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Latest Developments in Medical Science, Shaping The Future of Healthcare

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ABSTRACT

The field of medical science is undergoing a revolution, with groundbreaking discoveries turning healthcare into remarkable destinations. This detailed overview explores several recent innovations. A significant advancement is the use of artificial intelligence (AI) in diagnosing various health conditions, such as cardiovascular diseases and cancers. For instance, a digitally enhanced stethoscope equipped with AI has been created to analyze the sounds heard during auscultation, aiding in the early identification of heart illnesses. The SSI mantra aims to boost the efficiency and effectiveness of minimally invasive surgeries, while the R12 vaccine is designed to enhance immunity. Additionally, lab-grown cells and regenerative medicine are being utilized to restore functionality in patients with injuries or degenerative conditions. There are also Kras-targeted therapies for pancreatic cancer and the Organ-on-a-Chip (OoaC) technology, an advanced microphysiological system designed to replicate critical physiological processes like tissue communication and biochemical interactions. Recent progress in medical science has transformed healthcare, providing innovative solutions that impact millions of lives. These advancements not only improve patient outcomes but also enhance healthcare accessibility and efficiency. Nonetheless, they confront substantial challenges and obstacles that impede widespread use. Despite these obstacles, ongoing research and collaboration among scientists, healthcare professionals, and policymakers are vital to ensuring these innovations reach their full potential. The future of medicine is becoming increasingly patient-centric, driven by technological advancements and interdisciplinary approaches.

INTRODUCTION

In recent years, medical science has experienced a transformative shift, with pioneering discoveries altering the landscape of healthcare. These achievements have significantly enhanced the diagnosis, treatment, and management of various diseases, leading to improved therapeutic outcomes and an increased quality of life for many.This article aims to spotlight groundbreaking developments that have the potential to revolutionize healthcare practices and significantly enhance patient care. To achieve this, we conducted a comprehensive review of esteemed scientific journals and reports from reputable healthcare organizations and institutions. Our selection process emphasized the originality and importance of these advancements, their capability to address existing healthcare challenges, the strength of the scientific evidence backing their effectiveness, and their potential for widespread adoption. This rigorous approach guaranteed that the advancements chosen address a broad spectrum of medical implications and could lead to major enhancements in patient care, diagnostics, treatment techniques, and healthcare delivery. Our thorough analysis covers numerous recent breakthroughs, such as organ-on-chip technology, the R21/Matrix M^{TM} vaccine, lab-grown cells and regenerative medicine, KRAS treatments for pancreatic cancer with Daraxonrasib, digital stethoscopes, and robotic surgery systems powered by the SSI
mantra[1].

Organ-on-a-Chip (OoaC) technology represents an advanced microphysiological system (MPS) that simulates the structure and function of human organs on a compact chip platform. These microfluidic devices integrate living cells and extracellular matrices within precisely controlled environments, enabling researchers to simulate essential physiological processes such as tissue interactions, mechanical forces, and biochemical responses. This technology offers a more advanced and dynamic alternative to traditional 2D cell cultures and animal models, facilitating improved drug testing, disease modeling, and the development of personalized medicine. By providing a sophisticated and dynamic alternative to conventional 2D cell cultures and animal models, this technology enhances drug testing, disease modeling, and the development of personalized medicine. Equipped with biosensors for real-time monitoring, these chips enable the assessment of organ functionality, metabolism, and responses to external stimuli, making them invaluable in biomedical research. OoaC systems offer precise control over tissue architecture and nutrient diffusion, ensuring their viability for extended durations, ranging from weeks to months. The advantages include enhanced research and drug testing capabilities, the ability to mimic natural microenvironments, user-friendly designs, and portability. However, there are drawbacks, such as surface effects potentially affecting accuracy, product adsorption possibly altering results, and poor fluid mixing due to laminar flow[2].

The R21 vaccine comprises a virus-like particle that contains a key segment of the circumsporozoite protein, specifically the central repeats of Asn-Ala-Asn-Pro (NANP) along with the C-terminal sequence. This component is combined with the hepatitis B surface antigen (HBsAg), enhancing the immune response.This vaccine is costeffective, and its primary benefit is its 75% efficacy in treating malaria, outperforming RTS,S/AS01[2]. However, it has limitations, such as primarily targeting Plasmodium falciparum and lacking long-term data, as its durability and long-term effectiveness are still under investigation. Although clinical trials have demonstrated up to 75% efficacy, its effectiveness may vary depending on factors like age, geography, and previous malaria exposure[3].

The field of lab-grown cells and regenerative medicine involves using cultured cells, tissues, or organs to repair or replace damaged biological structures. This area encompasses stem cell therapy, tissue engineering, and gene editing to restore function in patients with injuries or degenerative diseases.

