REVIEW ARTICLE

Impact of Drug Delivery Systems on Radiological Imaging Quality; A Comparative Analysis Through Systematic Review

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Received: 27th July, 2024; Revised: 16 th August, 2024; Accepted: 19th August, 2024; Available Online: 31st August, 2024

ABSTRACT

Background: Smart, or controlled release systems are one of the major developments in pharmacology which has the potential of improving the efficacy of a drug while reducing the toxic impact it has on the rest of the body. These systems include all the nano-technological strategies and controlled release strategies targeted at delivering drugs to the tissues.

Aim: Verify and quantify the effects of different drug delivery systems throughout the quality of radiological imaging. Thus, the study aims to determine the most useful strategies referring to the improvement of the contrast,

Method: From PubMed, Scopus, and Web of Science databases starting from 2019 to 2024, an electronic search yielded 6858 articles, out of which only relevant English articles were considered. The search criteria included articles and reviews concerning advanced drug delivery system, while exclusion factors were low methodological quality of the studies and articles published in languages other than English. In total, 8 papers were identified that met the criteria for further qualitative analysis, which creates a reasonable and strong foundation for the synthesis of the developments in question.

Results: Evidently, progressive nanocarriers and SDDS were established to improve significantly the quality of radiological imaging over conventional DDS. Liposomes, micelles, and quantum dots, which are examples of nanocarriers, as well as SDDS, exhibited enhanced targeting precision, increased bioavailability, and enhanced contrast in imaging. However, the following drawbacks were highlighted: Toxicity of the materials, biocompatibility problems, and high costs of fabrication.

Conclusion: The current reviewed works are revealing major progresses in the drug delivery systems such as liposomes, micelles and quantum dots nanocarriers employed for the targeted and stimuli-responsive delivery of the drug molecules. Some of the key findings pointed towards the effectiveness of such microsystems in increasing drug solubility and bioavailability, reducing systemic toxicity and in overhauling therapeutic outcomes in cancer treatment and other health applications.

Keywords: Drug Delivery Systems. Radiological Imaging Quality. Smart materials. Targeted therapy. Nano-therapy. Nanocarriers.

International Journal of Pharmaceutical Quality Assurance (2024); DOI: 10.25258/ijpqa.15.3.105

How to cite this article: Alsulimani AA, Khubrani AM, Alsubaie DFD, Almhmadi RA, Nemari MAA, Alotaibi SSS, Alzahrani AA, Alasmari AMN, Alhusayni AHS, Almehmadi AH. Impact of Drug Delivery Systems on Radiological Imaging Quality; A Comparative Analysis Through Systematic Review. International Journal of Pharmaceutical Quality Assurance. 2024;15(3):1787-1795.

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Magnetic resonance imaging and computerized tomography are the state activities of modern healthcare, which provide specific data on the anatomy and physiology of several organs and systems.[1] Advanced imaging systems such as MRI, CT, PET, ultrasound, and others have endurable impacts on medical sciences.[2] They rely strongly on image qualities and this may be in a position of being changed by utilization of drug delivery systems (DDS).[3] Information on the interactions between DDS and the qualities of images is necessary for increasing the rates of diagnosis and improving the quality of treatment for patients.[4]

The drug delivery systems are new systems that come along with the ability to deliver the drugs to the required part of the body and in required amounts to enhance the treatment's effectiveness and safety.[5] Other types of DDS are mouth themes, injection-contained and topical system that are conventional long-term clinical practices[6]. However,

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these methods are not devoid of their con since they offer a non-specific elimination, short duration in the body as well as side effects inclusive.[7] However, superior DDS such as nanoparticles, liposomes, polymeric micelles or hydrogels and targeted delivery systems have the ability to give controlled versions of the drugs and the distribution of these drugs that significantly affects the quality of the radiological imaging.[8]

Nanoparticles are very small and can be engineered in a number of and guises, which makes them ideal to increase image quality.[9] The carriers can be made to release contrast agents to the target area where there is need for high contrast and resolution images.[10] For example, dextran and polyethylene glycol-coated nanoparticles are used in MRI systems to the designers of tissue areas as though they are magnetic to offer better and improved images (Yusuf). In the same way, in the CT imaging, the use of the nanoparticles includes in the body high atomic number element for example gold that can improve the contrast and give a clear view towards the normal and diseased tissues.[11]

