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### A REVIEW ARTICLES ON PULSATILE DRUG DELIVERY SYSTEM

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#### ABSTRACT

Over the last 30 years the pharmaceutical market has been demonstrated increasing preferably for controlled and targeted drug delivery system. Such systems have been focused on constant variable sustain drug release and/or targeting the therapeutic agent to a specific site/tissue/ organ. However, recently there are certain conditions for which such release pattern is not suitable. Such conditions that lead to the requirements of a time programmed therapeutic system, which capable of releasing drug after predetermined time delay and maintain constant drug levels throughout the day. This article includes the development of pulsatile drug delivery system and about the body biological rhythms.

#### KEYWORDS

Controlled drug delivery system, Targeting drug delivery system, Pulsatile system, Biological rhythms and Therapeutic system.

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#### INTRODUCTION

Pulsatile drug delivery system is developed based on the body biological rhythms. To introduce the concept of chronotherapeutics, it is important to define the following concepts.

##### Chronobiology<sup>1</sup>

Chronobiology is the science concerned with the biological mechanism of the diseases according to a time structure. “Chrono” pertains to time and “biology” pertains to the study, or science, of life.

### **Chronopharmacology<sup>2</sup>**

Chronopharmacology is the science concerned with the variations in the pharmacological actions of various drugs over a period of time of the day.

### **Chronopharmacokinetics<sup>3</sup>**

Chronopharmacokinetics involves study of temporal changes in drug absorption, distribution, metabolism and excretion. Pharmacokinetic parameters, which are conventionally considered to be constant in time, are influenced by different physiological functions displaying circadian rhythm.

### **Chronotherapy<sup>4</sup>**

Co-ordination of biological rhythms and medical treatment is called Chronotherapy.

### **Chronotherapeutics<sup>4</sup>**

Chronotherapeutics is the discipline concerned with the delivery of drugs according to inherent activities of a disease over a certain period of time.

### **Biological rhythms<sup>1</sup>**

#### **Ultradian rhythms**

Oscillations of shorter duration are termed Ultradian Rhythms (more than one cycle per 24 h). E.g. 90 minutes sleep cycle.

#### **Infradian rhythms**

Oscillations that are longer than 24 hours are termed as Infradian Rhythms (less than one cycle per 24 hours). E.g. Monthly Menstruation.

#### **Circadian rhythms**

Circadian rhythms are self-sustaining, endogenous oscillations that occur with a periodicity of about 24 Hours. Figure No.1 shows the biological rhythms of human body.

### **Classification of Pulsatile Systems<sup>5-10</sup>**

Pulsatile systems can be classified into single- and multiple-unit systems. Single-unit systems are formulated either as capsule-based or osmosis-based systems. Single-unit systems are designed by coating the system either with eroding/soluble or rupturable coating. In multiple-unit systems, however, the pulsatile release is induced by changing membrane permeability or by coating with a rupturable membrane.

#### **Single unit pulsatile systems**

These are sub-classified as capsule-based systems, osmotic systems, delivery systems with soluble or

erodible membranes, and delivery systems with rupturable coating.

### **Capsule Based Systems**

Single-unit systems are mostly developed in capsule form. The lag time is controlled by a plug, which gets pushed away by swelling or erosion, and the drug is released as a "Pulse" from the insoluble capsule body. Pulsincap® was developed by R. P. Scherer International Corporation, Michigan, US, and is one such system that comprises of a water-insoluble capsule enclosing the drug reservoir. A sellable hydrogel plug was used to seal the drug contents into the capsule body. When this capsule came in contact with the dissolution fluid, it swelled; and after a lag time, the plug pushed itself outside the capsule and rapidly released the drug. Polymers used for designing of the hydro gel plug were various viscosity grades of hydroxyl propyl methyl cellulose, poly methyl methacrylates, poly vinyl acetate and poly ethylene oxide. The length of the plug and its point of insertion into the capsule controlled the lag time. Pulsincap® was studied in human volunteers and was reported to be well tolerated. A low-volume diagnostic test kit was marketed in 1997 under the trade name of 'Sprint Salmonella by Oxoid Ltd., Basingstoke, U.K. Steven *et al.* developed a Pulsincap® system with erodible compressed tablet. As the swelling hydrogel polymer plug replaced the erodible tablet, the dependence of the dimensional accuracy between the plug and the capsule for the pulling mechanism of the plug from the capsule was also overcome. Ross *et al.* used low substituted hydroxyl propylcellulose for the expulsion system for the release of propranolol over a time period of 2-10 h. This could be controlled using compressed erodible tablets made of lactose and HPMC. Krogel and Bodmeier studied the release of chlorpheniramine utilizing the erodible plugs fitted in the capsules. Altering the composition and the weight of the erodible plug could control release of drug. Stevens *et al.* designed a hydrophilic sandwich capsule that was based on a system where a capsule was enclosed within a capsule and the space in between was a gel barrier layer composed of HPMC. When the outer