Its benefits encompass:

- Disease Treatment and Tissue Repair**: This technology can regenerate damaged tissues and organs,
  providing potential solutions for ailments such as heart disease and spinal cord injuries.
- Personalized Medicine**: Using patient-specific cells reduces the risk of immune rejection in transplant
  situations.
- Alleviating Organ Shortages**: Lab-grown tissues and organs could substitute for donor organs, thus shortening transplant waiting times.Drug Testing and Development – Provides human-like models for
  evaluating new drugs, reducing the dependence on animal testing.
- Decreased Risk of Transplant Rejection – Stem cells derived from the patient's own body (autologous
  transplants) can be utilized to create compatible tissues.

Drawbacks include:

- High Expense – Treatments are costly, not easily affordable, and not yet broadly accessible.
- Ethical Issues**: Certain methods, especially those involving embryonic stem cells, raise ethical concerns.Tumor Formation Risk – Certain lab-cultivated cells, particularly stem cells, might turn into tumors
  if they grow uncontrollably.
- Immune System Challenges – Although personalized medicine lowers rejection risks, some therapies can still
  trigger immune responses.
- Regulatory Hurdles**: Regulatory processes can slow the approval of new therapies.[4].

KRAS-targeted therapies for pancreatic cancer, such as daraxonrasib, represent a rapidly advancing field of study. With KRAS mutations found in over 90% of pancreatic ductal adenocarcinomas (PDAC), focusing on these mutations has emerged as a promising treatment strategy. The approaches to KRAS treatment include: 1. KRAS G12C Inhibitors (e.g., Sotorasib, Adagrasib): These medications are designed to target the KRAS G12C mutation, which is more prevalent in lung cancer but also appears in a smaller percentage of pancreatic cancers. 2. KRAS G12D Inhibitors (e.g., MRTX1133 - currently under investigation): The KRAS G12D mutation is more frequently observed in pancreatic cancer, and drugs targeting this mutation are still undergoing clinical trials. 3. Pan-KRAS Inhibitors: These aim to block multiple KRAS mutations at once. 4. KRAS-Targeting Immunotherapy: Cancer vaccines and immune-based strategies are being explored to enhance the immune system's ability to attack tumors with KRAS mutations.

Benefits of KRAS Treatments

✓ Focused Strategy – Specifically targeting the mutations responsible for cancer progression.
✓ Potential for Enhanced Survival – KRAS inhibitors might improve patient outcomes compared to traditional chemotherapy.
✓ Reduced Side Effects (in some instances) – More precise targeting could minimize damage to healthy cells.
✓ Combination Possibilities – These can be combined with other treatments like chemotherapy, immunotherapy, or MEK inhibitors.

Drawbacks of KRAS Treatments

- Limited Effectiveness in Pancreatic Cancer – While KRAS inhibitors have been successful in treating lung cancer, pancreatic cancer remains challenging due to the complexity of the tumors.
- Development of Resistance – Cancer cells might adapt and discover alternative growth pathways.
- Limited Availability – Some KRAS-targeted medications are still in early trial phases and not widely accessible.
- Toxicity Concerns – Certain KRAS inhibitors can cause hepatotoxicity, gastrointestinal problems, and other side effects[5].

Digital Stethoscope: The first stethoscope, introduced by Rene Laennec in 1818, has been a vital instrument in medical practice. Over time, it has transformed from a simple monoaural wooden tube into sophisticated electronic devices. This evolution signifies continuous efforts to enhance diagnostic capabilities in auscultation. Modern digital stethoscopes feature electronic amplification, noise reduction, and recording functions, addressing the limitations of traditional acoustic models. These innovations improve the detection of heart and lung sounds, even in noisy environments.A significant advancement is the incorporation of artificial intelligence (AI) to aid in diagnosing cardiovascular conditions. For instance, an AI-enhanced digital stethoscope has been developed to analyze auscultated sounds, assisting in the early detection of heart disease. Beyond traditional auscultation, digital stethoscopes have facilitated telemedicine consultations by transmitting high-quality heart and lung sounds remotely, enabling accurate assessments without the need for in-person visits. Additionally, these devices allow for the storage and playback of auscultation sounds, which is valuable for monitoring disease progression and educational purposes. Besides, they enable the storage and playback of auscultation sounds, helpful for monitoring disease progression and educational needs, and can filter and amplify specific sound frequencies, improving the identification of subtle murmurs or pulmonary issues, which can lead to timely interventions[6].

