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High Performance Chromatography in Modern Drug Research: From Bioanalysis to Personalized Therapy

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Abstract

In recent years, chromatography has emerged as a favoured analytical approach in the area of medicine, particularly for the purpose of identifying and quantifying a medication and its metabolites. Chromatography is considered to be one of the most essential analytical procedures. There are several different chromatographic methods that have been created in order to separate medications according to the features and kinds of interactions that they have. For pharmaceutical applications, these methods, in particular "High Performance Affinity Chromatography" (HPAC), "Cell Membrane Chromatography" (CMC), "Mixed Mode Chromatography" (MMC), and "High Performance Liquid Chromatography" (HPLC), are used for the aim of conducting bioanalysis of pharmaceuticals in both preclinical and clinical research. When it comes to the investigation of pharmacokinetic features of pharmaceuticals in research and development, the success of chromatography in the creation of speedy and accurate analytical procedures gives better specificity and sensitivity. In personalised medicine, it is essential to take into account the fact that the dose and impact of medications differ from one individual to the next. The use of chromatography as a promising approach in the investigation of drug-protein binding and in the assessment of clinical or pharmaceutical samples has become more popular in recent years at the expense of other methods.

Keywords
Chromatography in medicine, High Performance Affinity Chromatography (HPAC), Pharmaceutical bioanalysis.

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1. INTRODUCTION:

The use of chromatographic methods in clinical analysis has been more widespread over the last several years, and this trend can be seen in both laboratory settings and research facilities. Clinical analysis is "the study of biological materials with the objective of identifying the diagnostic and therapeutic processes, as well as their reliability and efficacy. When we speak about clinical analysis, we are talking to the clinical analysis of biological materials. It is impossible to find a suitable replacement for the vital function that chromatographic techniques provide, particularly in the areas of drug research, toxicology, and biomarker analysis. These studies make use of a broad range of biological materials, including whole blood, serum, plasma, urine, faeces, and tissues, as well as macromolecules, including lipids and proteins.

Generally speaking, clinical analysis may be divided into three separate areas: therapeutic drug monitoring, biomarkers' analysis for laboratory-based diagnostic purposes, and clinical toxicology.

Each of these categories addresses a specific aspect of clinical analysis. The use of therapeutic drug monitoring, which is often referred to as TDM, is a common procedure that is utilised in order to determine the extent of the gap that exists between the least dangerous concentrations and the minimal active concentrations of a medication. It is feasible to operationalise biomarkers as an indicator of normal biological processes, pathogenic processes, and pharmacological responses. This is something that can be done. Biological compounds that are capable of performing this role are referred to as biomarkers. Among the substances that fall under this group are metabolite compounds that have a low molecular weight, vitamins, hormones, lipids, peptides, and proteins. In particular, they are vital for the early diagnosis of sickness, the assessment of the development of the disease, the monitoring of drug response, and the engagement in therapeutic action. When doing an analysis in clinical toxicology, the primary emphasis is on the many hazardous compounds that have been linked to diseases or clinical symptoms that manifest themselves after exposure to the material for either a short or a long length of time.

When doing clinical analysis, it is necessary to use methods that are not only relatively fast but also very effective and trustworthy. In addition to the nonspecific interactions that take place in the studies that are used in typical clinical applications, the poor efficiency and sensitivity of these procedures are also factors that lead to a deterioration in the dependability of these methods. As a direct result of this, it is essential that more specialist analyses be selected in place of traditional processes in the current day. Over the last several years, there has been a growth in the use of chromatographic techniques, notably in research laboratories as well as in regular laboratories. The findings of this research are going to be presented in the form of a summary of the current state of the chromatographic methods that are used in clinical analysis. The purpose of this study is to offer a succinct review of the chromatographic trends in clinical analysis, analyse the merits and downsides connected with these trends, and finish by giving an original opinion on the route that future research should go. In order to achieve this purpose, the chromatography methods that are presented in the review have been selected. This is due to the fact that, in contrast to the routine analysis and other chromatography techniques, these methods provide higher characteristics in terms of sensitivity, selectivity, time, and efficiency.

2. USING CHOROMATOGRAPHY FOR CLINICAL EVALUATION:

From the perspective of clinical analysis, a broad variety of chromatographic techniques have been developed in order to identify the unique qualities and interactions of a number of different drugs. For the purpose of this section, the characteristics of chromatographic methods that are used in clinical analysis are investigated in sufficient detail. Selectivity, sensitivity, analysis time, and yield sensitivity are some of the properties that fall under this category.

