Short Communication
Volume 10:03, 2025

Journal of Forensic Medicine

ISSN: 2472-1026

Open Access

Advancements in Forensic Body Fluid Identification

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Introduction

This research focuses on developing a new multiplex mRNA panel that can identify five crucial body fluids: blood, saliva, semen, vaginal fluid, and menstrual blood, all at once. The method utilizes a 20-plex assay targeting specific mRNA markers, showing impressive specificity and sensitivity, making it a powerful new tool for forensic investigations to enhance evidence analysis.[1].

This study thoroughly evaluates microRNA (miRNA) profiling for identifying body fluids in actual forensic casework samples. The findings demonstrate that miRNA markers offer reliable and robust detection of blood, saliva, and semen, even from degraded or mixed samples, proving their practical utility in forensic serology for accurate evidence interpretation.[2].

This research explores the use of hyperspectral imaging for quick and non-destructive identification of human blood in forensic contexts. The technique effectively distinguishes blood from other substances and even determines its age, offering a significant advantage for crime scene investigators by preserving evidence and speeding up preliminary analysis.[3].

This paper presents a new quick and accurate method for identifying human semen by simultaneously detecting prostate-specific antigen (PSA) and semenogelin. This dual-marker approach enhances specificity and reliability, which is crucial for sexual assault cases where semen identification is paramount for investigative leads.[4].

This research evaluates four specific mRNA markers for forensically identifying saliva, employing a very sensitive Luminex-based assay. The study confirms the markers' high specificity and sensitivity, even with small or degraded samples, which is vital for detecting saliva evidence at crime scenes and linking individuals to crimes.[5].

This study investigates how various surfaces and storage conditions affect the stability of mRNA and miRNA markers used for identifying body fluids. The findings provide crucial insights into RNA degradation rates, helping forensic scientists understand the limitations and reliability of molecular evidence recovered from diverse crime scene environments.[6].

This paper presents an innovative method for forensically identifying vaginal secretions by combining both mRNA and microbial markers. This dual-marker approach significantly improves the specificity and reliability of detection, which is vital in sexual assault investigations where distinguishing different body fluids is often challenging.[7].

This research thoroughly evaluates enhanced presumptive tests for blood and semen, specifically in the context of sexual assault cases. The study assesses the sensitivity, specificity, and potential interferences of these tests, providing important guidance for forensic laboratories on their appropriate use and interpretation at crime scenes.[8].

This study details a multiplex RNA profiling method for identifying menstrual blood, specifically by targeting both mRNA and long non-coding RNA (lncRNA) markers. This innovative approach offers improved accuracy and sensitivity for distinguishing menstrual blood from peripheral blood, which is crucial for interpreting evidence in complex forensic cases.[9].

This research explores using MALDI-TOF MS-based proteomic analysis to distinguish human bloodstains from non-human ones. The method identifies species-specific proteins, providing a highly reliable and sensitive technique for forensic serology to determine the origin of blood found at crime scenes, significantly aiding investigations.[10].

Description

Forensic science consistently seeks improved methodologies for identifying biological fluids, a cornerstone for effective evidence analysis in criminal investigations. One significant development involves a new multiplex mRNA panel that identifies five crucial body fluids simultaneously: blood, saliva, semen, vaginal fluid, and menstrual blood [1]. This sophisticated 20-plex assay specifically targets particular mRNA markers, demonstrating impressive specificity and sensitivity. Such a tool significantly enhances evidence analysis and strengthens forensic investigations by providing a comprehensive profile of biological traces. Complementing this, a thorough evaluation of microRNA (miRNA) profiling confirms its utility for body fluid identification in routine casework, offering reliable detection of blood, saliva, and semen, even from degraded or mixed samples, which is vital for accurate evidence interpretation in forensic serology [2]. The ability of miRNA markers to perform well under challenging conditions underscores their practical value.

Beyond broad-spectrum identification, specific techniques target individual body fluids with enhanced precision. For instance, hyperspectral imaging provides a rapid, non-destructive method for identifying human blood in forensic contexts [3]. This technique not only distinguishes blood from other substances but also helps determine its age, offering a significant advantage for crime scene investigators by preserving valuable evidence and accelerating preliminary analysis. The identification of human semen has seen notable advancements with a new rapid and accurate method that simultaneously detects prostate-specific antigen (PSA) and semenogelin [4]. This dual-marker approach substantially boosts both specificity and reliability, features especially crucial in sexual assault cases where definitive semen identification is paramount for generating accurate investigative leads and

judicial outcomes.