The SSI Mantra robotic surgical system, introduced in 2023 by SS Innovations International Inc., marks a significant advancement in medical technology by making advanced surgical care more accessible globally. The system is designed to enhance precision and efficiency in minimally invasive procedures. A key feature of the SSI Mantra is its adaptable multi-arm setup, allowing surgeons to use three to five robotic arms for greater flexibility and control, especially in confined surgical spaces. This system stands out as a cost-efficient and flexible solution, making high-quality robotic surgery more attainable across various regions. Its successful application and features in complex procedures highlight its potential to revolutionize modern surgical techniques [7].

ORGAN ON A CHIP

An organ-on-a-chip (OOC) is a three-dimensional microfluidic cell culture device with multiple channels, designed to mimic the functions, mechanics, and physiological responses of a whole organ or organ system. This technology is a focal point in biomedical engineering research, particularly in bio-MEMS. The combination of labs-on-chips (LOCs) and cell biology has enabled investigations in human physiology tailored specifically to individual organs. These devices represent a promising alternative to animal models for drug development and toxicity assessments, as they provide a more advanced in vitro representation of complex tissues when compared to traditional culture methods[8].

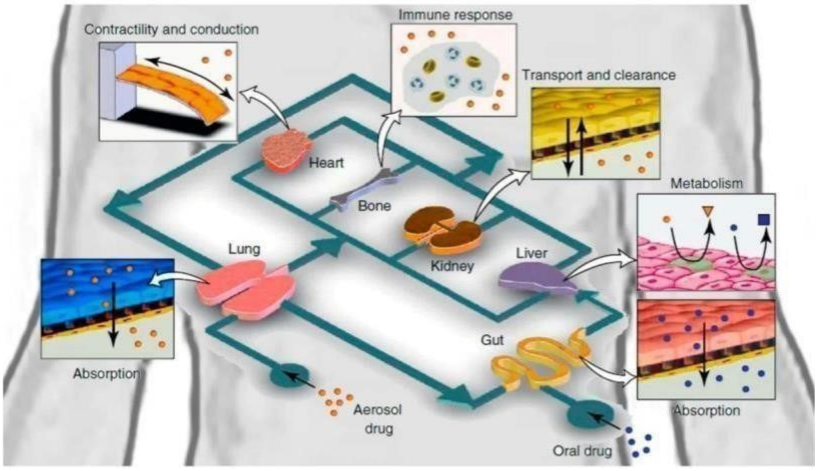


Figure (1.1) : Representing Organ on a chip concept[9].

Advancing 3D cell culture technologies have led to the creation of more sophisticated models, such as organoids and organ-on-a-chip systems. These models simplify research into disease mechanisms, drug responses, and tissue development with greater accuracy by closely mimicking in vitro conditions. Additionally, 3D cultures support personalized medicine approaches by allowing patient-derived cells to be grown in environments that are physiologically relevant. Despite these advantages, challenges persist, including the need for standardized protocols, issues with reproducibility, and higher costs compared to traditional 2D cultures. However, as technology advances, improvements in biomaterials, imaging techniques, and automation are anticipated to further enhance the utility and accessibility of 3D cell culture systems[10].

The incorporation of human pluripotent stem cells in 3D culture systems increases the physiological relevance of in vitro models, allowing for more accurate predictions of drug efficacy and toxicity. These advanced models offer a controlled setting to explore complex cellular interactions, genetic variations, and patient-specific responses, making them a powerful tool in personalized medicine. Moreover, integrating microfluidic technologies with stem cell-derived cultures has paved the way for organ-on-a-chip platforms, which can further refine disease modeling and high-throughput drug screening. In sum, the potential for stem cell-based models to transform biomedical research and therapeutic development is becoming increasingly evident as research progresses in optimizing differentiation protocols and scalability [11].

Table (1.1). Comparison of Organ-on-a-Chip Models: Materials, Applications, and Challenges

Organ on chip	Materials used	Applications	Challenges
Gut on a chip	PDMS, collagen	Microbiome studies,drug absorption	Maintaining gut flora conditions
Skin on a chip	PDMS, collagen	Wound healing, cosmetic testing	Accurate replication of skin layers
Brain on a chip	Hydrogels, biomaterials	Neurodegenerative disease research	Neuron network complexity
Lung on a chip	PDMS, hydrogels	Drug testing, disease modelling (asthma, copd)	Complex airflow Stimulation
Heart on a chip	PDMS, biomaterials	Cardio Toxicity Testing Heart Modelling	Replicating Mechanical Contractions
Liver on a chip	PDMS, glass, microfludis	Drug metabolism, toxicity studies	Long term viability of hepatocytes
Kidney on a chip	PDMS, ECM, proteins	Nephrotoxicity studies, dialysis stimulation	Mimicking complex filtration