2.1. High Performance Liquid Chromatography (HPLC) Applications

For the purpose of overcoming challenges associated with the analysis of TDM, steroid hormones, and vitamins, as well as new-born screening and immunoassay, high-performance liquid chromatography-mass spectrometry (HPLC-MS) has been used as a selected alternative approach in clinical labs, particularly in the fields of endocrinology and toxicology. This has been done in order to overcome these challenges. Selectivity, precision, efficiency, and analysis time are the four hallmarks that characterise high-performance liquid chromatography-mass spectrometry (HPLC-MS).

High-performance liquid chromatography-mass spectrometry, often known as HPLC-MS, is a quantitative technique that is both trustworthy and practical, and it is used for the purpose of diagnosing and evaluating illnesses. When it comes to the process of developing the approach, it is suggested that a universal LC technique be used. Particularly in the C18 column and gradient mode, the reversed-phase mode is the one that is used the most often for the evaluation of a mobile phase that is constituted of acetonitrile/methanol and formic/acetic acid, in addition to a drug and a biomarker. This mode is also the one that is utilised the most frequently." Fig. 1 shows that the C18 column and the mobile phase, which is composed of acetonitrile/methanol and formic/acetic acid in the gradient mode, are the ones that are used the most often in drug and biomarker research.

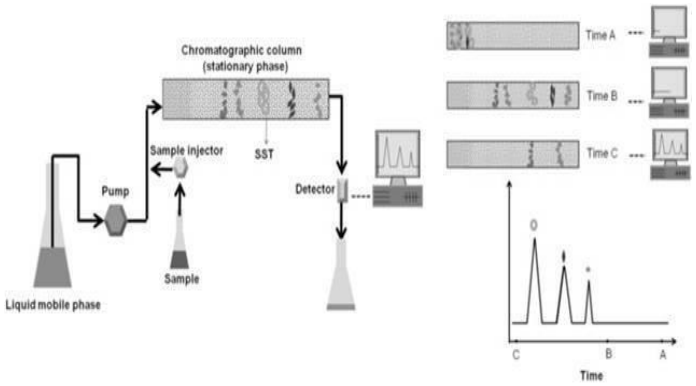

Fig 1. LC-MS's schematized presentation

2.2. Gas Chromatography (GC) Applications

Gas chromatography (GC) is often used as an alternative to "Gas Chromatography" (GC-MS/MS) and "High-Performance Liquid Chromatography" (HPLC-MS/MS) techniques in forensic toxicology, doping analysis, and conventional bioanalytical laboratories. This is because GC is able to get more accurate results than these other techniques. The reason for this is that gas chromatography (GC) has a high degree of precision and may be used to a wide variety of physicochemical agents. "The vast majority of gas chromatography techniques include the use of open tubular capillary columns and the deposition of a liquid film on the wall of the column (Figure 2). Among the many uses of gas chromatography, two more applications are metabolomics and lipidomics. These applications are used in the targeted examination of a wide variety of volatile compounds. During clinical GC procedures, the chemicals that are commonly recognised include drugs like cocaine, cannabinoids, amphetamines, MeOH, and breath volatile compounds. Other compounds that are often identified include MeOH. Endogenous chemicals, which include fatty acids, steroids, and other hormones, as well as anaesthetics, analgesics, antidepressants, antipsychotics, and antiepileptics, are also included in this group. Clinical analysis has the potential to identify the biomarkers of certain diseases, including tuberculosis (TB), cancer, neurological ailments, and diseases associated with metabolic imbalances. This research project may be finished in a span of ten minutes, which is the only time requirement.

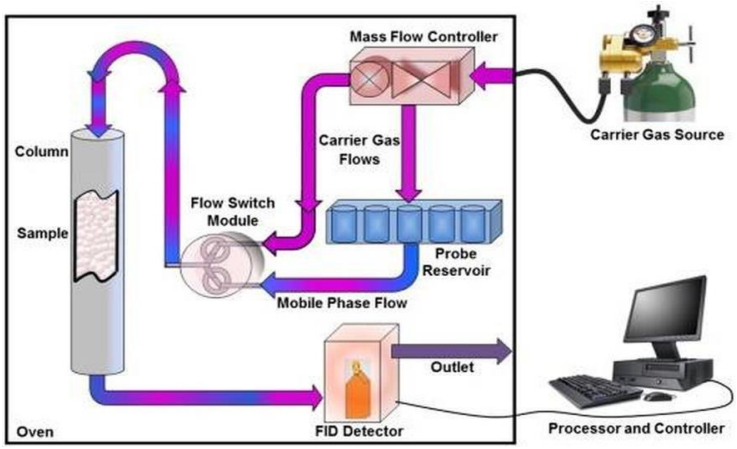

Fig 2. Schematized representation of Gas Chromatography

2.3. Supercritical Fluid Chromatography (SFC) Applications

As is the case with gas chromatography, supercritical fluid chromatography makes use of open tubular columns. Compared to GC and HPLC, this method has a number of benefits, including the following:

1. With a lower viscosity and a higher dispersion, separation may be accomplished more quickly and with more efficiency.
2. mobile phase that is not harmful to the environment and is based on carbon dioxide and organic solvents
3. The stationary phase with a broad spectrum.

Because of these characteristics, supercritical fluid chromatography makes it possible to conduct an analysis at a higher resolution and in a shorter amount of time. In addition, this method is a useful supplement to the gas chromatography and high-performance liquid chromatography that are often used in clinical studies. It is for this reason that SFC has the potential to become a technique that garners a significant amount of attention in clinical investigations (Fig.3). Additionally, it is used extensively in the process of medication discovery and development.

Fig 3. Supercritical chromatography in pharmaceutical analysis

SFC is conducted in clinical research for the purpose of monitoring medications that have significant side effects, such as citalopram in plasma and ketamine metabolites in urine. Additionally, SFC is used for the goal of monitoring antiepileptics and chemotherapeutics. The identification of lipophilic compounds, carotenoids, and fat-soluble vitamins E and D may be achieved by HPLC in a period of ten minutes; however, this can be accomplished by SFC in a matter of minutes (Fig. 4). In general, the identification of these constituents can be accomplished by HPLC.

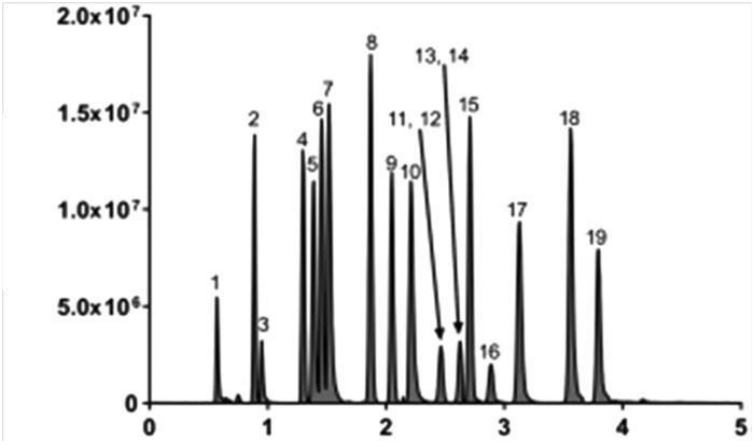

Fig 4. 4-min analysis of 19 endogenous steroids by SFC

SFC is an excellent method for screening endogenous hormones, particularly steroids, and for quantifying neurotransmitters. This is made possible by the physicochemical property of the mobile phase. A presentation of the structural separation of steroids that are comparable may be seen in Figure 4. These findings may be used in the process of diagnosing a wide variety of disorders.

2.4. High Performance Affinity Chromatography Affinity Chromatography (HPAC)

It is important to note that the interaction of hormones with their receptors, the binding of medicines with their biological targets or their carrier agents, the binding of biochemical and chemical agents inside the body, and the binding of antibodies with antigens are all relevant in a number of clinical processes. High Performance Affinity Chromatography has become a technology that is commonly used for the aim of exploring and explaining the interactions that take place between proteins and drugs. This technique has developed as a popular approach.

Affinity chromatography is a method that is based on the selective and reversible absorption of a targeted biomolecule by ligands that are immobilised on an

insoluble support material (matrix) and comprise binding ends that are complementary to the target molecule (Fig. 5). This technique is referred to as affinity chromatography. It is possible to elute the target molecule from the medium by using a racing ligand or by modifying the polarity, pH, or ionic power of the medium (mobile phase). Both of these methods are viable options. These two approaches are both reasonable possibilities to consider. The compound should not be denatured by the mobile phase that is used during the elution of the compound from the column, and the mobile phase should not induce any changes in the specific activity and function of the particular chemical. Both of these goals should be met.

