Evaluation of Forensic Techniques for Postmortem Drug Detection and Identification in Thailand

การประเมินผลทางเทคนิคนิติวิทยาศาสตร์เพื่อตรวจหาและวิเคราะห์สารเสพติดจากการชันสูตรศพในประเทศไทย

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Abstract

Despite the extensive research done on forensic techniques for postmortem drug detection and identification, the unique perspective of developing countries has yet to be properly investigated. These are countries where drug fatalities are frequent, but available forensic resources are meager, especially when compared to such resources of more economically developed countries. This work attempts to address this issue by reviewing six of the most frequently used forensic techniques for postmortem drug detection and identification, and evaluate them based on a fixed set of objective criteria, including sensitivity, specificity, expertise cost and need for major instrumentation. The results are then compared qualitatively and used to develop alternative best-practice recommendations that align better with the socioeconomic realities of developing countries - with a particular focus on Thailand, a country with a major problem of drug abuse in the Southeast-Asian region. These recommendations may enable a more efficient allocation of forensic resources in countries that would benefit from it the most.

Keywords : Forensic techniques, postmortem, Thailand, drug detection, budget

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บทคัดย่อ

แม้จะมีการวิจัยอย่างกว้างขวางเกี่ยวกับเทคนิคการตรวจวิเคราะห์ทางนิติวิทยาศาสตร์ในการตรวจหายาเสพติดและการวิเคราะห์ยาเสพติดจากสิ่งส่งตรวจของศพแล้วก็ตาม แต่ในประเทศที่กำลังพัฒนายังไม่มีระบบที่เป็นมาตรฐานเดียวกันในการตรวจสอบอย่างเหมาะสม ประเทศเหล่านี้มีประชากรที่เสียชีวิตจากยาเสพติดเป็นจำนวนมาก แต่ทรัพยากรในการตรวจทางนิติเวชมีจำนวนน้อย โดยเฉพาะอย่างยิ่งเมื่อเทียบกับประเทศที่มีการพัฒนาทางเศรษฐกิจ บทความนี้จึงมีวัตถุประสงค์ในการช่วยลดปัญหานี้โดยการรวบรวมค้นคว้าเทคนิคการวิเคราะห์ทางนิติวิทยาศาสตร์มา 6 วิธี ซึ่งเป็นวิธีที่ใช้บ่อยในการตรวจหาและวินิจฉัยยาเสพติด และประเมินผลโดยใช้เกณฑ์ที่เป็นในการวิเคราะห์ ซึ่งประกอบด้วย ความไว ความจำเพาะ ความชำนาญของผู้ใช้งาน ราคา และความต้องการเครื่องมือที่มีความสำคัญในการวิเคราะห์ การเปรียบเทียบดังกล่าวเป็นข้อมูลเชิงคุณภาพและใช้เพื่อการพัฒนาสำหรับเป็นคำแนะนำทางเลือกในการปฏิบัติที่ดีที่สุดและสอดคล้องกับความเป็นจริงทางสังคมและเศรษฐกิจของประเทศกำลังพัฒนา โดยเฉพาะอย่างยิ่งในประเทศไทยซึ่งเป็นประเทศที่มีปัญหาทางด้านยาเสพติดอย่างมากในภูมิภาคเอเชียตะวันออกเฉียงใต้ คำแนะนำเหล่านี้อาจช่วยให้การจัดสรรทรัพยากรทางนิติวิทยาศาสตร์มีประสิทธิภาพเพื่อที่ประเทศต่างๆ จะนำไปใช้ให้เกิดประโยชน์อย่างสูงสุด

คำสำคัญ : เทคนิคทางนิติวิทยาศาสตร์ การชันสูตรศพ ประเทศไทย การวิเคราะห์หายาเสพติด งบประมาณ

Introduction

Drug-related fatalities have been on the rise in Thailand in recent years. Although steps are continually taken to decrease the exposure of narcotics to society, persistent issues such as the rapid increase of amphetamine use among teenagers indicate that the drug situation of the country is still in serious need of improvement (Cheurprakobkit. 2000 : 17).