R21/MATRIX-M^{TM} VACCINE

Malaria, a deadly disease caused by the plasmodium parasite and spread through mosquito bites, remains a leading cause of mortality among children under five years old[12]. Annually, it affects millions, particularly in tropical and subtropical regions. In 2021, around 247 million people across 85 countries were diagnosed with malaria, leading to over 600,000 deaths. A promising advancement in the fight against malaria is the recent World Health Organization (WHO) endorsement of the R21/matrix-M^{TM} vaccine for at-risk populations[13]. This subunit vaccine is designed to protect young children by targeting the CSP protein and is the first to meet the WHO's 75% efficacy target. Ghana approved its use on April 13, 2023, followed by the WHO's official recommendation on October 2, 2023.Research indicates that this vaccine significantly reduces malaria cases and deaths in children, especially when administered before peak transmission seasons. Like the RTS,S/AS01 vaccine, R21 stimulates the immune system but uses the adjuvant Matrix M, derived from saponins, to enhance both humoral and cellular immunity. These cells carry the antigen to lymph nodes, where B and T lymphocytes recognize it. These dendritic cells transport the antigen to lymph nodes, where B and T lymphocytes recognize it. Following this, B lymphocytes mature into plasma cells producing CSP-specific antibodies, while T cells differentiate into helper and cytotoxic T cells. The vaccine is administered in four intramuscular doses starting at five months of age[14]. This preerythrocytic malaria vaccine consists of HBsAg fused with the C-terminus and central repeats of the
circumsporozoite protein (CSP), forming virus-like particles in yeast. It lacks excess HBsAg, resulting in a higher
density of CSP epitopes and strong malaria-specific anti-Asn-Ala-Asn-Pro (NANP) antibody responses. Preclinical trials examined different adjuvants, with Matrix-M selected for clinical advancement due to its strong immunogenicity. [15]. In April 2023, Ghana's food and drugs authority authorized the R21 vaccine for children aged five months to three years. Subsequently, Nigeria also granted provisional approval for its application. The Serum Institute of India intends to produce between 100-200 million doses annually and is constructing a vaccine manufacturing facility in Ghana.

Feature	Rts,s vaccine	R21 vaccine
Developer	GlaxoSmithKline(GSK) with PATH and WHO	Oxford University with Serum Institute of India
Approval	2021	2023
Vaccine Type	Recombinant protein based	Recombinant protein based
Adjuvant used	ASO1(Developed by GSK)	Matrix -M (Developed by Novavax)
Efficacy (1 year)	~56% in young children	~75% in young children
Efficacy (after 3-4 years)	Drops to ~36% without booster	~75% sustained
Dosing schedule	4 doses (3 initial doses + 1 booster)	4 doses (3 initial doses + 1 booster)
Cost and production	More expensive,limited production	Lower cost,scalable production
Mass production	GSK, Bharat Biotech	Serum institute of india

Table(1.2). Comparison between rts,s and r21/matrix -m vaccines

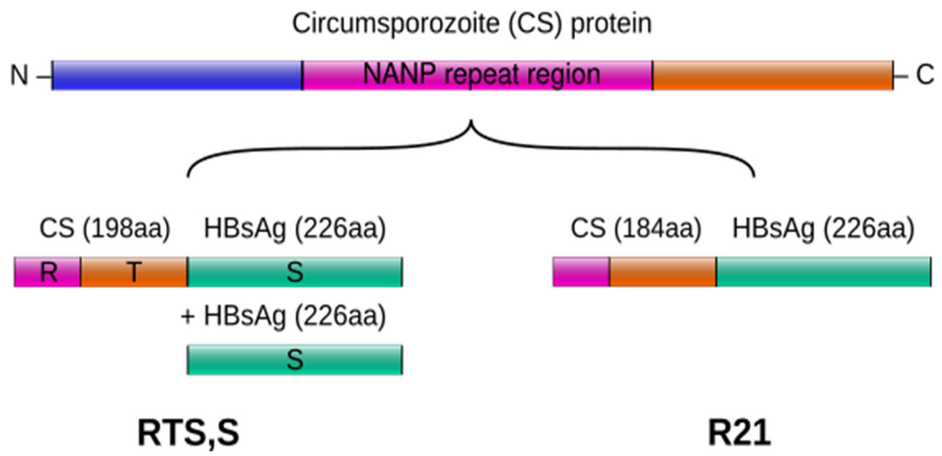


Figure (1.2). Comparison between rts,s and r21/matrix -m vaccines[16].