An affinity chromatography technique is able to function as a result of the reversible connection that takes place between a protein and a specific ligand that is immobilised in a chromatographic matrix. There is a kind of liquid chromatography that is known as affinity chromatography. This technique is a method that use a material that is connected to biology as a stationary phase in order to purify or analyse certain components of a sample. This technology makes it feasible to employ high performance affinity chromatography (HPLC) supports and equipment for the purpose of affinity-based separation or analysis. This technique is also known as affinity-based separation."

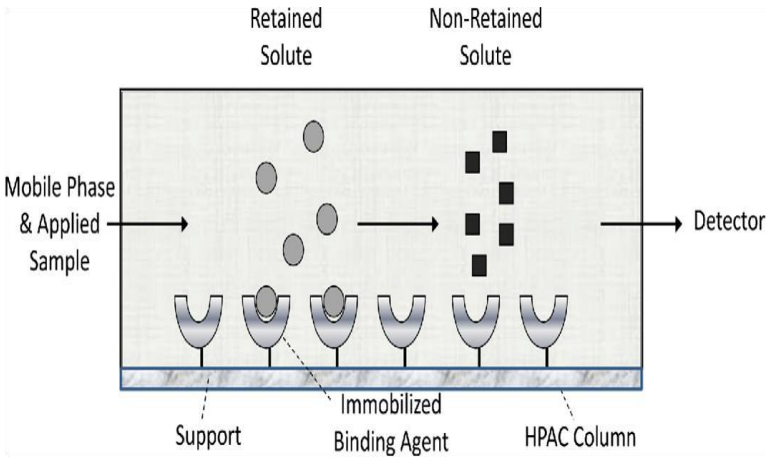

Fig 5. Basic components of High Performance Affinity Chromatography

Numerous applications include high-performance drug screening, research on modified proteins, research on personalised medicine, and research on medication-drug interactions. These are only few of the fields of use. For the aim of conducting research on drug-protein binding, HPAC has a few features that make it an appealing choice. As an example, this method has a very high degree of sensitivity, in addition to being relatively high and being easy to include into the routine. A number of studies have shown that it obtains a reasonable correlation with reference procedures when it is used to explore the interaction between serum proteins and pharmaceutical compounds. In addition to this, it can be used in combination with a broad variety of detectors, and it may be employed in a variety of different ways. The fact that the HPAC has the capability of reusing the same protein or binding agent for a number of different tests is yet another useful aspect of this laboratory equipment.

There are a variety of distinct ways in which a disease might affect the interactions that take place between medications and proteins in the blood (blood proteins). Among all of these many approaches, the most important one is the change in the concentration of a protein or a binding agent. For example, the fluctuations in the concentration of different binding agents, such as HSA, in the blood, as well as the compounds of these agents, such as lipoproteins, and the molecules themselves (also known as the molecules themselves). Furthermore, it is a well-established fact that during the acute phase of some illnesses, the quantity of AGP (α1-acid glycoprotein) has the ability to increase by a factor of two to five.

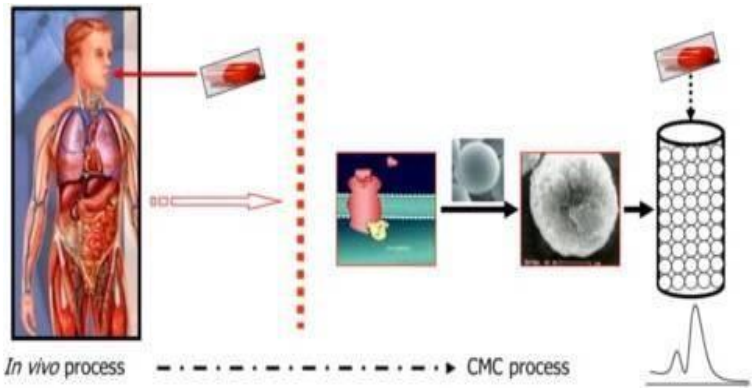

Fig 6. Recent advances in Cell Membrane Chromatography

2.5. Applications of Cell Membrane Chromatography (CMC)

The use of cell membrane chromatography as a practical instrument for the screening of active components and the investigation of the interaction between medications and receptors is something that has only lately become feasible (Fig. 6). In order to analyse the interaction that occurs between the drug and the cell membrane receptors, an in vitro research is carried out. CMC is advantageous for a variety of reasons, including the fact that it is both quick and accurate, and that it is suitable for the screening of active components in mixed solutions. These are just a few of the advantages that it offers. Cell membrane recognition, often known as "CMC, is a biomimetic affinity chromatography technique that employs cell membrane receptor as the stationary phase. The stationary phase of the cell membrane is produced by the fusion of the cell membrane and the adsorption of silicon hydroxyl (Si-OH) groups on the surface of the silica gel." Both of these processes take place simultaneously. Within the realm of possibilities, silica gel has the ability to function as the most effective transporter of cell membrane.

