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The Past, Present and the Future of Drug delivery: An Empirical Study

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Abstract
In India, drug delivery has advanced significantly since the country's early use of crude injections and oral tablets. In the past, creating medications for oral or intravenous administration was the main focus. This sparked the creation of several top-selling medications for the Indian market, including antacids and antibiotics.In the present, attention is being paid to the creation of more sophisticated drug delivery systems, such as transdermal patches, inhalers, and implants. This has led to the creation of more precise and efficient treatments as well as increased patient compliance and convenience.With a focus on personalized medicine and the use of cutting-edge drug delivery technologies like nanotechnology and gene therapy, India's drug delivery sector is predicted to grow and innovate in the future. The industry is prepared to meet this need because of the country's huge and diversified population, which has a substantial need for cost-effective and efficient drug delivery methods.Overall, India has a strong commitment to innovation and growth in the healthcare industry, with an emphasis on enhancing patient outcomes and accessibility. This commitment is seen in the history, present, and future of drug delivery.
Keywords: Drug delivery, Transdermal patches, Nanotechnology, Gene therapy, Personalized medicine.

Introduction

The demand for accessible and economical drug delivery systems has a significant impact on India's history of drug delivery. Drugs that could be successfully administered by oral and injectable routes were developed with an emphasis on medication delivery. According to Tiwari et al. (2012), the Indian pharmaceutical sector was instrumental in the invention of drug delivery methods. This emphasis allowed the sector to flourish, leading to the development of numerous blockbuster medications for the Indian market, including antacids and antibiotics. The development of medication delivery technologies in India was acknowledged to have been greatly aided by the pharmaceutical industry.It brought attention to the requirement for more focused and efficient drug delivery systems in India, with an emphasis on personalized treatment. They also mentioned how crucial regulatory bodies are to guarantee the security and effectiveness of medicine delivery systems. With an emphasis on creating cutting-edge medication delivery technologies like nanotechnology and gene therapy that may address the particular needs of patients, the future of drug delivery in India is anticipated to continue evolving. It emphasized the necessity of ongoing innovation to satisfy patients' evolving requirements, as well as the crucial role that the pharmaceutical industry has played in advancing India's development of drug delivery systems.

Drug delivery techniques have developed with the development of technology. Exosomes, nanoparticles, and liposomes are a few of the novel delivery systems being observed by researchers to cross biological membranes. The use of solid lipid nanoparticles (SLNs) in drug delivery systems has grown in popularity in India (Mukherjee et al. 2009). The creation of more specialized and efficient medicines is a result of these developments in drug delivery technologies.

Exosomes have also recently become a viable drug delivery method with potential uses in a number of disorders. Exosomes are a viable medication delivery method because, as mentioned by Ha et al. (2016), they can pass biological membranes and transfer therapeutic chemicals to target cells.With a focus on personalized treatment and the use of cutting-edge drug delivery technologies like nanotechnology and gene therapy, it is anticipated that medication delivery in India will continue to advance in the future. With a focus on creating economical and efficient medication delivery methods that can cater to patients' unique demands, the pharmaceutical sector in India is prepared to meet this need.

Literature Review

According to Vashist et al. (2014), hydrogels were one of the first drug delivery technologies to be employed in India because of their biocompatibility and controlled release characteristics. Cross-linked polymer networks in three dimensions, known as hydrogels, have a high water absorption capacity while retaining structural integrity. They are helpful for drug delivery because they can offer sustained drug release over an extended length of time, eliminating the need for regular dosage. To increase patient compliance and therapeutic efficacy, hydrogel-based drug delivery methods have been developed in India. The creation of stimulus-responsive hydrogels, which may react to changes in pH, temperature, and other environmental stimuli to release pharmaceuticals in a regulated manner, is a recent discovery in hydrogel-based drug delivery systems. These technologies have the potential to increase the therapeutic effectiveness of medications while lowering side effects and enhancing patient outcomes.

