Received: 9 March 2022 | Revised: 6 April 2022 | Accepted: 7 April 2022

DOI: 10.1111/jch.14486

REVIEW

WILEY

Pseudo and resistant hypertension: A chaotic perspective

Heitor Moreno MD, PhD

Laboratory of Cardiovascular Pharmacology & Hypertension, School of Medical Sciences, University of Campinas (UNICAMP), Campinas, São Paulo, Brazil

Correspondence
Heitor Moreno, MD, PhD, Laboratory of Cardiovascular Pharmacology & Hypertension, School of Medical Sciences, University of Campinas (UNICAMP), R. Tessália Vieira de Camargo, 126 – Cidade Universitária, Campinas CEP: 13083-887, SP, Brazil.
Email: hmoreno@uol.com.br

Funding information
Fundação de Amparo à Pesquisa do Estado de São Paulo, Grant/Award Number: #2016/18104-5

Abstract

Systemic blood pressure (BP) may oscillate for homeostatic needs (equilibrium by constancy) or just as shifts in other intrinsic and extrinsic variables known as allostatic changes. This transitory pressure often rises alerts physicians to out-of-control hypertension or even hypertensive crisis. There is a very complex theory underlying these stochastic phenomena, which physicists and mathematicians translate into a single word: chaos. These changes happen according to a stochastic probabilistic pattern that presumes chaotic but somewhat predictable and nonlinear modeling of BP-related dynamics as a mathematical approach. Based on the chaos theory, small changes at the initial BP (baseline overtime) values could disturb the homeostasis leading to extreme BP chaotic shifts. These almost insignificant oscillations may also affect other variables and systems, leading to the misdiagnosis of hypertension, "out-of-control" BP levels, and resistant hypertension (RHT). Thus, these unpredictable and transient increases in BP values may be improperly diagnosed as the white coat and masked or resistant hypertension. Indeed, the interference of the chaos in any phenotype of (true or false) hard to control BP is not considered in clinical settings. This review provides some basic concepts on chaos theory and BP regulation. Besides pseudoresistant hypertension (lack of adherence, circadian variations, and others (white-coat, masked, early morning effects or hypertension), chaotic changes can be responsible for out-of-control hypertension.

KEYWORDS
chaos, Lorenz's attractor, refractory hypertension, resistant hypertension, stochastic system

1 | INTRODUCTION

Recently, the definition of resistant hypertension (RHT) has been updated, excluding the white-coat, masked hypertension, medical inertia, and lack of adherence bias.[1,2] Besides pseudo hypertension, lack of adherence, circadian variations, and conditions of increasing blood pressure (BP) (white-coat, masked, early morning effects or hypertension), chaotic changes can be responsible or coresponsible for out-of-control hypertension. The professionals, when measuring BP levels, should have considered these concepts.

Here, we presented another form of interpreting the BP levels in uncontrolled hypertensive subjects as chaotic and partially deterministic. Additionally, unpredictable BP levels syndrome using concepts derived from the field of nonlinear dynamics math (the *chaos theory)* is addressed.

There has been a growing interest in the nonlinear autoregressive integrated process derived from Newton's second law to stochastic

TABLE 1 Premises that characterize chaotic behavior (chaos theory)

Periodicity	Final determined by onset	Predictability (Polynomial)	Tendency to go back to the beginning	Cyclicity
No (Aperiodic)	Yes	Partially (Imprecise)	Yes (Close to, but not exactly)	Yes

self-restoring systems.[3–5] A plan is stochastic self-restoring if it sustains (nonlinear autoregressive integrated conditions): A random force or an unpredictable disturbance that may cause a deviation from equilibrium; A restoring force that reduces the negative (or positive) deviation from equilibrium via its upward (downward) component; A resistance force that prevents rapid change in response to the perturbations.

Systemic BP may oscillate to maintain homeostatic needs and the *body constancy*, or just as shifts in other intrinsic and extrinsic (*allostatic equilibrium*) variables and systems. These latter changes happen according to a stochastic probabilistic pattern, which means "randomly determined"[3] that may be statistically analyzed but may not be predicted precisely. This approach requires a mathematic nonlinear dynamics regressive analysis based on the *chaos theory*.[3,6]

This critical review reproaches some crucial topics on resistant hypertension and chaotic or complex BP system.

