Enhancing Cancer Treatment with Circadian-Timed Drug Delivery: Chronotherapeutics in Oncology

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Received: 05-04-2025; Revised: 05-05-2025; Accepted: 19-05-2025; Published: 02-06-2025

Abstract

Treatments for cancer have advanced greatly lately, yet the side effects can still reduce what the patient enjoys in life. Because of this, chronopharmacology now exists to help match cancer treatments to the patient's circadian cycles. It investigates how the circadian clock relates to cancer susceptibility, the actions of clock genes in both cancer prevention and suppression and how timed medications might improve specific types of cancer therapies. Additionally, it reviews how findings on circadian rhythms can be used in palliative medicine and hormone treatments, as well as how treatments can be adjusted to meet the needs of each patient. Regulatory and ethical aspects related to chronopharmacology are studied. By relying on chronopharmacology, doctors may provide better and more personalized cancer treatments that help improve patient quality of life.

Keywords: ***Chronopharmacology; Circadian rhythms; Cancer treatment; Molecular targets; Patient-centered care.***

1.Introduction

Significant steps have been made in cancer treatment during recent decades, thanks to new discoveries about cancer and targeted therapy. Mad science has led to key changes in cancer care and a rise in the number of patients who survive cancer. Even so, the side effects and poisons that come with these treatments commonly harm patients' day-to-day living. Though we appreciate how modern cancer treatments can help patients live longer, the negative side effects from simple ones like tiredness or queasiness, to serious ones like problems with the heart, nerves or immune system are still a significant issue in cancer treatment(1).

Since reducing adverse effects is a priority for many, both researchers and healthcare workers are looking into new ways to boost the treatment for various cancers. Chronopharmacology, among these new methods, is especially promising because it looks at when drugs should be given and when they are most effective. Those who practice this area of medicine understand the key role of timing and use that insight to create more successful therapies.

This discipline is concerned with planning when to take medication to suit the body's regular 24-hour schedule of biological cycles. Your body maintains an internal time system which is organized from the suprachiasmatic nucleus in the hypothalamus and appears in the biological clocks of most cells. It impacts the body's clock, temperature, hormone release, energy levels, as well as activities such as repairing DNA, cell division and apoptosis. Importantly, how we handle medications depends on circadian rhythms which influence their absorption, how well they distribute, how they are metabolized, their elimination and the effects they have.

Drug metabolism and tolerance can depend a lot on time, so there are special periods when taking medicines can be most effective with the least chance of negative effects. As an example, the liver's ability to break down drugs changes during the day, as do the filtration rates in the kidneys, the amount of stomach acid excreted and how much blood reaches various organs. Likewise, the levels of drug targets and receptors usually go up and down as the body's clock directs. Timing the delivery of cancer therapeutics to suit the body's rhythms may allow clinicians to help patients in several ways(2).

The main ideas in chronopharmacology for cancer treatment are based on a number of significant observations. For one, cancer cells might behave differently at certain times, so using treatments at the right time could help eliminate them. Second, there are regular changes during the day in the way anticancer agents are distributed and work inside the body. Third, the systems that protect the body from drug damage function best at different times each day, so following this schedule may decrease harm to healthy tissues.

Early medical research shows that using chronopharmacology may improve cancer treatment. Giving some chemotherapy agents at particular times of the day appears to both reduce side effects and improve how well the

medicine works on cancer. Many studies have found that giving 5-fluorouracil, oxaliplatin and irinotecan according to natural rhythms is very promising for treating colorectal cancer. This same pattern has been found for other cancer drugs such as targeted therapies and immunotherapeutics.

Over and above its role in better cancer treatments, chronopharmacology brings about possibilities for customized medicine. Every person's circadian characteristics are determined by genetics, age, sex, lifestyle and environment. Accordingly, doctors can develop strategies that will match the specific needs of their patients. The ability to personalize healthcare is now possible in hospitals with wearable devices, circadian markers and computer models.

