The Future of Hair Testing: Fingernail?

Joseph Jones, MS, NRCC-TC
EDUCATIONAL OBJECTIVES

- Brief history of hair testing
- Discussion of limitations of hair testing
- Advantages of nail testing
- Anatomy of nail and nail formation
- How drug and drug metabolites are incorporated into nail
- Comparison of hair and nail
- Case studies
National Survey of Drug Use and Health
Illicit Drug Use Ages 26 and Up

Prevalence (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Past Year Use</th>
<th>Past Month Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>10.8</td>
<td>6.3</td>
</tr>
<tr>
<td>2012</td>
<td>12.2</td>
<td>7.0</td>
</tr>
<tr>
<td>2013</td>
<td>12.3</td>
<td>7.3</td>
</tr>
</tbody>
</table>

www.drugabuse.gov
Prevalence of Substance Use Disorders Among Healthcare Professionals

- Approximately 10%–15% during career

- Most frequent misconduct
- Most frequent disciplinary action
  - NCSBN, Drug Screening as a Regulatory Tool-Executive Summary
Sophisticated and Knowledgeable

The Right Test, Right Technology
Tools in the Tool Belt
Tools in the Tool Belt
Tools in the Tool Belt
Tools in the Tool Belt
Tools in the Tool Belt

- Interview
- Urine
- On-site Urine devices
- Hair
- Oral Fluid
- Blood
- Nails
Detection Windows

- Nail
- Mec/Cord
- Hair
- Urine
- Oral Fluid
- Blood

Detection Window (days)
Hair Drug Testing
Hair - Advantages

1. Simple, rapid, non-invasive collection
2. Yields long window of exposure - 90 days+
3. Low $$/day
4. Easy to ship and store
5. Relatively simple to analyze
6. No known infection risk
Barcode Matching Receipt Of Specimen Test Request
HOW DO DRUGS GET INTO THE HAIR?

#1 ENVIRONMENTAL EXPOSURE

- SMOKE
- TRANSFERANCE
- FUMES
- CONTACT
HOW DO DRUGS GET INTO THE HAIR?

#2 SWEAT AND OIL

THESE DRUG AND METABOLITE CONTAINING FLUIDS BATHE THE HAIR SHAFT
HOW DO DRUGS GET INTO THE HAIR?

#3 THE BLOOD
Interferants

- Bleach
- Perm
- Dye
- Chemical Relaxer
Limitations

Interferants

Methamp + H₂O₂
Host of hydroxy products
## Limitations

### Effect of Chemical Relaxer

<table>
<thead>
<tr>
<th></th>
<th>Untreated pg/mg</th>
<th>Treated (Lye) pg/mg</th>
<th>Treated (Non-lye) pg/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>BZE</td>
<td>4430</td>
<td>1200</td>
<td>1230</td>
</tr>
<tr>
<td>COC</td>
<td>6460</td>
<td>910</td>
<td>440</td>
</tr>
<tr>
<td>CE</td>
<td>2420</td>
<td>160</td>
<td>220</td>
</tr>
<tr>
<td>PCP</td>
<td>6160</td>
<td>3130</td>
<td>3270</td>
</tr>
<tr>
<td>THC</td>
<td>880</td>
<td>530</td>
<td>590</td>
</tr>
</tbody>
</table>

Fortified specimens

## Limitations

### Effect of Chemical Relaxer

<table>
<thead>
<tr>
<th></th>
<th>Untreated pg/mg</th>
<th>Treated (Lye) pg/mg</th>
<th>Treated (Non-lye) pg/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>BZE</td>
<td>6560</td>
<td>1140</td>
<td>460</td>
</tr>
<tr>
<td>COC</td>
<td>2870</td>
<td>200</td>
<td>280</td>
</tr>
<tr>
<td>CE</td>
<td>270</td>
<td>79</td>
<td>25</td>
</tr>
</tbody>
</table>

Authentic specimens

Adulteration of Specimens

- Bleaching, permanents, dyeing and other cosmetic treatments will cause drugs present to degrade
- Damaged hair is more porous than non-treated hair, therefore more drugs will be incorporated into the hair shaft
- Conversely, more drug will be washed out with normal hygiene
Limitations