The situation is worsened by drug trafficking, local drug production and overdose. Drug trafficking has historically been a prevalent issue in this region. Methamphetamine, heroin and marijuana are manufactured in clandestine laboratories just outside the Thai borders with Myanmar, Laos and Cambodia (Narongchai, Narongchai and Thampituk. 2007 : 137). These narcotics, along with ecstasy from China's Yunnan province and Indonesia, make their way into Thailand due to drug distributors taking advantage of the country's unique geographical location and developed infrastructure. Inside the country, narcotics networks cater to not only local but also international demands; a 2010 narcotics reported by the Office of the Narcotics Control Board (ONCB) identifies West African and Iranian groups as key regional narcotics networks. A smaller but growing related issue is local narcotics production: between 2009-2010, opium poppy cultivation areas saw a 37% increase to a total of 288 hectares, producing 4.51 metric tons of opium - a marked increase from the 3.29 metric tons produced the year before (Office of the Narcotics Control Board (ONCB). 2010: online). The other issue, accidental overdose, is identified as one of the main contributors to drug-related fatalities (Bargagli et al. 2006: 199), and a common event among Thai injection drug users (Milloy et al. 2010 : 3-5).

In this context, detecting the presence of drugs in fatal incidents becomes essential, not only for aiding law enforcement, but also for helping government agencies identify patterns of drug-related fatalities across the country. Therefore, postmortem forensic techniques for drug detection and identification are essential tools both on the individual and on the national level, and their appropriate use is of critical importance.

Despite the importance of the issue, Thailand is in a precarious position where the high demand for drug-related postmortem forensic investigation needs to be balanced by a budget significantly more limited than that of developed countries. A 2012 comparison that highlights this issue involves the city of Houston, TX USA, which reported a forensic services budget totaling US $20 million (Houston Police Department. 2013 : online), while in the same year Thailand allocated the equivalent of US $7.7 million for forensic services – nationwide (Central Institute of Forensic Science Thailand. 2012 : Online). This economic disparity necessitates the reassessment of forensic technique usage in Thailand and in developing countries in general, because with such severe budget limitations it becomes impractical to perform the ideal full regimen of forensic drug tests indiscriminately, even in cases where there is little or no suspicion of drug abuse.

This work reviews six of the most frequently used forensic techniques for postmortem drug detection and identification, and re-evaluates them from the perspective of developing countries, particularly Thailand. The result is used to derive best-practice recommendations that align with their unique socioeconomic realities.

Forensic Drug Testing Techniques

Several methods are available for forensic drug testing, and their utility is based on two principal qualities: sensitivity and specificity. Sensitivity is defined as the ability of the test to detect a drug when it is present at greater than or equal to its predetermined analytic cutoff point. Specificity is defined as a measure of certainty in the identity of a substance detected by the test (Ostrea. 1999 : 42). These two qualities determine whether any given technique is more suitable for screening or diagnostic procedures. Screening procedures are used when the probability that any prior test condition exists is unknown or low, which is the case in many forensic toxicology situations. Therefore, tests used for screening need to be highly sensitive, while specificity is not a requirement at this point. On the other hand, when a prior positive test condition has already been established, or its probability is relatively high, the need for specificity is more emphasized and the need for sensitivity is less pronounced, thus procedures are adapted this way for diagnostic testing. Without this distinction, the chance for false positives is high (Khantzian and Treece. 1985 : 1070-1071).

Chemical Spot Test: Sometimes also called color test, the chemical spot test is one of the earliest presumptive drug identification methods, and it is still a widely used screening method today. Several reasons contribute to its popularity: it is easy to use, produces results rapidly and it doesn't require extensive training nor expensive materials or machines. As its name suggests, the chemical spot test subjects analytes to specific chemical reactions. The resulting reaction product has a unique color, which indicates the presence of the drug. Its limitations are those typical of any qualitative screening methods: low specificity and the subjective interpretation of its results, especially when the visual change is minimal. Therefore, positive results are best considered only as presumptive evidence, to be confirmed by an unrelated diagnostic method (O'Neal, Crouch and Fatah. 2000 : 199).

Spectrophotometry (Visible or UV): Spectrophotometry is similar in principle to the chemical spot test, but in this case materials are identified by their unique spectrum of radiant energy absorbance. Typical absorbance values are either in the ultraviolet (UV) (180-390 nm) or visible (390-780 nm) range. The quantitative nature of the test comes from the absorbance values being proportional to the amount of tested substance. However, this quantification is reliable only in uncomplicated cases and where the drug is present in a sufficiently large amount, such as in situations. Spectrophotometry is moderately specific and its sensitivity ranges from moderate to high. The disadvantages of the method are that it can test for only one drug at a time, short part-length in the absorbling medium and that it requires moderate initial costs and expertise (Tyson. 1986 : 51). Another significant caveat is interference by pre-existing conditions: phenylketonuria and ketoacidosis can cause false positive salicylate readings, while bilirubin can cause false positive acetaminophen determination (Bertholf et al. 2003 : 696-697).