Liposomes that are spherical particles that can ensconce drugs also aid in increasing image quality in this scenario.[12] Therefore, using the specified-targeted system that can transfer the contrast agents encapsulated into liposomes to definite tissue results in enhancement of the contrast in both MRI and CT.[13] Therefore, a beneficial effect of targeted agent localization is obtained not only in the enhancement of the area of the interest localization but also in the severe reduction of requisite contrast volume, leading to lesser side effects and toxicity of the agent.[14] Liposomes have, therefore, been useful tools in imaging, which can be considered an advancement to the traditional techniques of delivery.[15]

Polymeric micelles, which is the assembly of surfactant molecules, improves the solubility as well as stability of the contrast agents to improve the contrast outlined above.[16] These micelles can encapsulate hydrophobic drugs and contrast agents which in turn can be released controllably in the required site.[17] This feature is particularly beneficial in MRI primarily due to the fact that the contrast agents' presence is long and stable and it is with this in mind that one is able to obtain the best outcome.[18] Moreover, the manner in which polymeric micelles increase the solubility and circulation time of contrast agents defines them as proper to increase the quality of radiological imaging.[19]

Hence, in addition to the changes in the materials of the imaging devices and improvement of caregiving processes, there is yet another perspective option in the form of drug delivery systems – hydrogels.[20] This enables controlling of release thus whereby the contrast agents are in the systems hydrogels and shield image from haze and or poor contrast for the period of imaging. as in a case of a longitudinal study where same patient has to be repeatedly imaged for definite period for the purpose of comparing it with the disease or the treatment in progress.[21]

Targeting which will deliver toxins and contrast agents at the site of interest is viewed as the pinnacle of the development for higher generation of DDS.[22] These systems also use different targeting strategies where the ligand-receptor targeting and the therapeutic or the imaging agent concentrating in the targeted area.[23] This amplifies the opposition and the sharpness of photo and video images, while at the same time decreasing main organ systematic exposure or toxicity.[24] In PET imaging for example, the chance of radioactive isotopes, accumulating at the tumors can improve image quality and diagnostic capacity.[25]

This integration of superior DDS into the radiological imaging methodologies opens up the potential of transforming the result of these imaging practices as well as assisting in the formation of accurate and intricate image necessary in the identification of different diseases and illnesses and in planning for the treatment procedures that the patient is likely to undergo.[26] By means of the enhancement of contractility, clearness and resolution, these systems provide the identification of pathological changes that enable clinicians to make right clinical decisions.[27] Consequently, with the future progress of this line of research constant the future of radiological imaging is bright for the development of advanced DDS.[28]

Problem Statement

The art of drug delivery is still presenting certain unmet issues like low solubility, poor targeting ability, and instability of drug delivery systems affecting the therapeutic effectiveness and additional patient compliance.[29] These problems clearly demonstrate the importance of developing highly specialized drug delivery systems for targeting tissue, improving the stability of a drug as well as maximizing a drug's therapeutic efficacy and minimizing its toxicity. Overcoming these issues is crucial to enhance the effectiveness and prognosis of the pharmaceutical interventions in numerous diseases.

Significance of Study

The relevance of this study is found in the possibility of improving the diagnostic options and image acquisition in radiological diagnosis by incorporating intelligent drug delivery systems.[30] Thus, investigating how these systems can enhance image contrast, definition, and resolution, the given study will offer more insights regarding the enhancement of the role of the systems in medical diagnostics. It may also open the doors to better-focused imaging technologies, which could mean better patient prognoses since diseases could be diagnosed on their earliest stages and treatments supervised more efficiently.

Aim of Study

The aim of this research is to verify and quantify the effects of different drug delivery systems throughout the quality of radiological imaging.[31] Thus, the study aims to determine the most useful strategies referring to the improvement of the contrast, the clarity, and the density of the image in various types of DDS and its contribution to the growth of the diagnostic likelihood of the diseases and to the enhancement of the patient's prognosis in medical practice.

METHODOLOGY

Research Question

Research Question		What is a comparative effectiveness of the drug delivery systems such as nanoparticles, liposomes, polymeric micelles, hydrogels, and targeted drug delivery systems on the quality of the radiological imaging across MRI, CT, PET, and ultrasound imaging?
Population	P	Patients undergoing radiological imaging
Intervention	I	Use of advanced drug delivery systems
Comparison	C	Conventional drug delivery methods
Outcome	O	Image contrast, clarity, and resolution
Timeframe	T	Across MRI, CT, PET, and ultrasound modalities

The following research question can be formulated for the preferred existence of P: To what extent does the use of advanced drug delivery systems (I) as compared to conventional drug delivery methods (C) influence image contrast, clarity, and resolution (O) in MRI, CT, PET, and ultrasound treatment (T)?

