†**	Base; Black Rock†; Blow; Cola; Crack†; Dice†; Grit†; Ice; Nose Candy; Nuggets†; Paste†; Sleet†; Snow; Space†; Talco;	6 – 8 hours for cocaine; 2-5 days for metabolite (benzoylecgonine)
Methamphetamine **MDMA¤**	Crystal Meth; Ecstasy/E¤; Fast; Ice; Pink [elephants] Rave energy¤; Smurfs¤; Trash; Yaba; XTC¤	2-3 days
Amphetamine	Black and White; Blue Devils; Diet Pills; Eye Openers; Horse Heads; Rippers; Snow; Uppers	2-3 days
Barbiturates‡	Amobarbital; Butalbital; Pentobarbital; Phenobarbital; Secobarbital	24 hours – 16 days (short vs. long acting)
Benzodiazepines‡	Bromazepam; Clonazepam; iazepam; Lorazepam (Ativan®); Oxazepam;	14 hours – 7 days (short vs. long acting)
Opiates‡	Codeine (Tylenol® No. 1-4, Codeine Contin®) Morphine (Kadian®, MS-Contin®); Oxycodone (Percocet®, Percodan®, Oxycontin®)	~ 1-2 days
Heroin	Al Capone; Aries; Chip; Diesel; Junk; Mac; Pure; Red Rock; Smack	2 – 4 hours for metabolite of heroin (6-Monoacetylmorphine);
Methadone‡	Fizzies	7 – 9 days
Cannabinoids **(Marijuana)**	Cheeba; Chronic; Dope; Ganja; Herb; Joint; Mary Jane; Pot; Roacha; Sasfras; Spliff; Swag; Weed	3 days single use; 10 days heavy use; up to 36 days chronic heavy use
Phencyclidine	Angel [dust, mist, hair]; Crazy coke; Crystal joint; Magic [dust]; Super [joint, weed] Zombie	8 days
Ethanol (Alcohol)	Booze, Hooch, Juice, Sauce	~ 12 hours (after a binge episode) **~ 80 hours (Ethylglucuronide- alcohol metabolite)****

Adapted from: Canadian Pharmacists Association: Compendium of Pharmaceuticals and Specialties – The Canadian Drug Reference for Health Professionals. 2003; Office of the National Drug Control Policy. Street Terms: Drugs and the Drug Trade, Executive Office of the President (US). 2006; Wolff et al., 1999

* Examples of common names which may exist to represent multiple types of drugs of abuse;
‡ Generic drug name (trade name in brackets if available)
****Available only in select laboratories world wide**

Hair sample collection is particularly easy and non-invasive, and most importantly, it is nearly impossible for the patient to compromise sample integrity. Contrary to urine, which is generally sampled in private and given to the collector thereafter, hair samples are collected directly from the scalp of the patient by the sample collection agent (e.g. technician, nurse, physician, etc.). This feature of hair testing and the maintenance of sample integrity is a significant benefit in substance abuse monitoring. Hair samples are generally collected from the vertex posterior (i.e. "crown") of the scalp, as this is the location of the most uniform hair growth in humans. If scalp hair is unavailable, body hair can be sampled such as arm, leg, armpit, chest, or pubic hair. It is important to note however, that body hair analysis provides much less interpretative value than head hair due to more inter individual variability in rates of growth, shedding, and drug incorporation.[30] Additionally, reference ranges available from some laboratories for interpretation purposes are usually for scalp hair only and therefore would not be applicable to body hair. That body hair analysis can tell us is if someone has or has not used a particular drug in "the recent past". Essentially, body hair provides a qualitative analysis indicating if the individual has a recent history of drug use.