Immunoassay: The first use of immunoassay was described in 1960 by Rosalyn and Solomon, making it one of the earliest analytical techniques employed in the field of forensic toxicology (Rosalyn and Solomon. 1960 : 1157). Immunoassays are based on unique antigen-antibody reactions. In forensic context, a biological sample consisting of a complex mixture of substances is first subjected to specific antibodies; if analyte drugs (antigens) are present, then antigen-antibody complexes are formed. These complexes are then separated from the mixture and subsequently quantitated using an easily detectable label. Several kinds of labels have been described in literature; of these, radioactive, enzyme-linked and fluorescent labels are the most relevant for the purpose of forensic analyses.

Radioimmunoassays (RIA): RIA involve a known quantity of radioactive-labeled ligand and the antigen of interest binding competitively to a limited number of antibody binding sites. Since the introduced unlabeled antigen displaces some of the labeled variant, a decreased concentration of the labeled antigen-antibody complex indicates the presence of the antigen of interest. Radioactive label concentrations are measured and plotted against a known dose-response curve, from which the concentration of analytes is derived. The advantage of RIA lies in its high sensitivity, moderate specificity and relatively low cost. However, the increased risks, high regulations and required training associated with radioactive reactions, along with the short shelf-life of radioactive materials make the technique less suitable for general forensic use in Thailand.

Enzyme-Linked Immunosorbent Assay (ELISA): ELISA reactions involve enzyme-labeled ligands binding to immobilized antibodies anchored to a solid base. Unbound components are removed by repeated buffer washings. The subsequent addition of an enzymatic substrate produces a signal that can be used to quantify the analyte concentration in the sample. One advantage of ELISA is that using enzymes offsets the drawbacks of RIA's radioactive labels while maintaining comparable sensitivity and specificity levels. However, ELISA comes with its own disadvantages, mainly that the structural changes necessary for the antibody to adhere to solid surfaces also negatively affect its antigen-binding capacity. This can be overcome by modified, indirect capture phases (Ostrea. 1999 : 43). Another setback of the method is the relatively high financial and expertise requirements of its initial development, although subsequent applications of the technique are less intensive in both aspects.

Gas chromatography–Mass Spec-trometry (GC-MS): GC-MS is analytical method that combines the features of gas chromatography and mass spectrometry to identify various substances various within a sample. Developed in the 1950s (James and Martin. 1952 : 679) and widely used ever since with a variety of applications, GC-MS gained popularity in post-mortem forensics due to its ability to identify trace elements in materials that were previously thought to have disintegrated beyond identification (Lancashire. 2012 : Online). Today, GC-MS is regarded as the gold standard in forensic drug confirmation because of its exceptionally high specificity (Ostrea. 1999 : 47).

Gas chromatography, the first of the two major components of GC-MS, is a separation process in which a mixture of compounds is first vaporized, then carried in a column using an inert gas through a stationary phase that interacts with the mixture on the molecular level. The difference in the chemical properties between various molecules creates differential partitioning, thereby ensuring the separation of the compound to its components as it moves up the length of the column. The retained molecules are eluted from the stationary phase at various times, referred to as the retention time, and as the carrier gas exits the column, a detector senses the separated compounds. In case of GC-MS, this detector is a mass spectrometer. Mass spectrometry works on the principle that charged particles have a unique mass-to-charge ratio that can be used to separate them as they move through magnetic or electric fields (Ostrea. 1999 : 44-45). As the gas carrying the separated compounds leaves the column, the molecules get ionized and fragmented. These charged fragments are then turned into electrical signals and analyzed. The combined ion values and intensities make up the spectrum of the analyzed compound. The unknown compound is identified when its spectrum is compared to a set of known reference spectra. Besides performing qualitative analyses, GC-MS results can be used for quantifying compounds as well, by comparing the relative concentrations among the atomic masses in the generated spectrum. One of the challenges of using GC-MS in post-mortem forensics is that the sample must be relatively volatile, since it will be separated in the gas phase, meaning that biological samples usually need to be derivatized prior to analysis (Hill. 2012 : Online). Other factors that may make GC-MS less of a viable option for general forensics use in Thailand are its high cost, high expertise requirement, need for major instrumentation and longer run times.

