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Foundations to Frontiers: Advanced Techniques in Allied Sciences

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PREFACE

The field of Allied Sciences has undergone remarkable expansion and transformation in recent years. This volume, Foundations to Frontiers: Advanced Techniques in Allied Sciences, aims to capture the latest advancements, research and emerging trends that are defining these dynamic disciplines today.

The collection of research papers and reviews in this volume highlights the increasingly interdisciplinary nature of modern science, where the boundaries between Clinical Biochemistry, Physiotherapy, and Microbiology (Infectious Disease) are becoming more interconnected. This convergence is fostering innovation and leading to new therapeutic approaches, state-of-the-art technologies and a deeper understanding of the fundamental biological processes.

The goal of this book is to provide readers—whether researchers, educators, or students—with a thorough overview of the most recent developments in these fields. It also serves as a platform for scholars to present their work and contribute to the shared knowledge within these disciplines. We are living in a transformative period where the intersection of multiple fields is opening up new opportunities for exploration and discovery. The contributions in this volume are a testament to the dedication, creativity and intellectual rigor of the scientific community and we hope this work will inspire further research and advancement.

I would like to express my sincere thanks to all the authors who have contributed to this volume, as well as to the reviewers whose feedback has ensured the quality and relevance of the material. It is our hope that this book will be a valuable resource for all those working in the areas of Clinical Biochemistry, Physiotherapy and Microbiology (Infectious Disease).

- Editors

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The completion of this book would not have been possible without the generous contributions of many individuals whose support, expertise and dedication have played a crucial role throughout this journey.

First and foremost, I would like to express my deepest gratitude to the esteemed authors who contributed their insightful research and expertise to this volume. Your hard work, dedication and passion for advancing knowledge in the fields of Clinical Biochemistry, Physiotherapy and Microbiology (Infectious Disease) have been invaluable in shaping the content of this book.

I would also like to thank the reviewers for their meticulous feedback and guidance. Your careful evaluation and thoughtful suggestions ensured that the quality and relevance of the material met the highest standards.

- Editors

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SECTION A: MEDICAL MICROBIOLOGY

INNOVATIVE APPROACHES TO COMBAT EMERGING VIRUSES

Priti Das

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Introduction:

Over the past few years, a sudden onset of emerging and re-emerging viruses were it was noticeable that viruses emerge and re-emerge all of a sudden and out of relative obscurity to wreak havoc on worldwide health concerns; potentially epidemiological transmission among immune-compromised individuals. Vaccine production is crucial to prevent such rapid spread of novel viruses. Treatment option may not be available or less effective due to hasty clinical worsening. In such cases, vaccinations actually make up an integral element of prevention for developing viral infections. Molecular techniques in virology have had a profound impact on understanding the characteristics of viruses and understanding host pathogenesis.

A disease caused by an infectious agent that has not previously been reported in a given population or geographic location is termed an emerging infectious disease, or EID. In a similar way, a re-emerging infectious disease is caused by an existing pathogen that has spread to a new location or that was previously under control but now appears more frequently (Dikid *et al.,* 2013). Viral infections account for the majority of newly identified and re-identified infectious diseases, and their incidence is increasing. Some viral diseases are emerging/re-emerging in the global scenario as alarming health risks, for instance, Ebola epidemic in West Africa , HIV, and Nipah virus, West Nile virus, yellow fever virus, and several other viral epidemics (Löscher & Prüfer-Krämer, 2009).

Factors contributing the development of emerging and re-emerging infections-

Several factors affect the mode of exposure to the virus, which determines the date of onset or re-emergence of viral infections. Zoonoses account for nearly two-thirds of newly emerged and re-emerged diseases. Most of these originate from wildlife, though infections can also be acquired through contact with domesticated animals or via vectors such as ticks and mosquitoes. Additionally, reduced vaccination rates alter the

susceptibility of the human population to viruses, contributing to the reappearance of other viral infections, such as measles (Carlson *et al.,* 2022).

i) Trading and globalization- Various factors linked to human social life and behaviour are responsible for the re-emergence or emergence of viral infections. People have urbanized themselves instead of leading life in villages. In urban culture, the population is scattered densely, and it is easily susceptible to the infectious diseases. This is common in urban towns that are congested and do not have clean water sources or sufficient sanitary facilities. Today, with globalization, infectious diseases can easily be transferred from one country to another within a short time through travel and trade, particularly those found in food or animal products. Illicit commerce such as bushmeat trading, promotes the spread out of retro and herpes infection. Indeed, infected meat harbouring simian immunodeficiency viruses may have opened the door for the HIV pandemic (Kurpiers *et al.,* 2016; Rush *et al.,* 2021; Sheikh, 2020).

ii) Zoonotic importation- In many cases, certain animal or insects that can be imported carry viruses with them into the newer environment. Flavivirus West Nile was first identified in Uganda in 1937 and later found in other parts of Africa, Asia, Europe, and the Middle East. It can cause fever, body aches, joint pain and in severe cases fatal meningitis or encephalitisIn October 1999, the virus caused a human and bird epidemic in New York City, with the strain closely resembling the virus found in Israel. Although the historical origin of the virus in the United States remained unknown, it was believed to have been introduced into North America through vectors such as imported birds or mosquitoes. These vectors may have arrived as unaccompanied cargo on international aircraft or been carried by their natural avian hosts. The Centers for Disease Control and Prevention (CDC) reported 41,762 cases of West Nile Virus (WNV) in the United States between 1999 and 2014. Of those, 4.2% of cases resulted in death due to the 1999 epidemic (Sejvar, 2003). In 2003, after the importation of infected rodents by an exotic animal distributor in Texas, a multistate outbreak of the Mpox virus occurred. This outbreak led to human-to-human transmission, resulting in 71 reported cases (Liu *et al.,* 2022). Traceback studies suggested that the zoonotic transmission occurred due to vicinity of infected rodents to the distributors' prairie dogs. At this point, the secondary host for transmission from person to person was the prairie dogs that were bought by the general public or other animal wholesalers (Centers for Disease Control and Prevention (CDC), 2003).

iii) Travel and tourism- Apart from such emerging zoonoses, people are exposed to new infections due to increased travel to remote and wild regions. It also exposes local animal species to human infectious diseases. A disease that is transferred to other animals from human beings is known as an anthroponosis. Ecotourism and adventure travel contribute towards the emergence of zoonotic diseases. Travel and tourism encourages different activities including safaris, extreme travel and adventure sports providing a reasonable chance to get affected by certain diseases (Chomel *et al.,* 2007). Seropositive Macaques with herpes B antibodies freely roamed in Indonesian Balinese Hindu temple and adventure travel and it had been assumed that contact between the tourists and native macaques could result in zoonotic transfer (Huff & Barry, 2003).

iv) Transmission through air- Air is another factor that can cause transmission of disease across the globe. The recent pandemic of SARS-CoV-2 was characterized by fever, pneumonia, dyspnea, muscle soreness and transmitted by the respiratory droplets (Tsai *et al.,* 2021). According to our current understanding on the transmission chain of SARS-CoV2, bat is its original host while pangolin is likely its intermediate host (Zhao *et al.,* 2020). Although the disease originated in Wuhan, Hunan province of China in 2019, soon it started to spread rampantly in other provinces of China, i.e., Hubei, Zhejiang, Guangdong, Henan, Hunan, and the cities of Beijing and Shanghai, and other nations, affecting thousands of people. Such a robust outbreak outside Hubei province could be due to the substantial transportation load during the Chinese Lunar New Year on 25th January, 2020 (Wu *et al.,* 2020). By January 2020, WHO identified 28,276 confirmed cases with 565 fatalities around the world (Grewal *et al.,* 2021).

v) Climate- The transmission of viral infection is sharply impacted by geoclimatic variables that encompass land and ocean temperatures, wind patterns, intense weather events, and terrain characteristics (Rupasinghe *et al.,* 2022). The changes from climate affects all host, pathogen, and vector, modifying its pattern, geographic abundance, and vector-borne transmission dynamics, as its influence can develop changes in the natural ecosystem (Rocklöv & Dubrow, 2020). For example emission of low greenhouse gas is associated with fewer transmission cases and lesser risk to people from vector-borne malaria and dengue (Colón-González *et al.,* 2021). Human cases of vector-borne West Nile virus reaches it's maximum peak in the United States at 24 °C (Shocket *et al.,* 2020).

