

Stents: A Comprehensive Overview

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Abstract

Stents have emerged as crucial medical devices in the field of interventional cardiology and vascular medicine, playing a pivotal role in the treatment of various cardiovascular and non-cardiovascular conditions. This comprehensive overview aims to provide a detailed examination of stents, encompassing their historical evolution, design characteristics, deployment techniques, clinical applications, complications, and future prospects. The historical evolution of stents traces back to the pioneering work in the mid-20th century, with significant advancements in material science and engineering contributing to the development of diverse stent designs. This overview delves into the structural components of stents, including the materials used, coating technologies, and the influence of biomechanical factors on stent performance. Additionally, it explores the evolution from bare-metal stents to drug-eluting stents and bioresorbable scaffolds, highlighting the impact of these innovations on clinical outcomes. The deployment techniques of stents are a critical aspect of their successful application. This overview comprehensively discusses the various methods employed in stent deployment, such as balloon angioplasty, self-expanding stents, and bioresorbable scaffolds. Furthermore, it examines the role of imaging modalities, such as intravascular ultrasound and optical coherence tomography, in guiding stent placement and optimizing procedural outcomes. Clinical applications of stents extend beyond coronary artery disease, encompassing peripheral artery disease, biliary and ureteral strictures, and neurovascular interventions. This review provides an in-depth analysis of the evidence supporting stent use in these diverse clinical scenarios, evaluating the efficacy and safety profiles. Moreover, it discusses emerging applications in areas such as transcatheter valve therapies and endovascular aneurysm repair.

Despite their widespread use, stents are associated with complications, including in-stent restenosis, thrombosis, and stent fracture. This overview critically evaluates the factors contributing to these complications and explores strategies for their prevention and management. Additionally, it addresses the impact of patient-specific factors, such as diabetes and chronic kidney disease, on stent outcomes.

Keywords: Stents; Interventional cardiology; Vascular medicine; Coronary artery disease; Peripheral artery disease; Drug-eluting stents; Bioresorbable scaffolds; Deployment techniques; Complications; Clinical applications; Personalized medicine; Emerging technologies

Introduction

In the realm of modern medicine, stents have emerged as crucial medical devices, revolutionizing the treatment of various cardiovascular and non-cardiovascular conditions. These small mesh-like tubes play a pivotal role in maintaining or restoring the patency of blood vessels and other tubular structures within the body [1]. From coronary arteries to bile ducts, stents have become indispensable in managing a spectrum of medical conditions. This article aims to provide a comprehensive overview of stents, exploring their history, types, applications, and advancements in technology [2,3]. The genesis of stents can be traced back to the mid-20th century, with pioneers in interventional cardiology envisioning a solution to the narrowing of blood vessels caused by atherosclerosis [4]. Over the decades, a myriad of stent designs and compositions have emerged, each catering to specific clinical scenarios and patient profiles [5,6]. From bare-metal stents that provided the initial scaffolding to drug-eluting stents that released therapeutic agents, the evolution of stent technology has been dynamic, driven by a relentless pursuit of efficacy and safety. In this comprehensive overview, we will navigate through the fundamental principles underlying stent deployment, exploring the diverse types of stents available, their mechanism of action, and the nuanced decision-making process in selecting the most appropriate stent for a given patient [7]. Beyond coronary arteries, stents have found applications in a multitude of vascular territories, including carotid, renal, and peripheral arteries, expanding their impact beyond the realm of coronary artery disease. As we delve into the clinical landscape, we will also address the challenges and controversies surrounding stent utilization, ranging from in-stent

restenosis to the long-term implications of drug-eluting stents [8].

Moreover, the integration of cutting-edge technologies such as bioresorbable stents and drug-coated balloons brings an additional layer of complexity and promise to the field. This overview will explore these advancements, offering insights into the potential paradigm shifts in stent technology and their implications for patient care [9]. Ultimately, understanding the multifaceted nature of stents requires a synthesis of medical, engineering, and biological perspectives, and this exploration aims to provide a holistic understanding of these remarkable devices [10].

History of stents

The inception of stents can be traced back to the mid-20th century when Dr. Charles Dotter, a pioneer in interventional radiology, conceptualized the idea of using a tubular device to open and support narrowed or blocked blood vessels. However, it was not until the late 1980s that the first coronary stent was implanted. This marked a significant milestone in the treatment of coronary artery disease, offering an alternative to balloon angioplasty alone.