Codeine Color bias

- White, Brown, & Black Rats
- 40 mg/kg daily
- 5 days

Limitations

Color bias

<table>
<thead>
<tr>
<th>Codeine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>White Rat</td>
<td>980 pg/mg</td>
</tr>
<tr>
<td>Brown Rat</td>
<td>5990 pg/mg</td>
</tr>
<tr>
<td>Black Rat</td>
<td>111,930 pg/mg</td>
</tr>
</tbody>
</table>

Limitations

PCP Color bias

• White & Black hair
• Same animal
• 12 mg/kg daily
• 5 days

Limitations

PCP COLOR BIAS

Human Studies
Limitations

Color bias

Zolpidem
• 10 mg daily
• 3 days
• Separated by color

Limitations

Color bias

Zolpidem

- White hair 0.4 pg/mg
- Black hair 39.7 pg/mg

CODEINE CONCENTRATIONS

- Each subject received 30 mg oral dose
- 3x daily for 5 days
- Hair collected weeks 0, 4, 5, 6, and 7.
- Analyzed first 1.5 inches

CODEINE CONCENTRATIONS (pg/mg hair)

1134.0

250.8

119.6

66.6

CORRELATION BETWEEN CODEINE CONCENTRATION AND MELANIN IN HAIR

\[ y = 70.565e^{0.2447x} \]

\[ R^2 = 0.7318 \]

## ROLE OF COLOR FOR THCA

<table>
<thead>
<tr>
<th>Hair Color</th>
<th>Mean THCA (pg/mg)</th>
<th>Std Deviation (pg/mg)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0.692</td>
<td>0.837</td>
<td>1038</td>
</tr>
<tr>
<td>Brown</td>
<td>0.728</td>
<td>1.017</td>
<td>2376</td>
</tr>
<tr>
<td>Blond</td>
<td>0.659</td>
<td>0.691</td>
<td>144</td>
</tr>
<tr>
<td>Gray/Dark</td>
<td>0.797</td>
<td>1.105</td>
<td>85</td>
</tr>
<tr>
<td>Gray</td>
<td>1.251</td>
<td>1.704</td>
<td>8</td>
</tr>
<tr>
<td>Red</td>
<td>0.366</td>
<td>0.348</td>
<td>17</td>
</tr>
<tr>
<td>Blond (Dyed)</td>
<td>0.728</td>
<td>0.587</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.716</strong></td>
<td><strong>0.959</strong></td>
<td><strong>3678</strong></td>
</tr>
</tbody>
</table>

ANOVA: F = 1.148; \( p = 0.332 \); \( \eta_p^2 = 0.002 \)
Other Limitations

Hair?
Nail
Anatomy of Fingernail

NAIL PLATE

NAIL MATRIX

NAIL BED
Incorporation of Drug into Nail: The Evidence

“Nails grow according to 2 different directions, Length and Thickness”

Incorporation of Drug into Nail: The Evidence

Length and Thickness

• Length
  - Fingernails approx 0.10 mm/day
  - Toenails approx 0.03 mm/day

Incorporation of Drug into Nail: The Evidence

Length and Thickness

- Thickness
  - Formation of ventral layers by nail bed
  - Thickening rate = 0.027 mm/mm length
  - 20% of total nail clipping mass

Incorporation of Drug into Nail: The Evidence

**Terbinafine (Lamisil®)**
- Antifungal therapy
- Lipophilic
- Penetrates keratinized tissue

Incorporation of Drug into Nail: The Evidence

Distribution of Terbinafine during and after 28 days of treatment (250 mg/day).

