VANISHED INTO THIN AIR:
The Search for Children's Fingerprints

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Reprinted from Analytical Chemistry, July 1, 1995

Good experiments can be done almost anywhere, even in the back seat of a police cruiser. This is how one police investigator and spare-time scientist made a startling discovery about children's fingerprints and brought it to Michelle Buchanan's MS laboratory at the Oak Ridge National Laboratory (ORNL; Oak Ridge, TN) for a closer look at the chemistry involved.

In July 1993, Art Bohanan, a criminologist with the Knoxville Police Department (TN), was working on the case of a three-year-old girl who'd been abducted and brutally murdered. The defendant, who had confessed early on, later recanted, which made finding the little girl's fingerprints in his car essential to the case. This was Bohanan's second child abduction case in less than a year, and what worried him was that in the first one, the child's fingerprints could not be detected where they should have been.

"The first kidnapping was in April 1993," he recalls, "and we didn't get the car for four days." He was certain the child had been inside the car; witnesses said they saw her being pulled into it. But when Bohanan and other crime scene investigators examined the inside of the car, the girl's fingerprints were nowhere to be found. "We couldn't find anything, and I started thinking that maybe the child's fingerprints just weren't lasting very long. After that, I promised myself I would do whatever I could to look for fingerprint evidence much earlier."

When the car from the second abduction case was brought in only seven hours after the three-year-old was taken, Bohanan's team rushed to examine it within half an hour and was able to find the little girl's palm prints inside the back windows.

Apparently no one, not even experts at the Federal Bureau of Investigation (FBI), had ever considered the possibility of a difference between the fingerprints adults leave behind and the ones children produce. "That's not all that surprising," Bohanan says. "The FBI works mostly with adult criminals. Usually if they're involved in one of these child abduction cases they're analyzing fingerprints we send in to them, not collecting the evidence, so they don't get the kind of routine experience that we do investigating these crime scenes."

Still, the lack of any formal data on children's fingerprints bothered him. He realized he needed to test his idea and find out for certain why the children's fingerprints were undetectable in one case and present in another. "The month after the murder I took every car we had in the pound, had children sit in them and touch the insides, waited 24 hours, and examined the cars for their fingerprints," he says. "We didn't find a thing." He then got 10 cases of new plastic and glass soda bottles donated by a local bottling company, cleaned them, and had adults touch half the bottles in each case and children touch the other half for a series of experiments he conducted over the next year. Half the cases he stored in his basement as controls; the others he left in the back of his police car. "The inside of a car is exactly the environment we were trying to investigate," he says.

Bohanan found that the adults' prints lasted at least several days, but the children's prints often vanished within 24 h. On average, he says, the adults' prints lasted four times longer than the children's. The fingerprints on the bottles in his car disappeared faster than the ones in his basement, which was cooler. Time, temperature, and humidity all appeared to affect how long the fingerprints lasted on the nonporous surface of the bottles. "These were crude experiments," says Bohanan, "but he was able to show proof of principle."

Taking it to the lab

Given the typical constraints on police budgets and the limited sophistication of chemical analysis methods available to most police departments, Bohanan's back-seat experiments could have ended there. But the criminologist had met Al Trivelpiece, director of ORNL, during a tour of the Knoxville Police Department. Bohanan knew he needed more detailed information about the disappearing fingerprints if he ever wanted to convince a jury. Last August he talked with Trivelpiece about his frustration over the first abduction case, described his experiments, and asked if it was possible that the fingerprints left by young children just weren't durable at the high temperatures of an east Tennessee summer day. Trivelpiece promptly invited Bohanan to ORNL to consult with a roundtable of researchers from several laboratories about possible causes for what he'd observed.

At that first meeting, says Michelle Buchanan, "It sounded like the children's fingerprints were evaporating faster. Maybe they didn't have the longer lasting compounds that are in adult fingerprints. Suspecting chemical differences, we did literature searches on CAS, Medline, and other databases using every search strategy we could think of. There was nothing out there on kids' fingerprints and very little on fingerprints in general. We eventually decided that the fastest way to find out what was in them was to do GC/MS profiles and compare them, so my lab took on the project." Trivelpiece allocated Buchanan some internal funding, and two undergraduate students, Jennifer Fletcher of Auburn University and C. Scott Shultz of Transylvania University, have conducted the first experiments under the direction of Buchanan and her colleague Kuiji Asano. The students rounded up 50 subjects, half of them children from 4 to 12 years old,

the other half adults from 17 years old to over 40. The subjects shook 2-ml glass vials of ordinary rubbing alcohol from a local pharmacy (isopropanol ~ 70% v/v with water) against their fingers for 1 min to collect fingerprint secretion samples. "We used rubbing alcohol instead of the kinds of pure solvents you'd usually extract with because of the potential toxicity problem," Buchanan explains. "First of all, we were collecting the secretions right off their skin, but there was also the risk of the younger kids might put their fingers in their mouths."