2 | PSEUDO-RESISTANT HYPERTENSION

Despite advances in diagnosis and management strategies, uncontrolled hypertension remains a challenging problem and a primary cause of death for 7.5 million people each year globally.[1] Eleven years ago, De la Sierra et al. observed the prevalence of RHT at 12.2% of treated hypertensive patients included in the Spanish Ambulatory Blood Pressure Monitoring Registry.[7] In 2011, Sim et al.[8] reported the prevalence of RHT at 12.8% of all hypertensive patients and 15.3% of hypertensive patients receiving treatment within the Kaiser Permanent Southern California healthcare system. The authors reinforce that the BP technique may overestimate the prevalence of uncontrolled RHT by 33%. On the other hand, out-of-office BP monitoring modalities (home blood pressure measurement and 24 h-ambulatory blood pressure measurement) were essential tools in distinguishing between normotension, masked hypertension, white-coat hypertension, and sustained (including uncontrolled or drug-resistant) hypertension.[9,10] Out-of-office BP is a more significant predictor of renal and cardiac morbidity and mortality compared to in-office readings.[10,11]

BP oscillation should lead to (false) diagnoses such as pseudo resistance, including white-coat and masked hypertension.[9–12] Thus, understanding some major concepts on "general systems," BP regulation, and "*chaos theory*" can help physicians treat these clinical conditions.

To understand the occasional increases in BP, some definitions of "general systems" and "chaos theory" are below[3,6,13–18]:

Homeostasis: self-regulation processes to maintain stability while adjusting to a dynamic equilibrium by continuous changes;

Allostatic: state of internal and physiological equilibrium maintained by an organism in response to actual or perceived environmental stressors;

Stochastic: property of a random probability distribution;

Chaos: random or unpredictable behaviors in complex systems governed by deterministic laws. Deterministic chaos suggests a paradox connecting randomness/unpredictability and deterministic processes.

2.1 | The general system theory and chaos

In 1925, Ludwig von Bertalanffy,[19] not satisfied with the physical and deterministic approaches to Biology, proposed an organismic conception (Organismic Biology) emphasizing the consideration of the organism as a group or system. The biological systems may be the cells, organisms, or populations presenting the common characteristic of being composed of many other systems in interaction; these mechanisms were nominated cum plicate (Greek: complicated) systems.[20] Fundamentally, these hard-to-understand subsystems work jointly to produce coherent behaviors (constancy or equilibrium). This initial concept led to many articles, books, and conferences on "general system theory" in many areas of knowledge. Thus, the human organism should be a system of much smaller subsystems with common characteristics.[19] Actually, this most profound intuition concerning real-life "cum plicate" systems historically dates back to Heraclitus (about 540 BC) and Claude Bernard (1813–1878) with the concept of Homeostasis. This term was perfected and coined later by Cannon[20]: Homeostasis results from the response to a system perturbation and occurs as a retro alimentation looping called feedback mechanisms, well known nowadays as positive *or* negative stimuli. The concepts above gained space in many other areas of knowledge as a new paradigm called "general systemic thought".[19] A nonlinear or chaotic system behavior of almost the totality of the existing systems, including BP control, has grown since the 1960s. The complex nonlinear systems obey the *chaos theory*, which studies the foresight and order of the complex (chaotic) systems, although random.[6]

The antique *determinism* and complete *predictability* do not have to space in the chaotic theory because of its nonlinear expression.[6,13] Later on, chaotic systems and outcomes were included in the *chaos theory*.[13,14] For five decades, theoretical arguments were presented seeking the consideration of the human body as a nonlinear dynamic deterministic system and, therefore, dependent on the laws of chaos.[14–17] Accepting such ideas without the restrictions of the traditional, linear, perfect, and immutable determinism in all sciences seemed closer to human thought and the universe (Table 1). Thus, a partial fusion of classical determinism and entropic chaos has occurred, but homeostasis, general systems, allostasis, *milieu internet*, and equilibrium still have space in human physiology and medicine.[16,17] Finally, the chaos and the random determinism regulation of such general physiological mechanisms modulate biological systems (including BP) from cell to population levels.[16,18]

