Review Article Open Access

ARTICLE LINK

ISSN: 2349-9818

NOV. - DEC.2021, VOL. 8 (6), 12-24

TROPICAL JOURNAL OF PHARMACEUTICAL AND LIFE SCIENCES

(An International Peer Reviewed Journal)

Journal homepage: http://informativejournals.com/journal/index.php/tjpls

A REVIEW ON HPLC APPROACHES FOR SIMULTANEOUSLY DETERMINING ANTIHYPERTENSIVE DRUG COMBINATIONS

Pramod Kumar Goyal* and Manish Jaimini

Dept of Pharmacy, Maharishi Arvind University, Jaipur

ARTICLE INFO:

Received: 8th Nov. 2021; **Received** in revised form: 28th Nov. 2021; **Accepted:** 19th Dec. 2021; **Available online:** 30th Dec. 2021.

ABSTRACT

Recent demand for high-throughput analyses with high sensitivity and selectivity to molecules and drugs in different classes with different physical-chemical properties and a reduction in analysis time is a major milestone for novel methodologies, especially when analytical procedures are applied to clinical purposes. Multi-drug therapy are used to treat multiple diseases to prevent high doses of a single medicine that could produce negative effects. In recent years, fast approaches for analysing mixed compounds have been in high demand. New procedures and devices were created to meet these needs. Complex matrices can slow sample preparation and processing. Quantitative drug association profiles face issues with components, matrices, compounds, and physical-chemical complexity. We discuss HPLC methods for the determination of different combination of Benidipine hydrochloride, Metoprolol succinate, Azelnidipine, Bisoprolol Fumarate, and Cilnidipine. This study covers recently optimised procedures such as chromatographic separation, as well as methodologies that have improved accuracy, sensitivity, and selectivity in quantitative drug association analyses.

Keywords: Simultaneous analysis, RP-HPLC method, Antihypertensive dosage form, Validation parameters

INTRODUCTION[1-8]

A matter of great concern for a pharmaceutical molecule is its chemical stability as it has direct influence on safety and efficacy of the drug product. The requirement of stability testing data has been recommended by the USFDA and ICH guidance to understand the influence of various environmental factors on the quality of a drug substance and drug product with time. Selection of suitable formulation and package as well as providing proper storage conditions and shelf life, which is essential for regulatory documentation, depends upon the stability of molecule. A process that involves degradation of drug products and drug substances at conditions more severe than accelerated conditions and thus generates degradation products

***Corresponding Author:**
Pramod Kumar Goyal,
Maharishi Arvind College of Pharmacy,
Jaipur, Rajasthan, India
,

that can be studied to determine the stability of the molecule is known as Forced degradation. According to ICH guideline stress testing is intended to identify the likely degradation products which further helps in determination of the intrinsic stability of the molecule and establishing degradation pathways and to validate the stability indicating procedures used. Forced degradation studies are a regulatory requirement and scientific necessity. It has become mandatory to perform stability studies of new drug moiety before filing in registration dossier. Forced degradation studies can be used to develop the stability indicating method which can be applied latter for the analysis of samples generated from accelerated and long-term stability studies. Titrimetric, Spectrophotometric and Chromatographic techniques have been commonly employed in analysis of stability samples.

All chromatographic separations are carried using a mobile and a stationary phase. Thus, all separation processes that utilize a gas as the mobile phase are classed as gas chromatography. Conversely, all separation processes that utilize a liquid as the mobile phase are classed as liquid chromatography.

Classification depending upon type of Stationary Phase used and Principle of separation involved is as follows:

A) Adsorption Chromatography

• Gas-solid chromatography
• Liquid column chromatography
• High performance liquid chromatography
• Thin layer chromatography

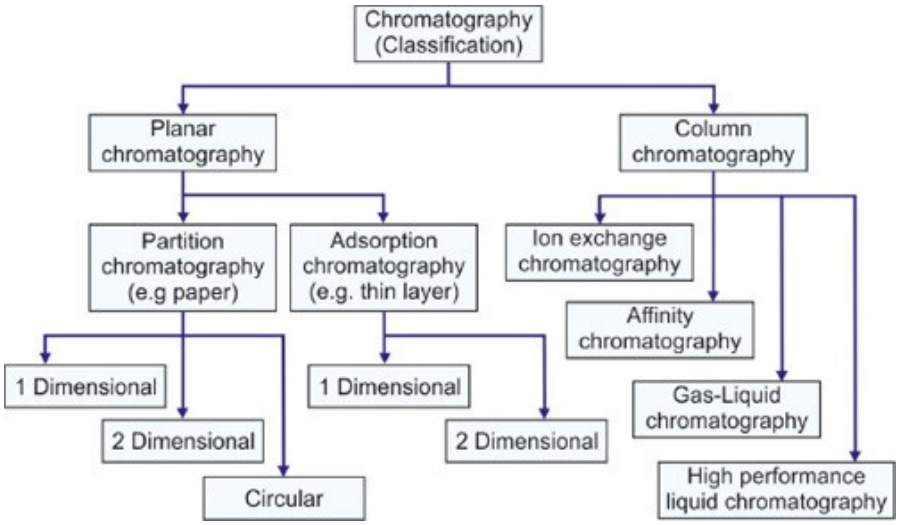

Figure 1 Classification of chromatographic methods

B) Partition Chromatography

• Gas-liquid chromatography
• Super critical fluid chromatography
• Liquid-liquid chromatography
• Paper chromatography
• High performance liquid chromatography