LAB GROWN REGENERATIVE MEDICINE

Regenerative medicine offers significant promise for treating a variety of medical conditions, including degenerative diseases, injuries, and congenital disorders. Researchers are focused on creating novel therapies that encourage healing and tissue regeneration by utilizing advanced technologies like stem cell therapy, gene editing, and biomaterial scaffolding. The FDA plays a vital role in ensuring the safety, efficacy, and quality of these products by implementing rigorous regulatory measures, including clinical trials and approval processes.As scientific progress continues to expand the possibilities of regenerative

medicine, regulatory frameworks adapt to balance innovation with patient safety, fostering the development of groundbreaking therapies that could revolutionize modern healthcare[17]. Moreover, cell therapies are being investigated for their prospective applications in regenerative medicine, organ transplantation, and even anti-aging solutions. Scientists are increasingly exploring ways to harness stem cells for the creation of functional tissues and organs, which could lessen the reliance on donor transplants in the future. Additionally, advancements in immunotherapy utilize engineered immune cells, like CAR-T cells, to specifically target and eliminate cancerous or diseased cells. As research progresses, cell-based therapies may revolutionize personalized medicine by offering tailored treatments that address each patient's distinct genetic and biological characteristics, ultimately aiming to improve both quality
of life and survival rates. [18].

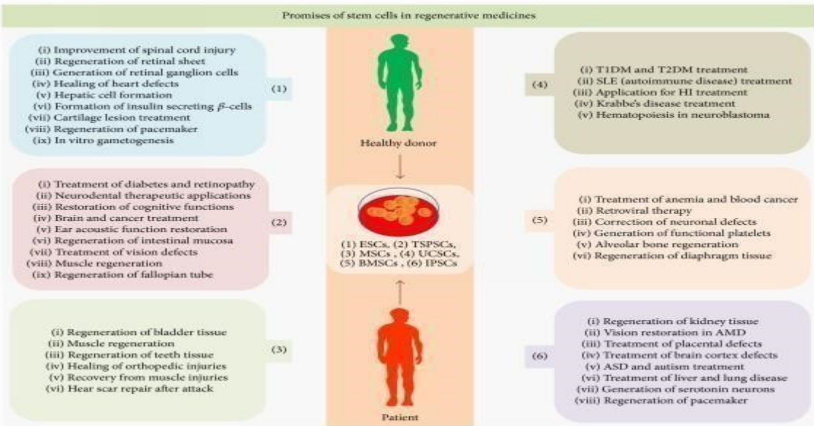
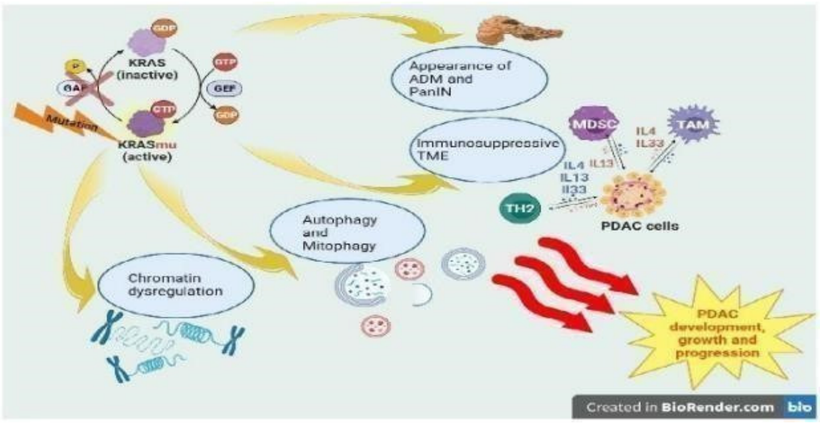


Figure (1.3). Representing application of stem cells in regenerative medicine [19].

KRAS PANCREATIC CANCER TREATMENT BY DARAXONRASIB

Daraxonrasib (RMC-6236) is an orally administered medication specifically designed as a treatment option for pancreatic cancer, particularly against the KRAS mutations prevalent in this form of cancer.This bRo5 macrocyclic compound acts as a powerful and direct agent by employing an innovative tri-complex formation strategy. It brings together a minor patch agent, the abundant chaperone protein CypA, and the target protein RAS, creating a distinctive compound library that enhances RAS inhibition. [20].



Figure(1.4). Representing KRAS-dependent tumorigenesis in PDAC [21].