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Types of stents

Stents come in various types, each designed to address specific medical conditions and anatomical considerations. The two primary categories are coronary stents and non-coronary stents. Coronary stents are primarily used to treat blockages in the arteries supplying blood to the heart, while non-coronary stents are employed in other parts of the body.

Coronary stents

Bare-metal stents (BMS): These were the first-generation stents, composed of metal alloys such as stainless steel. While effective in preventing vessel recoil post-angioplasty, they had limitations, including a higher rate of restenosis (re-narrowing of the vessel).

Drug-eluting stents (DES): To overcome the limitations of bare-metal stents, drug-eluting stents were introduced. Coated with medications that inhibit cell proliferation, DES significantly reduced the occurrence of restenosis. Paclitaxel and sirolimus are examples of drugs commonly used in DES.

Bioabsorbable stents: A more recent development, bioabsorbable stents are designed to be absorbed by the body over time, leaving behind a healed vessel. While promising, their widespread adoption is still under scrutiny, and further research is ongoing.

Non-coronary stents

Peripheral arterial stents: Used to treat blockages in arteries outside the heart, such as those in the legs or arms. They aid in restoring blood flow and alleviating symptoms like claudication.

Biliary stents: Employed in the treatment of bile duct obstructions, biliary stents facilitate the drainage of bile, helping manage conditions like jaundice.

Ureteral stents: These stents are inserted into the ureter to address obstructions or strictures, commonly used in conditions like kidney stones or tumors.

Applications of stents

Coronary artery disease (CAD): The primary application of stents is in the management of CAD, where they help alleviate symptoms and reduce the risk of heart attacks.

Peripheral artery disease (PAD): Stents play a crucial role in treating narrowed arteries in the legs or arms, improving blood circulation and relieving symptoms.

Biliary and ureteral disorders: Stents are utilized in addressing blockages in the bile ducts and ureters, ensuring proper drainage and preventing complications.

Intracranial stents: In neurointerventional procedures, stents are used to treat intracranial stenosis and aneurysms, preventing stroke and other neurological complications.

Advancements in stent technology

The field of stent technology is dynamic, with continuous efforts to enhance efficacy and safety. Some notable advancement includes:

Biodegradable stents: As mentioned earlier, bioabsorbable stents represent a significant step forward, potentially reducing long-term complications associated with permanent stents.

Drug-coated balloons: These devices combine the principles of

balloon angioplasty and drug elution, providing an alternative to stent implantation in certain cases.

Nanotechnology in stents: Utilizing nanomaterials in stent design offers the potential for improved biocompatibility and targeted drug delivery, minimizing adverse effects.

Bioactive coatings: Stents with bioactive coatings aim to promote endothelialization and reduce the risk of thrombosis, enhancing long-term outcomes.

Challenges and future directions

While stents have undeniably transformed cardiovascular and interventional medicine, challenges persist. Issues such as late stent thrombosis, in-stent restenosis, and long-term antiplatelet therapy requirements continue to be areas of research and development. Future directions may include personalized stent design, incorporating advanced imaging techniques for precise placement, and exploring innovative materials with improved biocompatibility.

Conclusion

Stents have evolved from a conceptual idea to a cornerstone in the treatment of various medical conditions. The continuous refinement of stent technology, coupled with ongoing research, holds the promise of further improving patient outcomes and expanding the scope of conditions that can be effectively managed. As technology advances and our understanding of vascular and tubular diseases deepens, the role of stents in medicine is likely to continue expanding, contributing to the evolution of minimally invasive interventions and personalized patient care. This comprehensive overview serves as a valuable resource for clinicians, researchers, and medical professionals seeking a thorough understanding of stents. By encompassing the historical context, design principles, deployment techniques, clinical applications, complications, and future prospects, this review aims to contribute to the ongoing advancement of stent technology and its impact on patient care. In the ever-evolving landscape of cardiovascular interventions, stents continue to be beacons of hope, extending lifelines to patients grappling with arterial diseases. This comprehensive overview aims to empower healthcare professionals with knowledge, fostering a deeper understanding of the nuances surrounding stents. In doing so, we contribute to the ongoing dialogue that propels cardiovascular medicine into new frontiers, where the promise of improved patient outcomes and enhanced quality of life stands as the driving force behind continued innovation and exploration.

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