C) Ion Exchange Chromatography

D) Permeation Chromatography

• Size exclusion chromatography

E) Affinity chromatography

• DNA Affinity chromatography

F) Electrophoresis

• Capillary electro chromatography.

Instrumentation of HPLC

The essential features of modern liquid chromatography are solvent delivery system, pump, sample injection system, column, detector and data collection devices.

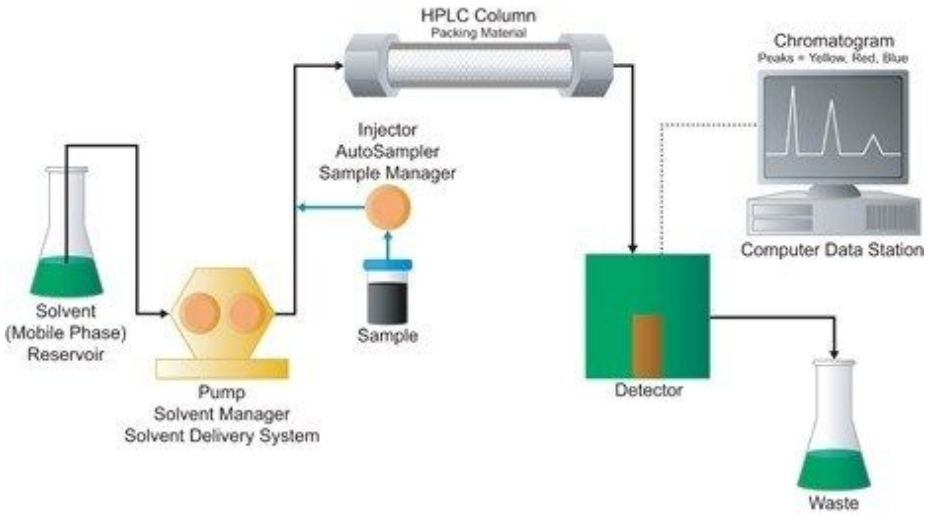

Figure 2 Components of HPLC system

Need and Steps in Analytical Method Development

Method development in chromatography is the setting up of an analytical procedure that will be appropriate for the analysis of a particular sample. In industries, new measurement technologies can only be adopted if a sound scientific rationale for the application has been developed, proven, justified and the developed method has been approved by internal company procedures. Newer analytical methods are developed for these drugs or drug combinations because of the following reasons

• The drug or drug combination may not be official in any Pharmacopoeia. A literature search may not reveal an analytical method for the drug or its combinations.

• Analytical methods may not be available for the drug combination due to the interference caused by excipients.

• Analytical methods for the quantification of drug or drug combination from biological fluid may not be available.

• Analytical methods for a drug in combination with other drugs may not be available.

There are various aspects which should be kept in mind while developing a method for HPLC such as:

• Selection of the HPLC method which includes choosing either of the two, reverse phase or normal phase HPLC depending upon the nature of the sample, for example, for polar analytes the reverse phase HPLC is used to obtain better retention and resolution and for low or medium polarity samples, generally normal phase chromatography is preferred.

• Selection of proper mobile phase for the analyte is the most crucial stage in developing a method for HPLC. A mobile phase which has the capability of pulling the analyte from the column is chosen. When dealing with weak acids and bases, pH should be adjusted which has effect on the retention of the analyte.

• A stationary phase is generally C18 bonded in the case of reverse phase HPLC and cyano-bonded in the normal phase

• The detectors are selected based on the nature of the analyte. If the analyte has chromophores it is detected by UV-detectors. Fluorescence detectors are used in the case of trace analysis and in preparative HPLC refractive index detectors are used.

Step 1: Define method objectives and understand the chemistry.

Determine the goals for method development (e.g., what is the intended use of the method?), and to understand the chemistry of the analytes and the drug product.

Step 2: Initial chromatographic conditions Develop preliminary chromatographic conditions to achieve minimally acceptable separations. These HPLC conditions will be used for all subsequent method development experiments.

Step 3: Sample preparation procedure

Develop a suitable sample preparation scheme for the drug product

Step 4: Standardization

Determine the appropriate standardization method and the use of relative response factors in calculations.