The international standard assigned to human scalp hair growth is one centimetre per month (Society of Hair Testing, 2004). By assessing the analysis in terms of length of hair versus the concentration of drugs found, the average pattern of drug use/exposure over relatively long periods of time can be determined. This is achieved by comparing sample results collected once every few months or by conducting segmental analysis of a single hair sample. Segmental analysis is carried out by cutting the hair into a series of sections of defined length, representing a chronological sequence of specific time-frames (e.g. 1cm = one month, 3cm = three months). Consequently, toxicological analysis of the segment closest to the scalp represents the most recent drug exposures, as diagrammed in Figure 1.
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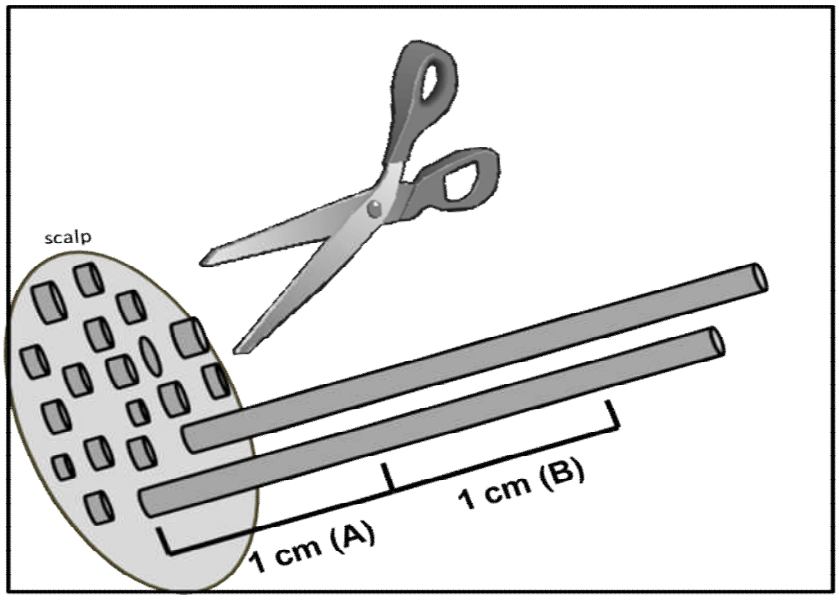
FIG. 1 Average Rate of Hair Growth and its Application to Sampling



Hair is cut as close to the scalp as possible, and segmented for analysis. The first 1 centimetre segment **(A)** represents the month prior to sampling. The second centimetre segment **(B)** represents the month before A, and so on.

Subsequent segments represent earlier time periods, thereby describing changes in the average intensity of drug use from one period to the next (counting backward). It should be noted that these time period are *approximated* based on a consensus standard hair growth rate: time frames cannot be considered exact to the day or week.

Although the primary route of drug deposition into the hair is through the blood, dugs can also be deposited via sweat and sebum. Additionally, drugs may also be deposited onto the external part of the hair shaft through environmental contaminants such as smoke and residues[31,32]; this is of particular importance for the determination of frequent second-hand drug exposure for both caregivers and young children. The degree to which a drug is incorporated into the hair shaft depends on the physiochemical properties of that drug, how it interacts with the hair, its primary route of deposition, and the structural integrity of the hair strand itself. For instance, cannabinoids have been found to incorporate poorly into the hair (relative to other substances) just by virtue of the chemical structures and the way they interact with the hai.[30] Alternatively, once deposited into the hair, cannabinoids are harder to remove through aggressive chemical treatments such as bleaching.[33] Overall, cocaine is thought to have the highest incorporation rate into hair and cannabinoids have the lowest.[34] Therefore, while a positive hair test result for cannabinoids gives strong evidence for marijuana use, a negative finding should not rule it out.

Just as there are a variety of processes for drug deposition, there are also processes that contribute to the removal of drugs from hair. While regular shampooing is not considered a major contributor to the removal of drugs, aggressive cosmetic agents can variably decrease drug concentrations. Studies vary in their observations, but overall it is estimated approximately 30-60% of drug content can be removed through cosmetic hair treatment; cannabis is least affected followed by cocaine and then opiates (such as morphine).[33,35] The extent of such removal is thought to be highly dependent on original concentrations of drugs as well as conditions of the hair strand (i.e. severely damaged and porous vs. relatively healthy and structurally integral).[36] Overall, while the deposition, retention, and stability of drugs in hair is considered good, it is by no means perfect and is likely a large source of variation among hair test results. The type of drug tested, mechanism of incorporation and removal, and sources of environmental exposure should all be considered in devising the most accurate interpretation of such results. Ultimately, while cosmetic hair treatment can reduce the levels of drugs determined through hair analysis, false negative results are rare and regular drugs users are generally still identified.