This article explains the importance of chronopharmacology in treating cancer and how different drug timing can improve outcomes and lower side effects. We will look at circadian rhythms from a biological standpoint, understanding their role in cancer therapy and studying how the body's internal clock changes the ways drugs are used, how cancer cells become vulnerable and how tissues are recovered. It will also discuss the challenges that arise when trying to use chronopharmacological strategies such as assessment, the search for standard treatments and ensuring patients follow the regimens.

Besides, we will discuss several cancer drugs that have been found to show changes in how effective and toxic they are over time, by looking at both research on animals and clinical testing on humans. The role of chronopharmacology in helping chemotherapy, targeted therapy, immunotherapy and hormonal therapy will be described, as well as the use of new technical tools to deliver drugs when needed(3).

Using chronopharmacology, oncology hopes to design treatments that are kinder, more effective and better suited to individual needs. It replaces the usual methods of dosing based only on body size, with regimens that follow the natural daily changes in the body. In the long run, chronopharmacology could boost the success of cancer treatment while making cancer patients' lives easier, possibly leading to major changes in cancer care.

2. The Circadian Clock: Cancer's Molecular Targets

The circadian clock makes sure that the body's functions are carried out with surprising accuracy over a 24-hour span. The master clock for mammals, the SCN in the hypothalamus, keeps this vital molecular structure running. Yet, peripheral clocks are present in many organs and tissues in the body, building a structure where all the clocks are synchronized to both respond to changes outside and organize work within each organ. The body's temporal organization anticipates what is needed each day and makes sure functions are regulated accordingly.

Instead of a central clock, the molecular clock is made up of feedback loops between groups of key genes that control the body's rhythms. This loop is mainly made up of CLOCK and BMAL1 that heterodimerize and trigger expression of Period and Cryptochrome by attaching to E-box parts of their promoters. An increase in PER and CRY proteins leads to their aggregation which is then transported to the nucleus, where they block CLOCK-BMAL1 activity and lowers their own transcription. Robust and long-lasting 24-hour oscillations are maintained by secondary feedback mechanisms involving REV-ERBs and RORs that control the expression of Bmal1.

Researchers are paying increased attention to how circadian rhythms are related to getting cancer. Studies have shown that a regular disturbance to a person's circadian cycle such as that faced by shift workers, travelers and people with sleep difficulties, increases the chance of developing cancer. Shift work that disrupts the normal circadian cycle, according to the International Agency for Research on Cancer, is highly likely to be a cancer risk factor(4).

There are different factors that explain this link. When our circadian rhythms are affected, cells may multiply at the wrong moment, reducing the ability of mitotic checkpoints to prevent errors in the DNA. Moreover, when circadian rhythms are disrupted, DNA repair is not properly activated, since cell activity during sleep is not directed toward repair. The part of the immune system that helps detect cancerous cells is also under circadian control. If the circadian patterns are disrupted, immune cells may not recognize and fight transformed cells before they start tumor growth.

Clock genes found to be part of the circadian system have been discovered to have direct effects against tumor formation. In addition to setting the body's circadian rhythm, Period 2 also appears to control cellular homeostasis. Per2-deficient mice have been shown to develop more tumors than normal mice and to have less apoptosis after gamma radiation, possibly due to a decreased response to possible DNA damage. At this scale, PER2 appears to connect with tumor suppressor pathways such as the p53 signals, the projections affecting the cell cycle and death signaling. With Per2 expression disrupted by genetic changes or epigenetic reasons, cells grow out of control and DNA is repaired poorly which helps cancer start and spread(5).

Other clock elements are also thought to have similar tumor-suppressing activities. BMAL1 helps to regulate p53 in

pancreatic cancer, but CRYs have an influence on how cells react to genotoxic damage. Some clock genes may, under given conditions, support cancer development, indicating that their function in cancer biology can change depending on the situation. That makes it clear why exploring the exact roles of each clock component is important in different cancers.

The science of chronopharmacology for cancer, known as chronochemotherapy, applies daily body cycles to optimize the success of cancer treatment. The response of anticancer drugs toward time is often clear in many of their pharmacokinetic, pharmacodynamic and target cell sensitivity properties. For example, the toxicity toward cells of 5-fluorouracil, one of the universal chemotherapy drugs, is very dependent on the time of its administration in studies. The ability to improve treatment results with platinum drugs was also shown with oxaliplatin which acts most effectively when taken during certain phase cycles of the day.