Step 5: Final method optimization/robustness

Identify the "weaknesses" of the method and optimize the method through experimental design. Understand the method performance with different conditions, different instrument set ups and different samples.

Introduction to disease

Hypertension is one the major leading causes of mortality and morbidity of cardiology patients as it is one of the major leading causes of cardiovascular events and requires a lifelong treatment. It affects about one fourth of the population worldwide. The main reason behind this is estimated as uncontrolled hypertension as it leads to complications which are very serious. By controlling hypertension or raised blood pressure one can prevent the occurrence of cardiovascular events, many studies conducted previously had evidence. The uncontrolled hypertension may have many factors like patients access to health care, drug compliance, prescriber practicing pattern, age, obesity and physical activity etc.

Introduction to properties of antihypertensives drugs: [9-16]

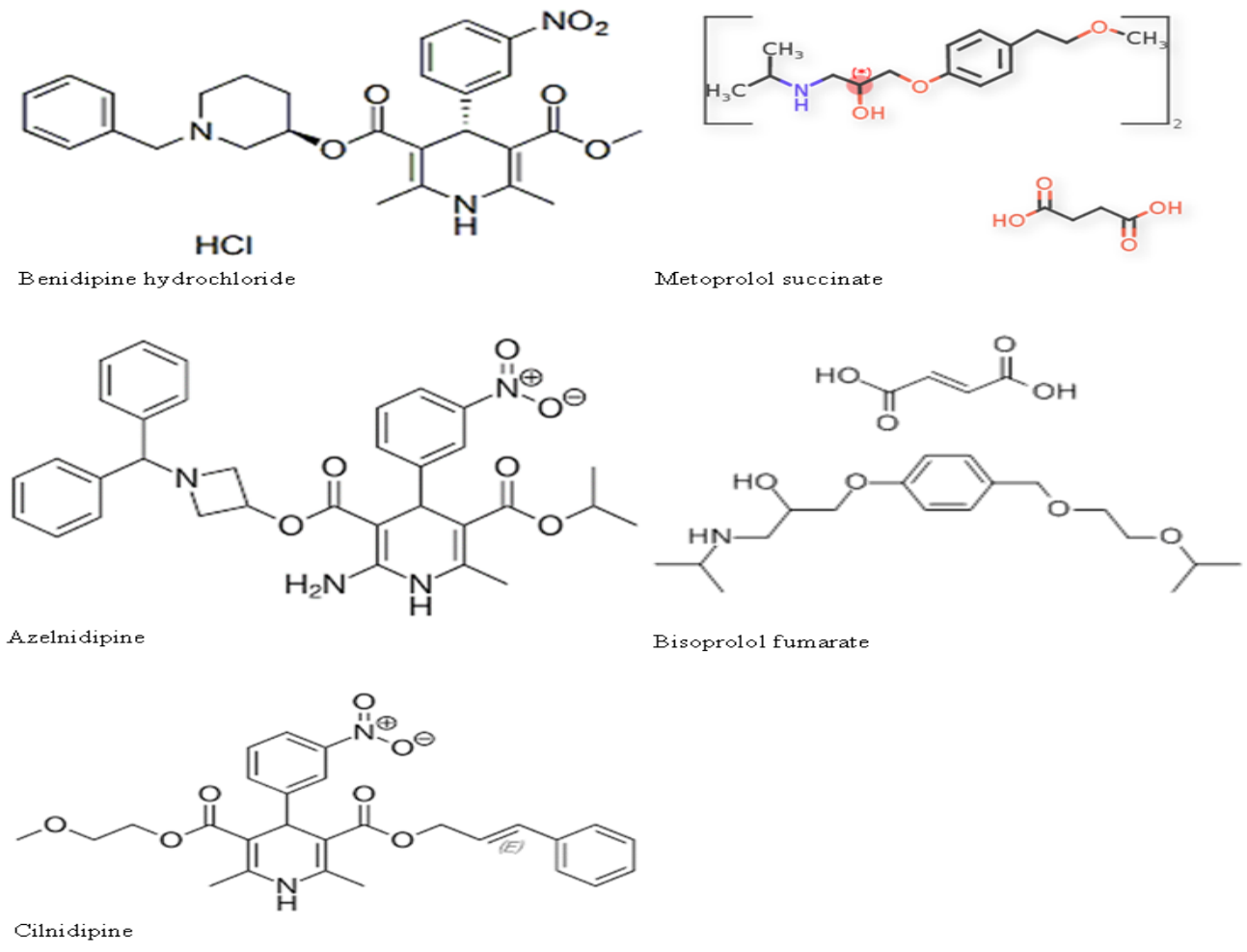

Figure 3 Structures of antihypertensives

Table 1 physical properties of antihypertensives

Name of drug	Molecular formula	Molecular weight	Log P
Benidipine hydrochloride	$C_{28}H_{32}ClN_3O_6$	542.02	4.28
Metoprolol succinate	$C_{34}H_{56}N_2O_{10}$	652.8	1.8
Azelnidipine	$C_{33}H_{34}N_4O_6$	582.65	5.12
Bisoprolol fumarate	$C_{22}H_{35}NO_8$	441.5	2.3
Cilnidipine	$C_{27}H_{28}N_2O_7$	492.52	4.39