Meconium Analysis

Meconium is the contents of a neonate's first few bowel movements and is characterized by a dark, shiny texture and lack of odour. Meconium begins to form during fetal life around the 12th week of pregnancy, corresponding to the time frame of initiation of fetal swallowing.[37] Drugs and alcohol metabolites (Fatty Acid Ethyl Esters or "FAEE") are incorporated into meconium through their presence in the shared maternal-fetal circulation and concentrated in meconium through fetal swallowing and digestion of amniotic fluid.[38] The fetus may also release drug-containing urine into the amniotic fluid that is later swallowed and subject to metabolism in the gastrointestinal tract (and therefore deposited into the meconium).[39]

Evidence that formation of meconium begins around the 12th week of pregnancy translates to the notion that drugs and FAEEs are thought to accumulate throughout the remainder of the pregnancy (i.e., the second and third trimesters) until delivery, at which point the meconium is passed and can be sampled for analysis. Recent data has emerged indicating that third trimester exposure to drugs is more closely associated with positive meconium results than second trimester exposures. This suggests that while it is possible both the second and third trimester are represented in a meconium sample, the meconium drug-positive neonate is at a higher risk for late pregnancy drug exposure.[40]

Meconium is optimally collected within twenty-four hours of birth; however some neonates are known to pass meconium for several days after birth thereby enabling later sample collection. After three days post-partum, it is highly unlikely that meconium will still be

available: the newborn will likely have started to pass stool which results from post-natal digestion and no longer reflects *in utero* exposures.[41-44]

Determining Drug Exposures in Pregnancy and Breastfeeding

The persistence of substance abuse is particularly illustrated by the fact that pregnancy does not appear to deter women from using drugs. Estimates from the United States' National Survey on Drug Use & Health state that among pregnant women aged 15 to 44 years, 5.1% used illicit drugs in the past month (based on data averaged for 2007 and 2008), and 10.6% were currently using alcohol. One study based on another national home survey found approximately 2.8% of all pregnancies were affected by illicit substance use and that cocaine constituted 10% of this.[45] Moreover, prevalence rates for prenatal methamphetamine use have been found to vary from 0.7 – 5.2% and appear to be on the rise.[46,47] Canadian studies conducted in the general obstetric population reflect similar trends: over 6% of babies were exposed to maternal cocaine use within the last trimester of pregnancy and 3% of babies were born to mothers who regularly consumed alcohol after the first trimester.[48,49]

While the detrimental *in utero* effects of drug abuse on the neonate are well documented — approximately 75% of drug exposed infants required medical attention for major problems as compared to 27% in non-exposed infants[50] — it remains unclear whether these problems may be directly attributed entirely to the drug itself or to other risk factors associated with maternal drug abuse.[51] Pregnant women who abuse drugs often have little or no prenatal care, are frequently of low socioeconomic status, have inadequate nutrition and live in unaccommodating environments.[52] What's more, *in utero* exposure to substances such as opiates, benzodiazepines, barbiturates, or alcohol may precipitate withdrawal, albeit featuring mostly treatable symptoms in the neonate.[53,54]