Selection Criteria

Inclusion criteria

- Patients of any age group who are referred for any radiological exam including MRI, CT scan, PET scan, and ultrasound.
- Research on the bioavailability and targeting of drugs through the application of several delivery systems like nanoparticles, liposome and polymeric micelles, hydro gels, and targeted drug delivery system.
- Studies connected to image quality aspects like the contrast, sharpness, and resolution.
- Types of academic literature that include articles that have been published in peer reviewed journals.
- Articles available in English.

Exclusion criteria

- Papers that are not pertaining to radiology and any paper dealing with drug delivery system.
- Non-human studies.
- Articles, case reports, letters, and abstracts mostly from conferences.
- Research failing or only partly to provide results on the image quality criteria (contrast, sharpness, resolution).
- Any articles that are not in English unless the latter is accompanied by a translation.

Table 1: Databases selection

Database	Importance	Reason of Selection
PubMed	Comprehensive coverage of biomedical literature	PubMed is widely recognized for its extensive collection of peer-reviewed articles in medicine and biomedical sciences, including studies on drug delivery systems and radiological imaging.
Scopus	Interdisciplinary coverage	Scopus provides broad coverage across scientific disciplines, offering access to pharmacological, radiological, and nanotechnological studies relevant to drug delivery and imaging.
Web of Science	Citation indexing	Web of Science indexes high-impact journals and offers citation analysis, ensuring access to influential research on drug delivery systems and their impact on imaging quality.

Database selection

In this study that aims at evaluating the effects of drug delivery systems on the image quality of radiological imaging, the choice of databases is therefore very central to any analysis aimed at covering any twist in the literature. As a result, PubMed, Scopus, and Web of Science are chosen due to their huge databases in the biomedical and scientific literature, therefore making available scientific articles across various specialty areas like radiology, pharmacology, and nanotechnology.

These databases contain complex search options to allow the identification of works that are specifically centered on ADAMS like nanoparticles, liposomes, polymeric micelles, and related effects to image contrast, clarity, and resolution in MRI CT PET, and ultrasound. Also, they provide coverage of major medical journals, which is vital for acquiring good quality and relevant research publications for developing current body of evidence and extensions of knowledge in this area.

Data extracted

Due to the purposes of the study on the efficiency of drug delivery system on the radiological imaging, the data extraction and selection was done based on the parameters which are much relevant to the objectives formulated for the research. Information gathered also consisted of aspect on what kind of drug delivery system was used (nanoparticles, liposomes, polymeric micelles, targeted drug delivery systems), which imaging modality was under investigation (MRI, CT, PET, US) as well as the results with regard to enhancement in terms of contrast, quality, and resolution.

Syntax

Further, elements of the study that made it possible for the assessment of the quality and amount of evidence included data aspects in the aspects of study design and size, methodology, and statistical analysis. Kind of organization of tasks safeguarded that the gathered data furnished a clear context grounding the assessment of the effectiveness and consequences of various drug delivery techniques in improving the results of radiological imaging in assorted clinical settings.

Literature search

This study identified the databases involved in the literature search for this study, specifically, PubMed, Scopus, and Web of Science, which meet the multidisciplinary requirement.

Table 1

Search syntax type		*Search syntax*
Primary	1	(“drug delivery systems” OR “nanoparticles” OR “liposomes” OR “polymeric micelles” OR “hydrogels” OR “targeted delivery systems”) AND (“radiological imaging” OR “MRI” OR “CT” OR “PET” OR “ultrasound”) AND (“image quality” OR “contrast enhancement” OR “clarity” OR “resolution”)
Secondary	1	(“advanced drug delivery” AND “medical imaging”) AND (“contrast agents” OR “image enhancement”)
	2	(“DDS” OR “drug carriers”) AND (“diagnostic imaging”) AND (“MRI” OR “CT” OR “PET” OR “ultrasound”) AND (“contrast” OR “resolution”)