2.2 | Blood pressure as a nonlinear variable

Nonlinear behavior is present in almost the totality of the existing systems, including biological ones.[6,15,17,21-23] In this scenario, BP is a major complex variable, ranging between randomness linearity, and health-disease, using the heart-rate variability, using techniques of the chaotic domain.[6,24-26]

Some authors use it to calculate a deterministic critical value to the concept of risk, superior to the habitually limited time and frequency domains.[23,26] Finally, the chaotic, discontinuous, and uncertainty of nature, always an enigma to the researchers, has been integrated into biological and health sciences.

Hypervolemia and autonomic nervous system imbalance are the most relevant factors for RHT and refractory hypertension. Obesity, endothelial dysfunction, hyperaldosteronism, sleep apnea, arterial stiffness, and inflammation are also involved in this complex syndrome.

The nonlinearity of BP and its chaotic nature may not be considered during the efforts to reduce the BP in truly RHT subjects or "false out-of-/control." These later patients are usually normotensives by 24 h-ambulatory blood pressure monitoring or home blood pressure monitoring, but the BP increase (office or night) may be concomitant with chaotic variations.[14,25] The main premises of chaos[6] are shown in Figure 1.

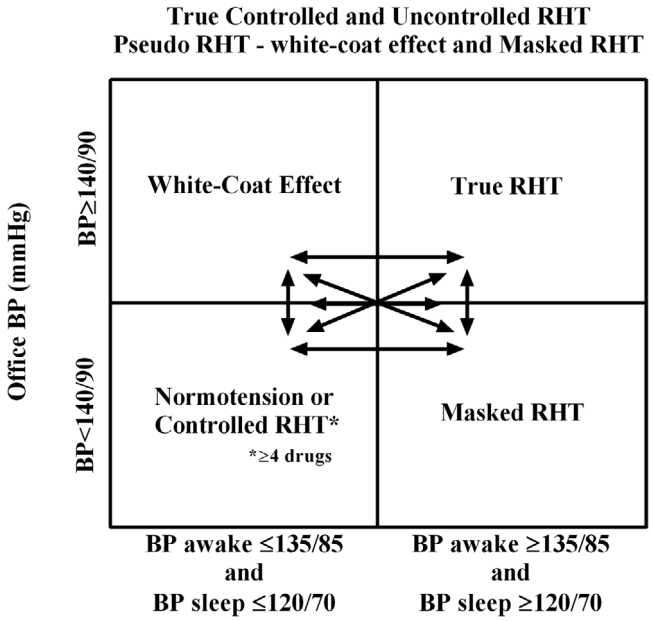

FIGURE 1 Orchestra and storm: variations of blood pressure according to "normal" levels (normotension, controlled resistant hypertension (RHT), white-coat effect) and hypertension (masked RHT, true RHT) in individuals taking four or more classes of antihypertensive drugs. Comparison between blood pressure values obtained by the office and ambulatory blood pressure monitoring methods. All the interchangeable possibilities may occur in normotensive, pseudoresistant, and true hypertensive patients. These transient modalities of blood pressure changes illustrate the RHT as an unstable, stochastic, and probably chaotic behavior of the variable in this syndrome. Emergency crises can happen anytime and from any of these modalities