In utero alcohol exposure is of particular concern as prenatal alcohol exposure is the only drug of abuse that is known to cause a diagnosable disorder. While neonatal withdrawal from other substances such as opiates is generally short-lived and highly treatable, the adverse clinical outcomes related to prenatal alcohol exposure far exceed those related to any other drugs of abuse.[55,56] Fetal Alcohol Spectrum Disorder (FASD) is a continuum of adverse neurodevelopmental outcomes associated with prenatal alcohol exposure. Approximately 40% of alcohol-exposed neonates are estimated to be affected by FASD with approximately 4% exhibiting the features and severe delays of the full-blown Fetal Alcohol Syndrome.[57,58] It is important to note that just because a newborn was alcohol-exposed does not mean they have FASD; mislabelling of a child can have significant adverse effects on their development as well.[59,60] Newborns determined to be prenatally exposed to alcohol should be followed up prior to six years of age with a comprehensive neurodevelopmental assessment to determine the presence/absence of FASD.[61-63]

There are a select few methods that are specifically useful for the assessment of prenatal exposures. The speed and likelihood of drug incorporation into different tissues and fluids is dependent upon those specimens' properties and the physiochemical properties of the drug in question.[64] Traditionally, both maternal and neonatal urine can be tested for drugs of abuse however relatively short detection windows of drugs in urine should be kept in mind. Though a positive result is very striking, indicating drug use essentially within days of delivery (with the exception of marijuana and long-acting prescription formulations; *see* Table 2), a negative result provides little reassurance of long-term gestational abstinence, especially if additional evidence (e.g. third-party reports, etc.) indicate use of drugs in pregnancy.

Neonatal hair and meconium have been recognized to be particularly useful for the long-term and sensitive detection of drug use/exposure in pregnancy.[65] Meconium analysis can provide evidence of the average level of drug exposure over the last two trimesters of pregnancy. Meconium FAEE analysis can provide clinically valuable evidence of prenatal alcohol exposure, which can be invaluable in diagnosing FASD later in life. Neonatal hair is a unique and valuable matrix when evaluating *in utero* drug exposure. Akin to maternal hair, follicular incorporation of drugs into this specimen is an important mechanism of deposition; however deposition from the drug containing amniotic fluid plays a significant role as well.[66] Neonatal hair begins to

grow at approximately 28 weeks *in utero*, reflecting late pregnancy drug use at a time where the mother most likely knew she was pregnant.[67] This highlights that use of illicit or non-prescribed drugs during the last trimester was occurring, which is a strong risk factor for possible maternal addiction to these substances. Moreover, neonatal exposure to drugs in pregnancy, especially late pregnancy, may precipitate undesirable symptoms in the neonate- both immediately following birth and long-term- and must be considered.[68,69] One study found that for cocaine, benzoylecgonine, and cannabis, meconium testing seemed to be more sensitive (95% and above) than neonatal hair testing for the detection of *in utero* exposures.[70] This may be partly explained by the earlier formation of meconium compared with hair (roughly the second trimester compared with the third trimester). A significant advantage to neonatal hair testing, however, is that the prenatally grown hair can remain on the infants scalp up until 3-5 months post-partum. This allows for the determination of prenatal drug exposure history well after birth and after the short window for meconium collection has passed.[70]

Social workers concerned with infant exposure to drugs through breast-milk often inquire on the availability of breast-milk analysis for drugs of abuse. The usefulness of breast milk has yet to be fully evaluated. Limitations innate to this biological fluid are common to those previously mentioned, such as invasive sample collection, timing of exposure vs. sampling, as well as inconsistent matrix composition and drug excretion.[71,72] Essentially breast-milk analysis is of little value to determine safety of breast-feeding in real-time. More universally available rapid-turn around or point-of-care testing of urine or oral fluid is a much more viable alternative to determine safety of breast-feeding: if drugs are present in the breast-milk, they must be present in blood; if present in blood, they will be present in urine or oral fluid.

Determining Drug Exposures in Children

Environmental Drug Exposures

One of the major benefits of hair analysis is that it not only provides information about active drug use, but because the hair is located external to the body, it can absorb valuable information about environmental drug exposure. This is of particular benefit when assessing child safety concerns due to parental drug use.