It is possible for paraformaldehyde to have a cross-linking reaction with the amino group that is located on the surface of the protein. Additionally, the membrane protein of the protein contributes to the preservation of the spatial arrangement. Using paraformaldehyde as a protein cross-linking agent has the potential to cause damage to the structure of the protein and limit its activity, which renders it incapable of ensuring the dependability of scanning results. This is an additional point of interest that should be taken into consideration. As a result of this, there is a need for a novel strategy that has the potential to enhance the cell membrane's ability to attach to the silica gel without adversely affecting the cell membrane in any way.

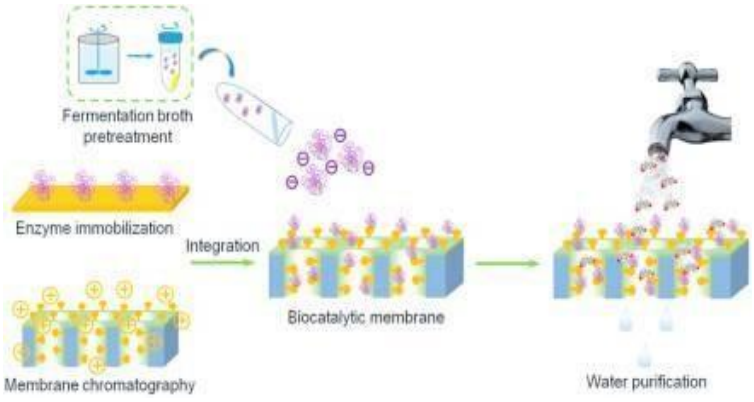

Fig 7. Cell Membrane Chromatography analysis

"There are a number of problems associated with CMC, one of which is the fact that colons have a relatively short lifetime. Both the stability and the replicability of the screening results are significantly affected when membrane proteins that are adsorbing on silica gels are unable to maintain their fast movements or activities running continuously. When cell membrane columns are used, it is feasible that receptors that are located on the surface of a cell membrane may gradually lose their inherent biological function. Additionally, when the mobile phase is washed, it is feasible to easily separate a membrane that has been adsorbed on the surface of the mobile phase. This is because the membrane is

attached to the mobile phase. The column of the cell membrane has a relatively short lifetime (Fig. 7), which may be attributed to these two separate processes. After being used continuously for forty-eight to seventy-two hours, they often cease to function properly. There is reason to be optimistic about the high-performance drug receptor that was designed by CMC for the aim of interaction characterisation. In terms of integration and automation, it is projected that CMC, which is a method for drug analysis that has separation and activity screening capabilities, would see rapid advancements in the near future.

2.6. Applications of mixed-mode chromatography (MMC)

It combines enhanced properties for the separation of compounds that fail to bind well or solve effectively using conventional reversed phase LC procedures, especially for molecules that are polar or charged. When the parameters of the mobile phase of the MMC column are adjusted, it adds an extra dimension to the separation process. This is due to the fact that a single MMC column displays the ability to bind several molecules simultaneously. In addition, MMC is an efficient technique of purification that may be used to separate complicated compound matrices or to carefully investigate trace amounts of analytes. The presence of several retention methods is one of the reasons why mixed-mode columns are beneficial columns. Mixture-mode columns are the most frequent kind of column that exhibits reversed-phase and ion exchange (anionic, cationic, or zwitterionic) behaviour. They are also the most common type of column.