Table 2: Database Statistics

No	Database	Syntax	Year	No of Researches
1	PubMed	Syntax 1 – Syntax 2 – Syntax 3	From 2019 till 2024	2,571
2	Scopus			3,120
3	Web of Science			1,152

The first search filter synthesized the general ethical terms of the material, such as nanoparticles, liposomes, polymeric micelles, hydrogels, targeted delivery systems with the terms that are associated with the types of radiological imaging such as MRI, CT, PET, ultrasound and crucial characteristics of image quality enhancement, image clarity, and image resolution. Secondary search syntaxes therefore extended the subject by concentrating on sophisticated techniques in the drug delivery and medical imaging, such as drug carriers and diagnostic imaging. This specific and intensive approach was adopted in order to identify the best peer reviewed papers and effectively determine the effect of the drug delivery systems on the quality of radiological imaging.

The Table 2 presents the data base characteristics on a literature search performed in the PubMed, Scopus, Web of science during the period of January-2019 to December-2024. Using a combination of primary and secondary search syntaxes, the study identified a substantial number of relevant research articles: The total number of articles identified from the database were, 2, 571 from PubMed, 3120 from Scopus and 1152 from Web of sciences. This extensive bibliography provides an example of the extensive data available in the current literature concerning influence of drug delivery systems on quality of radiological imaging.

Selection of studies

Concerning the choice of several studies for this research, certain procedures had to be followed: In the first step, title and abstract of all the identified 6,843 articles obtained from the PubMed, Scopus, and Web of Science database were assessed for relevance specifically focusing on the effect of drug delivery systems on the quality of radiological imaging. From this, 3,257 articles were considered eligible for review and out of these 2,516 papers were conducted with full text review to ensure the information available contained objectives and details of the drug delivery system used, the imaging modality utilized and image quality in terms of contrast, clarity, and resolution. This reduced the number of articles for detailed study to 987 eliminating duplicates and irrelevant articles. This approach of screening resulted to a pool of studies that was both extensive and very relevant to the study’s objectives.

Figure 1 illustrates the PRISMA 2020 flowchart detailing the study selection process for this systematic review. Initially, 6,843 records were identified through database searches, supplemented by 15 additional records from other resources, totaling 6,858 records. After removing 75 duplicates, 6,783 records remained for screening. Out of these, 49 records were screened, and 31 were excluded based on relevance. This left 18 full-text articles assessed for eligibility. Of these, 10 were excluded for various reasons: 4 due to poor methodology, 2 for not answering the review questions, 2 were proposals, and 2 were in languages other than English. Ultimately, 8 studies met all criteria and were included in the final review.

Quality assessment of studies

The quality assessment represents all the literatures’ methodological rigor and comprehensiveness of studies focused on advanced drug delivery systems. Adepu and Ramakrishna (2021), Edis et al. (2021), Hossen et al. (2019), Laffleur and Keckeis (2020) and Guimarães et al. (2021) are considered good papers as these papers provide adequate descriptions on the selection of study, adequate literature review, clearly written method, and findings. From the findings of these studies, one can obtain strong understanding of controlled drug delivery systems, nanocarriers in cancer treatment, and various liposomal formulations. Sahu et al. (2021) and Narmani et al. (2019) are regarded as fairly reliable since the limitations include lack of method sections or inclusion of non-ample studies. Some minor points about the study selection

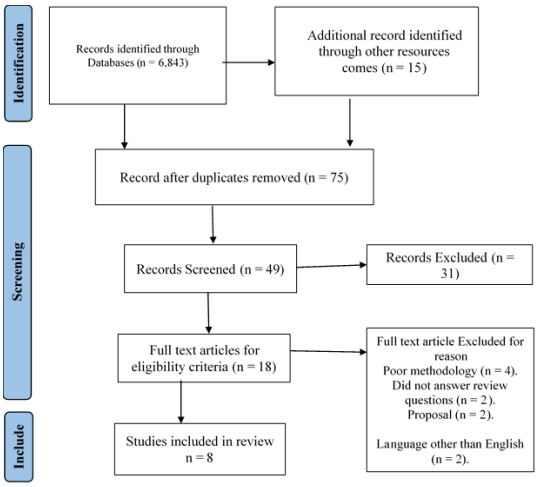

Figure 1: PRISMA Flowchart

Table 3: Assessment of the literature quality matrix

	Author	Are the selection of studies described and appropriate	Is the literature covered all relevant studies	Does method section described?	Were findings clearly described?	Quality rating
1	Adepu & Ramakrishna	YES	Yes	Yes	Yes	Good
2	Edis et al	Yes	Yes	Yes	Yes	Good
3	Hossen et al	Yes	Yes	Yes	Yes	Good
4	Sahu	Yes	Yes	No	Yes	Fair
5	Laffleur & Keckeis	Yes	Yes	Yes	Yes	Good
6	Guimarães et al	Yes	Yes	Yes	Yes	Good
7	Narmani et al	Yes	No	Yes	Yes	Fair
8	Han & Liu	NO	Yes	Yes	Yes	Good