2.3 | Both allostatic and stochastic processes in homeostasis

Besides the above relevant clinical bias in assessing RHT subjects, systemic BP may also oscillate for: (i) homeostasis needs (body or cardiovascular regulation); (ii) just shifts in other systemic variables (extrinsic and intrinsic, allostatic). This latter possibility may happen according to a stochastic probability pattern and includes deterministic and chaotic processes. A stochastically probabilistic approach is a family of randomizing variables representing not a state but changes over time. Instead of a single-way evolution process, there are infinite directions to follow. As opposed to continuous-time, the stochastic process is a sequence of random variables in discrete-time cases. A possible approach is modeling the random variables as arbitrary functions of one or several deterministic ratios to the time parameter. Although the random values of a stochastic process, at different times, seem to be independent random variables, especially in biology, a complex statistical dependence is almost ever-present. These complex concepts and transformations are somewhat challenging comprehension but fundamental to addressing the BP equilibrium, variables, chaotic oscillations, and even the misdiagnosis of out-of-control (pseudo resistant hypertension) levels and RHT.[3,6,27,28] The sum of random small shifts may result in an unpredictable effect known as the "butterfly effect".[15,29] In addition, intrinsic variables in the BP regulation system depend on other extrinsic conditions; (iii) confirming and treating true RHT require surveys to point out an RHT prevalence between 6 and 12% of the general population of the hypertensives in comparison to later rates reached 21%.[1,27,28] Often, we undervalue the effects of randomized processes. In addition, intrinsic variables in the BP regulation influence other extrinsic conditions. Confirming and treating true RHT requires surveys to point out an RHT prevalence between 6 and 12% of the general population of the hypertensives or later rates observed around 21%.[1] Finally, the BP technique overestimated the prevalence of uncontrolled RHT in approximately 33% of the patients emphasizing the importance of obtaining accurate BP measurements.[1] Due to inadequate BP technique and adherence, clinical inertia over-or underestimates RHT diagnosis.[29] Thus, falsely high or "normal" BP readings can be responsible for misdiagnosing RHT. Specialists must pay attention to BP oscillations, always aiming for "controlled levels" and cardiovascular equilibrium by stochastic self-restoring disease mechanisms (allostasis). These harmful and spurious BP oscillations may be due to some failures in the stochastic chaos process of BP regulation and not a part of an allostatic self-restoring condition in RHT individuals. In this sense, the crucial issue is to avoid maintaining a patient's lifetime with a mistaken diagnosis and prognosis based only on the initial, punctual, or historical BP measurements. It is a medical obligation to question the BP values periodically, caring out correctly at the medical office, at home, and even by ambulatory blood pressure monitoring. Finally, reviewing some pivotal contents on general systems and deterministic nonlinear processes is critical to

the better comprehension of outlier and unstable BP values in these hard-to-control patients.

2.4 | Blood pressure and chaos

BP is a nonlinear dependent variable (*y*) related to many other influences and factors that aim at cardiovascular homeostasis in a chaotic (complex) general system. Office BP is the gold standard for the screening, diagnosis, and management of hypertension. However, optimal diagnosis and successful management of hypertension cannot be exclusively obtained by a handful of conventionally acquired BP readings. BP and blood flow patterns in humans are variable, allowing energy-efficient responses to diverse stimuli from outside (environmental) and inside (individual's daily, postural, metabolic, emotional).[30] Pressure-flow regulation is a significant component of virtually all integrated physiologic responses and can be systemic or organ-selective.[30]

Usually, the most crucial factor in BP regulation is the level of outflow of the sympathetic nervous system, which affects immediate (seconds, minutes) and long-term (weeks to months) cardiovascular and BP responses.[30] BP variation is the result of normal and abnormal discharges from the central nervous system (e.g., posterior hypothalamus); however, abnormalities of feedback mechanisms (parasympathetic reflexes) lead to clinical abnormalities.[31] Besides all these participants in BP control, many other components in the blood/plasma/serum, cellular and subcellular levels, and other extrinsic interferences integrate the fine-tuned adjustments to get stable and optimal pressor values.[32] However, some "small shifts and mistakes" may probably happen in this well-tuned equilibrium and, analogously, turn a calm, silent and blue sky into an unstable, dark, and noisy tempest.[33]