It has been thought that global warming influences disease dynamics, although the transmission of mosquito-borne viral illness may increase in cooler areas rather than the warmer ones (Lafferty, 2009; Ryan *et al.,* 2015). The spread of Rift Valley fever virus is impacted by drought as well as the El Niño–Southern Oscillation effect. Hot surface temperatures, heavy drought, and low vegetation coverage unfavoured the hatching of River Valley viral mosquito vector in South Africa during 2015-2016, however in later years heavy rain fall caused the outbreak of the virus (Anyamba *et al.,* 2022).

vi) Geoplitics- Geopolitics plays a significant role in controlling the spread of diseases. For example, Indonesia's "viral sovereignty" policy let down a vaccine research program designed to respond to the Asian breakout of H5N1 bird flu (Elbe, 2022). Civil instability and terrorist organizations attacking health care workers were factors in the vicious Ebola virus breakout in the Democratic Republic of the Congo (Letko *et al.,* 2020).

vii) Social factors- With the evolving nature of science, often predictions made upon earlier outbreaks, are not accurate enough for the new emerging viral infections due to genomic mutation. Lot of misinformations are shared through social media platforms during serious pandemic or epidemic situations that can cause fatal disaster in one's life (Carlson *et al.,* 2021). The early period of the COVID-19 pandemic was indeed riddled with misinformation and conspiracy theories that revenged the public's distrust over the top. Negative tweets had a close relationship with the number of new cases, while measures that could prevent the disease, like mask-wearing and social distancing, were debated (Agley & Xiao, 2021). The Ebola virus breakout in West Africa is another example of attitudes and knowledge gaps in society. Many of the everyday behaviours that probably helped spread the infection were - unsafe burial rituals, skepticism about the Ebola virus test, and delaying care from medical professionals (Yamanis *et al.,* 2016).

viii) Laboratory accidents and lapses in biosafety practices- Emerging or re-emerging pathogens can also result from laboratory mishaps and neglected biosafety regulation. An incident of buffalopox (BPX) lesion was observed in a palm of a biomedical researcher and he required surgery after suffering from a shrapnel injury (Riyesh *et al.,* 2014).

Table 1: List of emerging/re-emerging viruses (Wang *et al.,* 2021)

Emerging Infections	Causative Agent	Mode of Transmission	Vaccine availability	Antiviral Treatment
COVID-19	SARS-CoV-2	Respiratory droplets, contact	Covishield (Adeno viral vector vaccine), Covaxin (Whole inactivated virus vaccine), Pfizer-BioNTech & Moderna (mRNA vaccines)	Remdesivir, Paxlovid, Molnupiravir
Nipah Virus Infection	Nipah virus	Animal contact, respiratory droplets	No approved human vaccines are available	Experimental treatments, Ribavirin*
Severe acute respiratory syndrome	SARS-CoV	Respiratory (person-to-person)	No approved vaccines are available	Supportive care
MERS	MERS-CoV	Respiratory droplets, camel contact	No approved vaccines are available	Supportive care
Highly pathogenic avian influenza	H5N1, H7N9 influenza virus	Direct contact with infected birds and their secretions	No approved human vaccines are available	Oseltamivir
2009 Pandemic influenza	Swine-origin H1N1 influenza virus	Respiratory droplets from person to person	Annual influenza vaccines	Oseltamivir, Zanamivir
Hendra virus infection	Hendra virus	Close contact with infected horses and their fluids	Equivac HeV for horses	Intensive supportive care
Hantavirus Pulmonary Syndrome	Hantavirus	Aerosolized rodent excreta	No approved human vaccines are available	Supportive care

Monkeypox	Monkeypox virus	Contact with infected animals, respiratory droplets	Modified Vaccinia Ankara	Tecovirimat (Tpoxx)
Ebola Virus Disease	Ebola virus	Contact with bodily fluids	rVSV-ZEBOV or ERVEBO (replication-competent), Ad26.ZEBOV or Zabdeno (replication-incompetent)	Investigational antivirals, Inmazeb
West Nile fever	West Nile virus	Vector-borne (Culex mosquitoes)	No approved vaccines are available	Supportive management
Rift Valley fever	Rift Valley fever virus	Vector-borne (Aedes, Culex)	No approved vaccines are available	Supportive therapy
Zika	Zika virus	Mosquito-borne (Aedes species)	No approved vaccines are available	Supportive care
Dengue	Dengue virus	Mosquito-borne (Aedes species)	Dengvaxia, Qdenga (recombinant vaccine)	Supportive care
Yellow Fever	Yellow fever virus	Mosquito-borne (Aedes species)	YF-VAX (Live-attenuated)	Supportive care
Japanese encephalitis	Japanese encephalitis virus	Vector-borne (Culex tritaeniorhynchus)	Ixiaro (Inactivated vaccine)	Supportive care
Marburg Virus Disease	Marburg virus	Contact with bodily fluids	No approved vaccines are available	Supportive care
Lassa fever	Lassa virus (arenavirus)	Cotact with urine or faeces of infected Mastomys rats	No approved vaccines are available	Ribavirin

Such newly developed virus infections are challenging to combat. Understanding the characteristics of viruses, host pathogen interactions and genomic study using various innovative approaches are essential to prevent the spread of the virus.

1. Early detection of the pathogen- Early and accurate diagnosis plays a very crucial role in the management and control of newly emerging and re-emerging viral infections, particularly in comorbid patients. Advanced technologies that include ELISA, PCR assays to detect nucleic acids with high sensitivity, and next-generation sequencing have expedited the identification and characterization of novel viruses (Blyn *et al.,* 2008; Johnson *et al.,* 2000; Voelkerding *et al.,* 2009). Quick, portable, and easy point-of-care testing have greatly enhanced our ability to do on-site diagnostics, enabling doctors to quickly identify and treat possible epidemics (K. S. R. Kumar *et al.,* 2021). Nanotechnology is utilized in biosensors to create highly sensitive and targeted detection platforms. Functionalized nanoparticles with viral-specific ligands enable the specific binding of viral components, generating detectable signals. This technology facilitates the development of small, portable diagnostic devices while significantly enhancing detection sensitivity. The integration of biosensors with AI algorithms enables instant data analysis, improving the speed and accuracy of viral detection (Lai *et al.,* 2018; Vorou, 2016). Surveillance and monitoring greatly contribute to early detection. Anomalous trends or spikes in disease incidence can be identified through the integration of environmental monitoring and sentinel surveillance systems with epidemiological data. Sero-surveillance in COVID-19 helped identify the SARS-CoV-2 transmission rate and aided in designing specific preventive measures against the virus. Longitudinal studies are useful for understanding the public health response, whereas peak trends can be identified through cross-sectional studies (M. Kumar *et al.,* 2020). Early warning systems enable public health authorities to take proactive measures against potential outbreaks, minimizing the impact of newly emerging infections on susceptible populations with the help of data analytics and machine learning. The diagnosis and early detection of emerging viral infections require a collaborative approach that combines modern and conventional diagnostic methods. A comprehensive strategy for the rapid and accurate identification of viral threats must integrate cutting-edge technologies with point-of-care testing, nanotechnology, and reliable surveillance systems. These components

form the first line of defense in protecting populations from the effects of potent viral pathogens (Korber *et al.,* 2020; Rambaut *et al.,* 2020).