Saliva identification also greatly benefits from highly sensitive molecular methods. One particular study evaluates four specific mRNA markers for forensic saliva identification, employing a very sensitive Luminex-based assay [5]. The markers consistently show high specificity and sensitivity, even when presented with small or degraded samples, which is critical for effectively detecting saliva evidence at crime scenes and potentially linking individuals to crimes. Furthermore, research explores innovative methods for identifying vaginal secretions by combining both mRNA and microbial markers [7]. This dual-marker strategy considerably improves detection specificity and reliability, directly addressing a common and often challenging aspect in sexual assault investigations, where distinguishing different body fluids is key.

The stability of molecular markers under varying environmental and storage conditions is a critical consideration for their reliable application in forensic contexts. A dedicated study investigates the effect of different substrates and storage conditions on the stability of mRNA and miRNA markers used for body fluid identification [6]. The findings from this research offer crucial insights into RNA degradation rates, enabling forensic scientists to better understand the inherent limitations and overall reliability of molecular evidence recovered from diverse and often harsh crime scene environments. This understanding is absolutely essential for the accurate interpretation of evidence, particularly when dealing with older, environmentally exposed, or otherwise compromised biological samples.

In the realm of blood analysis, distinguishing between human and non-human sources is a fundamental initial step. MALDI-TOF MS-based proteomic analysis provides a highly reliable and sensitive technique for this purpose, adept at identifying species-specific proteins to accurately determine the origin of bloodstains found at crime scenes [10]. This method significantly aids investigations by clarifying whether blood evidence is relevant to a human-involved crime. Additionally, focused research details a multiplex RNA profiling method specifically for identifying menstrual blood, targeting both mRNA and long non-coding RNA (lncRNA) markers [9]. This innovative approach offers improved accuracy and sensitivity for differentiating menstrual blood from peripheral blood, which is essential for interpreting evidence in complex forensic cases. Even foundational methods, like enhanced presumptive tests for blood and semen, are subject to rigorous evaluation to assess their sensitivity, specificity, and potential interferences, providing important guidance for forensic laboratories on their appropriate use and interpretation at crime scenes [8].

Conclusion

Recent advancements in forensic science have significantly improved body fluid identification, a critical aspect of evidence analysis. Researchers are developing new multiplex mRNA panels for simultaneous detection of multiple crucial body fluids like blood, saliva, semen, vaginal fluid, and menstrual blood, enhancing evidence analysis in investigations. MicroRNA (miRNA) profiling has also shown promise, offering reliable detection of blood, saliva, and semen, even from degraded or mixed samples, demonstrating practical utility in forensic serology.

For specific body fluids, innovative methods are continually emerging. Hyperspectral imaging provides a rapid, non-destructive way to identify human blood and even determine its age, offering advantages for crime scene investigators by preserving evidence. The identification of human semen is being refined through dual-marker approaches, simultaneously detecting prostate-specific antigen (PSA) and semenogelin, improving specificity for sexual assault cases. Similarly, highly sensitive Luminex-based assays are being evaluated for specific mRNA markers to identify saliva, crucial for linking individuals to crimes.

Understanding the stability of these molecular markers is also essential. Studies investigate how various surfaces and storage conditions affect mRNA and miRNA marker stability, providing insights into RNA degradation rates and the reliability of molecular evidence from diverse crime scene environments. Vaginal secretions can now be identified with improved specificity by combining mRNA and microbial markers, addressing challenges in sexual assault investigations.

Traditional methods are also being enhanced; for instance, presumptive tests for blood and semen are continually evaluated for sensitivity, specificity, and potential interferences, offering guidance for forensic laboratories. More refined techniques focus on distinguishing specific types of blood, such as identifying menstrual blood using multiplex RNA profiling targeting both mRNA and long non-coding RNA (lncRNA) markers. Beyond human fluids, proteomics, specifically MALDI-TOF MS-based proteomic analysis, helps differentiate human from non-human bloodstains, a reliable technique for determining blood origin at crime scenes. These collective efforts highlight a comprehensive push to refine and expand forensic capabilities in body fluid identification.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Okonkwo, Adebayo J.. "Advancements in Forensic Body Fluid Identification." *J Forensic Med* 10 (2025):420.

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Received: 01-May-2025, Manuscript No. jfm-25-173739; **Editor assigned:** 05-May-2025, PreQC No. P-173739; **Reviewed:** 19-May-2025, QC No. Q-173739; **Revised:** 22-May-2025, Manuscript No. R-173739; **Published:** 29-May-2025, DOI: 10.37421/2472-1026.2025.10.420