As stated in the *chaos theory*, small changes at the initial condition (BP) are decisive to determine the duration, strength, disarranges, and damages (hypertensive disease) to the general system. Indeed, this "storm" in the BP system is not predictable by usual mathematical modeling, probabilistic calculus, or well-established statistical methods.[3-5] The key to previewing BP values over time is a nonlinear autoregressive integrated process that applies Newton's second law to stochastic self-restoring systems.[3,6,34] Even though these mathematical *cum plicate or cumplex* equations, just the short-time course can approach biological systems using a chaotic method. As in Meteorology, where weather forecasts have accuracy only for the next 5–7 days, predicting BP levels is difficult because of the high number of variables involved in a multiple-order polynomial function. On the other hand, the overall peculiarities in the physiopathology of RHT syndrome superpose the BP allostatic modulation: (i) small shifts leading to erratic, dramatic, and outlier BP patterns; (ii) apparent aperiodicity of BP occurrences (not circadian); (iii) hard to predict the evolution and medium-long term clinical outcomes; (iv) diversity of BP responses (even none) to external stimuli including therapeutics.

2.5 | Consequences of blood pressure dynamics in a chaotic system

Poincare was the first scientist to glimpse the possibility of chaos. A deterministic system exhibits aperiodic behavior that depends sensitively on the initial conditions, rendering long-term prediction.[34] Human organisms work as complex (meaning, chaotic) nonlinear systems and almost all the totality of systems known in the Universe. The nature of this characteristic does not exclude *determinism*, which makes possible the prediction of BP values over time. However, BP measurements in RHT patients depend on a constellation of intrinsic and external interferences that impede these pressure levels' precise evolution forecast. Unfortunately, multiple exponents (degrees) in a polynomial function equation to model the BP interfering factors work only as a theoretical concept in clinical hypertension.

Analytical techniques derived from chaos theory can help characterize the stability and complexity of blood pressure control, which may provide essential measures for predicting cardiovascular risk. Chaos is located in electroencephalogram data, R-R intervals from electrocardiograms, and cellular level, but only a few studies deal with chaos in sustained hypertension.[35]

According to these premises, as with almost all biological systems in humans, stochastic BP is a form of maintaining the body's homeostasis. For example, heart-rate amplitude depends on parasympathetic and sympathetic nervous activities; when the autonomic activity remains unchanged, heart-rate amplitude during resting reflects basal metabolism. Thus, heart rate parameter alterations suggest that age-related decreased heart-rate variability, ultra-reduced heart-rate variability in heart failure, and ultra-elevated heart-rate variability in ST-segment alterations refer to age-related decreased basal metabolism, impaired myocardial metabolism, and sympathetic nervous system hyperactivity triggered by myocardial ischemia, respectively.[36]

Finally, occasional and circumstantial BP measurements taken and rated in pseudo and true RHT can avoid under- and overdiagnoses in out-of-control subjects.

3 | CONCLUDING REMARKS

When failing the best pharmacological treatment in patients with true refractory hypertension and even in the hard to control hypertension, clinicians need to understand the possibility of chaos as taking part in BP arises.

ACKNOWLEDGMENTS

The author thanks Dr. Juan Carlos Yugar-Toledo, Dr. Silvia Elaine Ferreira-Melo, and Dr. Bruno Rodrigues for the extensive review of the manuscript.

COMPETING INTEREST

The authors have no competing interests.

AUTHOR CONTRIBUTION

Heitor Moreno-Junior contributed to the conception, design, and manuscript draft.