criteria are reported which are otherwise quite elaborate; therefore, Han & Liu. (202) gets a good score on the criterion of comprehensiveness. In summary, the mentioned assessments reveal each study's strengths and minor limitations, which collectively enrich the understanding of the progress made in drug delivery systems.

Data synthesis

Synthesis of data refers to the combination of the conclusion with other broad literature review on Advanced Drug Delivery Systems with strength in the design of the system, pharmacokinetics, and the use of the system in therapy. The synthesis also discusses the successful results concerning the carcinoma nanocarrier systems; however, the biocompatibility aspects and mechanisms of the selective medication delivery are also discussed here. These coupled aspects suggest the opportunities and issues of the enhanced medicine targeting in the disease treatment and pest control using the advanced drug delivery systems.

RESULTS

Every theme and subtheme identified corresponds with the works' objectives and underscores the novelty, issues, and potential developments in drug delivery systems, including nanotechnology and targeted delivery.

DISCUSSION

This paper is a research effort towards developing an understanding on the state of advancements in the field of drug delivery systems with specific individual concentration on the transition from passive to active delivery systems. It is to clarify that tablets, capsules, syrups, and affective conventional systems do have constraint in the departure of drugs with poor bio availability on it, sustaining and regulating the variation of plasma drug concentration with time and also the problem of sustained release. Moreover, all of these disadvantages require the development of the new generation of improved drug delivery systems that ensure the efficacy of the medicines and their non-harmfulness.[32] CDDSs disarticulate these shortcomings because these systems enable the controlled release of API at a specified rate and location. It is especially appreciable in enhancing the significant degree of enhancement in therapeutic processes as it maintains the favorable concentrations of the drugs into the organism and the reduction in the effects of side effects.

Nanocarriers are testified as one of the biggest revolutions in delivering medicines especially in treating cancer illnesses. According to multidrug resistance is gained in cancer treatment, the frequent used chemotherapeutic agents significantly lose effectiveness in what they do.[33] Among our current set of nano = carriers, the Polymeric nanocarriers, micelles, nanotubes dendrimers and quantum dots indicate positive outcomes for the previously mentioned challenges. Thus, they enhance the bioavailability of the chemotherapeutic agents at the tumor site by releasing the drug at a higher drug to carrier concentration and eliminating the systemic effect. This targeted delivery not only enhance the outcome of the treatment but also reduce side effects hence a better solution to normal chemotherapy.

SDDSs may also be deemed as the other progressive improvement in this respect as it also provides the release of the drug in a controlled as well as site specific way. Note that SDDS along with smart nanocarriers, targeting mechanisms

Table 4: Research Matrix The following table also helps give a summary of the selected studies in terms of their aims, design, results, and conclusions alongside noted relevance to the present study in view