The Kirsten rat sarcoma viral oncogene (KRAS) encodes the KRAS protein, the most commonly altered protein in solid tumors, underscoring the significance of effective targeting.KRAS is a membrane-bound protein found in all human cells and serves as a central hub for various signaling pathways crucial for normal cellular functions. It alternates between inactive and active states, facilitated by the exchange of guanine diphosphate (GDP) and guanine triphosphate (GTP) bound to KRAS. Guanine exchange factors (GEFs) and GTPase-activating proteins (GAPs) supervise this exchange, which is vital for maintaining KRAS's activity.This tightly regulated cycle was long deemed 'undruggable' due to two primary reasons: KRAS's high affinity for GTP and the lack of suitable binding pockets for developing small molecule inhibitors. KRAS mutations are observed in over 90% of pancreatic ductal adenocarcinoma (PDAC) cases, making it a key genetic change in this cancer type. These mutations drive tumor initiation, progression, and resistance to treatment. Common KRAS mutations in pancreatic cancer occur at codon 12 of the KRAS gene, resulting in single amino acid substitutions that impair GTP hydrolysis, keeping KRAS in a constantly active state. The most prevalent mutations include G12D (40-50%), which significantly stimulates downstream signaling, G12V (30-35%), which accelerates aggressive tumor growth, and G12A (15%), which, while less frequent, remains important, alongside other rare mutations like G13D and Q61H.Impact of KRAS Mutations:

1. Persistent Activation: Mutant KRAS remains in an active, GTP-bound state, continuously activating downstream pathways.
2. Pro-Tumorigenic Signaling:

- RAF-MEK-ERK Pathway:** Encourages cell proliferation and survival.
- PI3K-AKT Pathway:** Aids metabolism, survival, and immune evasion.
- Ral-GDS Pathway:** Promotes invasion and metastasis[22].

Most pancreatic cancers develop resistance to chemotherapy (e.g., gemcitabine, FOLFIRINOX) and targeted therapies. Daraxonrasib, as a direct KRAS inhibitor, offers a unique approach for patients with treatment-resistant tumors. This novel application of Daraxonrasib in pancreatic cancer represents a promising advancement in targeted therapy, providing a new treatment option for KRAS-mutant tumors, overcoming drug resistance, and
paving the way for future personalized medicine approaches in oncology[23].

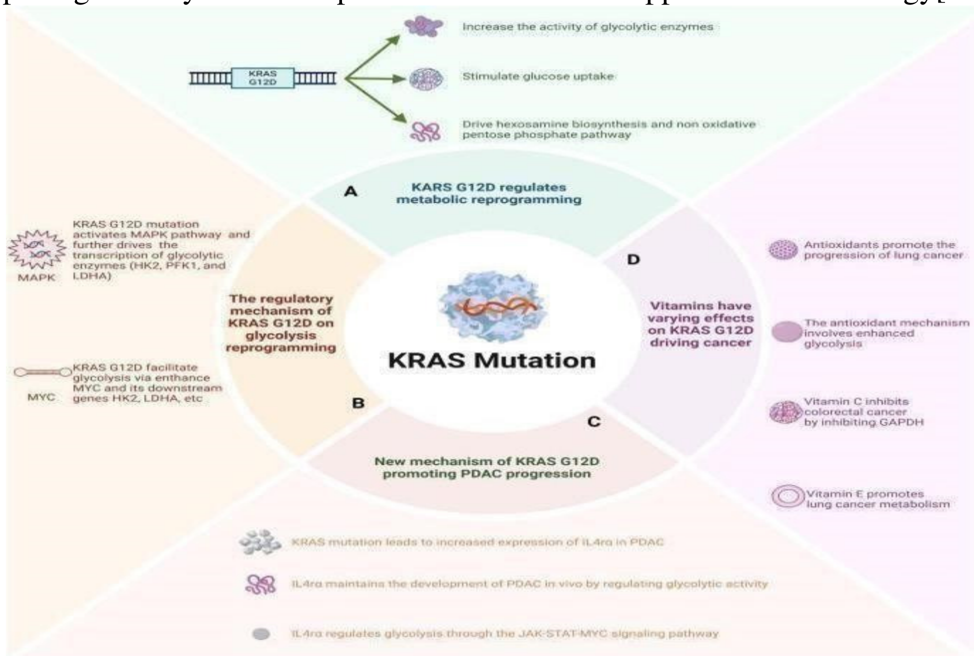


Figure (1.5). Representing Kras mutation [24].

DIGITAL STETHOSCOPE:

A digital stethoscope is a sophisticated medical instrument that transforms acoustic sounds into electronic signals, which can be amplified for clearer listening. These signals can also be processed and digitized for transmission to a computer or laptop. By enhancing diagnostic abilities, digital stethoscopes assist physicians in making more accurate clinical decisions.This device operates through three main modules: data acquisition, preprocessing, and signal processing, which work in unison before the user hears the auscultated sound. (a) The data acquisition module comprises a microphone and a piezoelectric sensor, which capture, filter, buffer, and amplify sounds while converting acoustic signals into digital ones. (b) The preprocessing module improves the digital signal by eliminating noise and unwanted artifacts. (c) The signal processing module organizes and classifies the processed data, facilitating easier analysis and use by physicians for clinical diagnosis. The most commonly used handheld auscultation devices with a digital stethoscope are the Litmann 3200 and EKO Core (Core 500^{TM}) [25].