ORCID

Heitor Moreno MD, PhD https://orcid.org/0000-0001-6330-697X

REFERENCES

1. Carey RM, Calhoun DA, Bakris GL, et al. Resistant hypertension: detection, evaluation, and management: a scientific statement from the American Heart Association. *Hypertension*. 2018;72(5):e53-e90. https://doi.org/10.1161/HYP.0000000000000084.
2. deSouza WA, Sabha M, deFaveri Favero F, Bergsten-Mendes G, Yugar-Toledo JC, Moreno H. Intensive monitoring of adherence to treatment helps to identify "true" resistant hypertension. *J Clin Hypertens (Greenwich)*. 2009;11(4):183-191. https://doi.org/10.1111/j.1751-7176.2009.00102.x.
3. Wagner CD, Nafz B, Persson PB. Chaos in blood pressure control. *Cardiovasc Res*. 1996;31(3):380-387.
4. He Z. Dynamics and stability of a new class of nonlinear integrated models with resilience mechanisms. *Far East J Theor Stat*. 2013;21(1):1-32.
5. He Z. Integer-dimensional fractals of nonlinear dynamics, control mechanisms, and physical implications. *Sci Rep*. 2018;8(1):10324. https://doi.org/10.1038/s41598-018-28669-3.
6. James GD. The adaptive value and clinical significance of allostatic blood pressure variation. *Curr Hypertens Rev*. 2019;15(2):93-104. https://doi.org/10.2174/1573402115666190301144316.
7. dela SierraA, Segura J, Banegas JR, et al. Clinical features of 8295 patients with resistant hypertension classified on the basis of ambulatory blood pressure monitoring. *Hypertension*. 2011;57(5):898-902. https://doi.org/10.1161/HYPERTENSIONAHA.110.168948.
8. Sim JJ, Bhandari SK, Shi J, et al. Plasma renin activity (PRA) levels and antihypertensive drug use in a large healthcare system. *Am J Hypertens*. 2012;25(3):379-388. https://doi.org/10.1038/ajh.2011.216.
9. Modolo R, Ruggeri Barbaro N, deFaria AP, et al. The white-coat effect is an independent predictor of myocardial ischemia in resistant hypertension. *Blood Press*. 2014;23(5):276-280. https://doi.org/10.3109/08037051.2014.883194.
10. Ghazi L, Cohen LP, Muntner P, Shimbo D, Drawz PE. Effects of intensive versus standard office-based hypertension treatment strategy on white-coat effect and masked uncontrolled hypertension: from the SPRINT ABPM Ancillary Study. *Hypertension*. 2020;76(4):1090-1096. https://doi.org/10.1161/HYPERTENSIONAHA.120.15300.
11. Mancia G, Facchetti R, Grassi G, Bombelli M. Adverse prognostic value of persistent office blood pressure elevation in white coat hypertension. *Hypertension*. 2015;66(2):437-444. https://doi.org/10.1161/HYPERTENSIONAHA.115.05367.
12. Pierdomenico SD, Lapenna D, Bucci A, et al. Cardiovascular outcome in treated hypertensive patients with responder, masked, false resistant, and true resistant hypertension. *Am J Hypertens*. 2005;18(11):1422-1428. https://doi.org/10.1016/j.amjhyper.2005.05.014.
13. Persson PB, Wagner CD. From crude cardiovascular signals to chaos. *Fundam Clin Pharmacol*. 1998;12 Suppl 1:6s-10s.
14. Wessel N, Riedl M, Kurths J. Is the normal heart rate "chaotic" due to respiration?. *Chaos*. 2009;19(2):028508. https://doi.org/10.1063/1.3133128.
15. Brunton SL, Brunton BW, Proctor JL, Kaiser E, Kutz JN. Chaos as an intermittently forced linear system. *Nat Commun*. 2017;8(1):19. https://doi.org/10.1038/s41467-017-00030-8.
16. Oestreicher C. A history of chaos theory. *Dialogues Clin Neurosci*. 2007;9(3):279-289. 10.31887/DCNS.2007.9.3/coestreicher.
17. Ch Skokos, Gkolias I, Flach S. Nonequilibrium chaos of disordered nonlinear waves. *Phys Rev Lett*. 2013;111(6):064101. https://doi.org/10.1103/PhysRevLett.111.064101.
18. Friston K, Heins C, Ueltzhöffer K, Da Costa L, Parr T. Stochastic chaos and markov blankets. *Entropy (Basel)*. 2021;23(9):1220. https://doi.org/10.3390/e23091220.