### OVERVIEW OF FACTORS INFLUENCING GROWTH RATE

<table>
<thead>
<tr>
<th>Faster growth rate</th>
<th>Slower growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingernails</td>
<td>Toenails</td>
</tr>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Young age</td>
<td>Old age</td>
</tr>
<tr>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>Malnutrition</td>
</tr>
<tr>
<td>Increased blood supply</td>
<td>Decreased circulation</td>
</tr>
<tr>
<td>Hyperthyroidism</td>
<td>Hypothyroidism</td>
</tr>
<tr>
<td>Onycholysis</td>
<td>Acute Infection</td>
</tr>
<tr>
<td>Minor trauma</td>
<td>Onychomycosis</td>
</tr>
<tr>
<td>Regeneration</td>
<td>Immobilization</td>
</tr>
<tr>
<td>Drugs – biotin, terbinafine</td>
<td>Drugs – methotrexate, cyclosporine</td>
</tr>
</tbody>
</table>

Comparing Nail to Hair

- 8 healthy African American (AA) males
- 10-week in-patient study
- 3 week washout period
- Drug administered over 6 days
  - Cocaine 75 mg/70 kg x3
  - Codeine 60 mg/70 kg x3

## Comparing Nail to Hair

<table>
<thead>
<tr>
<th>Subject Cocaine (AA Males)</th>
<th>Hair Cmax (pg/mg)</th>
<th>Nail Cmax (pg/mg)</th>
<th>Nail/Hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6800</td>
<td>820</td>
<td>0.12</td>
</tr>
<tr>
<td>C</td>
<td>5800</td>
<td>250</td>
<td>0.04</td>
</tr>
<tr>
<td>F</td>
<td>2900</td>
<td>1600</td>
<td>0.55</td>
</tr>
<tr>
<td>G</td>
<td>5400</td>
<td>640</td>
<td>0.12</td>
</tr>
<tr>
<td>H</td>
<td>2800</td>
<td>700</td>
<td>0.25</td>
</tr>
<tr>
<td>K</td>
<td>7900</td>
<td>750</td>
<td>0.09</td>
</tr>
<tr>
<td>M</td>
<td>15000</td>
<td>540</td>
<td>0.04</td>
</tr>
<tr>
<td>N</td>
<td>3300</td>
<td>1500</td>
<td>0.45</td>
</tr>
</tbody>
</table>

## Comparing Nail to Hair

<table>
<thead>
<tr>
<th>Subject Codeine (AA Males)</th>
<th>Hair Cmax (pg/mg)</th>
<th>Nail Cmax (pg/mg)</th>
<th>Nail/Hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1900</td>
<td>120</td>
<td>0.06</td>
</tr>
<tr>
<td>C</td>
<td>3300</td>
<td>120</td>
<td>0.04</td>
</tr>
<tr>
<td>H</td>
<td>1800</td>
<td>170</td>
<td>0.09</td>
</tr>
<tr>
<td>K</td>
<td>5900</td>
<td>310</td>
<td>0.05</td>
</tr>
</tbody>
</table>

## Comparing Nail to Hair

<table>
<thead>
<tr>
<th>Drug (AA Males)</th>
<th>Hair Mean (pg/mg)</th>
<th>Nail Mean (pg/mg)</th>
<th>Nail/Hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocaine</td>
<td>6100 ± 400</td>
<td>850 ± 470</td>
<td>0.14</td>
</tr>
<tr>
<td>Codeine</td>
<td>3225 ± 160</td>
<td>180 ± 90</td>
<td>0.06</td>
</tr>
</tbody>
</table>

CODEINE CONCENTRATIONS
(pg/mg hair)

CODEINE CONCENTRATIONS
(pg/mg hair)

1134.0

119.6

250.8

66.6

CODEINE CONCENTRATIONS
(pg/mg hair)

1134.0 180 250.8 119.6 66.6

CODEINE CONCENTRATIONS
(pg/mg hair)

1134.0

250.8

180

119.6

66.6

Comparing Nail to Hair Cocaine

<table>
<thead>
<tr>
<th>Dose</th>
<th>Hair Color</th>
<th>Hair Max (pg/mg)</th>
<th>Nail (pg/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mg/kg x1</td>
<td>Black mixed</td>
<td>1120</td>
<td></td>
</tr>
<tr>
<td>2 mg/kg x1</td>
<td>Brown</td>
<td>390</td>
<td></td>
</tr>
<tr>
<td>1.1 mg/kg x3</td>
<td>Black AA</td>
<td>2997</td>
<td>850</td>
</tr>
</tbody>
</table>


Comparing Nail to Hair Methamphetamine

- Perform 3000 hair test/month
- Perform 500 nail test/month
- 91 Matched pairs in 12 months
- 17 head/finger Meth users