The Litmann 3200, one of the first digital stethoscopes to utilize a piezoelectric sensor, is manufactured by 3M Company in St. Paul, MN, USA. This device offers three auscultation modes: bell, diaphragm, and extended, along with 12 built-in recording tracks for audio storage. However, when transferring recordings from the Litmann 3200, it remains unclear if the device shares raw or filtered audio with its companion software, Steth Assist.

With a 4kHz sampling rate, it is unclear if this is achieved directly by the device or if the audio is downsampled from a higher rate. The stethoscope provides up to 24 levels of sound amplification, with level 3 being the default as advised by the manufacturer. Moreover, it features ambient noise reduction technology and utilizes materials that minimize frictional noise. EKO CORE: This is a contemporary digital stethoscope produced by EKO Health in Oakland, CA, USA. The device can function in both analog and digital modes and connects to a mobile app called EKO, allowing users to record and store sounds in the cloud, although it does not support on-device recording. It offers as much as 40 levels of sound amplification and wireless listening capabilities. EKO Core is designed with active noise cancellation and provides three app-selectable modes: cardiac, wideband, and pulmonary.This device also has a 4 kHz sampling rate. Recently, EKO Health launched the EKO CORE 500^{TM} in 2023[26].

EKO CORE 500^{TM}: This digital stethoscope features a chest piece, a detachable earpiece, the Eko app, a fullcolor digital display, and integrated electrodes for a 3-lead electrocardiogram (ECG). It offers real-time heart rate monitoring and includes options for noise cancellation, high-definition audio with sound amplification, and filters optimized for heart, lung, and body sounds. The chest piece diaphragm allows the device to amplify, filter, and transmit body sounds, while the integrated electrodes around the chest piece enable 3-lead ECG recording. The Eko app records sounds with the CORE 500^{TM} and displays AI analysis results on the device's screen, which is also necessary for viewing the phonocardiogram and 3-lead ECG. The device is primarily designed for clinicians to electronically amplify, filter, and transmit body sounds. The data provided by the device is only meaningful when interpreted alongside a clinician's evaluation and other relevant patient information [27]. Table(1.3).

Comparison between features of eko core and eko core 500^{tm}

Feature	**Eko core**	**Eko core 500^{TM}**
Type	Stethoscope attachment (for analog models)	Fully integrated digital stethoscope
ECG Capability	No ECG support	Integrated 3 lead ECG
Display	No display: requires mobile app	Full color digital display

Recording	EKO App	EKO App and on device storage
AI disease detection	No AI support	AI powered analysis with EKO App
Design	Clip on attachment for analog stethoscopes	Standalone digital stethoscope
Price	Lower	Higher

Figure (1.6) . Representing EKO CORE 500^{TM} Digital stethoscope[28]

SSI MANTRA ROBOTIC SURGERY SYSTEM

The term "Robot" originates from the Polish word "robota," which means forced labor, and it also denotes a machine capable of performing a variety of tasks autonomously[29]. Robotics is a sector of artificial intelligence focused on designing intelligent machines by combining AI algorithms with mechanical systems to carry out physical activities.This field holds the potential to transform every aspect of patient care, medical procedures, and clinical operations[30]. Robotic surgery is an emerging field that is quickly transforming the landscape of medicine. [31]. The SSI Mantra Surgical Robotic System, developed by Sudhir Srivastava Innovations Pvt Ltd in India, is the first surgical robotic system of its kind. It is a dual-console, multi-arm system designed to aid surgeons in conducting minimally invasive procedures. The system includes one surgeon console located in the operating room near the patient and another at a distant site for expert oversight[32]. The SSI Mantra robotic system platform comprises three main components: (a) the surgeon command center (SCC), (b) patient-side arm carts (PSAC), and a vision cart. The SCC is equipped with an interactive touchscreen for controlling the system, addressing faults, and reviewing patient information via PACS.It is an open console equipped with a 32-inch 3D HD display, an ergonomic armrest, and a head-tracking camera synchronized with the surgeon's 3D glasses for safety. Robotic movements are managed through two palm grip manipulators with pinch grip buttons and a finger clutch button, while a foot pedal unit provides precise control over energy sources, the master clutch, endoscope operation, and instrument switching. Each PSAC contains three components: the robotic arm, the boom, and the cart, with only the robotic arm placed within the sterile area.During procedures, the vision cart offers essential imaging and support for visualization[33]. The Mantra system made medical history by successfully performing an ultra-low anterior resection for rectal cancer at Aster DM Healthcare in Bengaluru in October 2023. This operation involves the removal of a section of the left colon, including the entire rectum, along with the associated tissue and lymph nodes.With robotic assistance, the surgery was completed with minimal invasion, leading to reduced blood loss, less postoperative pain, a shorter hospital stay, and quicker recovery. Typically, recovery from a robotic rectal resection takes two to three weeks, compared to four to six weeks for traditional open surgery. SSI Mantra is recognized internationally for its versatility and effectiveness across various procedures—from throat operations to gynecological surgeries—while also being cost-efficient.. It has received regulatory approval from the Indian Central Drugs Standard Control Organization (CDSCO)[34]. To date, the Mantra system has successfully undergone two clinical trials and has been utilized in more than 2,000 surgeries. Future advancements in technology, along with improved methods and growing global acceptance, are expected to fuel rapid growth. The precision and capabilities of robotic systems will progress further with innovations like tremor filtering and enhanced three-dimensional (3D) imaging. [35].