The development of numerous peptide and protein-based drug delivery systems in India has been attributed to improvements in biotechnology, according to Bruno et al. (2013). Peptides and proteins are excellent medication candidates because they have high specificity and focused drug delivery, which reduces adverse effects and improves patient outcomes.The potential for enhanced therapeutic efficacy, tailored delivery, and decreased toxicity of peptide and protein-based drug delivery systems has led to a surge in their use in India. These drug delivery systems can be made to release pharmaceuticals in response to particular triggers, including pH changes or changes in enzyme activity, enabling a regulated and sustained drug release.Noble metal nanoparticles' inherent therapeutic uses in drug transport were highlighted by Arvizo et al. (2012). Noble metal nanoparticles, like gold and silver nanoparticles, have special characteristics

that make them effective as drug delivery systems. These characteristics include their large surface area, variable size and shape, and distinctive optical and magnetic properties. Various drug delivery methods, including the use of noble metal nanoparticles as contrast agents, have been used in India.

Transdermal medication delivery, which has been utilized to deliver pharmaceuticals for a variety of illnesses, has made important strides in India's past, present, and future. Drugs are delivered via the skin to the systemic circulation using transdermal drug administration, according to Prausnitz and Langer (2008). Initially, only a small number of drugs could be delivered transdermally, and the method was fairly straightforward. A wide variety of medications, including peptides and proteins, can now be delivered using more sophisticated transdermal drug delivery systems as a result of recent technological advancements.In order to promote drug absorption, the skin's permeability has been improved. Additionally, innovations to improve the efficiency of transdermal drug delivery systems have been developed.With the incidence of cardiovascular diseases (CVDs) rising over time, India faces serious health issues. According to Prabhakaran et al. (2016), the prevalence of risk factors like obesity, diabetes, and hypertension has been increasing, and CVDs are a major cause of death in India. The development of accessible and affordable medications to address the large burden of the illness has been the main goal of CVD medicine delivery in India in the past. The development of more focused medication delivery systems, however, as a result of recent developments in drug delivery, can

The prevalence of type 2 diabetes is predicted to increase dramatically in the next few years, which is an increasing health problem in India. According to Kahn et al. (2014), type 2 diabetes is characterized by insulin resistance and beta-cell dysfunction, and current treatment options for the condition are geared at enhancing glycemic control. The development of economical and readily available medications, such the commonly used medicine metformin, has been the main emphasis of drug delivery for type 2 diabetes in the past in India. The introduction of novel medication delivery systems, such as oral insulin, as a result of recent developments in drug administration, however, has allowed for a more focused and efficient method of treating the illness.Samad et al. (2007) discussed the salient characteristics of liposomal drug delivery systems, such as their capacity to improve the bioavailability and effectiveness of medications, lessen their toxicity, and extend their time of action. Due to a lack of knowledge and expensive production costs, liposomal drug delivery technologies have just recently found widespread application in India. But with technological advancements and a rise in the need for targeted drug delivery, liposomal drug delivery systems have emerged as a promising strategy for drug delivery in India.

In India, transdermal drug delivery has become a viable alternative to injectable and oral drug delivery. Through the skin, drugs are delivered directly into the bloodstream, skipping the

digestive system and liver metabolism in the process. The use of chemical enhancers, iontophoresis, and microneedles were some of the methods covered by Alexander et al. (2012) for improving medication absorption through skin. The advantages of transdermal medication administration over traditional drug delivery systems, such as greater patient compliance, continuous drug release, and less side effects, have led to substantial expansion in the transdermal drug delivery market in India in recent years.

Azo dyes, which are widely used in the food, pharmaceutical, and textile industries, have raised concerns in India due to their negative impact on the natural world and human health. Bafana et al. (2011) discussed about the historical and contemporary applications of azo dyes and the demand for substitute, environmentally acceptable dyes. The environmental impact of azo dyes can be greatly reduced by the development of eco-friendly dyes and their effective supply to the textile sector.Kolate et al. (2014) emphasized the special characteristics of PEG, such as its biocompatibility, non-toxicity, and capacity to extend the duration that pharmaceuticals spend circulating in the bloodstream. PEGylation has been utilized to create a variety of drug delivery systems, including micelles, nanoparticles, and liposomes.PEGylation is anticipated to play a crucial part in the advancement of medication delivery systems in India in the future. PEGylation has shown promise in enhancing the pharmacokinetics and pharmacodynamics of medicines when used in medication delivery.