In routine cases where frequent parental drug use is suspected, the analysis of child hair can provide valuable information regarding the drug use behaviour occurring in the home. The presence of drugs in a child's hair indicates that caregiver drug use is occurring within the context of caring for the child. One of the most common arguments put forward when a parent is accused of drug use is that they are "only using recreationally, when out of the house- never around the children." Analysis of children's hair can provide evidence supporting or disproving such assertions.

Children are much more sensitive to picking up environmental exposure to drugs than adults are, likely because they are so frequently handled. Minute drug residues present on a caregiver's hands and/or clothing after use will be transferred to a child's hair if they are handled shortly after drug use occurred. Moreover, routine hygiene will remove externally deposited drugs over time, therefore, when a child's hair tests positive, this indicates a high risk that this child is repeatedly exposed to drugs passively in their environment.[73] The fundamental conclusions that can be drawn from a positive hair test in a child are as follows:

1. This child has a caregiver who is a regular user of the drug in question
2. This child's home environment may be contaminated with drug residues or drug smoke
3. This child may be at risk for drug ingestion or inhalation.

It is important to recognize that while drug ingestion may be identified as a risk, it is much less probable than scenarios 1 and 2 listed above. The presence of benzoylecgonine (cocaine is converted to benzoylecgonine by the body after administration of the drug) is generally an indicator of active cocaine use in adult hair samples, however it is often present in child hair samples in the absence of any drug intake.[74] In children, especially infants and toddlers, frequent handling by regular cocaine users can result in the transfer of benzoylecgonine present in caregiver sweat to the child's hair. This means that while the presence of benzoylecgonine in a child's hair

sample may indicate ***a risk*** of systemic (i.e. internal) cocaine exposure, it is likely only present as a result of external passive exposure to cocaine. In approximately 90% of cases where a parent's hair test result is positive for cocaine, the children in the home test positive for cocaine as well.[74]

Due to a number of factors, it is common for older children in families with cocaine-using caregivers to exhibit lower results than their younger siblings.[32] First, in the case of passive cocaine smoke exposure, very young children have higher respiratory rates than older children and adults, making passive inhalation more significant with decreasing age. Second, older children are handled less, and therefore have a lower rate of cocaine transfer via hand-to-hair contact with drug using caregivers. Third, older, school-age children tend to spend less time in the family home and therefore have a lower average duration of exposure to the cocaine-contaminated environment.

It is important to bolster one's understanding of the child's level of risk by incorporating information from the home inspection into the assessment of positive hair test results. For example, does the home smell like smoke? If the answer is yes, this significantly raises the risk of inhalational exposure. If caregivers are smoking their cigarettes inside, they are more likely to be smoking their other drugs (e.g. cocaine, marijuana) inside as well. If the home does not smell smoked in, then caregiver-handling (soon after drug use) is the more plausible explanation for the positive results.

High-Risk Situations: Drug Houses and Possible Drug Ingestions

In the rare instances when children ingest drugs of abuse, be it accidentally or through intentional administration, the medical, child welfare, and often criminal justice fields finds themselves thrown together in assessing the situation. In such instances, consulting individuals with toxicological expertise is paramount in order to effectively investigate and obtain timely biological evidence. For children and infants living in homes where drugs are abused, the potential for passive exposures to these substances has been assessed to be a valid point of concern.[75-79] For example, passive inhalation of 'crack' cocaine by the paediatric population has been found to be more common than once thought and can precipitate a variety of dangerous outcomes, including but not limited to seizures and obtundation (i.e. sensory loss), delirium, and can also be fatal.[80-82] In many of these situations, exposure to drugs was confirmed by urinalysis in hospital. Urine testing may be conducted in such cases when children who present in emergency departments have suspicious or unexplained symptoms.