Author, Year	Aim	Study Design	Type of Studies Included	Total Number of Studies Identified, and Only Selected Studies	Result	Conclusion	Study Support the Present Study Under Consideration
Adepu, S., & Ramakrishna, S. (2021)	To provide a comprehensive review on controlled drug delivery systems, their design, and future directions	Review	Controlled drug delivery systems, conventional drug delivery systems, nano-drug delivery, smart drug delivery	100+ studies reviewed, focusing on key advancements	Detailed discussion on the evolution, design, and types of controlled drug delivery systems. Emphasized pharmacokinetics and intelligent biomaterials.	Controlled drug delivery systems offer improved efficacy and safety over conventional systems. Future directions include addressing current challenges and optimizing intelligent biomaterials.	Yes, by providing insights into intelligent and targeted drug delivery systems.
Edis, Z., et al. (2021)	To review nano-carriers-mediated drug delivery systems for anticancer agents	Review	Nano-carriers, anticancer agents, nano-medicine	Numerous studies on nano-carriers for cancer treatment, highlighting key advancements and clinical trials	Nano-carriers showed promising outcomes in targeting cancer cells and overcoming multidrug resistance. Different types of nano-carriers were discussed.	Nano-carriers can effectively target cancer cells, enhance drug delivery, and overcome resistance. Future exploration is needed for clinical application.	Yes, by emphasizing the potential of nano-carriers in targeted drug delivery.
Hossen, S., et al. (2019)	To review smart nanocarrier-based drug delivery systems for cancer therapy and toxicity studies	Review	Smart drug delivery systems (SDDSs), nano-carriers, chemotherapy	Extensive review of SDDSs and their applications in cancer therapy	SDDSs offer targeted delivery, reduced side effects, and controlled release. Various types of smart nano-carriers were analyzed.	SDDSs provide significant advantages over conventional chemotherapy. Toxicity and biocompatibility studies are crucial for future development.	Yes, by highlighting the benefits and challenges of smart drug delivery systems.
Sahu, T., et al. (2021)	To discuss the current strategies and emerging therapeutic potential of nanotechnology-based drug delivery systems	Review	Nanotechnology, nano-medicine, drug delivery systems	Review of various nanotechnology platforms and their applications in medicine	Nanotechnology improves the safety and efficacy of drug delivery, especially for high-toxicity drugs like chemotherapy agents.	Nanotechnology holds great potential for advancing drug delivery systems, despite some limitations. Future opportunities in human health are vast.	Yes, by providing a broad overview of nanotechnology applications in drug delivery.
Laffleur, F., & Keckeis, V. (2020)	To review advances in drug delivery systems and highlight ongoing work and needed progress	Review	Novel drug delivery systems, conventional dosage forms	Comprehensive review of novel strategies and their comparison with traditional systems	Novel drug delivery systems offer better bioavailability, reduced side effects, and enhanced patient compliance. Various advanced systems were discussed.	Advanced drug delivery systems provide significant improvements over conventional forms. Ongoing research is needed to address current limitations.	Yes, by comparing novel and traditional drug delivery systems and emphasizing advancements.
Guimarães, D., et al. (2021)	To explore the design and therapeutic applications of liposomes as a drug delivery system	Review	Liposomes, drug delivery, therapeutic applications	Extensive review of liposome design, characterization, and applications	Liposomes improve drug stability, bio distribution, and targeting while minimizing toxicity. Detailed characterization techniques were discussed.	Liposomes are effective drug delivery systems with various therapeutic applications. Stability and targeting strategies are crucial for their success.	Yes, by detailing the design and benefits of liposome-based drug delivery systems.
Narmani, A., et al. (2019)	To review folic acid functionalized nanoparticles as pharmaceutical carriers in drug delivery systems	Review	Nanoparticles, folic acid, drug delivery, cancer therapy	Review of recent works on FA-functionalized nanoparticles and their clinical applications	FA-functionalized nanoparticles enhance targeting and delivery of therapeutic agents to cancer cells. Various types and applications were analyzed.	FA-functionalized nanoparticles show great potential in cancer therapy due to their targeted delivery capabilities.	Yes, by providing insights into targeted delivery mechanisms using functionalized nanoparticles.
Han & Liu, 2021	To review CEST MRI trackable nanoparticle drug delivery systems and their applications.	Literature Review	Reviews on CEST MRI trackable nanoparticle drug delivery systems	Total: 6,858, Selected: 8	Discusses the application of CEST MRI in tracking nanoparticle drug delivery systems. Highlights the advantages of non-invasive, high-resolution imaging.	CEST MRI enhances the ability to monitor and optimize nanoparticle drug delivery in vivo. Future perspectives are discussed.	Reinforces the importance of advanced imaging techniques in the development and application of drug delivery systems.