Objective

To measure the various elements constituting the past, present and the future of drug delivery

Methodology

This study is descriptive in nature in which the data were obtained from the 207 respondents which includes patients who have received or are currently receiving drug treatments, healthcare providers and professionals in the pharmaceutical and biotech industries. A checklist question was used to analyse and interpret the data. In a checklist question respondents choose “Yes” or “No” for all the questions.

Data Analysis and Interpretations

Table 1 The Past, Present and the Future of Drug delivery

SL No.	The Past, Present and the Future of Drug delivery	Yes	% Yes	No	% No	Total
1	New technologies such as 3D printing and artificial intelligence (AI) can help design and manufacture drugs and delivery systems.	185	89.37	22	10.63	207
2	Drug delivery systems may be developed to treat a wider range of	155	74.88	52	25.12	207

	conditions, including chronic diseases					
3	Drug delivery has been an essential part of medicine since ancient times.	195	94.20	12	5.80	207
4	nanotechnology-based delivery systems use nanoparticles to transport drugs to specific cells or tissues.	180	86.96	27	13.04	207
5	New materials such as biodegradable polymers and metal-organic frameworks could be used to create more targeted drug delivery systems.	171	82.61	36	17.39	207
6	Drug delivery systems were often limited by the availability of materials & manufacturing techniques.	177	85.51	30	14.49	207
7	Drug delivery systems were often designed to treat acute conditions such as infections or pain.	162	78.26	45	21.74	207
8	Advances in technology and research have led to the growth and development of new drug delivery systems.	191	92.27	16	7.73	207

Table 1 presents an analysis of the past, present, and future of drug delivery. The results show that a vast majority of respondents, around 94.2%, believe that drug delivery has been a crucial aspect of medicine since ancient times. Additionally, advancements in technology and research have contributed to the growth and development of new drug delivery systems, as agreed by 92.2% of the respondents. New technologies such as 3D printing and artificial intelligence (AI) have also emerged as potential tools to aid in the design and manufacture of drugs and delivery systems, according to 89.3% of the respondents. Furthermore, nanotechnology-based delivery systems that employ nanoparticles to transport drugs to specific cells or tissues have gained considerable interest, with 86.9% of respondents acknowledging their potential. Drug delivery systems were often constrained by the availability of materials and manufacturing techniques, as indicated by 85.5% of the respondents. However, new materials, including biodegradable polymers and metal-organic frameworks, could be leveraged to create more targeted drug delivery systems, as stated by 82.6% of respondents. Drug delivery systems were historically designed to treat acute conditions such as infections or pain, according to 78.2% of the respondents. Nevertheless, the study shows that drug delivery systems may be developed to treat a wider range of conditions, including chronic diseases, as recognized by 74.8% of the respondents.

Conclusion

The pharmaceutical industry is dependent on drug delivery, which has become increasingly significant over the past few decades. The importance of medication delivery has been shown in

India in the past, is obvious in the present, and will continue to influence the pharmaceutical industry's future.Previously, the main goal of drug delivery was to enhance the pharmacokinetic characteristics of already-available medications. The disadvantages of conventional drug delivery techniques, such as tablets and capsules, included poor solubility, poor bioavailability, and a lack of site-specific targeting. However, improvements in drug delivery technologies have completely changed the field, inspiring the creation of cutting-edge drug delivery systems like liposomes, nanoparticles, and transdermal patches.There has been a substantial trend towards personalized medicine in India's drug distribution system as of late. For example, controlled-release formulations, implantable technologies, and nanotechnology-based drug administration are among the novel drug delivery systems being developed to meet the demands of particular patient groups. The rise of chronic diseases, the aging population, and the rising demand for efficient and secure medication delivery methods all contribute to this transition.The delivery of drugs in India is expected to continue expanding and progressing in the future. A number of factors, including increased research & development, technological improvements, and rising healthcare costs, are likely to fuel a large expansion of the drug delivery industry.The use of cutting-edge technology, such as artificial intelligence and machine learning, is also anticipated to revolutionize medication delivery, resulting in the creation of more effective and tailored drug delivery systems.The past, present, and projected future of drug delivery in India illustrate the crucial position that drug delivery plays in the pharmaceutical sector. medication delivery in India will become increasingly significant as the demand for personalised care and more efficient medication delivery systems increases. Without a question, the future of medication delivery will be shaped by the creation of new drug delivery systems and the use of cutting-edge technology, improving patient outcomes and healthcare.

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