Extracting samples directly from the subjects' fingertips allows the collection of much more material than extracting individual latent fingerprints off glass or cellulose might, although it may also introduce compounds that would not ordinarily be found in a latent print left on a surface. "Fingerprint extracts contain hundreds of different compounds, so for the initial experiments, quantity has been a factor." Individual components in the sample extracts range from the low part-per-million level to high part-per-billion concentrations, enough to get good quality mass spectra.

The extracted samples from individual children or adults were derivatized with a methylating reagent to enhance the determination of polar compounds such as amino acids, fatty acids, and other compounds known to make up much of the residue of a fingerprint. They were then separated and analyzed on a Finnigan MAT ITS 40 GC/ion trap MS system using both electron impact ionization and isobutane chemical ionization.

That greasy kid stuff

Despite the relatively simple analytical treatment, differences between children's and adults' fingerprints showed up clearly on the total ion chromatograms (TICs). "You can lay the TICs down one by one and say 'this is an adult' or 'this is a child'," says Buchanan. Free fatty acids, which are fairly small and volatile, appear to be the major component in children's fingerprints, whereas adult fingerprints, although they contain some free fatty acids, contain larger concentrations of long-chain alkyl esters and other heavy, later eluting compounds. The preliminary results indicate that fingerprint composition tends to change around puberty, Buchanan says. " The esters of the fatty acids are probably not coming from the finger itself - they're more typical of sebaceous secretions." Samples taken from the faces and freshly washed hands of adults indicate the longer chain alkyl esters are probably transferred to the subjects' fingertips whenever they touch their faces.

Another important difference, says Buchanan, is that cholesterol is found at higher levels in the children's samples, whereas the adults' samples contain higher levels of cholesterol esters. "We see a big squalene peak in the fingerprints of both children and adults. Squalene is a precursor for cholesterol, hormones, and other compounds," she notes. There also appear to be subtle differences between male and female subjects, but those differences are not yet well characterized.

Then there are the odd findings. One adult's fingerprints extracts contained an as-yet unidentified compound that wasn't found in any of the other subjects' samples. Nicotine has been found in the extracts from smokers; another adult quit smoking two weeks before the experiment but was chewing nicotine gum. Nicotine appeared in his chromatograms, but Buchanan says she is unsure whether the nicotine was being secreted actively from his skin or was the result of contamination (e.g., from touching furniture or other objects with old traces of nicotine on them).

Toward a child fingerprint test

So Far, the work done by Buchanan's students to identify volatile compounds has demonstrated why children's fingerprint residues don't last as long as adults'. After 24 h, there's a lot less material left in the fingerprints, and the compounds that do remain may not be very reactive with the conventional cyanoacrylate, ninhydrin, and amido black dyes used in police work. To develop a new test for children's fingerprints, Buchanan's lab must determine what's left in the residues when the free fatty acids and other volatile compounds evaporate.

Buchanan says that more specific experiments to identify signature compounds will have to include MS/MS structural analysis; derivatization and GC/MS protocols for nitrogen-containing compounds and basic compounds, which the group has not yet studied; and electrospray ionization MS for nonvolatile compounds that may be present in all fingerprints but aren't being detected by current visualization methods. Once target compounds are identified, she hopes to do matrix-assisted laser desorption/ionization MS studies of latent prints on glass, cellulose, and other supports, as well as volatility studies to get temperature-dependent spectrum profiles of the target compounds. If all goes well, some relatively nonvolatile signature compounds will be present and another lab at ORNL will try to develop a sensitive chemical visualization field kit for them.

At the moment, the fingerprint project is being funded internally at ORNL, so research is being run on a small scale. Setting a timetable for future experiments, says Buchanan, will depend on whether her group can get additional support from the FBI, the Department of Justice, or other sources. Bohanan's discovery may have serious implications for numerous cases involving child victims as well as for child protection efforts such as the "Thumbs Up" National Fingerprint Program, operated through the University of Illinois (Chicago). Program director Diana Apa says the voluntary child fingerprint registry, which has worked with the FBI and provides database searches for identification of juvenile accident or crime victims, has grown steadily in the 12 years since she started it and is set for significant expansion next year from the current ~ 15,000 a year through promotion in shopping malls.

Clinical applications

In addition to providing information on the compositional differences of fingerprints, Buchanan says the research her students are doing eventually might lead to skin tests for the clinical laboratory. If drugs such as the nicotine in the ex-smoker's fingerprint extract really are secreted in sweat or skin oils, she says, GC/MS profiling of skin secretions could be used to monitor physiological levels for therapeutic drug monitoring or clinical research. Biochemical indicators for some diseases may also be present on skin. "We do have reason to believe some compounds in skin secretions change with metabolic disorders," Buchanan says. One of the few relevant studies Buchanan found in her literature searches reported changes in the skin secretions of chronic alcoholics, who produced ethylester compounds instead of the normal long-chain alkyl esters.