19. Von Bertalanffy L. *General system theory: foundations, development*. George Braziller; 1969:296.
20. Cannon WB. *The wisdom of the body*. W. W. Norton & Company; 1963:333.
21. Sorrentino F, Ott E. Using synchronization of chaos to identify the dynamics of unknown systems. *Chaos*. 2009;19(3):033108. https://doi.org/10.1063/1.3186458.
22. Cugini P. Exploiting the ambulatory blood pressure monitoring via chronobiometric and chaosbiometric methods for a more exhaustive diagnostic approach to arterial hypertension. *Clin Ter*. 2008;159(6):e1-7.
23. Wagner CD, Persson PB. Chaos in the cardiovascular system: an update. *Cardiovasc Res*. 1998;40(2):257-264. https://doi.org/10.1016/s0008-6363(98)00251-x.
24. Alwan A, Maclean DR, Riley LM, et al. Monitoring and surveillance of chronic non-communicable diseases: progress and capacity in high-burden countries. *Lancet*. 2010;376(9755):1861-1868. https://doi.org/10.1016/S0140-6736(10)61853-3.
25. He Z. The control mechanisms of heart rate dynamics in a new heart rate nonlinear time series model. *Sci Rep*. 2020;10(1):4814. https://doi.org/10.1038/s41598-020-61562-6.
26. Cuspidi C, Tadic M, Grassi G. Blood pressure variability: a new therapeutic target on the horizon. *J Hypertens*. 2021;39(9):1771-1773. https://doi.org/10.1097/HJH.0000000000002865.
27. Yugar-Toledo JC, Brunelli V, Vilela-Martin JF, Fattori A, Moreno H. Controlled versus uncontrolled resistant hypertension: are they in the same bag?. *Curr Hypertens Rep*. 2018;20(3):26. https://doi.org/10.1007/s11906-018-0825-7.
28. Moreno HJr, Coca A. Resistant and refractory hypertension: reflections on pathophysiology and terminology. *Blood Press*. 2012;21(4):209-210. https://doi.org/10.3109/08037051.2012.701419.
29. Redón J, Coca A, Lázaro P, et al. Factors associated with therapeutic inertia in hypertension: validation of a predictive model. *J Hypertens*. 2010;28(8):1770-1777. https://doi.org/10.1097/HJH.0b013e32833b4953.
30. Guyton AC, Cowley AWJr, DB Young, Coleman TG, Hall JE, DeClue JW. Integration and control of circulatory function. *Int Rev Physiol*. 1976;9:341-385.
31. Grassi G, Pisano A, Bolignano D, et al. Sympathetic nerve traffic activation in essential hypertension and its correlates: systematic reviews and meta-analyses. *Hypertension*. 2018;72(2):483-491. https://doi.org/10.1161/HYPERTENSIONAHA.118.11038.
32. Mancia G, Facchetti R, Seravalle G, Cuspidi C, Corrao G, Grassi G. Adding home and/or ambulatory blood pressure to office blood pressure for cardiovascular risk prediction. *Hypertension*. 2021;77(2):640-649. https://doi.org/10.1161/HYPERTENSIONAHA.120.16303.
33. Boer-Martins L, Figueiredo VN, Demacq C, et al. Relationship of autonomic imbalance and circadian disruption with obesity and type 2 diabetes in resistant hypertensive patients. *Cardiovasc Diabetol*. 2011;10:24. https://doi.org/10.1186/1475-2840-10-24.
34. Elbert T, Ray WJ, Kowalik ZJ, Skinner JE, Graf KE, Birbaumer N. Chaos and physiology: deterministic chaos in excitable cell assemblies. *Physiol Rev*. 1994;74(1):1-47. https://doi.org/10.1152/physrev.1994.74.1.1.
35. Wagner CD, Mrowka R, Nafz B, Persson PB. Complexity and "chaos" in blood pressure after baroreceptor denervation of conscious dogs. *Am*

J Physiol. 1995;269(5 Pt 2):H1760-H1766. https://doi.org/10.1152/ajpheart.1995.269.5.H1760.
36. Lee SW. A Copernican approach to brain advancement: the paradigm of allostatic orchestration. *Front Hum Neurosci*. 2019;13:129. https://doi.org/10.3389/fnhum.2019.00129.

How to cite this article: Moreno H. Pseudo and resistant hypertension: A chaotic perspective. *J Clin Hypertens*. 2022;24:698–703. https://doi.org/10.1111/jch.14486