2. Gene therapy and vaccine production- Gene therapy and vaccine development need to be applied clinically to the control of novel viral infections. Some innovative technologies that are currently in use include mRNA vaccines, RNA/CRISPR modalities, and long-acting nano-therapeutics. These have become promising avenues for improvement in the relative safety and efficacy of treatment for emerging and re-emerging viruses. Targeted intervention against novel viruses can take various forms, including mRNA vaccines, RNA interference (RNAi), and CRISPR-Cas9 systems (Figure 1). Novel Cas9 enzyme variants are designed to target both DNA and RNA viruses, enhancing specificity and functional activity (Hilton *et al.,* 2015; Maruggi *et al.,* 2019). The SpCas9-NG and SpCas9-NG3 variants are engineered for improved specificity and activity against DNA viruses, whereas RNA viruses are targeted using RNA-specific CRISPR-Cas systems, such as Cas13a. Cas13a functions as an RNA-guided RNase, making it a promising candidate for the destruction of RNA viruses, including SARS-CoV-2 and influenza viruses.

(Abudayyeh *et al.,* 2017; Konermann *et al.,* 2018).

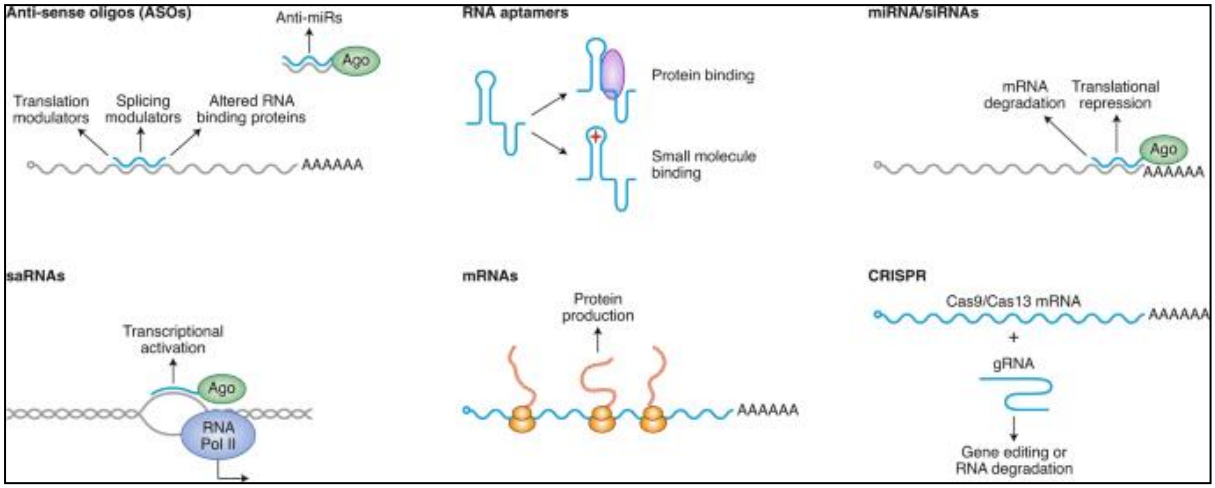

Figure 1: RNA based approaches to detect newly developed viruses (Meganck & Baric, 2021)

The benefits of long-acting nano-therapeutics include the encapsulation of antiviral agents, improved therapeutic efficiency, and reduced frequency of administration. On the other hand, nanotherapeutics may also provoke immune responses, leading to adverse effects. Scientists have developed methodologies to modify nanoparticle interactions with the immune system through surface

modifications, polymer coatings, and adjustments in dimensions, shape, or composition to regulate biodistribution and immunogenicity (Kushnir *et al.,* 2012).

Nanotherapeutics, especially long-acting formulations, have the potential for extended drug release and improved patient compliance. These nanoparticles can encapsulate therapeutic agents and provide controlled delivery, thereby reducing the frequency of administration. However, issues related to biocompatibility and clearance may arise with such particles. Lipid nanoparticles have been extensively developed as delivery systems for nucleic acid-based therapeutics, including mRNA vaccines such as the Pfizer-BioNTech and Moderna COVID-19 vaccines (Baden *et al.,* 2021; Polack *et al.,* 2020). They have also been investigated for the targeting and delivery of small interfering RNA (siRNA) against viral genes; they have proven to be successful in inhibiting viral replication both in vitro as well as in preclinical models of respiratory syncytial virus, influenza, as well as hepatitis B virus infections. Furthermore, nanoparticles interact with the immune system, and surface modulations of nanoparticles resist immune recognition and activation (Dong *et al.,* 2015; Van Rijt *et al.,* 2014).

Inspite of multiple functional improvements these technologies bear many disadvantages. One of the major challenges with mRNA vaccines is that they need ultra-cold storage conditions, possessing logistical challenges. Sometimes, mRNA vaccines cause certain adverse reactions although they are mild and short-lived. Improvement of specificity and efficiency of these modalities is being pursued through optimization of delivery methods, sequence design, and Cas9 variants.

3. Long-term consequences of nano-therapeutics- Long-acting nanotherapeutics have become relatively better known because they can release antiviral drugs over a long period of time and provides creative avenues for enhancing efficacy and safety of treatment in the combat against new emerging viral infections. Systems of lipid and polymeric nano-particulates are flexible drug delivery systems, offering encapsulated medicinal agents a safe and regulated environment. Lipid nanoparticles enable the targeted delivery of siRNA, mRNA vaccines, and antiviral drugs to specific cell types and pathological sites. On the other hand, polymeric nanoparticles support sustained release, resulting in a long-term

therapeutic effect and minimizing the frequency of administration of nano-therapeutics for prolonged action (Al-Halifa *et al.,* 2019; Kushnir *et al.,* 2012).

Small molecule inhibitors and biologics are examples of nano-therapeutics that can be used in combination with traditional antiviral drugs. Encapsulating peptides, fusion proteins, or monoclonal antibodies within nanoparticles enhances the stability and bioavailability of medicinal drugs. This approach maximizes the antiviral response while reducing potential adverse effects by increasing the drug's half-life and enabling controlled release. Long-acting nano-therapeutics provide a solution to the challenge of maintaining sustained therapeutic levels in the body, ensuring prolonged drug exposure. In addition to enhancing antiviral therapeutics, the continuous release of the drug reduces dosing frequency, thereby improving patient compliance (Al-Halifa *et al.,* 2019; Chakravarty & Vora, 2021).

4. Cell culture models of viral infections- These are critical in developing the development of new therapies. Innate immunodeficient or receptor-expressing cells will increase the likelihood of successful culture. Screening methods need to be performed at a high throughput level in order to decrease time, manpower, and cost. Transformed human cell lines are most common, but these could influence drug bioavailability, transport, and metabolism (Hou *et al.,* 2020). There are primary cell lines and organ-on-a-chip systems as well. For improved efficacy, initial screening should be conducted in primary cell lines. This would allow pooling of the expertise in virology, culture models, and screening methods (Tang *et al.,* 2021).

5. DBS testing- In certain infections (HIV, HBV, HBC) dried blood spots or DBS testing is much efficient techniques to monitor therapeutic improvements and qualitative detection of pro-viral DNA. It is easy to transport, store and greater alternative of venous puncture, although it has a lower analytical sensitivity (Tuaillon *et al.,* 2020).

6. Targeted treatments- It is critical to develop the exact and targeted therapeutic approaches for neutralizing the new viruses. Monoclonal antibodies are engineered to specifically recognize and bind to viral antigens such that it can effectively neutralize the virus and inhibits host cell interactions, replication, or assembly of the virus. Because of the selective nature ofsuch antibodies, it would be possible to target the virus precisely with the least adverse effects on host cells (Breedveld, 2000; Taylor *et al.,* 2021).

According to Apellániz *et al.,* fusion proteins are designed structures that combine the functional domains of a number of proteins into a single therapeutic agent that has increased efficacy (Apellániz *et al.,* 2014). They can be designed to target a specific stage of the viral lifecycle. For example, a single chimeric protein might combine elements that both prevent viral entry and replication (White *et al.,* 2008).