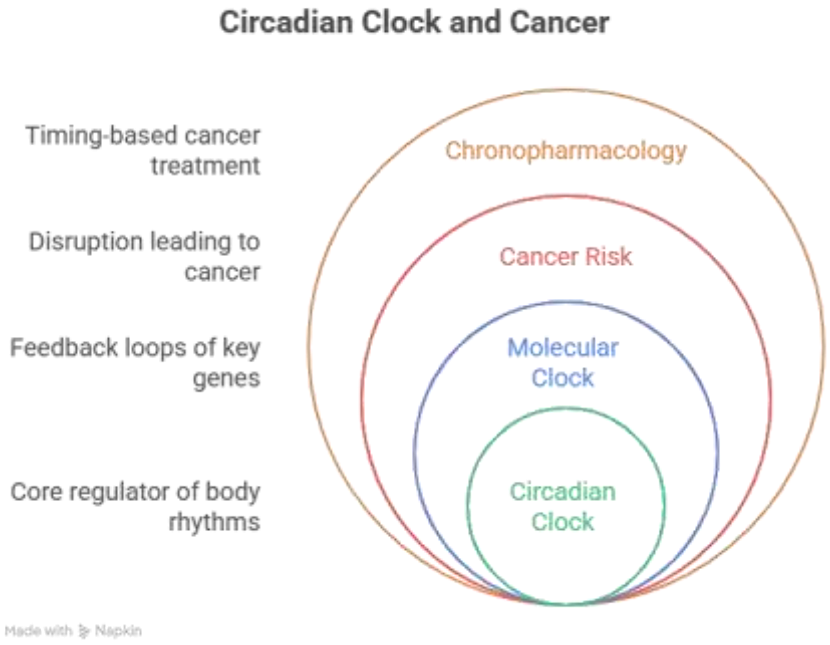

FIGURE 1 Circadian Clock and Cancer

Such effects are caused by changes in biological activities at different times of day. Circadian variations in drug-metabolizing enzymes in the liver influence when and at what rate drugs are absorbed or removed from the system. How much drug enters or leaves the cell depends on the oscillating transport proteins throughout the daytime. At the cellular level, the levels of drug targets, genes that repair DNA and the genes that cause cells to die all rise and fall in a circadian rhythm, so the best time for drugs to work can change over time.

Chronopharmacology supports new targeted therapies and immunotherapeutic approaches, going beyond what is offered by traditional chemotherapy. The expression and responsiveness of some drug targets, including growth factor receptors, kinases and immune checkpoint proteins, vary with the time of day, so when a therapy is given could potentially be very important for its success. Chronopharmacology tries to find the best windows in time to give the drugs, in the hope of making therapy more effective and less harmful to healthy tissue.

Improvement in cancer care is expected as chronicology moves to recognize and adapt to differences in individual circadian rhythms. An individual's circadian pattern and therefore their best treatment schedule can be affected by genetic changes in clock genes, aging, the presence of multiple diseases and their overall habits. By using modern devices to monitor internal clocks and computer models of how drugs work through the day, it is becoming easier to choose the best treatment schedule for a person, possibly changing cancer treatment for the better.

3. Opportunities for Circadian-Driven Drug Development

Using circadian science, drug makers can find new ways to create medicines that are more effective and have fewer negative side effects through proper timing. Since the body's functions are tied to its circadian rhythms, this new

field creates moments when medicines can be deployed with greater effectiveness. Following chronobiological principles in drug discovery may allow researchers to bring about major changes in cancer treatment and other important therapeutic fields(6).

The use of circadian timing to improve drug pharmacokinetics offers an immediate and important chance in this area. ADME of drugs changes a lot during the day as different bodily functions change at different times. For example, how gastric emptying rates, blood flow through the intestines, liver circulation and enzymatic activity happen is not the same over time. Using formulations that match the body's natural rhythms, drug developers can make it easier for the drug to be used and to keep blood levels steady. By using this approach, scientists are able to give peak doses just when the body is least likely to be affected by side effects.