Table (1.4). Representing information about the new surgical platform.

SL NO	SURGICAL PLATFORM	YEAR	COMPANY	COUNTRY	FDA APPROVAL
1	Senhance®	2017	Trans Enterix surgical, Durham	USA	Yes
2	Revo-i®	2017	Meerecompany, Yongin	Korea	No
3	Micro Hand S	2017	Shandon Wego Surgical Robot Co.,Weihai	China	No
4	Toumai®	2018	Shanghai Micropart Medbot, Shanghai	China	No
5	Avatera	2019	Avatera medical, Jena	Germany	NAI
6	Versius®	2019	CMR surgical, Cambridge	UK	No
7	Hinotori™	2020	Medicaroid Inc, Kobe.	Japan	Yes
8	KangDuo	2020	Suzhou Kang Duo Robot Co., Suzhou.	China	No

9	Hugo^{TM}	2021	Medtronic, Minneapolis, Minnesota.	USA	Yes
10	Dexter	2022	Distal motion	Switzerland	No
11	Mantra	2023	SS innovation, Gurugram, Haryana	India	Ongoing

Figure(1.7). Representing SSI Mantra robotic surgery instruments[36].

CONCLUSION

Recent breakthroughs in medical science have transformed healthcare by introducing novel approaches to disease prevention, diagnosis, and treatment. Advances in AI-powered diagnostics, gene editing, stem cell research, and regenerative medicine are greatly enhancing patient outcomes and reshaping the medical landscape. These studies also underscore a move towards personalized and preventive healthcare. These innovations not only boost patient outcomes but also enhance healthcare accessibility and efficiency. However, despite their potential, these advancements face significant challenges, including ethical issues, regulatory obstacles, accessibility, and cost, which hinder widespread adoption. To maximize the benefits of these advancements, ongoing investment in research, collaboration between scientists and policymakers, and ethical considerations must be prioritized. Regenerative medicine and stem cell therapy are making strides in repairing damaged tissues and treating degenerative diseases. Researchers are developing 3D bioprinted tissues and functional organs, which could help address the global shortage of transplantable organs. Stem cell therapies offer significant potential for conditions such as Parkinson's disease, spinal cord injuries, and heart disease, providing new hope for patients with chronic and incurable illnesses. The cost of advanced treatments, like gene therapies and immunotherapies, presents a major barrier to widespread adoption, necessitating policies that promote affordability and equitable access. Additionally, integrating these new technologies into existing healthcare systems requires infrastructure development, training, and global collaboration. Looking forward, the future of medicine is likely to be shaped by further integration of AI, precision medicine, and biotechnology, ultimately leading to more effective, affordable, and accessible healthcare for all. Emphasizing responsible innovation will be crucial to ensuring that these advances benefit patients worldwide.

FUTURE SCOPE:

The field of medical science is poised for even more groundbreaking innovations, with the future likely to witness a deeper integration of AI, robotics, and nanotechnology in healthcare, resulting in more effective and less invasive treatments. Progress in microbiome research, targeted drug delivery, and synthetic biology could transform the management and prevention of diseases. Furthermore, the success of these advancements will rely on sustained investment in research, ethical oversight, and initiatives to make healthcare more inclusive and accessible. Recent developments in medical science hold the potential to revolutionize healthcare and enhance the lives of millions.

While challenges persist, the ongoing pursuit of scientific innovation, coupled with ethical responsibility and global cooperation, is expected to shape a future where medical breakthroughs benefit all of humanity.

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