Conclusion:

The ultimate strategy in developing and implementing effective treatments against emerging and re-emerging viruses would be a multidisciplinary approach at the front lines of research. The route to effective and safe treatments starts with precise and highly sensitive diagnostics, which enables early detection and response. Some of the most important therapeutic strategies available include long-acting prodrugs, nanoparticles, immunotherapeutic modalities, and CRISPR Cas9 systems, which have successfully opened channels to additional directions of viral restriction and clearance. Identification of variants using bioinformatics could be beneficial for certain mutated viruses like SARS-CoV-2 and to understand the burden of the mutant strains in the population.

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CARBAPENEM RESISTANCE: A GROWING GLOBAL CONCERN

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Abstract:

Carbapenem resistance has emerged as a significant challenge in the treatment of bacterial infections, particularly in healthcare settings. As a critical class of antibiotics, carbapenems are often considered the last line of defense against multidrug-resistant Gram-negative bacteria. This chapter examines the mechanisms of carbapenem resistance, the epidemiology of resistant pathogens, and the implications for public health. Additionally, we discuss strategies for combating this growing threat, including surveillance, infection control measures, and the development of novel therapeutic agents. Understanding and addressing carbapenem resistance is essential to preserving the efficacy of existing antibiotics and improving patient outcomes.

Introduction:

Carbapenems are a class of broad-spectrum β-lactam antibiotics effective against a wide variety of bacteria, including those resistant to other antibiotic classes. They are often reserved for severe or high-risk infections, especially those caused by multidrug-resistant organisms. However, the rise of carbapenem-resistant bacteria poses a significant threat to global health (Verma G, Nayak SR, Jena S, *et al.,* 2023) complicating treatment regimens and increasing morbidity and mortality associated with infections. Carbapenemases are enzymes capable of degrading carbapenems, monobactams, cephalosporins, and penicillins (Ghosh, A., & Dutta, S., 2020). As carbapenems are often the preferred treatment for infections caused by multidrug-resistant Gram-negative bacteria, there has been a significant increase in the prevalence of carbapenem-resistant Enterobacteriaceae (CRE), carbapenem-resistant Pseudomonas aeruginosa (CRPA), and carbapenem-resistant Acinetobacter baumannii (CRAB) in recent years. Accurate and timely detection of carbapenem-resistant strains is essential for effective patient management and for preventing the further spread of resistance within the community (Nordmann, P., & Poirel, L., 2019).

Mechanisms of Carbapenem Resistance

Carbapenem resistance can arise through various mechanisms:

Production of Carbapenemases

The most notable mechanism is the production of carbapenemases, enzymes that hydrolyze carbapenems and render them ineffective. The most common types of carbapenemases include:

- **KPC (Klebsiella pneumoniae carbapenemase)**: Predominantly found in Enterobacteriaceae, particularly Klebsiella pneumoniae.
- **NDM (New Delhi metallo-β-lactamase)**: Associated with several Gram-negative bacteria, including E. coli and Klebsiella spp.
- **OXA-48-like enzymes**: Found in various Enterobacteriaceae and Pseudomonas aeruginosa (Tzouvelekis, L. S., *et al.,* 2014)**.**

Alterations in Porin Channels

Gram-negative bacteria possess outer membranes that act as barriers to antibiotic penetration. Alterations in porin channels, which facilitate the uptake of nutrients and antibiotics, can limit the entry of carbapenems, thereby contributing to resistance.

Efflux Pumps

Increased activity of efflux pumps can lead to the expulsion of antibiotics from bacterial cells, further enhancing resistance. These pumps can reduce intracellular concentrations of carbapenems and other antibiotics (Tzouvelekis, L. S., *et al.,* 2014).

Epidemiology of Carbapenem-Resistant Infections

Global Distribution

Carbapenem-resistant organisms have been reported worldwide, with particularly high prevalence in healthcare settings in low- and middle-income countries. Outbreaks have been linked to the misuse and overuse of antibiotics, inadequate infection control practices, and globalization (World Health Organization., 2017).

Common Pathogens

The most commonly encountered carbapenem-resistant pathogens include:

- **Klebsiella pneumoniae**
- **Escherichia coli**
- **Pseudomonas aeruginosa**
- **Acinetobacter baumannii**

These pathogens can cause severe infections, including bloodstream infections, pneumonia, and infections in surgical sites (Tzouvelekis, L. S., *et al.,* 2014).

Impact on Public Health

Morbidity and Mortality

Infections caused by carbapenem-resistant bacteria are associated with higher mortality rates compared to infections caused by susceptible strains. The limited treatment options often lead to prolonged hospital stays, increased healthcare costs, and a greater risk of complications.

Economic Burden

The economic implications of carbapenem resistance are significant. Costs associated with longer hospitalizations, additional diagnostic testing, and more expensive alternative therapies can place considerable strain on healthcare systems (World Health Organization., 2017).

Strategies to Combat Carbapenem Resistance

Surveillance and Monitoring

Robust surveillance systems are crucial for tracking the emergence and spread of carbapenem resistance. Data collection on resistance patterns can guide empirical treatment choices and inform public health interventions (CDC. 2019).

Infection Control Measures

Implementing stringent infection control practices is essential in healthcare settings. Key measures include:

- **Hand hygiene**: Ensuring strict adherence to hand-washing protocols among healthcare workers.
- **Environmental cleaning**: Regular disinfection of surfaces and equipment to reduce the risk of transmission.
- **Isolation of infected patients**: Implementing contact precautions for patients infected with carbapenem-resistant organisms (CDC. 2019).

Antimicrobial Stewardship Programs

Antimicrobial stewardship is critical in minimizing the misuse and overuse of antibiotics. These programs aim to optimize antibiotic prescribing practices, enhance treatment efficacy, and reduce the development of resistance (CDC. 2019, World Health Organization., 2017).

Research and Development of Novel Therapies

Investments in research for new antibiotics, adjuvants, and alternative therapies are essential to combat the threat of carbapenem resistance. Innovative approaches, including bacteriophage therapy and immunotherapies, show promise in the fight against resistant infections.

Conclusion:

Carbapenem resistance represents a formidable challenge in modern medicine, necessitating a multifaceted approach to control its spread. By understanding the mechanisms of resistance, the epidemiology of resistant pathogens, and implementing effective infection control and stewardship strategies, healthcare providers can work towards preserving the efficacy of carbapenems and improving patient outcomes.

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THE PRESENT STATUS OF AMOEBIASIS

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Abstract:

Amoebiasis caused by the protozoan *Entamoeba histolytica* is a major public health concern in India. This chapter provides an overview of the amoebiasis scenario in India by integrating current research findings and epidemiological data, focusing on prevalence, risk factors, clinical manifestations, diagnostic challenges, by treatment options and preventive measures.

Introduction:

Amoebiasis is a gastrointestinal disorder primarily affecting the intestines, caused by *Entamoeba histolytica*. Although it can cause an asymptomatic infection, in severe cases it can lead to complications such as diarrhea and liver abscess. The disease is prevalent in many parts of India, especially in areas where sanitation and hygiene are inadequate. To understand the current status of Amoebiasis in India, it is important to implement effective public health policies. In India, the burden of amoebiasis is exacerbated by factors such as inadequate sanitation, poor hygiene practices, and limited access to clean drinking water. Studies indicate that about 10% of the Indian population is infected with *E. histolytica*, with higher prevalence rates in rural and urban slum areas (Bhatia *et al.,* 2020). The parasite is transmitted through the fecal-oral route, often via contaminated food and water, making it particularly rampant in settings where sanitation facilities are lacking.

Clinical manifestations of amoebiasis can vary widely. While many individuals remain asymptomatic, severe cases can lead to dysentery and complications like amoebic liver abscess, necessitating prompt medical intervention (Gupta *et al.,* 2020). Diagnosing amoebiasis poses challenges due to symptom overlap with other gastrointestinal diseases, which often leads to misdiagnosis or delayed treatment (Singh *et al.,* 2019).