High-Performance Liquid Chromatography (HPLC): HPLC is an adaptation of column chromatography, in principle similar to the above-mentioned gas chromatography, but with notable structural and functional differences. Analyte separation still involves stationary and mobile phases, but in HPLC these are solid and liquid, respectively. Another unique feature of this method is the use of high pressure (its namesake in some variations). The increased pressure allows the column to be packed with smaller-diameter phase particles, resulting in a larger relative surface area for interactions with the compounds in the mobile phase, which in turn leads to increased separation efficiency. Another positive effect of high pressure is decreased retention time, an important feature when it comes to forensic analyses.

HPLC be divided depending on the relative polarity of the stationary and mobile phases – a distinction especially useful when the polarity of the suspected analyte is known. Normal-phase chromatography involves a polar stationary phase and a nonpolar mobile phase, increasing the adsorption of polar compounds to the stationary phase, while more nonpolar molecules elute more readily (early in the analysis). Reversed-phase chromatography is the opposite: a nonpolar stationary phase and a polar mobile phase retains polar compounds better, resulting in more polar compounds leaving the column faster. Substance detection can take many forms in HPLC; the most commonly used detectors are fluorometers and photometers. An example of the latter is UV detection, where a beam of ultraviolet light is projected across the column and detected on the other side. Absorption values and retention times are then analyzed.

Table 1. Comparison overview of six forensic techniques for postmortem drug detection and identification

	Specificity	**Sensitivity**	**Expertise**	**Need for major Instrumentation**	**Cost**
Spot Test	Low	Low	Moderate	No	Low
Spectrophotometry	Moderate	Moderate to high	Moderate	Yes	Moderate
RIA	Moderate	High	Moderate	Yes	Moderate
ELISA	Moderate	High	Moderate	Yes	Moderate
GC-MS	High	High	High	Yes	High
HPLC	High	High	High	Yes	High

Source : (Ostrea. 1999 : 42, 44, 49-50 ; O'Neal, Crouch and Fatah. 2000 : 199).

Conclusion

Medical tests can be grouped based on three fundamental utilities: monitoring, screening and diagnostics. In particular, forensic medical tests make use of the latter two. This means that standard testing regimens usually consist of at least one highly sensitive test for screening, and one or more highly specific test for subsequent diagnostics. Circumventing this standard practice with the purpose of cost-effectiveness might appear feasible at first glance, but a closer look at Table 1 reveals that the only techniques that combine suitably high sensitivity and specificity in a single test (GC-MS and

HPLC) also require significant investment in instrumentation, expertise and operating cost, which makes their routine employment prohibitively expensive, particularly for countries with severely limited forensic budgets.

The budget dilemma that Thailand and other developing countries are facing could be solved by developing new best practices that align with the economic reality of developing countries, and to do that, the type of cases and the cost of forensic techniques need to be closely examined and matched appropriately. With regards to forensic techniques, the main sources of expense are material cost, instrumentation and personnel training/ salaries (Table 1). Therefore, techniques that are less resource-intensive but provide adequate results are best used for average or non-drug-suspect cases, while the expensive but optimal testing regimen is best performed whenever accuracy is of critical importance, including high-drug-suspect cases and high-profile cases where a failed outcome could cause significant economic loss, reputational harm or both. For example, the worldwide media coverage that mishandled tourist fatality cases receive tend to result in unfavorable views towards the host country, and result in significant negative impact on tourism – one of the main sources of income in Thailand.

Besides the financial incentive, best practices for postmortem forensic testing need to account for the unique challenge of deriving usable samples from materials obtained at the scene. It is important that the samples are free of interferants and that possible postmortem changes are taken into account or prevented when possible (e.g. toxicant biotransformation, the production of bacterial ethanol and postmortem redistribution of blood and its drug content) (Drummer. 2007 : 200-201).

Thailand and other developing countries tend to have severe drug problems and limited forensic resources – a fact that standard best practices for forensic postmortem drug detection techniques don't take into account. Reassessed best practices emphasize reasonable and educated compromises between optimal and practical solutions for the most effective approach.

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