capsule dissolved, the delay in the second pulse was provided by the barrier gel layer. Soutar *et al.* studied the delivery of 500 mg paracetamol with a gastroresistant hydrophilic sandwich capsule targeted to ileocaecal junction / proximal colon. Analysis of salivary samples gave a mean  $T_{max}$  of 7.9 h (SD±0.96).

### **Systems Based on Osmosis**

The Port® system was developed by Therapeutic system research laboratory Ann Arbor, Michigan, USA, and consists of a capsule coated with a semi permeable membrane. Inside the capsule was an insoluble plug consisting of osmotically active agent and the drug formulation. When this capsule came in contact with the dissolution fluid, the semi permeable membrane allowed the entry of water, which caused the pressure to develop and the insoluble plug expelled after a lag time. Such a system was utilized to deliver methylphenidate used in the treatment of attention deficit hyperactivity disorder as the pulsatile port system. This system avoided second time dosing, which was beneficial for school children during daytime. Linkwitz *et al.* invented an osmotic drug (single-unit) delivery capsule from which the delivery of the drug was driven by the osmotic infusion of the moisture by the capsule from a physiological environment. It was provided with a delivery orifice that opened intermittently to achieve a pulsatile delivery effect. The technology involves a movable position that divides the capsule interior into two compartments - one for the beneficial agent and the other for the osmotically active agent. The orifice is located on the capsule wall surrounding the beneficial agent side. The whole capsule is surrounded by an elastic wall in the osmotically active compartment due to inward diffusion of water, which is transmitted through the partition. When the pressure in the drug compartment exceeds the threshold, it results in opening of the orifice and as a result, an amount of beneficial agent is released and it relieves the pressure in the drug compartment. This release in pressure causes the elastic material to relax and results in closure of the orifice. There are various factors affecting the degree and manner in

which the pulsatile effect can be controlled, viz., the choice of elastic material, the thickness of the wall section, the configuration and location of the orifice and the viscosity and surface tension of the beneficial agent formulation. The choice of elastic material is done on the ability to stretch at least twice their original length and to retract very rapidly when released. Examples include styrene butadiene copolymer polychlorophene, nobile rubbers, butyl rubber and polycrylates. The thickness of the elastic material may vary, but best results are generally obtained with thickness of at least 0.06 cm. The pulsatile delivery provided by the aforementioned devices in this invention may be for therapeutic purpose, nutritional purpose, preventive purpose, and a wide variety of situations in general.

### **Drug Delivery System with Eroding or Soluble Barrier Coating**

These systems are based upon a drug reservoir surrounded with a soluble barrier layer that dissolves with time, and the drug releases at once after this lag time. Chronotropic® system consists of a core containing drug reservoir coated by a hydrophilic polymer HPMC. An additional enteric-coated film is given outside this layer to overcome intra-subject variability in gastric emptying rates. The lag time and the onset of action are controlled by the thickness and the viscosity grade of HPMC. The time clock system is a delivery device based on solid dosage form that is coated by an aqueous dispersion. This coating is a hydrophobic-surfactant layer to which a water-soluble polymer is added to improve adhesion to the core. Once in contact with the dissolution fluid, the dispersion rehydrates and redisperses. The lag time could be controlled by varying the thickness of the film. After the lag time, i.e., the time required for rehydration, the core immediately releases the drug. This system has shown reproducible results *in vitro* and *in vivo*. The effect of low calorie and high calorie meal on the lag time was studied using gamma scintigraphy. The mean lag time of drug release was 345 and 333 min respectively. Midha *et al.* invented a pulsatile delivery system for d-threomethyl phenidate, an additional CNS stimulant in a dosage form