Preventive measures are essential for controlling the spread of amoebiasis in India. These include improving sanitation infrastructure, promoting hygiene education, and ensuring access to safe drinking water. Understanding the epidemiology and risk

factors associated with amoebiasis is crucial for developing effective public health strategies to mitigate its impact on affected populations.

The Study of Epidemiology

The Expansion

Amoebiasis is quite common in India, and its incidence varies from place to place. Recent studies have shown that 10% of the Indian population is infected with *Entamoeba histolytica* has had a high prevalence of histolytica in rural areas. Urban slums also exhibit significant rates due to overcrowding and poor sanitation.

Geographical Distribution

The distribution of Amoebiasis in India is uneven. Maharashtra, West Bengal and Kerala have the highest number of cases. Factors such as climate, socioeconomic status, and access to safe water significantly affect the incidence of the disease.

Risk Factors

Socioeconomic Factors

Poor sanitation, loss of get admission to easy ingesting water, and socio-economic reputation are essential risk elements for Amoebiasis. Inadequate sanitation facilities make contributions to the transmission of the parasite through contaminated food and water.

Behavioral Factors

Practices consisting of open defecation, unwashed palms before ingesting, and intake of raw or improperly cooked meals also increase the chance of infection. Educational interventions are vital to alternate these behaviors.

Clinical Manifestations

Amoebiasis can present in various forms, ranging from asymptomatic infections to severe dysentery and extraintestinal manifestations. Symptoms may include:

- Diarrhea (which can be bloody)
- Abdominal ache
- Fever
- Weight loss
- In severe cases, complications like liver abscesses can occur.

Diagnostic Challenges

The diagnosis of Amoebiasis may be difficult because of the overlapping symptoms with other gastrointestinal infections. Common diagnostic techniques include:

- Microscopic examination of stool samples
- Serological checks
- Polymerase chain response (PCR) for definitive diagnosis

However, limitations in laboratory centers, specifically in rural areas, can avert correct prognosis.

Treatment Options

The primary treatment for Amoebiasis entails the usage of antiprotozoal medications. Commonly used tablets include:

- Metronidazole
- Tinidazole
- Iodoquinol

In cases of severe infection or complications like liver abscesses, surgical intervention may be essential. Despite the provision of effective treatments, adherence to medicine and follow-up care can be tricky in low-aid settings.

Prevention and Control

Public Health Strategies

Effective prevention of Amoebiasis requires a multi-faceted technique:

1. Improving Sanitation: Investments in sanitation infrastructure and get right of entry to clean water are crucial.

2. Health Education: Community cognizance applications specializing in hygiene practices can drastically reduce transmission prices.

3. Surveillance: Regular tracking of Amoebiasis instances can help become aware of outbreaks and tell public health responses.

4. Food Safety: Promoting secure food dealing with practices is critical, particularly in regions with high prevalence.

Conclusion:

Amoebiasis remains a significant public health issue in India, exacerbated by socio-economic and environmental factors. Addressing this mission requires coordinated efforts from authorities companies, healthcare companies, and

communities. Increased attention, improved sanitation, and on hand healthcare offerings are essential for decreasing the load of this disorder in India.

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Section B: Clinical Biochemistry

AVANCEMENTS IN CLINICAL BIOCHEMISTRY

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Introduction:

Clinical biochemistry (or clinical chemistry) is an important area of medical science, and it deals with the biochemical and chemical analysis of body fluids, which are used in the diagnosis, monitoring and therapeutic approaches of diseases. Significant enhancements in the quality, responsiveness, and individualization of care have been made throughout the past several decades with improvements in technology, automation, and molecular biology (Basu *et al.,* 2020). The emphasis in this chapter will be in the integration of automation, point-of-care, POCT, molecule diagnostics, proteomics and artificial intelligence (AI) in the field of clinical biochemistry with detailed explanation and supporting scientific references.

Automation in Clinical Biochemistry

Automation has revolutionized laboratory operations by increasing efficiency, accuracy, and throughput. Contemporary laboratories employ robotic systems for sample preparation, analysis, and result interpretation. These systems minimize human error, increase reproducibility and accelerate operations (Gruson *et al.,* 2019). Examples include automated immunoassays that enable sensitive and specific quantities of hormones, enzymes and other markers that can lead to early and accurate disease detection (Daves *et al.,* 2018). In addition, automated analyzers are connected to laboratory information systems (LIS), providing effective data management and reporting of results (Berger & Pantel, 2021).

Point-of-Care Testing (POCT)

The ability to generate diagnostic information close to the patient or at the point of care (POC), referred to as point-of-care testing (POCT), is proving revolutionary in clinical biochemistry. Diagnostic tests near the patient allow results to be generated more quickly, especially in settings such as critical care, the emergency department, and remote areas far from centralized laboratories (Jain *et al.,* 2021). Microfluidics and biosensor technology have progressed to the point that small devices can measure

glucose, electrolytes, cardiac markers, and other parameters accurately with small volumes of blood (Price *et al.,* 2017). For example, portable glucometers and home devices for troponin testing significantly improved the management of diabetes and myocardial infarction (Thygesen *et al.,* 2018).

Molecular Diagnostics

Molecular biology techniques have extended the diagnostics of clinical biochemistry. PCR, NGS, and microarray technologies enable detection of genetic mutations, infectious agents, and epigenetic modifications with unprecedented sensitivity and specificity (Slavin *et al.,* 2019). New technologies, such as NGS, allow us to perform broad genomic analyses to diagnose inherited disorders, cancer, or infectious diseases (Collins *et al.,* 2021). The field of molecular diagnostics has also progressed into the realm of pharmacogenomics, providing tailored drug therapy for an individual able to be deciphered from their genetic makeup (Roden *et al.,* 2019).

Biomarker Discovery and Proteomics

The large-scale analysis of proteins, known as proteomics, has been used extensively for biomarker discovery in the field of clinical biochemistry. Importance of Biomarkers in disease diagnosis, prognosis, and monitoring. For instance, mass spectrometry and protein microarrays are promising methods such as identifying and quantifying proteins related to certain diseases (Rifai *et al.,* 2020). Well-established examples include biomarkers such as C-reactive proteins (CRP) and procalcitonin widely utilized in the diagnosis of infections and inflammatory diseases, and cardiac troponins as golden standard in myocardial infarction diagnosis (Thygesen *et al.,* 2018).

Machine Learning & Artificial Intelligence

Artificial intelligence (AI) and machine learning (ML) are revolutionising clinical biochemistry through advanced data analysis, pattern recognition, and predictive modelling. AI requires the analysis of big data to identify trends and correlations which aids in early diagnosis and treatment planning (Rajkomar *et al.,* 2019). In clinical laboratories, AI serves in quality control, result validation, and workflow optimization. Using biochemical parameters and clinical data, AI-based tools can predict risk for sepsis and enable intervention when necessary (Topol, 2019). Additionally, AI enables precision medicine through the integration of multi-omics data to personalize therapies for specific patients (Chen *et al.,* 2020).

Progress in Analytic Approaches

The accuracy and reliability of biochemical assays have improved greatly due to modern analytical techniques. Some of the commonly employed techniques for profiling complex biological samples include high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and capillary electrophoresis (Kumar *et al.,* 2020). These technologies allow for accurate detection and quantification of metabolites, drugs and toxins, which aid in therapeutic drug monitoring and toxicological studies. Furthermore, new types of immunoassays like chemiluminescent immunoassays (CLIA) enhance the sensitivity and specificity of hormone and protein measurement (Daves *et al.,* 2018).

This concludes the overall process of quality control and standardization.