Table 2 Official RP-HPLC methods for selected antihypertensives

Drug	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
Metoprolol succinate	Bulk	S.S column 4.4mm × 12.5cm packed bonded to porous silica	M. P.: Mix of phosphate buffer and acetonitrile (60:40)	λ = 223 nm	[17]
Azelnidipine	Bulk	S.S column 25 cm × 4.6 mm packed with Octadecylsilane bonded to porous silica (5µm)	M. P. A: 0.03M potassium dihydrogen orthophosphate in water, B: acetonitrile, 80:20 (%v/v) Flow rate: 1.0 ml/min.	λ = 256 nm	[18]
Bisoprolol fumarate	Bulk	(5 µm, 12.5 cm × 4.6 mm)	M. P. To 1000ml of solvent mixture, add 5 ml of heptafluorobutyric acid, 5 ml of diethylamine and 2.5 ml of formic acid. Mix and filter Flow rate: 1.0 ml/min.	λ = 273 nm	[19]
Cilnidipine	Bulk	Phenomenex ODS (250mm × 4.6mm,5µm)	M. P. Acetonitrile: Sodium acetate buffer pH 5 (70:30) Flow rate: 1.0 ml/min.	λ = 240 nm	[20]

Reported analytical methods for Benidipine hydrochloride

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC	Mixture of drug with	C18 (100 mm × 4.6 mm, 3 μm)	M. P. Phosphate -buffer/ methanol/ THF (65/27/8) mixture	λ = 237 nm	[21]

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
	impurities	column (Hypersil BDS)	Flow rate: 0.75 ml/min.		
RP-HPLC (Simultaneous Estimation)	Tablet dosage form	C_{18} (250 mm x 4.6 mm, 5 µm) Hypersil BDS Column	M. P. Potassium Dihydrogen Phosphate Buffer (pH 4.0): Methanol (65: 35% v/v) F. R. 1.0 ml/min.	λ = 269 nm	[22]
RP-HPLC	Bulk and tablets	Lichrospher ODS RP-18	M. P. acetonitrile: 0.1M acetate buffer (45:55, pH 5.1) F. R. 1.0 ml/min.	λ = 249 nm	[23]
RP-HPLC (Simultaneous Estimation)	Bulk	Thermo scientific, C18 (25 cm × 0.46 cm) Hypersil BDS	M. P. Phosphate buffer, pH 4.0: Methanol (50:50) F. R. 1.0 ml/min.	λ = 210 nm	[24]

Reported analytical methods for Metoprolol tartrate

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC	Human plasma	250 mm × 4 mm, 10-µm particle, Novapack C-18 column.	M. P. acetonitrile–water–triethylamine 18:81:1 (v/v), pH adjusted to 11 by use of phosphoric acid Flow rate: 1.0 ml/min.	λ = 275 nm	[25]
RP-HPLC (Simultaneous estimation)	Tablets	Kromasil C18 (250 x 4.6 mm, 5 µm) column.	M.P. 0.02 M phosphate buffer solution: acetonitrile (70:30 v/v, pH 3.0) Flow rate: 1.0 ml/min.	λ = 221 nm	[26]
RP-HPLC (Simultaneous estimation)	Tablets	Hypersil BDS cyano (250 mm × 4.6 mm, 5 µm)	M.P. buffer (0.7% aqueous triethylamine, pH 3.0 adjusted with orthophosphoric acid) and acetonitrile in the ratio of 85:15 (v/v) Flow rate: 1.0 ml/min.	λ = 254 nm	[27]
RP-HPLC (Simultaneous estimation)	Human Urine	LiChroCART® Purospher® C18e column (125 mm×3 mm, 5 µm particles)	M.P. 0.05% trifluoroacetic acid in water (solvent A), methanol (solvent B), acetonitrile (solvent C) gradient	λ = 230 nm fluorescence detector	[28]