comprising at least two individual drugs containing dosage limit housed in a closed capsule. The dosage units are designed in the form of compressed tablets. The dosage form is designed in such a manner that upon ingestion, the first drug release pulse occurs within 1-2 h, followed by period during which no release occurs. Second dose is released in 3-5 h of ingestion. This is again followed by a second no-release interval. Release of third dose occurs within 7-9 h of ingestion. To provide such delayed-release dosage units, coating is done without bioerodible gradually hydrolysable polymers. The release amount of coating material per dosage unit decides the time interval between ingestion and drug release. Dittigen *et al.* planned a multiple unit dosage form comprising of compressed compositions having different amounts of ingredients and combinations. Hormones, viz., progesterone, testosterone, dehydro-epi-androsteron, estriol, and estradiol follow circadian rhythm and hence their concentration in blood varies over 24 h. Melatonin is also reported to be secreted mainly in the night. Some of the analogues and inhibitory substances for these hormones also follow a circadian rhythm. Examples of such classes include antidiabetics, glucocorticoids, mineralocorticoids and antihistamines. The formulation comprises of four compressed compositions in a capsule. The first composition is formed to provide a rapid release in which at least 75% of the effective ingredients are delivered within 45 min. The second compressed combination provides a uniformly maintained release profile in which 100% of effective ingredient is released within 3 h of ingestion. Third compressed combination delivers at least 75% of effective ingredient within 45 min of reaching duodenum and intestine at a pH of 6 to 7.5. Coating is given by gastric-resistant agents (PMMA or shellac). Fourth compressed composition releases 100% of the effective ingredient 3 h after reaching a pH of 6-7.5. Pope *et al.* developed a drug delivery device with readily adjustable intervals between drug delivery pulses. This could be accomplished by providing for a constant driving force against multiple layers contained in an impervious compartment having an

opening away from the constant driving force. The design of the multiple layers was such that the drug layer was adjacent to an expansion layer with an inert and impervious spacer layer alternating with the adjacent drug layer and so on. Two factors affected the duration between pulses, viz., the rate of constant driving force and the thickness of the spacer layer and the multiple layers (drug or combined drug/expansion layer). A thicker layer exhibited a longer duration between pulses of drug since it took a long time for thicker spacer layer to completely traverse the opening

#### **Drug Delivery System with Rupturable Layers/Membranes**

These systems are based upon a reservoir system coated with a rupturable membrane. The outer membrane ruptures due to the pressure developed by effervescent agents or swelling agents. Sungthongjeen *et al.* designed a pulsatile drug delivery system where the tablets of buflomedil HCl prepared by direct compression with varying amounts of spray-dried lactose and microcrystalline cellulose were coated with an inner swelling layer using croscarmellose sodium and an outer rupturable layer using ethyl cellulose. It was observed that by increasing the amount of ethyl cellulose coating, the lag time could be prolonged. Ethyl cellulose, being water insoluble, retarded the water uptake. Similar results were obtained with croscarmellose sodium. Increasing the amount of microcrystalline cellulose decreased the lag time substantially. Bussemer *et al.* worked on a pulsatile system with rupturable coating on drug present in hard gelatin capsules. These capsules were first coated with a swelling layer and then with an insoluble but water-permeable outer coating. These coated capsules when immersed in the release media could take up the media at a constant rate up to a point when the outer coating would rupture because of the pressure caused by the swelling layer. It could be concluded that by increasing the swelling layer, the lag time could be shortened. However, by increasing the outer coating, the lag time could be prolonged. It was also observed that addition of HPMC to the outer coating shortens the lag time. In another similar work,

Bussemer *et al.* studied the effect of various swelling agents and the outer polymeric coating on the lag time and the drug release. They developed a pulsatile system based on soft gelatin capsules with an inner swelling and outer polymeric coating. It could be concluded from this study that croscarmellose sodium was a better swelling agent as compared to HPMC (E5 and K100 M). Also, cellulose acetate propionate and ethyl cellulose gave better rupturing by virtue of their brittle nature when compared to Eudragit RS, which gave a flexible polymer coating. Cellulose acetate propionate coated capsules gave better drug release as compared to those coated with ethyl cellulose.