Quality control (QC) and standardization are important components of assuring laboratory result reliability. With a need for statistical frameworks to monitor assay performance and identify analytical errors, modern QC programs have emerged (Jameson & Longo, 2015). Standardized laboratory practices are recommended by international guidelines, such as the guidelines from the Clinical and Laboratory Standards Institute (CLSI), allowing for comparability of results from different laboratories (Berger & Pantel, 2021). These QC programs can be complemented by proficiency testing programs, which provide an independent assessment of laboratory performance against linearly defined external standards.

Emerging Technologies

Novel technologies such as digital health, wearable devices, and telemedicine are transforming clinical biochemistry. Wearable biosensors offer continuous monitoring of physiological parameters, such as glucose level and cardiac activity, in the management of the disease (Rajkomar *et al.,* 2019). Digital health platforms combine laboratory findings with their electronic health records (EHR) allowing better communication between healthcare providers and patients (Collins *et al.,* 2021). Moreover, telemedicine allows remote nurse consultations, tele-laboratory waste interpretation, and tele journey (Jain *et al.,* 2021).

Areas for Improvement/Future Directions

Although there have been tremendous developments, clinical biochemistry encounters problems including the high cost of cutting-edge technologies, synthesis of multi-omics information and the protection and security of data (Chen *et al.,* 2020).

Development of cost-effective diagnostic tools, improving the interoperability of laboratory systems, and the use of artificial intelligence (AI) for personalized medicine should constitute the focus of future research. In addition, addressing healthcare disparities and advancing the field requires global collaboration and knowledge sharing.

Conclusion:

As an example of such specialization, advances in clinical biochemistry have shown the potential to transform healthcare through enhanced diagnosis, efficiency, and individualization. Automated testing, point-of-care testing (POCT), molecular diagnosis, proteomics and cancer are examples of this transformation, which authorities are not afraid to supervise since they allow for early detection and proper disease control. With the advancements in technology, clinical biochemistry would become an integral part of future healthcare.

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TUBERCULOSIS: STUDY AND CURRENT STATUS IN WORLD

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Abstract:

Tuberculosis is the leading infectious disease responsible for the highest number of deaths globally, highlighting its importance as a public health challenge. The presence of multidrug-resistant bacteria has significantly hindered the effectiveness of treatment for tuberculosis patients. This chapter provides insights into the various strains of tuberculosis, their transmission dynamics, and their effects on health. A focus on the chronic stages of the disease is essential for developing effective control measures and reducing transmission, ultimately fostering better patient health outcomes.

Introduction:

Tuberculosis is an infectious disease caused by the bacterium Mycobacterium tuberculosis, primarily affecting the lungs but can also disseminate to other organs such as the brain, spine, and bloodstream in advanced cases. It is transmitted through airborne droplets, leading to a rapid spread. The primary symptom is a persistent cough, and the accumulation of sputum in the lungs can result in breathing difficulties. Fatalities from tuberculosis often occur due to chronic respiratory failure and hemoptysis, which is the coughing up of blood from the respiratory tract.

The transmission of M. tuberculosis bacilli primarily occurs through aerosol and inhalation of specific droplets. A staggering 95% of tuberculosis cases and 98% of related fatalities are reported in developing countries, highlighting its status as a significant global public health issue. The prevalence of the disease is particularly high in Southeast Asia, with China and India collectively representing approximately 40% of all TB cases worldwide (WHO, 2012). While other mycobacteria, including M. Bovis, M. Microti, M. Africanum, and M. Canetti, can also cause infections, tuberculosis remains the predominant pathogen responsible for the disease in humans. Timely detection of the disease can significantly reduce both the incidence and transmission of tuberculosis and other mycobacterial infections.[2]

Cause

Caused by Mycobacterium tuberculosis, a hazardous and potentially lethal bacterial disease that belongs to the Mycobacteriaceae family of the Actinomycetales order. This bacterium is difficult to remove due to its unique biological characteristics and complex interaction with the human immune system. [1]

Classification

Tuberculosis is classified into two types:

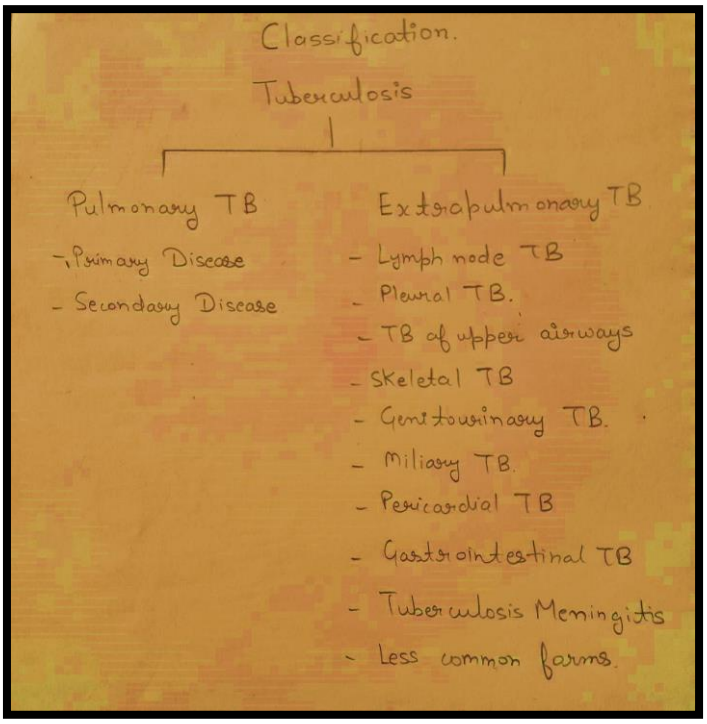

Figure 1: Flowchart showing types of Tuberculosis

Characteristics

1. **Shape:** M. tuberculosis has a characteristic rod-like shape, appearing as either straight or curved bacilli.
2. **Gram Staining:** Although classified as Gram-positive, its waxy cell wall makes it challenging to stain effectively using the Gram method.
3. **Acid-Fast Properties:** The significant presence of mycolic acid in its cell wall imparts acid-fast characteristics to M. tuberculosis, allowing it to retain certain dyes, such as carbol fuchsin, even after exposure to acidic alcohol.
4. **Oxygen Requirement:** This bacterium is aerobic, meaning it requires oxygen for survival and primarily infects the lungs.

5. **Growth Rate:** M. tuberculosis exhibits a slow growth rate, with a division time of approximately 15 to 20 hours, in contrast to bacteria that can multiply within minutes.
6. **Cell Wall Composition:** The cell wall is rich in acids, providing a waxy texture that protects the bacterium from harsh conditions and specific antibiotics.
7. **Intracellular Survival:** M. tuberculosis can evade the immune response by residing and multiplying within macrophages, which are immune cells.
8. **Environmental Resistance:** Its thick, lipid-rich cell wall grants it exceptional resistance to desiccation, disinfectants, and immune reactions.
9. **Phases of Infection:** M. tuberculosis can exist in a latent (dormant) state for years and may reactivate if the host's immune system becomes compromised.
10. **Granuloma Formation:** To contain the infection, M. tuberculosis induces the formation of granulomas—aggregates of immune cells that attempt to isolate the bacteria during infection. [2]

Pathogenesis

The bacilli enter the lungs through aerosol droplets and are engulfed by macrophages after *Mycobacterium tuberculosis* is transmitted to a new host. The formation of a granuloma, which is characteristic of tuberculosis, occurs as additional immune cells are recruited to isolate the infected macrophages. The defining feature of pulmonary tuberculosis is the granuloma, a disorganized aggregation of immune cells, particularly macrophages, that functions to contain the proliferation of the bacteria.

The virus is held at bay and remains latent in healthy individuals, but there is a chance that it could reactivate. When foamy macrophages necrotize, their lipid content is released, resulting in caseation, which is a structure like cheese.

The presence of caseum indicates decay at the center of the granuloma, which compromises its structural stability. As the granuloma progresses, bacilli start to leak from the macrophages into the caseous area. During reactivation, Mycobacterium tuberculosis proliferates, causing a dramatic rise in bacterial numbers. This surge leads to the rupture of the granuloma, dispersing the bacteria into the airways. The bacilli are then released as contagious aerosol droplets, initiating a new cycle of infection in other individuals. Inhalation is the most common route for the transmission of tuberculosis [3].