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
			Flow rate: 2 ml/min.		
RP-HPLC chiral (Simultaneous estimation)	Natural water	Lux® Cellulose-1/Sepapak-1 (cellulose tris-(3,5-dymethylphenylcarbamate)) (Phenomenex, Madrid, Spain) chiral stationary phase	M.P. gradient elution program optimized consisted of a progressive change of the mobile phase polarity from n-hex/EtOH/DEA 90/10/0.5 (v/v/v) to 60/40/0.5 (v/v/v) Flow rate: 1.0 ml/min.	λ = 290 nm	[29]
RP-HPLC (Stability indicating & Simultaneous estimation)	Bulk and Tablets	Denali C18 column of dimension 150 mm × 4.6 mm, 5 µm	M.P. orthophosphoric acid (0.1%) buffer: acetonitrile in the ratio of 60:40 V/V Flow rate: 0.8 ml/min.	λ = 260 nm	[30]
RP-HPLC	Bulk	A RP Spherisorb C-18 (Waters) 10µm column having 250×4.6 mm ID in isocratic mode	M.P. acetonitrile: methanol: 10 mM aqueous phosphate buffer (20:20:60%v/v) Flow rate: 1 ml/min.	λ = 254 nm	[31]

Reported analytical methods for Azelnidipine

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC	Human plasma	BDS Hypersil C18, 250 mm X 4.6 mm, 5µ analytical column	M. P.: Acetonitrile: Water, pH adjusted with ortho-phosphoric acid in the ratio 60:40 Flow rate: 1.0 ml/min.	λ = 256 nm	[32]
RP-HPLC (Stability indicating)	Bulk	Enable C18 (250×4.6mm.; 5 micron) column	M. P. Sodium diabasic Phosphate Buffer: Acetonitrile: Methanol in the ratio of (10:50:40 v/v/v) ph adjust 4.50 by o-phosphoric acid Flow rate: 1.0 ml/min.	λ = 257 nm	[33]

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC (Simultaneous estimation)	Tablets	Inertsil ODS 3V, C18 column was used with dimensions of 150 x 4.6mm and 5µm particle size	M. P. Acetonitrile and buffer as mobile phase in gradient mode Flow rate: 1.5 ml/min.	λ = 254 nm	[34]
RP-HPLC (Stability indicating)	Tablets	Denali C18 (150 x 4.6mm,5µm)	M. P. 0.1% OPA: Acetonitrile (60:40) Flow rate: 1.0 ml/min.	λ = 242 nm	[35]
RP-HPLC	Tablets	C18 (250 mm x 4.6 mm i.d., 5 µ) column	M. P. Aacetonitrile: 0.5% triethyl amine (adjusted to pH 3.5 using orthophosphoric acid) (70:30 v/v) Flow rate: 1 ml/min.	λ = 284 nm	[36]
RP-HPLC (Stability indicating & Simultaneous estimation)	Tablets	Hypersil GOLD C18 column (150 mm × 4.6 mm internal diameter, 5 µm particle size)	M. P. methanol, acetonitrile, and water in the ratio of 40:40:20 (by volume) Flow rate: 0.5 ml/min.	λ = 260 nm	[37]
RP-HPLC	Bulk	C18 column (250 mm x 4.5 mm, 5 µm)	M. P. Methanol: Water (75:25) v/v,0.1% glacial acetic acid Flow rate: 1 ml/min.	λ = 254 nm	[38]

Reported analytical methods for Bisoprolol fumarate

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC	Dissolution media	A C 18 column (Hi Qsil C18, 5 µm, 4.6x250 mm)	M. P. methanol: phosphate buffer solution (65:35, v/v) Flow rate: 1.0 ml/min.	λ = 225 nm	[39]
RP-HPLC (Simultaneous estimation)	Bulk and Tablets	250×4.6mm (i.d.) Shim-pack RP18 column (5µm particle size)	M.P. Acetonitrile and 0.01M KH_2PO_4 in a ratio of 40:60 v/v, pH was adjusted to 3.5 Flow rate: 1.0 ml/min.	λ = 232 nm	[40]
RP-HPLC	Tablets	Waters Symmetry C_{18} column (3.9 mm i.d. X	M.P. acetonitrile: phosphate buffer (25:75 v/v)	λ = 226 nm	[41]

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
		150 mm, 5 µm particle sizes)	Flow rate: 1.4 ml/min.		
RP-HPLC	Human plasma	C18 reversed phase column (Inertsil, 4 µm, 150 ×4.6 mm)	M.P. methanol-water (70:30, % v/v) Flow rate: 1.2 ml/min.	Fluorescence detector λ = 458 and 525 nm	[42]
RP-HPLC (Simultaneous estimation)	Bulk and Tablets	Phenomenex Polar Synergi, 5 µm, 4.6×50 mm	M.P. methanol: phosphate buffer solution (65:35, v/v) Flow rate: 1.0 ml/min.	λ = 240 nm	[43]
RP-HPLC (Simultaneous estimation)	Bulk and Tablets	Shiseido – C_{18} (250×4.6mm, 5 µm)	M.P. Phosphate buffer (pH-3.5): Methanol (60: 40) Flow rate: 1.0 ml/min.	λ = 225 nm	[44]
RP-HPLC	Dissolution media	column Hi Qsil C 18 (4.6x250 mm, 5 µm particle size)	M.P. methanol: phosphate buffer solution (65:35, v/v) Flow rate: 1 ml/min.	λ = 225 nm	[45]