Buchanan speculates that some "blue skies" health related applications that might come out of her lab's research on fingerprint extracts could include assays for diabetes and other metabolic disorders or diseases. The key question would be whether the diseases affect the composition of the normal skin secretion compounds, the way alcoholism appears to, or produce unusual compounds that are specific enough for accurate diagnosis.

GC/MS might be used either as the clinical assay itself or as a way of pinpointing signature compounds for a disease so that a specific assay could be developed for them. Bohanan says that if it's possible, he would like to see a color indicator-based skin patch assay developed for drugs of abuse. "It would be a big help if all a police officer had to do was touch a suspect with a reactive pad and get a possible or negative for a drug." How possible some of these applications are will be depend on how individual target compounds are distributed physiologically, what concentration of them can be detected in skin secretions, and whether effective indicator-based assays can be developed for them.

Forging new ties

Progress on Bohanan's fingerprint problem has been encouraging enough that ORNL, which is better known for its core of energy and environmental research, is now setting up a forensic program.

ORNL has lent its efforts to a few forensic investigations such as the neutron activation analysis (NAA) it performed four years ago on the exhumed remains of Zachary Taylor to determine whether the pre-Civil War president could have died of arsenic poisoning.

Trivelpiece says that ORNL has forged closer ties with forensic anthropology department at the University of Tennessee - Knoxville and local police departments to find practical forensic applications for ORNL's high-tech expertise and equipment. One project that's already in the works is to apply ORNL's supercomputer-based surface modeling programs to automated reconstruction of facial features from the skulls of unidentified corpses.

"Not all of these applications are really fundamental research," says Trivelpiece, "but they're also not routine testing; we can't get into the business of competing with commercial contract labs. Some of our projects might be to make simplified devices for blood testing at the sight of an accident or crime or, for samples like those in the Zachary Taylor case, we have people asking if we could make a portable little 252Cf source that they can carry to the crime scene for NAA."

Bohanan's second child abduction case went to court on May 1, and the jury returned a guilty verdict for first-degree murder on May 9. Bohanan says he believes the findings he made and continues to make from the back seat of his car (which now include comparisons of fingerprints on porous paper samples) , and the chemical explanations furnished by Buchanan's lab, bolstered the prosecution's case. Beyond the individual case, however, his collaboration with ORNL has produced valuable information for forensic investigators and provided ORNL with a project of public importance, Buchanan says. "Being given a good problem is what prompts an analytical chemist."

!Important Notice to All Gunshot Residue Analysis Contributors to FDLE!

Greg Scala
Senior Crime Lab Analyst
Firearm/Tool Mark and Gunshot Residue Analysis Sections
FDLE Orlando Crime Laboratory

Due to recently discovered technical difficulties associated with the cotton swabs used in Gunshot Residue (GSR) collection kits, we are discontinuing Atomic Absorption (AA) analysis of these kits.

In the place of AA, we are implementing particle analysis of GSR by Scanning Electron Microscopy (SEM). **Effective immediately, only SEM collection kits should be used for GSR**. For a short time we will analyze AA kits that have already been collected. After **August 31, 1996**, however, Atomic Absorption kits will no longer be routinely analyzed and only SEM kits should be submitted. We have been evaluating the SEM process for some time and are now able to utilize this more discriminating technique in the analysis of GSR cases. The collection kit for SEM consists of small metal sampling disks that are coated with an adhesive surface. This collection method is very simple and requires little training.

FDLE will make the SEM kits available to any Florida law enforcement agency at no expense in limited quantities and can be obtained from your nearest FDLE laboratory. As quality assurance procedures have already been performed on kits we provide, we ask that you avoid using kits from other sources. If larger quantities than we can provide are needed, orders can be made directly from our supplier.

SEM is more time consuming and our ability to handle the same volume of casework will be reduced. For this reason, we ask you to limit your submissions to only the most crucial investigations. As a minimum, all cases should meet the following criteria:

- Only shooting suspects should be sampled. When a shooting suspect is also a shooting victim, collect only if the known shooting distance exceeds approximately 5 feet.
- The time interval between shooting and sampling should not exceed 4 hours.
- Sample only subjects found not in the possession of a firearm.
- Sample only subjects known not to have washed their hands since the alleged shooting incident.
- Sample only the hands of individuals and not other surfaces or other materials.
- Sample individuals thought to be valid suspects in the case and not for "elimination" purposes

Should circumstances exist that differ from these guidelines or you need further information, please contact the Gunshot Residue Analysis section at the Orlando Regional Crime Lab (407) 245-0888.