Clinical Manifestations

The following are typical clinical signs of tuberculosis (TB):

1. Coughing that doesn't go away after three weeks
2. Hemoptysis, or coughing up blood or sputum
3. The chest Pain or discomfort, particularly during coughing or breathing
4. Inexplicable Loss of Weight
5. Fever (often mild and long-lasting)
6. Sweats at night
7. Weakness and exhaustion
8. Diminished Appetite
9. Breathlessness (in more severe or advanced forms)

Current epidemiology

Most TB patients are adults at the peak of their careers. However, TB affected the people of all age groups. More than 80% of deaths occurred by TB in rural countries.

TB exists worldwide. In 2023, the WHO concluded that South-East Asia Region had rapid TB growth up to 80%, the African Region countries has up to 24%, and the Western Pacific Region countries had up to 17%. Approximately about 87% increase is observed of tuberculosis in more than 30 countries. More than two-thirds of the world's cases came from Bangladesh China, the Democratic Republic of the Congo, India, Indonesia, Nigeria, Pakistan, and the Philippines. Not even close to the WHO End TB Strategy target of zero, are the economic effects on tuberculosis patients and their families all over the world; direct medical costs, non-medical costs and indirect financial losses such as lost income. These costs amount to more than 20% of family income. Individuals with a suppressed immune system—including the elderly and smokers, those living with diabetes or HIV, or malnourished—are more likely to fall ill. In 2023 alone, undernutrition is estimated to have caused an additional 0·96 million tuberculosis cases worldwide. At 3.40 million deaths, high blood pressure was followed in the statistics by two "metabolic" conditions — diabetes (0.38 million), HIV infection (0.61 million), smoking (0.70 million) and alcohol use disorders came in closer succession at 0.75 million deaths each. [4]

Diagnosis

Sample type: Sputum, bronchial aspirate, broncho alveolar lavage.

Advanced techniques in diagnosis: Enhanced specifics of the infecting agent are obtained in Nucleic Acid Amplification Tests (NAA) as M. tuberculosis complex unique nucleic acid regions are targeted for amplification. NAA tests can also be referred to directly as "direct amplification tests" because these tests can be utilized on clinical specimens such as sputum. NAA tests may be categorized as follows: in diagnostic testing done in-house or as commercial kits. There are various commercial kits such as BD ProbeTec ET assay (Becton Dickinson Biosciences, Sparks, MD), the Amplicor MTB tests (Roche Diagnostic Systems, Branchburg, NJ) and Amplified Mycobacterium tuberculosis Direct Test MTD (Gen-Probe, Inc., San Diego, CA). The Amplicor and MTD tests have been licensed by FDA. Tests performed on a polymerase chain reaction (PCR) assay that has been developed in the laboratory are termed in-house tests and vary considerably in their construct and performance [5, 7].

Treatment

For drug sensitive TB: It was English studies in the 1940s to the 1980s that tested one of the first multidrug treatment regimens they referred to as short course chemotherapy. The so-called "short-course chemotherapy" regimen which is administered over a period of six months has also been regarded as the most effective strategy against drug-susceptible TB for over fifty years — if not more. These studies demonstrated that a majority of patients can be cured with four months of rifampicin and isoniazid with two months of intensive treatment using rifampicin, isoniazid and pyrazinamide, at the very beginning. So, pyrazinamide was included in the regimen during the intensive phase in order to limit the total treatment time from nine to six months. This "one-size-fits-all" approach for managing all types of DS-TB has now become the global standard.

For the MDR TB: A significant change in the treatment of individuals with MDR/RR-TB was brought about by the suggestion to switch from an 18–20 months course of treatment to a shorter, alloral regimen lasting 9–12 months and to discourage the use of injectables, including kanamycin and capreomycin [6].

Conclusion:

Despite significant progress in diagnosis, treatment, and prevention, tuberculosis (TB) continues to pose a serious threat. Factors such as low economic development, inadequate healthcare resources, the prevalence of HIV, and the emergence of drug-resistant bacterial strains are significant contributors to the ongoing TB crisis,

particularly in low- and middle-income countries. Recent studies suggest that the proliferation of drug-resistant TB strains, including XDR-TB and MDR-TB, can be mitigated through enhanced diagnostic methods, the development of more effective vaccines, and innovative treatment strategies. To meet global objectives for eradicating TB, it is essential to adopt a holistic approach that integrates medical, social, and economic perspectives. Increased research efforts and international collaboration are vital to transforming tuberculosis into a preventable and treatable disease worldwide, ultimately reducing its burden and facilitating its elimination.

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Section C: Physiotherapy

CORONARY ARTERY BYPASS GRAFTING (CABG): AN OVERVIEW

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Abstract:

Coronary artery bypass grafting (CABG) is a definitive surgical treatment for patients with coronary artery disease (CAD). Despite advancements in techniques like off-pump minimally invasive direct coronary artery bypass (MIDCAB) and on-pump robotic-assisted total endoscopic coronary artery bypass (TECAB), rehabilitation remains essential for recovery. This chapter examines the evaluation and surgical management of CAD and emphasizes the role of the cardiopulmonary physiotherapist in assessing and treating this condition.

Keywords: CABG, Cardiac Rehabilitation, Coronary arteries, Angina, Myocardial infarction, Coronary intervention, Cardiac revascularization

Introduction:

Coronary artery bypass grafting (CABG) is the most common type of open-thoracic surgeries that are now-a-days performed by the cardiac surgeons. It is an intervention for the blocked coronary arteries due to atheroma via harvested conduits. CABG restores the blood flow of the ischemic myocardium and restores the function, viability, and relieves anginal symptoms.[1]

Approximately 400,000 coronary artery bypass graft (CABG) surgeries are conducted annually, making it the most prevalent major surgical procedure. However, there has been a decline in surgical trends due to the rise of alternative treatments, such as medical therapy and percutaneous coronary intervention (PCI). This activity explores the indications for CABG and emphasizes the importance of an interprofessional team in managing patients with coronary artery disease (CAD).[2]

Generally, CABG can be done via two types of procedures i.e. on-pump and off-pump, with the key distinction being the use of a cardiopulmonary bypass circuit and an arrested heart during an on-pump CABG procedure. In most of the cases, left internal mammary artery (LIMA) and saphenous vein grafts (SVG) are used as a conduit, however, other conduits are often grafted such as right internal mammary artery (RIMA), and radial artery and the gastroepiploic artery. The preference of the conduits depends on the type and the location of the arteries that are occluded. Typically, left anterior descending (LAD) artery is grafted by the LIMA, and other occluded arteries are bypassed via other conduits.[3]

Anatomy and Physiology

Coronary circulation supplies the myocardium of the heart that includes the left main coronary artery (LMCA) and the right coronary artery (RCA). LMCA divides into left anterior descending (LAD) artery and the left circumflex artery (LCX). The LAD further give territories to diagonal branches (D1, D2) and the LCX gives territories to obtuse marginal branches (OM1, OM2). The RCA bifurcates into the posterior descending artery (PDA) and the marginal branches (RM1, RM2).[4]

Coronary circulation is categorized into left-dominant, right-dominant, and co-dominant systems based on the artery supplying the posterior descending artery (PDA) and interventricular septum. In a left-dominant system, the PDA is supplied by the circumflex artery. In a right-dominant system, it is supplied by the right coronary artery (RCA). Co-dominant systems have the PDA supplied by both the RCA and circumflex artery.[5]

Ischemia may occur if there is any blockage in any of the coronary arteries due to the defect in myocardial perfusion and permanent infarct or damage to the myocardium can happen if left untreated.[6]

Indications

The initial data from the 1970s that endorsed CABG were collected before the development of minimally invasive catheter-based techniques. In 2011, the American College of Cardiology (ACC) and the American Heart Association (AHA) released updated consensus guidelines outlining which patients are most likely to benefit from CABG surgery compared to PCI.[7] These guidelines serve as the standard criteria for CABG, categorized into class I and class II recommendations, as summarized below.