Using circadian wisdom in cancer treatment is mainly appreciated for its contribution to treating toxic effects. Most anticancer drugs destroy abnormal cells, but they also become toxic to normal cells in the body, making treatment results less successful. Evidence from chronopharmacological studies indicates that cytotoxic drug tolerance in healthy tissues is greater at specific times within the day. Bringing chemotherapy schedules forward to times when cells are more resistant helps to reduce serious side effects during treatment. Because of this change, experimental treatments may be introduced earlier and with less likelihood of serious problems than before.

Individual schedule-based therapy is an important direction for circadian-based pharmacology. People's circadian traits are shaped by their genes, the way they live, their age, their sex and even environmental conditions. Taking medicine at a certain time depends a lot on a person's chronotype. By relying on chronotype assessment in their guidelines and making drugs that fit individual needs, companies can achieve true personalized medicine. The combination of electronic circadian monitors and computerized dosing prediction is making it possible for clinics to use personalized treatments.

Using chronobiology for specific diseases opens up the chance to create new therapies. There are many diseases that follow a daily cycle of affected symptoms and disease development. The night brings on more asthma symptoms, rheumatoid arthritis is more hurting the next morning and various cancers display periodic variations in how fast they develop and use energy. If drugs are formulated for when symptoms are most prominent, the treatment outcome can be much better. In fact, creating oncology drugs that work when cancer cells are most sensitive could make them even more effective and accurate.

Looking into circadian biology related to diseases can reveal previously unknown ways to help the body heal. Scientists are discovering, through better understanding of the molecular clock, that certain changes in certain clock elements play a role in disease. The findings open up the chance to make drugs that either adjust internal clocks or target important pathways controlled by them. Clock-targeting agents could correct disruptions in the cell cycles of cancer, restore healthy rhythms in metabolic diseases and improve the action of the immune system in immunotherapy(7).

Developments in technology are making it possible to improve drug development that works with the human body's circadian rhythms. Chronomodulated drug delivery systems which are programmed for timed release, allow doctors to control exactly when certain medicines become effective. Some of these technologies are straightforward, like those that ensure drugs are released when the body tells them to. On the other hand, more advanced versions place microelectronics in medicines that react to daily biomarkers. On top of that, monitoring devices that watch a person's physiological rhythms can update treatment timing in the moment, helping to maintain and improve the use of chronotherapy.

Adopting circadian concepts in clinical trial creation is an important method to prove and promote chronopharmacological techniques. In most clinical trials, important time-related effects are not considered. When applying chronobiology into trial design by measuring circadian biomarkers, sorting people by their sleep-wake tendencies and assessing effects based on administration time, researchers can collect clear evidence for chronotherapeutic strategies. As a result, these time-based drug trial findings could allow regulators to officially approve individualized timing for medicine, thus bringing chronopharmacology into general medical practice.

Cooperation between chronobiologists, pharmacologists, clinicians and technology developers will be required to make the most of circadian drug development. By using different areas of knowledge, scientists can move from the lab to clinical practice more quickly. Working together to convert basic chronobiology into treatments that can be used in clinical practice seems promising for the field. The broader and closer these networks become, the faster new discoveries in circadian-based drug development are expected to reach patients.

4. Obstacles in Circadian-Driven Drug Development

Although circadian rhythms can lead to better drugs, this sector still has to tackle several important scientific, medical and practical problems before chronopharmacology enters common practice. Both the basic problems related to our biology and the rules and restrictions in medicine hinder progress, so experts in many fields must join

forces to find answers.

The fact that each person's circadian rhythms differ poses the crucial challenge to using chronotherapy. Many individuals have a sleep and daily activity pattern that can be called "morning larks" or "night owls," but the vast majority fall in the middle of these two. Both behavioral habits and bodily processes linked to drugs are affected by chronotypes. Also, because circadian rhythms change based on age, sex, genes, health and environment, every person can experience them differently. As a result of these differences, making a single regimen for all patients is difficult and doctors instead rely on personal treatment options that can be tough to apply to larger groups(8).