Unpublished data, USDTL 2016
Comparing Nail to Hair Methamphetamine

N = 17

Mamp-Hair

Mamp-Nail

Unpublished data, USDTL 2016
Comparing Nail to Hair Oxycodone

Nail Oxycodone (pg/mg) vs Hair Oxycodone (pg/mg)

$r = 0.494$

Unpublished data, USDTL 2016
Comparing Nail to Hair
Marijuana

- Remnants of larger study
- 22 Matched hair/nail specimens
- College students in MidWest

Unpublished data, USDTL 2016
5x More THCA in Nail than Hair

22 matched pairs

Low Dose Oxycodone

- Caucasian, 60-69 YO Male
- 95 kg, BMI = 30
- 5 mg Oxycodone daily
- Followed with nail 18 months

Abbas et al (2014), Poster, SOFT Conference, Grand Rapids, MI
Nail Levels as Predictor of Health

- Health Professional Follow up Study
- Univ. California – San Diego
- 210 male lung cancer cases
- 630 controls
- Toenails tested for cotinine – 1987
- Followed for 12 years
Nail Levels as Predictor of Health

- Mean Nicotine Levels
  - Cases 950 pg/mg (0.09)
  - Controls 250 pg/mg (0.02)
  - $P$-value $<$0.0001
### Nail Levels as Predictor of Health

<table>
<thead>
<tr>
<th>Quintile</th>
<th>RR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.02</td>
<td>0.52</td>
</tr>
<tr>
<td>3</td>
<td>1.43</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>2.10</td>
<td>1.12</td>
</tr>
<tr>
<td>5</td>
<td>10.50</td>
<td>5.61</td>
</tr>
</tbody>
</table>

\( P \) for the trend <0.0001
“We found that levels of nicotine in toenail samples from our study population independently predicted lung cancer risk.”
Among U.S. adults over the age of 18:

- 15.3 million have an alcohol use disorder only.
- 2.3 million have both an alcohol use disorder and a drug use disorder.
- 1.9 million have a drug use disorder only.
Comparing Nail to Hair Ethanol

- Large NIAAA study
- 529 Matched hair/nail specimens
- College students in MidWest

Unpublished data, USDTL 2016
2.5x More EtG in Nail than Hair

529 matched pairs

EtG in Hair

Society of Hair Testing Suggestions

Consistent with Abstinence

Increasing Risk

Consistent with Chronic Excessive Drinking

0 10 20 30 40

EtG Hair (pg/mg)

http://www.soht.org/index.php/consensus
# EtG in Nail

**High-Risk Drinking**

> > 30 drinks per week

<table>
<thead>
<tr>
<th></th>
<th>30 pg/mg</th>
<th>20 pg/mg</th>
<th>8 pg/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>0.72</td>
<td>0.68</td>
<td>0.64</td>
</tr>
</tbody>
</table>

EtG in Nail

Any Alcohol Use
> 0 drinks per week

<table>
<thead>
<tr>
<th></th>
<th>30 pg/mg</th>
<th>20 pg/mg</th>
<th>8 pg/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.33</td>
<td>0.37</td>
<td>0.42</td>
</tr>
<tr>
<td>Specificity</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

# EtG in Nail

**Increasing-Risk Drinking**

> > 15 drinks per week

<table>
<thead>
<tr>
<th></th>
<th>30 pg/mg</th>
<th>20 pg/mg</th>
<th>8 pg/mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.82</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.79</td>
<td>0.75</td>
<td>0.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Any Drinking 0 drinks (pg/mg)</th>
<th>Increasing Risk &lt;15 drinks/wk (pg/mg)</th>
<th>High Risk &gt;30 drinks/wk (pg/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair</td>
<td>8</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Nail</td>
<td>8</td>
<td>37</td>
<td>56</td>
</tr>
</tbody>
</table>

EtG in Nail
Berger et al (2014)

Consistent with Abstinence

Increasing Risk

Consistent with Chronic Excessive Drinking

EtG Nail (pg/mg)
CONCLUSIONS

- Been around a long time
- Longer window of detection
- Difficult to adulterate
- Non-invasive
- Direct observed collection
- No color bias
- More studies needed – ideas anyone?
Thank You
Questions?