Table 5: Results indicating themes, Sub-themes, Trends, and explanation

Themes	Sub-Themes	Trends	Explanation
Controlled Drug Delivery Systems	Pharmacokinetics	Evolving from macro-scale to nano-scale delivery systems	Controlled drug delivery systems have evolved to address the limitations of conventional systems by enabling targeted, controlled, and sustained release of drugs, improving therapeutic efficacy and safety.
	Conventional Drug Delivery Limitations	Increased focus on intelligent targeted delivery	
	Design considerations, classifications, and drawings		
Nano-carriers for Anticancer Agents	Nanomaterials	Development of multidrug resistance in cancer therapy	Nanocarrier systems enhance the delivery of anticancer agents, overcoming multidrug resistance and enabling targeted delivery, which is crucial for effective oncotherapy.
	Recent Advances	Emphasis on polymeric nano-carriers, micelles, nanotubes, dendrimers, magnetic nanoparticles, solid lipid nanoparticles, and QDs	
	Challenges and future exploration opportunities		
Smart Nano-carrier-based Drug Delivery Systems	Site-specific drug delivery	Increased interest in smart drug delivery systems (SDDSs)	Smart nano-carriers provide controlled, site-specific drug delivery, reducing dosage frequency and side effects. However, concerns about toxicity and biocompatibility remain.
	Structures, classification, synthesis		
	Toxicity and biocompatibility		
Nanotechnology in Drug Delivery	Different nanotechnology platforms	Use of nanotechnology to improve safety profile of drugs	Nanotechnology is used to improve the bioavailability, targeting, and safety profile of drugs, particularly in oncology, despite some limitations.
	Future opportunities		
Advances in Drug Delivery Systems	Comparison of conventional and novel systems	Focus on oral administration	Novel drug delivery systems, like fast dissolving drug delivery systems and self-emulsifying formulations, improve oral bioavailability and patient compliance compared to conventional systems.
	Nanotechnology and formulation factors		
Liposomes as Drug Delivery Systems	Design aspects, production, and drug loading	Extensive characterization required	Liposomes are highly effective drug delivery systems due to their ability to enhance drug stability and target specific sites, while being nontoxic and biodegradable. Extensive characterization ensures their performance in vivo.
	Characterization and functionalization		
	Current market applications		
Folic Acid Functionalized Nanoparticles	Enhanced permeability and retention effect	Targeted delivery of therapeutic agents using folic acid receptors on cancer cells	Folic acid functionalized nanoparticles enhance targeted delivery of therapeutic agents to cancer cells, overcoming limitations of conventional chemotherapeutic approaches.
Image-Guided Drug Delivery	CEST MRI trackable nanoparticles	Non-invasive in vivo tracking of nanoparticles	CEST MRI enables high-resolution tracking of nanoparticle drug delivery systems, aiding in treatment planning and optimizing drug delivery by providing detailed imaging of drug distribution and degradation.

and stimulus techniques are more preferable than other drug delivery systems.[34] Such systems reduce the number of doses thereby eradicating side effects that are likely to occur due to frequent administration of drugs, and also it minimizes the chances of the drug to deposit itself in required places that is in the diseased organ. However, the issue of acute and chronic toxicity and biocompatibility of smart nanocarriers is still important, which is why further study of the corresponding securing should be elaborated to create perspective nanoscale drugs for trial.

Currently, nanotechnology or nanomedicine can be regarded as one of the most promising technologies in the field of drug delivery systems improvement. Expound on the use of nanotechnology to enhance the delivery process of the drugs as far as their bioavailability,[35] targeting ability and safety are concerned, especially for chemotherapeutic drugs. Integrating nanotechnology into medication is set to improve new techniques in medication as well as boost the health standards of many individuals. The values of utilizing this method can be analyzed as an answer to some of the issues relating to the conventional course of employing medications.

That is why, it has been accepted that the design of new ASD for oral drug delivery has introduced a number of changes in the management of avoiding the proverbial adverse effects of traditional formulations. The modern technique of drug delivery system such as fast dissolving drugs, self-emulsifying system and osmotic device.[36] These advance increases the dispensability, patience's adherence, and rate control release, especially when the normal multi-shaped tablets and capsules are a problem, especially to children and older people. These are among the novel strategies that are described as some of the emerging measures of the field of drug delivery that enhance therapeutic efficiency and the patient's compliance.

Liposomes are considered to be useful and a potential method by which the therapeutic activity can be raised through the stabilization of the substances, the increasing of the concentration of the agents at the cellular and tissue levels, and the augmentation of the delivery of the drug to the target areas. Liposomes identified them as nontoxic and biodegradable in the therapeutic formulation for various applications.[37] Some of these characters include; Size, poly disparity index, zeta potential, and encapsulation efficiency few properties have attracted much attention in regards to liposomes' perception *in-vitro* and in-vivo. This characterization elevates liposomes in such a way that they can well transport drugs in accordance with their intended destinations thus getting better results.