Reported analytical methods for Cilnidipine

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
RP-HPLC (Stability indicating)	Bulk	Cosmosil (4.6X250mm, 5 µ) column	M. P. Methanol: Potassium dihydrogen phosphate buffer (50:50) Flow rate: 1.0 ml/min.	λ = 241 nm	[46]
RP-HPLC	Bulk	Thermo scientific model C_{18} column (4.6 mm i.d. × 250 mm, 5µm particle size) (based on 99.999% ultra-high purity silica)	M.P. Acetonitrile: methanol (50: 50 v/v) Flow rate: 1.0 ml/min.	λ = 242 nm	[47]
RP-HPLC (Simultaneous estimation and Stability indicating)	Tablets	Waters C_{18} (250 mm × 4.6 mm i.d., 5 µm particle size) column at ambient temperature	M.P. ACN: 0.01 M sodium phosphates monobasic dehydrate buffer pH 3.0 with phosphoric acid (68: 32, v/v) Flow rate: 1.0 ml/min.	λ = 245 nm	[48]
RP-HPLC (Simultaneous	Bulk and Tablet	Inertsil ODS 3V (250 × 4.6 mm, i.d., 5 µm)	M.P. 0.025 M Potassium dihydrogen orthophosphate	λ = 240 nm	[49]

Method	Matrix	Stationary phase	Analytical conditions	Detection conditions	Ref. No.
estimation)		column in a Gradient mode	buffer whose pH was adjusted to 2.5 using dilute orthophosphoric acid (solvent A) and Acetonitrile (solvent B) Flow rate: 1.0 ml/min.		
RP-HPLC (Simultaneous estimation)	Bulk and Tablet	ODS C18, 250mm x 4.6mm, 5µm column	M.P. ODS C18, 250mm x 4.6mm, 5µm column Flow rate: 1.0 ml/min.	λ = 245 nm	[50]
RP-HPLC (Simultaneous estimation)	Bulk and Tablet	ODS column (250 x 4.6mm ID, 5 µm)	M.P. buffer: acetonitrile (42:58) Flow rate: 1.0 ml/min.	λ = 240 nm	[51]
RP-HPLC (Simultaneous estimation)	Bulk and Tablet	C-18 (250mm x 4.6mm, 5 µm) Column	M.P. Acetonitrile: Buffer (75:25 %v/v) pH 6.5 adjusted by 1 % Triethylamine Flow rate: 1 ml/min.	λ = 265 nm	[52]

CONCLUSION

In this overview, the process of developing and validating HPLC methods is discussed in general terms. The development of an HPLC method for the separation of substances using a generic strategy that is relatively straightforward was the topic of discussion. Prior to the construction of any HPLC method, having a solid understanding of the physiochemical characteristics of the primary component is of the utmost importance. The development of an HPLC method is determined by the chemical structure of the molecules, the synthetic route, solubility, polarity, pH and pKa values, functional group activity, and other factors.

We reviewed HPLC methods for the determination of different combinations of benidipine hydrochloride, metoprolol succinate, azelnidipine, bisoprolol fumarate, and cilnidipine in order to provide an overview of current trends and problems in the analysis of these compounds. Other compounds that were looked at included cilnidipine.

Determining the identities of such uncomplicated compounds may appear to be a simple task; nonetheless, doing so presents a significant analytical difficulty. Both the selection of the analytical separation method, particularly the mechanism of separation, and the selection of the detection technique, which must be suitable for a variety of different combinations of compounds as well as the instability of analytes are two of the most significant challenges, both of which were covered in our previous conversation.

The challenge of simultaneously detecting a wide variety of chemical combinations is one that has not yet been solved.

Conflict of interest

The authors have no conflict of interest.