In order to control the interactions of certain analytes, MMC makes it possible to change the parameters of the mobile phase and the eluant. The separation is improved thanks to the fact that it is a mixed-mode stationary phase of the latest generation (Fig. 8)

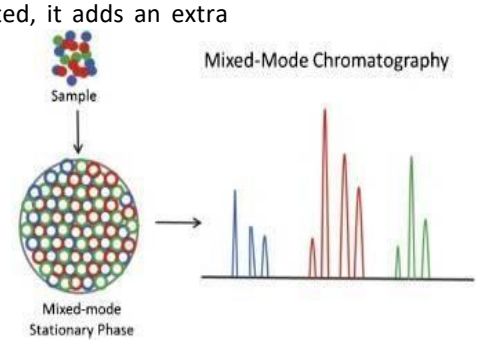

Fig 8. Mixed-mode Chromatography

Alternate Mode A type of chromatography that takes use of a variety of distinct interaction mechanisms between the solutes and the stationary phase is referred to as metal-matter chromatography (MMC), which is also commonly known as chromatography. In compared to more conventional approaches, such as reversed-phase (RP) chromatography, ion exchange (IEX) chromatography, hydrophilic interaction liquid chromatography (HILIC), and normal phase (NP) chromatography (see Figure 9), this technique is both an alternative and a complementary method. Over the course of the last several years, there has been a significant rise in the amount of scholarly interest in MMC, not just inside the biopharmaceutical industry but also to a wider extent. On the other hand, the analysis and purification of peptides and proteins are of the highest relevance when it comes to the characterisation of antibody production and heterogeneity."

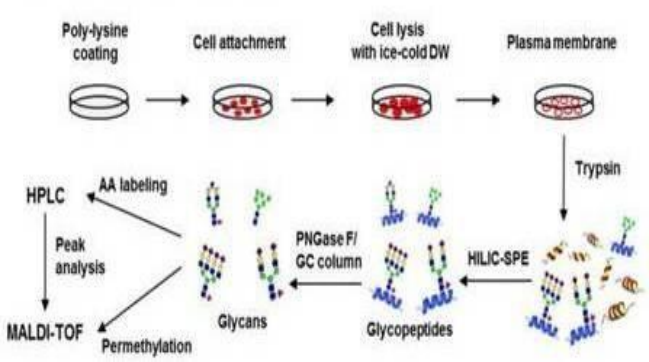

Fig 9. Plasma membrane protein isolation using the MMC technique

3. RESULTS AND ADVICE:

Focussing on key features of certain chromatographic techniques with clinical applications is the goal of this investigation. All things considered, these methods are tested for precision, efficiency, speed, and selectivity.

It is essential to use clinical analysis often and to conduct it quickly while keeping efficiency good. The process of assessing a large variety of compounds commonly makes use of spectrophotometric, electrochemical, and immunological tests due to their significant efficacy and universality. Clinical analytical diagnostics rely heavily on chromatographic technologies, especially in toxicology, biomarker analysis, and drug screening. A combination of existing methods with those that are being developed is necessary to reach more advanced practices in the field of affinity chromatography and high-performance liquid chromatography (HPAC) for the purpose of characterising biological interactions in clinical and pharmaceutical investigations.

A number of advantages have accrued from HPAC's substantial contribution to the fields of drug-protein interactions and tailored medicine. Among these advantages are the technology's rapidity and precision, its adaptability to different sensing modes and formats, the ease of automation, and the fact that it requires very little in the way of sample and binding agent. Over 30% of clinical chromatographic procedures in toxicology make use of GC. Chemical kinetic chromatography (CMC) is a simple, selective, and time-efficient approach to studying drug-receptor interactions, identifying product quality, and screening active chemicals from complex mixtures. As a method for separating highly polar compounds, MMC has become more popular in recent years. We do this by combining MMC with both conventional and non-traditional reversed-phase chromatographic methods.

Finally, well-designed universal chromatographic techniques are desperately needed in the clinical field to streamline the processes and approaches utilised to evaluate a myriad of biological components.

REFERENCES:

1. Denoroy L., Zimmer L., Renaud B. & Parrot S. (2013). Ultra high performance liquid chromatography as a tool for the discovery and the analysis of biomarkers of diseases: a review. *Journal of Chromatography B*, 927, 37-53.
2. Desfontaine V., Guillarme D., Francotte E. & Nováková, L. (2015). Supercritical fluid chromatography in pharmaceutical analysis. *Journal of pharmaceutical and biomedical analysis*, 113, 56-71.
3. Ding X., Chen X., Cao Y., Jia D., Wang D., Zhu Z. & Chai Y. (2014). Quality improvements of cell membrane chromatographic column. *Journal of Chromatography A*, 1359, 330-335.
4. Du Toit T., Bloem L. M., Quanson J. L., Ehlers R., Serafin A. M. & Swart A. C. (2017). Profiling adrenal 11β hydroxy androstenedione metabolites in prostate cancer cells, tissue and plasma: UPC2-MS/MS quantification of 11β hydroxy testosterone, 11 keto-testosterone and 11 keto-dihydrotestosterone. *The Journal of steroid biochemistry and molecular biology,* 166, 54-67.
5. Fan J., Luo J. & Wan Y. (2017). Aquatic micro-pollutants removal with a biocatalytic membrane prepared by metal chelating affinity membrane chromatography. *Chemical Engineering Journal*, 327, 1011-1020.
6. Fassauer G. M., Hofstetter R., Hasan M., Oswald S., Modeß C., Siegmund W. & Link A. (2017). Ketamine metabolites with antidepressant effects: fast, economical, and eco-friendly enantioselective separation based on supercritical-fluid chromatography (SFC) and single quadrupole MS detection. *Journal of pharmaceutical and biomedical analysis*, 146, 410-419.
7. Felletti S., Ismail O. H., De Luca C., Costa V., Gasparrini F., Pasti L. & Catani M. (2019). Recent achievements and future challenges in supercritical fluid chromatography for the enantioselective separation of chiral pharmaceuticals. *Chromatographia*, 82(*1*), 65-75.
8. Ghose, S. & Kumpalume P. (2003). Chromatography: the high-resolution technique for protein separation. *In Isolation and Purification of Proteins*, 44-69.
9. Hage D. S., Anguizola J. A., Jackson A. J., Matsuda R., Papastavros E., Pfaunmiller E. & Zheng X. (2011). Chromatographic analysis of drug interactions in the serum proteome. *Analytical Methods*, 3(*7*), 1449-1460.
10. Hage D. S., Jackson A., Sobansky M. R., Schiel J. E., Yoo M. J. & Joseph K. S. (2009). Characterization of drug–protein interactions in blood using high-performance affinity chromatography. *Journal of separation science*, 32(*5-6*), 835-853.
11. He L. C., Wang S. C., Yang G. D., Zhang Y. M., Wang C. H., Yuan B. X. & Hou X. F. (2007). Progress in cell membrane chromatography. *Drug Discov Ther*, 1(*2*), 104-107.
12. Higgins V, Nieuwesteeg M & Adeli K. (2016). Reference Intervals: Theory and Practice. Clarke W, editor. *Contemporary Practice in Clinical Chemistry, 3rd ed: AACC Press*, 21-36.
13. Hochepied T., Wullaert A., Berger F. G., Baumann H., Brouckaert P., Steidler L., & Libert C. (2002). Overexpression of α1-acid glycoprotein in transgenic mice leads to sensitisation to acute colitis. *Gut*, 51(*3*), 398-404.
14. Hou X., Zhou M., Jiang Q., Wang S. & He L. (2009). A vascular smooth muscle/cell membrane chromatography–offline-gas chromatography/mass spectrometry method for recognition, separation and identification of active components from traditional Chinese medicines. *Journal of Chromatography A*, 1216(*42*), 7081-7087.