The presence of drugs in an ill child's urine would indicate recent and systemic exposure to the drug likely related to the current medical event. The urine test, however cannot determine if the presence of the drug in this child's system is an isolated incident or a chronic ongoing concern. Hair testing is a valuable complementary analysis in these situations, as it would offer long term information regarding such environmental exposures or ingestions.[83] In many of the documented cases, it was found that children were being exposed to toxic concentrations of free-base 'crack' cocaine smoke in their immediate environment preceding their experienced morbidities, implicating [an] individual(s) (not necessarily the parent) in the vicinity or in the environment of that infant or child.[84] Since accurate drug exposure histories are often incomplete or omitted by parents implicated in these types of cases, health professionals and authorities must be vigilant in their assessments of such children. Suspicion of children residing in contaminated environments should be actively assessed through any means possible to rule out potential toxicological hazards and exposures.

Accidental ingestion or intentional administration of drugs of abuse in the paediatric population has also been reported in the literature and is of even greater cause for concern. When these children present to emergency rooms, quite ill and occasionally in life threatening conditions, accurate histories are commonly omitted by the caregivers for fear of judicial repercussions, thereby dangerously delaying the appropriate clinical care. For this reason, some common clinical findings such as cardiovascular and neurological symptoms as well as management tips for such patients have been outlined in the literature.[85] A handful of fatalities and intoxications have been documented regarding infants' ingestion of these substances, the most common including MDMA (ecstasy)[86-89] and cocaine.[90,91] There have been disturbing reports of

an intentional and repetitive administration of cocaine to a toddler as revealed by hair testing[92] as well as reports where an older sibling has gained access of free-base "crack" cocaine in the home and unknowingly fed it to his younger sibling.[91] In the latter case, the drug itself ("crack" cocaine) was discovered in the duodenum (or small intestine) of the child during forensic examination (as it was a fatality).

For the aforementioned reasons and possible scenarios, it is advisable to conduct hair analysis on children in homes where caregivers are suspected to be regular drug users. Positive findings will indicate that drug use is occurring in the context of parenting. If at all possible in higher-risk situations, such as the apprehension of children from a 'crack house' or 'meth lab' environment, urine samples should be collected from these children immediately following their removal from that environment. Hair and urine analyses are complementary methods, and in children who have possibly inhaled extensive amounts of cocaine, marijuana, or methamphetamine smoke, obtaining evidence of internal/systemic exposure through urinalysis as well as chronic environmental exposure through hair analysis may be very valuable in determining the level of physiological risk involved.

Confirming Abstinence of a Caregiver through Toxicology

The Detection of Metabolites and their Significance

When drugs of abuse or pharmaceutical agents are ingested, they are broken down, transformed, or conjugated with other molecules to create a variety of different compounds. These collectively are termed metabolites, and can aid in the accurate determination of active vs. passive drug exposures in an extracorporeal matrix such as hair. The presence of metabolites in a hair specimen indicates the *in vivo* conversion from the parent drug, giving evidence of active drug use.

Benzoylecgonine is the primary metabolite of cocaine that is found in the urine of cocaine users. When one actively uses cocaine, it is converted in the body to benzoylecgonine (as well as other metabolites) very rapidly. Benzoylecgonine and its parent compound (cocaine) present in the blood are incorporated into the growing hair shaft at the follicle; it is always tested for in conjunction with cocaine to assist in determining whether the individual actually *used* cocaine or was passively exposed to it.

The concentration differences found in different matrices (e.g. urine, hair, meconium, etc.) evident between parent drugs such as cocaine and their metabolite(s), such as benzoylecgonine, depend on the physiochemical properties of the different compounds and how these properties influence their entry into the respective matrix. The properties of benzoylecgonine and the way it interacts with the cells that make up the hair shaft does not allow integration of this molecule as efficiently as cocaine; therefore we see significantly less metabolite when compared to the parent compound.[93] In addition, small amounts of cocaine can spontaneously hydrolyze or transform into benzoylecgonine without the need for active metabolism of the parent compound. For this reason, a cut-off ratio has been established in order to differentiate between passive environmental exposure and active use of cocaine. Evidence of active use requires that the concentration of benzoylecgonine be at least 5% of that of cocaine.[30]