Folic acid conjugated nanoparticles are one of the targeted drug delivery systems in cancer therapy because cancer cells overexposed with folate receptors. The strategy eliminates the issues of the bio-distribution and targeting that is non-specific which is witnessed in conventional chemotherapy therapies.[38] Aim: As for the enhancement of the pharmacokinetic properties and therapeutic effects of folic acid functionalized nanoparticles, it is worth underlining that this particular scholarly work aims at enhancing the precision medicine for the oncological patients thrusted upon the contemporary society. This targeted approach is very critical because it makes certain that the drugs are only targeting the cancerous cell, and in the process not harming normal cells; thus, making the effectiveness of the drugs to be higher.

This talk can provide the concept that the integration of imaging approaches with nanomedicine as in CEST MRI is a significant advance in the field of drug delivery. CEST MRI is said to make it possible to follow nanoparticles and their loaded drugs with fine details and without interfering with the specimen.[39] This strategy based on identification assistance provides valuable information concerning the distribution and degradation of drugs and nanoparticles, and treatment planning, thus enhancing the design and optimization of nano DDSs. In this way, imaging-guided drug delivery can be regarded as one of the primary breakthroughs in the sphere of nanomedicine since it ensures that drugs are provided to the corresponding tissues and organs as necessary and with the required effectiveness.

In the present work, several other related current studies are reviewed directly related to the subject of the research, including controlled drug delivery system, nanocarriers, smart drug delivery system, and enhancement of the nanotechnology in drug delivery. Prolific research on drug delivery systems owing to the features offered by nanotechnology and advanced targeting potential indicates positive signs of improving the efficacy of the treatments and therefore exhibits the likelihood of improving the safety of the patients. However, there are some challenges that affect this field of research some of them include toxicity, biocompatibility of the materials, the characterization and validation of these structures still remains a challenge. The future research should be dedicated to solving these problems and develop the field of drug delivery and patient-specific needs.

Limitation

Thus, there are several drawbacks concerning some of the existing drug delivery systems: First of all, the problem of toxicity and biocompatibility of nanocarriers and the use of SDDSs is still open. More investigation has to be made in other to determine the long runs repercussions of using such materials in the improvement of occupants' health. Also, as seen with the pulmonary delivery system, the high cost of fabrication and development of these systems removes them from the reach of ordinary consumers and may not be economically viable across the global market. Another major obstacle is the regulatory issues, which always presents comprehensive testing and approval requirements for new technologies, which often prove to be costly and time-consuming. Moreover, the differences in the patients' reactions to such sophisticated systems present an argument for tailoring such messages, which is a difficult proposition when scaled up.

Recommendation

Based on these limitations some of the recommendations that can be made include: First, more investigations regarding the safety of nanocarriers and SDDSs have to be conducted to pave the way for their clinical application. Outlining the policies of testing and validating these systems can go a long way in ensuring that the systems meet the set standards hence improving on the testing and validation policies required for regulatory approval. More also, extensive attempts should be made to lower the cost and difficulty in producing innovative drug delivery systems for increasing the accessibility to the populace. This could include the consideration of different cheaper materials or cheaper ways through which the furniture

can be produced. Multisectoral initiatives by the researchers, industries, and regulatory agencies are possible ways of creating and licensing these systems. At last, the successful application of personalized medicine based on diagnostics utilization and patient monitoring guarantees the effectiveness of the mentioned drug delivery systems and patients' benefits.

CONCLUSION

The present study emphasizes the impotence of the novel drug delivery system and shifts from the conventional to the controlled drug delivery system and enhances the anti-cancer drug release efficiency. Nanocarriers, smart drug delivery systems and advanced nanotechnology used in the present years has drawn much attention and proved itself to be much effective for better efficacy and less toxicity. These improvements provide for greater selectivity, improved solubility, specific liberation from the blood serum, and minimum general toxicity, especially in oncologic treatment. Nevertheless, some challenges are observed and they include toxicity, biocompatibility, high cost and the issue with the regulatory bodies. Surmounting these drawbacks via future research in the area, improved standardized testing, inexpensive production, and customization processes is vital for DR for leveraging technologies' optimization. Technology advancements have really changed the world of drug delivery and the possibilities for its development are enormous, which in the future will bring positive changes in patients' conditions and the effectiveness and variability of medical treatments.

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