15. Hou X., Wang S., Zhang T., Ma J., Zhang J., Zhang Y. & He L. (2014). Recent advances in cell membrane chromatography for traditional Chinese medicines analysis. *Journal of pharmaceutical and biomedical analysis*, 101, 141-150.
16. Kalogria E., Pistos C. & Panderi I. (2013). Hydrophilic interaction liquid chromatography/positive ion electrospray ionization mass spectrometry method for the quantification of alprazolam and α-hydroxy-alprazolam in human plasma. *Journal of Chromatography B*, 942, 158-164.
17. Kortz L., Helmschrodt C. & Ceglarek U. (2011). Fast liquid chromatography combined with mass spectrometry for the analysis of metabolites and proteins in human body fluids. *Analytical and bioanalytical chemistry*, 399(*8*), 2635-2644.
18. Lämmerhofer M., Richter M., Wu J., Nogueira R., Bicker W. & Lindner W. (2008). Mixed-mode ion-exchangers and their comparative chromatographic characterization in reversed-phase and hydrophilic interaction chromatography elution modes. *Journal of separation science*, 31(*14*), 2572-2588.
19. Li Z., Beeram S. R., Bi C., Zheng, X. & Hage D. S. (2016). High-performance affinity chromatography: applications in drug–protein binding studies and personalized medicine. *In Advances in protein chemistry and structural biology*. 102, 1-39.
20. Matsuda R., Anguizola J., Joseph K. S. & Hage D. S. (2011). High-performance affinity chromatography and the analysis of drug interactions with modified proteins: binding of gliclazide with glycated human serum albumin. *Analytical and bioanalytical chemistry*, 401(*9*), 2811.
21. Mohammadi-Jam S. & Waters K. E. (2014). Inverse gas chromatography applications: A review. *Advances in colloid and interface science*, 212, 21-44.
22. Mun J. Y., Lee K. J., Seo H., Sung M. S., Cho Y. S., Lee S. G. & Oh D. B. (2013). Efficient adhesion-based plasma membrane isolation for cell surface N-glycan analysis. *Analytical chemistry*, 85(*15*), 7462-7470.
23. Natarajan P., Ray K. K. & Cannon C. P. (2010). High-density lipoprotein and coronary heart disease: current and future therapies. *Journal of the American College of Cardiology*, 55(*13*), 1283-1299.
24. Ostrove, S. (1990). Affinity chromatography: General methods. *In Methods in Enzymology*, 182, 357-371.
25. Quanson J. L., Stander M. A., Pretorius E., Jenkinson C., Taylor A. E. & Storbeck K. H. (2016). High-throughput analysis of 19 endogenous androgenic steroids by ultra-performance convergence chromatography tandem mass spectrometry. *Journal of Chromatography B*, 1031, 131-138.
26. Santos I. C. & Schug K. A. (2017). Recent advances and applications of gas chromatography vacuum ultraviolet spectroscopy. *Journal of separation science*, 40(1), 138-151.
27. Schiel J. E. & Hage D. S. (2009). Kinetic studies of biological interactions by affinity chromatography. *Journal of separation science*, 32(*10*), 1507-1522.
28. Silva C. G. A. D. & Collins C. H. (2014). Super/subcritical fluid chromatography with packed columns: state of the art and applications. *Química Nova*, 37(*6*), 1047-1057.
29. Tarafder, A. (2016). Metamorphosis of supercritical fluid chromatography to SFC: an overview. *TrAC Trends in Analytical Chemistry*, 81, 3-10.
30. Van den Ouweland J. M. & Kema I. P. (2012). The role of liquid chromatography–tandem mass spectrometry in the clinical laboratory. *Journal of chromatography B*, 883, 18-32.
31. Vlčková H. K., Pilařová V., Svobodová P., Plíšek J., Švec F. & Nováková L. (2018). Current state of bioanalytical chromatography in clinical analysis. *Analyst*, 143(*6*), 1305-1325.
32. Wei F., Hu Q., Huang J., Han S. & Wang S. (2017). Screening active compounds from Corydalis yanhusuo by combining high expression VEGF receptor HEK293 cell membrane chromatography with HPLC-ESI-IT-TOF-MSn method. *Journal of pharmaceutical and biomedical analysis*, 136, 134-139.
33. Wilchek M. & Chaiken I. (2000). An overview of affinity chromatography. *In Affinity Chromatography*, 1-6. Humana Press.
34. Xiao-Yu W., Xiao-Fei C., Yan-Qiu G., Yan C., Yong-Fang Y., Zhan-Ying H. & Yi-Feng C. (2018). Progress of Cell Membrane Chromatography and Its Application in Screening Active Ingredients of Traditional Chinese Medicine. *Chinese Journal of Analytical Chemistry*, 46(*11*), 1695-1702.
35. Xie S. M. & Yuan L. M. (2017). Recent progress of chiral stationary phases for separation of enantiomers in gas chromatography. *Journal of separation science*, 40(*1*), 124-137.
36. Yin L., Shi M., Wang T., Zhang M., Zhao X., Zhang Y. & Gu J. (2017). A Parallel-Column LC–MS/MS Method for High Through put Analysis of Eight Antiepileptic Drugs in Clinical Therapeutic Drug Monitoring. *Chromatographia*, 80(*1*), 137-143.
37. Zhang K. & Liu X. (2016). Mixed-mode chromatography in pharmaceutical and biopharmaceutical applications. *Journal of pharmaceutical and biomedical analysis*, 128, 73-88.
38. Zhang K., Dai L. & Chetwyn N. P. (2010). Simultaneous determination of positive and negative pharmaceutical counterions using mixed-mode chromatography coupled with charged aerosol detector. *Journal of Chromatography A*, 1217(*37*), 5776-5784.
39. Zhu M. Z., Wu W., Jiao L. L., Yang P. F. & Guo M. Q. (2015). Analysis of flavonoids in lotus (Nelumbo nucifera) leaves and their antioxidant activity using macroporous resin chromatography coupled with LC-MS/MS and antioxidant biochemical assays. *Molecules*, 20(*6*), 10553-10565.