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Short Communication

Liquid Chromatography in Clinical Diagnostics: Current Trends and Innovations

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DESCRIPTION

Liquid Chromatography (LC) has evolved into a cornerstone technology for clinical diagnostics, providing unparalleled capabilities for the analysis of complex biological samples. Broad range of biomolecules such as proteins, metabolites, nucleic acids, and drugs [1]. As clinical diagnostics increasingly demand faster, more reliable, and highly sensitive assays, liquid chromatography has emerged as a leading analytical technique. This manuscript explains the current trends, technological innovations, and applications of liquid chromatography in clinical diagnostics, emphasizing its impact on precision medicine, disease diagnosis, therapeutic drug monitoring, and biomarker discovery [2]. Liquid chromatography plays a pivotal role in clinical diagnostics due to its ability to separate components in complex biological matrices such as blood, urine, and tissue samples. The technique's high resolution and sensitivity make it ideal for detecting low-abundance compounds, such as hormones, peptides, or small molecules, which are essential in disease diagnosis and monitoring. LC methods are used to monitor drug levels in patient samples, ensuring effective and safe drug administration [3]. This is particularly important for drugs with narrow therapeutic windows, such as anti-epileptics, immunosuppressants, and antibiotics. LC is widely used in the discovery of disease biomarkers, which are essential for early detection and prognosis in conditions like cancer, cardiovascular diseases, and diabetes. By coupling Liquid Chromatography with Mass Spectrometry (LC-MS), clinicians can identify and quantify hundreds of metabolites or proteins in a single run, enabling a deeper understanding of disease mechanisms and metabolic disorders [4].

Several technological advancements have significantly enhanced the utility of liquid chromatography in clinical settings. The primary advancements include the development of Ultra High-Performance Liquid Chromatography (UHPLC), multidimensional chromatography, and coupling with mass spectrometry Liquid Chromatography-Tandem Mass Spectrometry (LC-MS/MS). UHPLC represents a significant improvement over traditional High-Performance Liquid Chromatography (HPLC) [5]. It uses smaller particle sizes (sub-2 µm) in the stationary phase, which results in faster and higher-resolution separations. UHPLC enables clinicians to obtain detailed results in a fraction of the time required for HPLC, without sacrificing performance or sensitivity. In clinical diagnostics, UHPLC has made it possible to conduct rapid analyses of patient samples, especially in cases where timely diagnosis is important, such as in emergency toxicology and pharmacokinetics. Moreover, UHPLC has reduced sample volumes and reagent consumption, making the technique more cost-effective and environmentally friendly [6]. LC-MS combines the separation capabilities of liquid chromatography with the high sensitivity and specificity of mass spectrometry, allowing clinicians to analyze complex biological samples with unparalleled accuracy. LC-MS has been instrumental in Therapeutic Drug Monitoring (TDM), where precise quantification of drug concentrations in plasma is critical for adjusting dosages to minimize side effects and prevent toxicity. Additionally, the use of LC-MS in clinical proteomics and metabolomics has enabled Multidimensional Liquid Chromatography (MDLC) involves coupling two or more chromatographic techniques to achieve greater separation power [7]. This is especially useful in complex sample matrices, such as plasma or tissue extracts, where hundreds or thousands of compounds may be present. MDLC increases peak capacity and resolution by separating analytes across multiple chromatographic dimensions, which can be based on differences in polarity, charge, or molecular size. In clinical diagnostics, MDLC is particularly useful in proteomics, where the goal is to separate and identify thousands of proteins in a biological sample [8]. This technique enables deeper proteomic profiling and has been widely used in cancer biomarker discovery and other research aimed at understanding disease mechanisms at the molecular level [9]. Biomarkers are molecules that can indicate the presence of disease, and they are essential for early diagnosis, treatment monitoring, and prognosis. Liquid chromatography, often coupled with mass spectrometry, allows for the high-throughput detection of biomarkers in various

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biological fluids. For instance, in cancer diagnostics, LC-MS has been used to detect tumor markers such as Prostate-Specific Antigen (PSA) and Cancer Antigen 125 (CA-125), which are essential for the early detection and monitoring of prostate and ovarian cancers, respectively [10]. Similarly, LC has been used to analyze lipid and protein biomarkers related to cardiovascular diseases, aiding in the early detection of atherosclerosis and other conditions.Therapeutic Drug Monitoring (TDM) is critical for drugs with narrow therapeutic windows, where maintaining a precise concentration of the drug in the blood is important to its efficacy and safety [11]. LC methods are used to measure the concentration of drugs in patient samples, ensuring that the correct dosage is administered to achieve the desired therapeutic effect while avoiding toxicity. For example, LC-MS is used to monitor immunosuppressants like cyclosporine and tacrolimus in transplant patients, where accurate dosing is necessary to prevent organ rejection without causing adverse side effects. LC is also employed in monitoring anticonvulsants, antibiotics, and antiretroviral drugs, among others [12].

CONCLUSION

Liquid chromatography has become indispensable in clinical diagnostics, providing critical tools for the precise detection and quantification of a wide array of biomolecules. The advancements in UHPLC, LC-MS, and multidimensional chromatography have significantly improved the speed, sensitivity, and resolution of analyses, making them invaluable in areas like therapeutic drug monitoring, biomarker discovery, and metabolomics. These innovations are pushing the boundaries of precision medicine, allowing for more personalized and accurate disease diagnosis and treatment monitoring. While challenges related to cost, throughput, and complexity remain, the future of liquid chromatography in clinical diagnostics is promising. Continued technological advancements will further enhance its role, opening up new possibilities for improving patient care and advancing medical science.

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