### **Multiple Units Pulsatile Systems**

More reliable gastric emptying patterns are observed for multiparticulate formulations as compared to single-unit formulations, which suffer from 'all or none' concept. As the units of multiparticulate systems are distributed freely throughout the gastrointestinal tract, their transport is affected to a lesser extent than single-unit formulations by the transit time of food. Multiparticulate systems are further classified as systems based upon change in membrane permeability and systems based upon rupturable coating.

### **Pulsatile System Based on Change in Membrane Permeability**

A Sigmoidal release system (SRS) is reported which is based upon the interaction of acrylic polymers with quaternary ammonium groups in the presence of different counter ions. SRS system consists of pellet cores having drug and succinic acid coated with ammonio-methacrylate copolymer USP/NF type (B). The water in the medium dissolves succinic acid. The drug inside and the acid solution increase the permeability of the polymer film. This system was used to design an acid-containing core. The system was tested in beagle dogs. Good *in vitro/in vivo* correlation of lag time was observed. Chen *et al.* developed an osmotic multiparticulate drug delivery system for diltiazem. It was designed in such a way that the drug released in divided doses over timed intervals throughout the day to produce a pulsatile blood concentration curve with time. The

dosage form comprised of a gelatin capsule containing three types of pellets. Each pellet contained a core that comprised of drug and water-soluble modulating agent (NaCl in this case). The core was held in place with the help of binding agent, viz., PVP. Enclosing each core was a water-insoluble and water-permeable film-forming agent and a hydrophilic agent. The thickness of this coating varied in each kind of pellet. In one kind of pellets, the thickness was the least; in the second kind of pellets, a thicker coating was given; and in the third kind of pellets, the thickest coating was given. When the dosage form was exposed to the physiological environment, the capsule dissolved and the pellets were exposed to the gastric environment. The rate of release was controlled by the relative thickness of the coating on the respective kind of pellets, the proportion of hydrophobic agent in the coating, and the proportion of osmotic agent in the pellet. To ensure that pH doesn't disturb the preset release time intervals, the coating given was of pH-independent material.