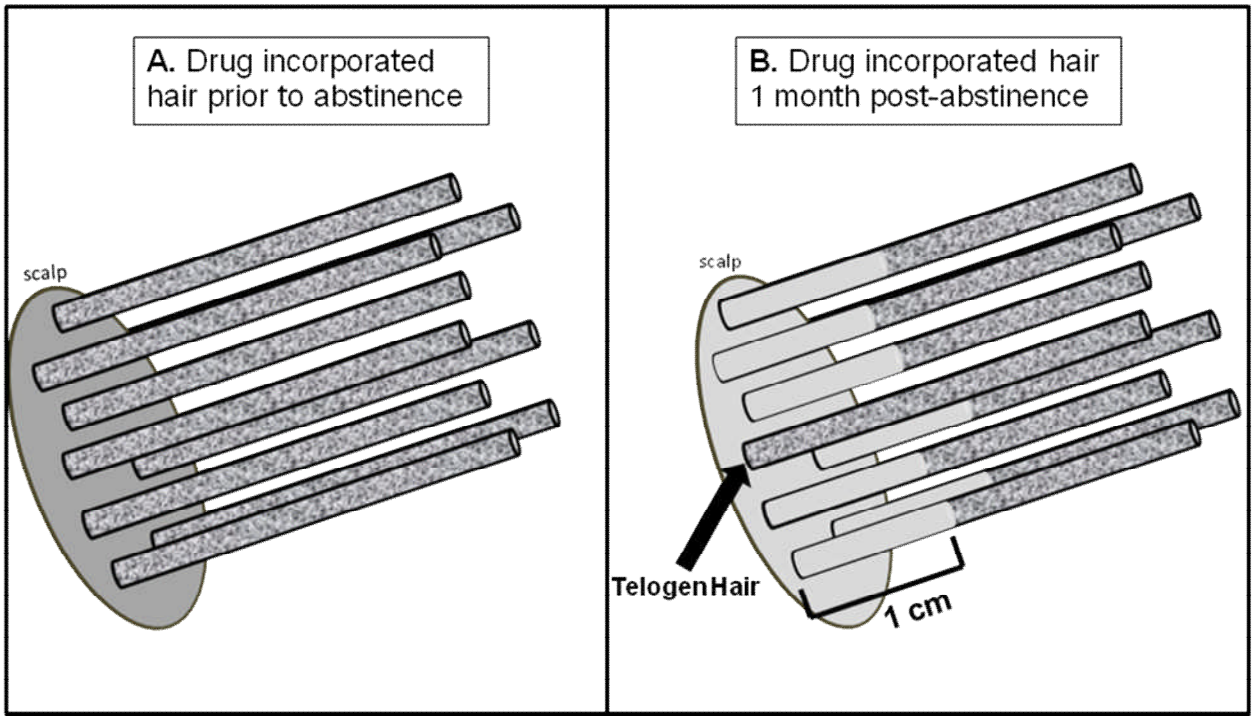
Alternatively, in meconium we may see a greater amount of benzoylecgonine than cocaine. The reason behind this difference has not yet been fully elucidated, but may be attributed to extensive maternal and fetal metabolism.[94] What's more, the physiochemical interaction between benzoylecgonine and meconium differs, perhaps favourably, than that of hair and the respective metabolite. Of course, the importance of metabolite detection in meconium is not related to distinguishing passive exposure from use, as meconium (like urine) is not exposed to the external environment and only represents systemic drug exposures. The detection of metabolites in meconium increases the sensitivity of testing as well. For example, there are many cases where cocaine may be absent from meconium, but benzoylecgonine is detected, thus identifying the child as prenatally cocaine-exposed whereas analysis of cocaine alone would have missed this observation.