REFERENCES

1. Nováková L, Solich P, Solichová D. HPLC methods for simultaneous determination of ascorbic and dehydroascorbic acids. TrAC Trends in Analytical Chemistry 2008; 27:942–958
2. Abd El-Hay SS, el Sheikh R, Gouda AA, et al. Simultaneous estimation of pantoprazole and piroxicam by HPLC: Response surface methodology approach. Microchemical Journal 2022; 176:10–24
3. Geetha G, Vignesh Kumar B, Gnana Raja M. Analytical Method Validation: an Updated Review. International Journal Of Advances in Pharmacy, Biology and Chemistry 2012; 1:
4. Shah BP, Jain S, Prajapati KK, et al. Stability indicating HPLC method development: A Review. Int J Pharm Sci Res 2012; 3:2978–2988
5. Paithankar H v. HPLC Method Validation for Pharmaceuticals: A Review. International Journal of Universal Pharmacy and Bio Sciences 2013; 2:229–240
6. Bharti Mittu AC, Chauhan P. Analytical Method Development and Validation: A Concise Review. J Anal Bioanal Tech 2015; 06:
7. . A Review of: Analytical Method Development and Validation. J Liq Chromatogr Relat Technol 1998; 21:
8. Kothari S, Tiwari N, Patani P. A Review on HPLC Method Development and Validation. J Emerg Technol Innov Res 2019; 6:1195–1203
9. . Benidipine hydrochloride | C28H32ClN3O6 - PubChem.
10. . Benidipine hydrochloride | DrugBank Online.
11. . Metoprolol succinate | DrugBank Online.
12. . Metoprolol | C15H25NO3 - PubChem.
13. . Azelnidipine | C33H34N4O6 - PubChem.
14. . 123524-52-7 | Azelnidipine | $C_{33}H_{34}N_4O_6$ | TRC.
15. . Bisoprolol fumarate | C22H35NO8 - PubChem.
16. . Cilnidipine | C27H28N2O7 - PubChem.
17. Commission. Indian Pharmacopoeia, 2018 - Metoprolol. 2018; II:2583–2584
18. Commission. Indian Pharmacopoeia, 2018 - Azelnidipine. 2018; II:1304–1305
19. Commission. Indian Pharmacopoeia, 2018 - Bisoprolol fumarate. 2018; II:1392–1393
20. Commission. Indian Pharmacopoeia, 2018 - Cilnidipine. 2018; II:1616–1617
21. Bellur Atici E, Karliıa B. Identification, synthesis and characterization of process related impurities of benidipine hydrochloride, stress-testing/stability studies and HPLC/UPLC method validations. J Pharm Anal 2015; 5:256–268
22. Patel DM, Patel D, Patel A, et al. Method Development and Validation for Simultaneous Estimation of Benidipine Hydrochloride and Metoprolol Succinate in Tablet. Journal of Drug Delivery and Therapeutics 2019; 9:28–33
23. Balaji Gupta Tiruveedhi VLN, Battula VR, Bonige KB. Novel determination of anti-hypertensive combination; benidipine hydrochloride and nebivolol hydrochloride by high performance chromatographic method. Res J Pharm Technol 2021; 14:5433–5438
24. Naim M, Ahmed A. Stability indicating reverse-phase high- performance liquid chromatography method development and validation for simultaneous estimation of telmisartan and benidipine hydrochloride in pharmaceutical dosage form. Asian Journal of Pharmaceutical and Clinical Research 2018; 11:342–350
25. Aqil M, Ali A, Ahad A, et al. A validated HPLC method for estimation of metoprolol in human plasma. Acta Chromatogr 2007; 19:130–140

26. Chitlange SS, Imran M, Sakarkar DM. RP-HPLC method for simultaneous estimation of amlodipine and metoprolol in tablet formulation. Asian Journal of Pharmaceutics (AJP) 2008; 2:232–234
27. Dongre VG, Shah SB, Karmuse PP, et al. Simultaneous determination of metoprolol succinate and amlodipine besylate in pharmaceutical dosage form by HPLC. J Pharm Biomed Anal 2008; 46:583–586
28. Baranowska I, Wilczek A. Simultaneous RP-HPLC determination of sotalol, metoprolol, α-hydroxymetoprolol, paracetamol and its glucuronide and sulfate metabolites in human urine. Analytical Sciences 2009; 25:769–772
29. Morante-Zarcero S, Sierra I. Simultaneous enantiomeric determination of propranolol, metoprolol, pindolol, and atenolol in natural waters by HPLC on new polysaccharide-based stationary phase using a highly selective molecularly imprinted polymer extraction. Chirality 2012; 24:860–866
30. Kanthale SB, Thonte SS, Mahapatra DK. Stability indicating RP-HPLC method for the simultaneous estimation of ivabradine and metoprolol in bulk and tablet formulation. J Appl Pharm Sci 2019; 9:137–144
31. Phale MD, Hamrapurkar PD. A validated and simplified RP-HPLC of metoprolol succinate from bulk drugs. Asian J Res Chem 2009; 2:119–122
32. Bhosale AP, Pingle AP. Bioanalytical RP-HPLC method development and validation for estimation of azelnidipine and Olmesartan medoxomil in human plasma.
33. Modi J, Patel SK, Parikh N, et al. Stability indicating analytical method development and validation for estimation of azelnidipine. World J Pharm Res 2016; 5:831–847
34. Kumar M, Chandra U, Garg A, et al. Development and Validation of In-vitro dissolution test using RP-HPLC Analysis for simultaneous estimation of Azelnidipine and Telmisartan in a Fixed-dose Combination. Res J Pharm Technol 2022; 15:1967–1972
35. Chaitanya DB, Ajitha M. Stability Indicating RP-HPLC Method Development and Validation for simultaneous estimation of Azelnidipine and Telmisartan in Bulk and Pharmaceutical Dosage Form: https://doi. org/10.54037/WJPS. 2022.100113. World Journal of Pharmaceutical Sciences 2022; 121–127
36. Muralidharan S, Parasuraman S, Venugopal V. Simple validation of Azelnidipine by RP-HPLC Method. Rapports De Pharmacie 2015; 1:43–45
37. Patel JK, Patel NK. Validated stability-indicating RP-HPLC method for the simultaneous determination of azelnidipine and olmesartan in their combined dosage form. Sci Pharm 2014; 82:541–554
38. Patel KH, Mahida RJ. A review on analytical methods for estimation of azelnidipine and telmisartan in pharmaceutical dosage form. 2021;
39. Logoyda L, Kovalenko S, Abdel-Megied AM, et al. HPLC method development for the analysis of bisoprolol in combined dosage form containing bisoprolol and enalapril and in vitro dissolution studied. International Journal of Applied Pharmaceutics 2019; 11:186–194
40. Mostafa A. Simultaneous Spectrophotometric Estimation of Bisoprolol Fumarate and Hydrochlorothiazide in Tablet Formulation using Partial Least-Squares, Principal Component Regression Multivariate Calibrations and RP-HPLC Methods. J Anal Pharm Res 2017; 4:1–9
41. Kondratova Y, Logoyda L, Voloshko Y, et al. Development and validation of HPLC-dad method for the determination of bisoprolol in tablet dosage forms. International Journal of Applied Pharmaceutics 2017; 9:54–59
42. Ulu ST, Aydoğmuş Z. An HPLC method for the determination of bisoprolol in human plasma and its application to a pharmacokinetic study. J Chromatogr Sci 2012; 50:615–619