### **Pulsatile Systems with Rupturable Coating**

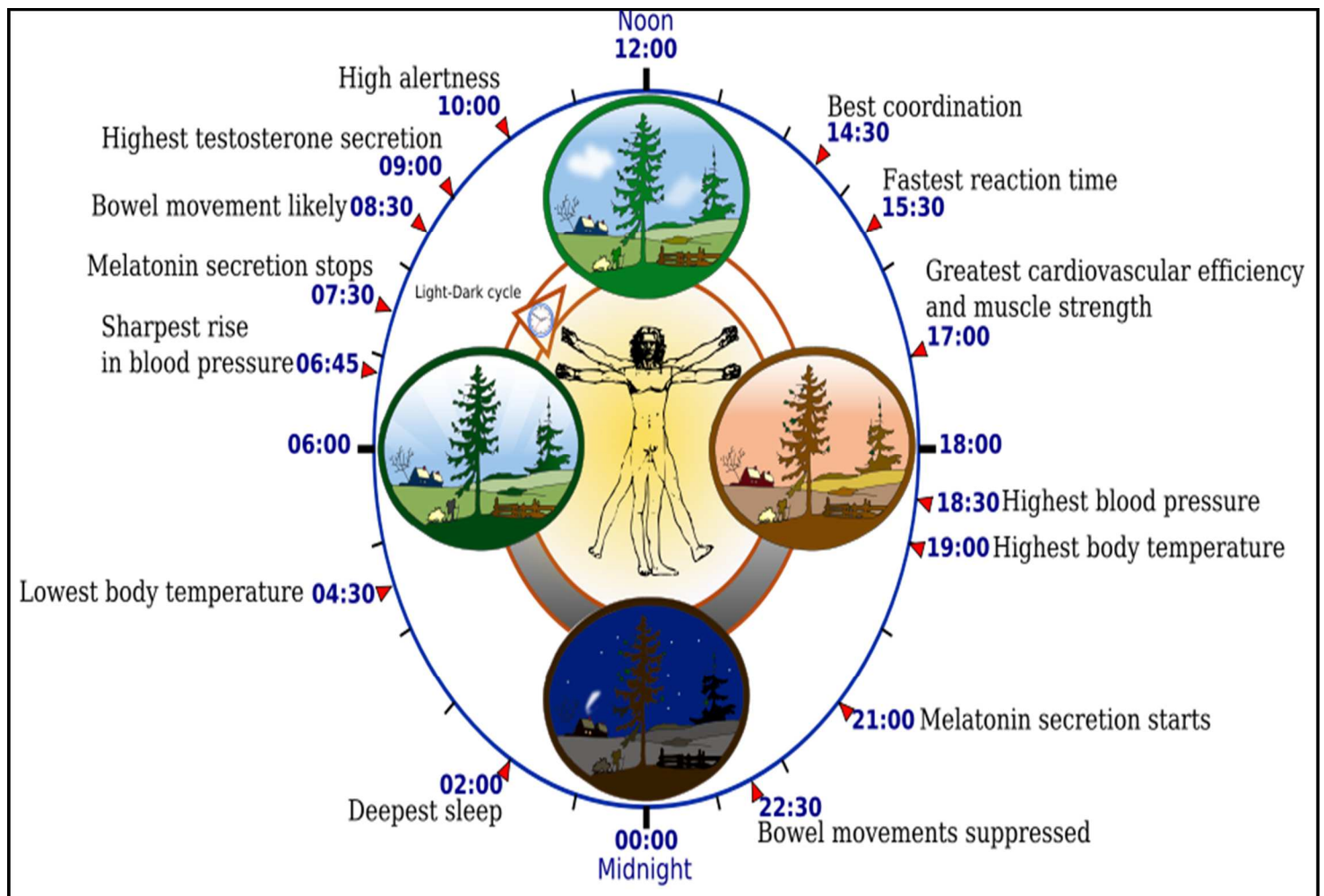
Similar to single-unit system, the rupturing effect is achieved by coating the individual units with effervescent or swelling agents. Bai *et al.* invented a pulsatile drug delivery system comprising of a plurality of particles that are divided into several individual delivery units, each having its own distinct composition. Drug delivery was controlled by the rupture of the membrane. The timing of release was controlled by the thickness of coating and the amount of water-soluble polymer to achieve the pulsed release. The individual particles had the same composition of internal core, but the thickness of the external coating layer varied.

### **Commercial Products**

A lot of work is being done to achieve pulsatile release so that the drug release can be delivered according to circadian rhythms of our body. Advancis Pharmaceutical Corp., German town, Maryland, USA has developed once-a-day pulsatile delivery system called Pulsys®, which enables the delivery of antibiotic amoxicillin in regular concomitant pulses. The rationale behind designing

such a system is that it has been reported that antibiotics are more effective against fast-growing bacteria. When an immediate release antibiotic is administered, bacteria respond to it by going into a dormant stage, while the administration of a pulsatile system in such a case is more effective because the regular release of increased pulses of antibiotic does not let defence system of the bacteria to go into a dormant stage. The preclinical studies have shown that pulsatile approach of delivering antibiotic is more effective. Advances is developing Pulsysβ versions of three of the top five most prescribed antibiotics in the United States. Asthmatic patients suffer from lung discomfort more in early morning due to circadian changes.

Therefore, it is desirable to get maximum bronchodilating effect in the morning hours. One such example is of a bronchodilator "Uniphyl" (theophylline), which was developed by Purdue Pharmaceuticals Products L. P., Stamford, USA, and approved by FDA in 1989. It's a once-a-day formulation. When taken in the evening, it reaches to peak blood levels in the morning hours, resulting in improved lung functioning and relief to the patient. There are examples where varying plasma levels are required during the day time. Elan applied this technology to a product of Novartis, Ritalinβ, containing methylphenidate to get a pulsatile once-daily dosage form that replaces the twice-a-day regimen.



**Figure No.1: Shows the biological rhythms of human body**

## CONCLUSION

There is a constant need for new delivery systems that can provide increased therapeutic benefits to the patients. Pulsatile drug delivery is one such system that, by delivering drug at the right time, right place, and in right amounts, holds good promises of benefit to the patients suffering from chronic problems like arthritis, asthma, hypertension, etc.

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## CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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