Recent Abstinence and the Residual Phenomenon in Hair Analysis

The residual presence of drugs after abstinence in the segment closest to the scalp has received more

attention in recent years. As a result, research has been dedicated to uncover the pattern of such a phenomenon, and correspondingly it is becoming more understood. It has been well established that each hair follicle grows independently from its neighbour. Additionally, each follicle may exist in any of three possible growth phases at any given time: *anagen, catagen, or telogen*. Anagen is considered the active growth phase of the hair cycle, usually lasting from 2-6 years while telogen is a resting phase where the hair follicle stops growing for 2-6 months after which the hair falls out. Catagen is a transitionary phase and is negligible since it only lasts about 2-3 weeks. Since approximately 10-15% of scalp hair is estimated to be in the resting or telogen stage[30], it is possible that this subset of hairs may retain old drug use history in newer segments, as seen in Figure 2.

FIG. 2 The Residual Presence of Drugs Post-Abstinence



A. Prior to abstinence from drug use, drug molecules are incorporated into the growing hair shaft.
B. 1 month post-abstinence, approximately 10% of telogen (non-growing hairs) contain old drug use history in the newest 1 cm segment

One case report described that when controlling for drug use through the employment of concurrent urine analysis, it took a female cocaine user 3 months post-abstinence for the segment closest to the scalp to be drug free.[95] Supporting this finding, we recently examined a cohort of nearly 140 samples with rapidly decreasing concentrations of cocaine and found 3-4 months worth of hair had to pass before the sample was negative.[96] Of course, this information should not be interpreted as a definitive guideline for post-abstinence drug patterns in hair since small concentrations may also indicate less, albeit, continued active use. Collectively, the evidence should be used as a tool for the most accurate interpretation of results. Careful consideration of each case must be made to try and differentiate between residual drug presence and low level of use and this often requires expertise in the field.

Essentially, what is important to keep in mind is that:

1. Immediately after abstinence, individuals may still test positive for drugs in their hair.

2. Having prior hair analyses available (e.g. from the time of intake) is highly beneficial in interpreting results. While drugs may still be present in the hair post-abstinence, the precipitous drop in concentration is well characterized and identifiable by an expert.
3. It is very important to access toxicological expertise where possible to ensure correct interpretation of results and to avoid undermining abstinence efforts.

Conclusions/Recommendations

We have described the ability of traditional and alternative matrices to effectively detect drug exposures in vulnerable populations. If prenatal drug exposure is suspected, it is recommended to collect at least one or a combination of fluids/matrices for toxicological testing. In the face of strong suspicion of drug abuse, it is advisable to keep in mind that if short-term matrices (e.g. blood, urine) return negative findings, that alternative long-term matrices (e.g. meconium, hair) are available for analysis and should be sought. Neonatal specimens have their drawbacks as well as their advantages as outlined in the text, and issues concerning collection, storage, and types of drugs able to be tested deserve great consideration. Most importantly, such adequate and meaningful toxicological testing can assist physicians, support staff, and social service workers in making appropriate decisions regarding the child's wellbeing and future.

Testing adults requires vigilance for both short and long-term periods, as well as the discretion of passive exposure versus active drug use. Segmental hair analysis or a program of hair sampling every few months on an individual can provide valuable information on changes in average drug use behaviour. Results may be compared to the client's own previous hair tests, or compared to a compendium of results derived from a uniform population (i.e. from the social services) tested in the same laboratory. Variability of test results produced by different laboratories can play a role in the respective interpretation and must also be considered. Consultation with appropriate laboratory personnel regarding interpretation of test results is not only ideal, but strongly recommended. It is clear that for toxicological results of urine, hair, and meconium analyses to be useful and accurate to child welfare workers, one must understand the basic concepts behind these methods. It is also particularly advisable that one should access expertise via consultation wherever possible. Here, we have explored a collection of important topics encountered in the domain of drug testing and unfortunately these are just a few of many issues that require great consideration when interpreting results. Since inherent advantages and limitations to such analyses do exist, the application of that basic knowledge behind such matrices should adequately determine the usefulness of individual results. While some cases will yield straightforward answers, we have found that many are much more complex. In these situations, it is often wise to consult a counsellor, technician, or toxicologist in the field in order to most accurately determine the client's drug use or abuse and/or prenatal drug exposure.

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