43. Logoyda L. Efficient validated method of HPLC to determine amlodipine in combinated dosage form containing amlodipine, enalapril and bisoprolol and in vitro dissolution studies with in vitro/in vivo correlation. Pharmacia 2020; 67:55–61
44. Patel H, Damahe DP, Narkhede SB. RP-HPLC Method Development and Validation for Simultaneous Estimation of Cilnidipine and Bisoprolol Fumarate in Tablet Dosage Form. Int J Chemtech Res 2019; 12:269–276
45. Logoyda L. Efficient validated method of HPLC to determine enalapril in a combined dosage form containing enalapril and bisoprolol and in vitro dissolution studies. International Journal of Applied Pharmaceutics 2019; 11:19–24
46. Tiwari B, Shirsat MK, Kulkarni A. Development and validation of stability indicating RP-HPLC method for estimation of Cilnidipine. Journal of Drug Delivery and Therapeutics 2020; 10:97–100
47. Sankar PR, Babu S, Ravi P. Development and Validation Of Novel UV And RP-HPLC Methods For Determination Of Cilnidipine (A New Generation Ca Channel Blocker) In Pharmaceutical Dosage Form. Int J Pharm Sci Res 2019; 10:1886–1894
48. Rupareliya RH, Joshi HS. Stability Indicating Simultaneous Validation of Telmisartan and Cilnidipine with Forced Degradation Behavior Study by RP-HPLC in Tablet Dosage Form. Int Sch Res Notices 2013; 2013:
49. Kudumula N, Prasad YR. Development and validation of RP-HPLC method for the simultaneous estimation of chlorthalidone and cilnidipine in bulk and combined tablet dosage form. Pharmacophore 2014; 5:442–450
50. Kachave R, Kale M, Wagh R. Simultaneous estimation of Cilnidipine and Valsartan by RP-HPLC in tablet formulation. Eurasian J. Anal. Chem 2016; 11:245–253
51. Sunitha N, Mariha SC, Venu A, et al. Method Development and Validation of RP-HPLC Method for the Simultaneous Estimation of Olmesartan and Cilnidipine in Bulk and Formulations. International Journal of Pharmaceutical Research & Allied Sciences 2015; 4:
52. Sidhdhapara Mital J, Patel B, Paramar A. Development and validation of RP-HPLC method for simultaneous estimation of Cilnidipine and Olmesartan medoxomil in their combined tablet dosage form. Int J Pharm Biosci 2014; 4:157–160

How to Cite: Pramod Kumar Goyal, and Manish Jaimini. "A REVIEW ON HPLC APPROACHES FOR SIMULTANEOUSLY DETERMINING ANTIHYPERTENSIVE DRUG COMBINATIONS". *Tropical Journal of Pharmaceutical and Life Sciences*, vol. 8, no. 6, Dec. 2021, pp. 12-24, https://informativejournals.com/journal/index.php/tjpls/article/view/105.

PUBLISHED BY:
INFORMATIVE JOURNALS
JADOUN SCIENCE PUBLISHING GROUP INDIA