Disruptions to a person's natural sleep cycle in various diseases add difficulty to chronotherapeutic strategies. Many diseases, including cancer, change or reduce the body's daily rhythm at the whole system and cellular level. When the body experiences inflammation, problems with metabolism or changes in tumor genes, it can throw off the cell clock so that time-based therapies may not function properly. These changes in our body clocks are not always well known and might shift as disease advances, making it harder to treat them with circadian medications. Finding drugs that work well with messed-up schedules or even undo some of the damage to the body clock is a big problem.

It is difficult to carry out accurate circadian assessment in clinical practice because the approach is complex. Representative methods for lab work such as transcriptomics and metabolomics, accurately identify circadian rhythms in research settings. However, using these techniques in daily medical practice is difficult due to their cost, invasiveness and time involvement. Though wearable monitors provide approximate timing data, they may not be precise enough for the best use of medicine. We still do not have accessible, repeatable biomarkers that would allow us to adjust treatment timing during everyday patient care.

Drug schedules set by time make it hard for many patients. Most chronotherapeutic methods ask for timely drug administration which may conflict with patients' daily routines, sleep or way of living. If a drug must be given during the deep of the night for the best results, patients in treatment at home may find it hard to follow the plan. It can be difficult for patients to keep to a specific schedule of medicines if they have to worry about work, family matters or social plans. Especially with permanently managed chronic diseases, it is important for patients to stick to their dosing schedules to gain the best results.

Because drug interactions are so complex, chronotherapy has become more challenging. Often, patients who have cancer or chronic conditions are given several medications all at once. Based on how the drug is processed by the body which tissue it targets and the risks involved, the best time to give it can differ. If the best time for each employee clashes, it becomes difficult to put together a workable schedule. Moreover, how one drug is taken relative to others can alter their effectiveness or the amount of damage they cause and these effects are not always simple to predict. Because of these interactions, building a chronotherapeutic protocol becomes more difficult.

Because the rules for chronotherapeutic drugs are still unclear, those who wish to develop these treatments have little guidance. Previous drug development efforts usually pay attention to how much of a drug is needed rather than how quickly it acts. There is little background for regulatory agencies in reviewing chronotherapeutic claims and chronotherapeutic indications on labels are not common. Despite interest in chronotherapy, there are no easy answers for running trials, choosing suitable endpoints or developing rules for chronopharmacological products which can discourage investment in this field.

Chronotherapeutics is more difficult to study in clinical trials than traditional medications because the studies require different methods. Because time-varying effects are so complex, the trials must be designed with many timepoints which may add to the overall costs and make things more complicated. When we factor in the effects of light, meal schedules and sleep routines, the study design becomes more complicated. Blinding is made more difficult when treatment schedules are not the same for both groups. Because they are complicated, these methods may stop sponsors from studying chronotherapy which means there is not much evidence to support circadian-based approaches(9).

Chronotherapeutic products have to deal with market difficulties related to how they are distinct, how much they cost and how much insurance will pay for them. Chronotherapeutic approaches might not attract support from pharmaceutical firms if the improvement over traditional ones is too small and costs from the added research are also high. It may be challenging for chronotherapeutic product companies to have payers cover their products at high costs without significant proof that their solutions are better or less costly. Furthermore, protecting these drug modifications with intellectual property is often simpler and narrower than with inventions of brand new drugs which could discourage companies from working on these treatments.

Lack of attention to chronobiology in medical schools and hospitals keeps many doctors from considering ways to use chrono-based therapies. Chronopharmacology is not broadly covered in healthcare professional training, so most practitioners might not understand the reasons for considering drug timing. Without recognizing the importance of

time, clinicians could be reluctant to take seriously findings related to chronotherapy. Widely spreading the benefits of time-specific drug therapy will require educating health workers, using guidance tools and writing practice standards.

5. Chronopharmacological Methods to Reduce Adverse Effects of Treatment

Even though cancer treatments are now better at killing cancer cells, the side effects they cause can reduce patients' quality of life and lead to fewer treatment alternatives. Using chronopharmacology, medicine is delivered when the body's clock is most helpful, reducing the likelihood of certain side effects. Using the timing of drug use to match the heightened tolerance of healthy tissues with the weakest point in cancer cells could transform the balance of risks and benefits for many types of cancer treatments.

Using circadian biology, chronotherapeutics basically changes the usual approach to taking drugs at fixed or scheduled times. Instead of concentrating only on how much is given, this approach believes that timing when the drug is provided can improve both the treatment and the possible side effects. The principle is based on known changes in hormone levels that affect how bodies use drugs, produce new cells, handle DNA and fight disease. When doctors match treatment plans to the body's natural cycles, toxicity can be lowered without affecting the results.

Researchers in chronopharmacology have found that drug-related toxic effects happen in a distinct way throughout the day in healthy tissues. Cells formed from the marrow of bones which chemo can hit hard, show circadian changes in their growth. It has been determined from studies that drugs that affect blood cell formation are less likely to cause hematological problems when given when less blood cell production is taking place. Oscillations in circadian control have been noted in gastrointestinal epithelia, where cells are renewed following that same pattern. Researchers have seen a major decrease in nausea, vomiting and diarrhea by ensuring chemotherapy is administered when mucosal cells divide less.

Many anticancer drugs often cause liver or kidney problems, called hepatic and renal toxicities which can be minimized with chronopharmacology. Throughout the day, changes in liver blood flow, levels of enzymes and metabolism cause the liver's capacity to detoxify to change. It has been found through studies that hepatotoxic drugs given during times of maximum detoxification can protect the liver from damage. Additionally, how quickly renal filtration happens and how tubules operate can vary according to the time of day and influence drug safety and proper elimination. Giving drugs for cancer when kidney function is best can reduce the risk of kidney problems, notably for medications such as cisplatin and methotrexate.

Toxicity to the heart related to anthracycline drugs and some targeted therapies often follows clear nighttime and daytime changes. Scientists have discovered that the heart is more likely to be damaged by drugs when certain protective systems are less active at night. Results from experiments demonstrate that applying doxorubicin during times of exercise causes less cardiac damage than when doxorubicin is given during rest. The study suggests that giving these drugs at a certain timing of the day may help avoid some serious heart problems linked to these treatments.

Both peripheral neuropathy and problems with thinking (cognition) are considered neurotoxic side effects and are influenced by the body's daily rhythm. How easily drugs can enter neural tissues through the blood-brain barrier is influenced by daily changes in its permeability. Furthermore, both neural repair processes and neurotransmitter mechanisms have their own circadian timing. By delivering neurotoxic agents such as taxanes and platinums when neural resilience is higher, chronotherapeutic methods want to decrease the continued side effects that often last after the treatment ends.

Tailoring time of drug delivery to an individual's needs is now essential for successful chronotherapy. People's circadian profiles often look different due to genetic, age, sex, medical condition and lifestyle factors. Using both basic questionnaires and more advanced measurement of body temperature, cortisol levels and activity levels, specialists can find out each patient's particular circadian phase. Anticipating that optimal drug administration could be different for individuals with similar toxicity, this method takes the individual into account. Designing treatment around each individual's chronotype allows clinicians to offer the most protection through chronotherapy to a wide variety of people.

More and more, technology is helping chronotherapeutic treatments become a standard in clinical practice. With advanced ambulatory pumps and timing control features, it is much easier to provide drugs in a precise, constant mode than by using regular non-programmable delivery systems. Email can release medicines at specific times that match the patient's natural circadian cycle, making complex chronotherapy available even at home. Also, wearable devices that monitor the body's processes in real-time can tell us when markers of the circadian system change, so treatments might be adapted each day.

Applying chronopharmacology in clinics has already noticeably reduced the side effects of drug treatment in various

cancer cases. In treating colorectal cancer, giving these medicines 5-fluorouracil, leucovorin and oxaliplatin (chronoFLOX) on a timed schedule has reduced severe mucositis, diarrhea and neutropenia more than standard use, so patients can tolerate stronger medicines without experiencing more side effects. Benefits similar to what is seen in chemotherapy were also studied for lung cancer, ovarian cancer and breast cancer, with some investigations finding up to half less of serious side effects with comparable or even enhanced results.

Using medical time-based ideas, researchers are looking for ways to solve side effects from targeted therapies, immunotherapies and supporting medicines. When using corticosteroids, given as antiemetics or to address immune-related problems, careful scheduling can support good health in the hypothalamic-pituitary-adrenal system. When giving growth factors, anticoagulants or analgesics, proper timing can benefit the procedure and cut back on problems that may arise. This approach handles the complete range of drugs used for treating cancer.

A multidisciplinary effort is needed to bring chronopharmacological strategies into mainstream oncology, with the input of oncologists, pharmacologists, chronobiologists, nurses and patients. Healthcare professionals should include information about circadian rhythms and when to take certain medicines both in their studies and in their discussions with patients. Also, systems in healthcare need to design schedules that fit with chronotherapeutic timing, as this timing is not always convenient for hospitals and clinics. Further work in chronopharmacology could improve how well cancer treatments are tolerated and the outcome for many patients. I suggest checking every answer carefully.

6.Conclusion and Future work

Chronopharmacology applies a new method to treating cancer by tapping into the regular changes in the body to help therapies become more effective. The approach intended to synchronize when drugs are given to the body's natural cycle, offers a possible way to achieve more effective treatment and lessen related toxic effects. We have looked at how chronopharmacology affects cancer treatment, from a molecular level to what it achieves in clinical practice and future plans. What we have seen in the evidence highlights how important chronotherapeutics could be in changing cancer care with better, optimized treatment timeframes.

The link between the circadian clock system and cancer biology is what chronopharmacology is based on. When circadian rhythms are thrown off, it seems to increase cancer risk, while some clock genes block the development and progression of cancer. The association between them forms both problems and opportunities in therapeutic use. Once clinicians know how circadian mechanisms affect drug metabolism, changes in cellular systems and tissue regeneration, they can decide when to give medications in order to decrease side effects. Temporal analysis brings extra value to precision oncology, along with the current focus on molecules and genetics.

Use of chronopharmacology in clinics has already provided positive outcomes for many cancer types and treatments. Reduced toxicity is possible with chronomodulated therapy without affecting how well it works. People are beginning to see similar benefits with therapies called targeted treatments, immunotherapies and morale-boosting drugs. They point out that when treatment happens matters as much as how much medicine and what agent is used. With the development of personalized medicine in oncology, adding chronopharmacology can consider each patient's natural biological timing, possibly letting doctors use higher amounts of medicine, helping patients stick to their treatment plans and improving how well they recover.

Our progress with chronopharmacology in cancer cannot be fully realized until we address the many challenges this method faces. The differences in people's circadian rhythms, how difficult it is to measure circadian markers clinically, challenges related to timing drugs and the lack of major clinical studies all keep circadian medicine from becoming popular. Because of this, devices that monitor the body's circadian rhythm, drugs that target the right time and chronotype analysis by AI are bridging these gaps in healthcare. Thanks to new technology and increased understanding of how circadian rhythms work, it now seems easier to apply chronotherapy in cancer care.

The future in cancer care for chronopharmacology links personal medicine, technological developments and team-based healthcare. As we study the molecular links between circadian rhythms and cancer, we will find new approaches for timing cancer treatment. New drug delivery techniques will make it possible to give medications at specific times throughout the day. Only when oncologists, chronobiologists, pharmacologists, engineers and data scientists cooperate can these scientific findings be put into practice for clinical use. Improved investment in research and application may make chronopharmacology an important part of modern cancer treatment.

All in all, chronopharmacology may greatly improve how cancer is treated by coordinating treatments with the body's natural rhythms. This way of prescribing medications can improve treatment results and also lower the

chances of serious side effects one of the toughest problems in contemporary oncology. With new discoveries about circadian systems and better technology, chronopharmacology could greatly influence the complete care of cancer patients. Emphasizing how time affects cancer gives oncologists a new reason to consider daily schedules as part of treating patients with personalized care. Using natural rhythms of the body and aiming at cancer's weaknesses is a big leap in helping more cancer patients have better outcomes everywhere.

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

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