Class I indications for CABG

- Stenosis of the left main artery (LM) greater than 50% without a patent bypass graft (unprotected left main disease).
- Stenosis of three vessels (TVD) exceeding 70%.
- Stenosis of two vessels (DVD) greater than 70%, provided one of them is the proximal left anterior descending artery (LAD).
- For single vessel stenosis greater than 70%, either CABG or PCI may be considered if the patient experiences unacceptable angina despite optimal medical treatment.
- CABG or PCI may be options for survivors of sudden cardiac death if ventricular tachycardia is linked to a vessel with over 70% stenosis.
- If a patient needs concurrent non-coronary cardiac surgery and has a left main stenosis greater than 50% or any other vessel with 70% stenosis.

Class II indications for CABG

- CABG is preferred over PCI for complex three-vessel coronary artery disease (CAD) with a medium-risk Syntax score greater than 22 (a scoring system based on the angiographic characteristics of coronary vessels).
- In cases of multivessel stenosis exceeding 70% with an ejection fraction (EF) between 35% and 50%.
- For two-vessel disease, where neither vessel is the proximal left anterior descending artery (LAD), if there is extensive or severe ischemia (greater than 20% perfusion defect).
- For single vessel stenosis greater than 70% in the proximal LAD accompanied by significant ischemia.
- CABG is favoured over PCI for multivessel disease in diabetic patients, especially when the surgeon utilizes a left internal mammary (LIMA) graft.

Contraindications

The ACC/AHA 2011 consensus guidelines also outline situations where CABG may be harmful and is contraindicated[8], as summarized below:

- Emergency CABG in a hemodynamically stable patient with persistent angina but only a small area of viable myocardium.

- Emergency CABG following PCI that successfully re-perfuses the epicardium but not the microvascular circulation (no reflow).
- Emergency CABG after failed PCI without active ischemia or imminent occlusion.
- Patients with ventricular tachycardia and myocardial scarring but no signs of active ischemia.
- Stable ischemic heart disease with less than 70% stenosis in non-left main vessels, disease involving only the RCA or circumflex artery (CX), or maintained fractional flow reserve greater than 0.80.
- The right coronary artery (RCA) should not be grafted with an arterial graft unless the stenosis exceeds 90%.
- Patients with end-stage kidney disease and a limited life expectancy due to non-cardiac conditions.

Other significant comorbid conditions, such as liver failure, end-stage pulmonary disease, severe psychiatric impairment, and advanced malignancy, should be evaluated on an individual basis.[9]

Preparation

Patients undergoing CABG surgery, will likely have been worked up with general investigations such as complete blood count, liver function test, kidney function test, thyroid profile, urine routine and microscopy along with angiogram, electrocardiogram, echocardiogram, studies of myocardial viability, carotid doppler and peripheral doppler results.[10]

A thorough physical examination and history taking should be done to eliminate the complications of operative plan, conduit choice and prognosis.

According to ACC/AHA consensus guidelines, beta-blockers should be administered for at least 24 hours before the surgery to prevent mortality and atrial fibrillation if the ejection fraction (EF) >30%. Amiodarone can be substituted as prophylaxis for AF if beta-blockers are contraindicated.[11]

The doses for statin should focus to reduce LDL to <100mg/dL or 30% reduction from prior levels that needs to be continued indefinitely to reduce mortality, major adverse cardiac events, and stroke. If blood sugar level is higher than 180 mg/dL before surgery, an insulin infusion should be started as prophylaxis for sternal wound infection.[7]

Researches on preoperative ACE inhibitors and ARBs are mixed, however such medications should be started back as early as possible after surgery. Dual platelet therapy medications such as clopidogrel should be stopped 5 days prior to the surgery to prevent excessive bleeding. Thyroid hormone supplementation should be given to hypothyroid patients to reduce atrial fibrillation, heart failure, and gastrointestinal complications. Cardiac rehabilitation should be started preoperatively and continued indefinitely to improve the ADLs.[12]

Technique

The procedure involves revascularization from the ascending aorta or the subclavian artery through a conduit to a target downstream of coronary occlusion, thereby "bypassing" the occlusion.[13]

The choice of conduit selection depends upon the patency of the vessel that has to be harvested. Internal mammary artery being the most patent (>90% at ten years), which in >96% of people is uniquely spared of atherosclerosis. The LIMA is the most common choice; however, some surgeons prefer both right and left.[14]

The radial artery is also a high patency conduit, but due to prone to vasospasm, should not be used to bypass a lesion that is stenosed less than 70%. The radial graft also remains unfavourable if the patient's profession requires an abundant blood supply to the hand.[15]

Another commonly used conduit regardless significantly reduced short-term and long-term patency characteristics is saphenous vein. Nearly, 10 to 25% occlude at one year after CABG, and only 50 to 60% are patent at ten years. Harvesting of greater saphenous vein can be performed endoscopically or in an open fashion with continuous incision.[16,17]

Lesser data are available that recommends the use of gastroepiploic artery conduit with mixed results, with ten-year patency rates reported at 62%. Some studies show the usage of lesser saphenous vein and inferior epigastric artery as conduits.[18]

On-Pump CABG

If CABG is performed with the use of cardiopulmonary bypass, it is known as On-pump CABG (ONCAB). It is the traditional method of bypass surgery. However, the inflammation it causes can lead to kidney problems, digestive issues, and heart irregularities, prompting surgeons to seek alternative techniques.[19]

Advantages of OPCAB

- Results in more thorough revascularization.
- Promotes greater formation of distal anastomoses.
- Is preferred in emergency cases.
- Most surgeons are experienced with this type of CABG.

Off-pump CABG

In off-pump CABG (OFCAB), the heart continues to beat while the surgeon grafts a blood vessel onto the blocked coronary artery. Unlike on-pump CABG, this procedure doesn't require a cardiopulmonary bypass machine.[20] These techniques were originally pioneered for the avoidance of the inflammatory side effects of cardiopulmonary bypass, renal failure, neurocognitive depression, bleeding, and the stroke risk of aortic cannulation. However, the overall outcomes do not show any significant difference in both the types of surgeries.[21,22]

Advantages of OFCAB

- Lower morbidity and mortality rates.
- Linked to reduced levels of post-CABG inflammatory cytokines.
- Decreases the risk of post-surgical cerebral microemboli.
- Recommended for high-risk patients and those with severe atherosclerotic aortic disease.
- Preferred for patients over 75 years old

Complications

Although CABG offers long-term mortality benefits for eligible patients, it carries an initial operative mortality risk. The FREEDOM and SYNTAX trials report rates of 1.7% and 3.5%. One-year mortality is about 6 to 8%, increasing to 11 to 23% at three years.[23,24] Factors like emergency procedures and re-explorations raise this initial risk, but by two years post-surgery, outcomes for these patients generally align with those of other CABG patients.[25,26]

CABG can lead to cardiac complications, including myocardial infarction and initial low cardiac output states, which may necessitate inotropes or intra-aortic balloon pump support to maintain systolic pressures above 90 mmHg. Post-operative atrial fibrillation occurs in 20 to 50% of patients and is lethal, increasing mortality threefold and the risk of disabling stroke fourfold, prompting recommendations for pharmacologic prophylaxis.[7]

Stroke is a notable risk in CABG, with an incidence of 1.4% to 3.8% and a tenfold increase in mortality. Causes include embolization from aortic cannulation and microemboli from cardiopulmonary bypass. Prevention strategies include optimal medical therapy, carotid endarterectomy when indicated, and intraoperative techniques like epiaortic ultrasound and transesophageal echocardiography (TEE) to enhance aortic cannulation.[7]

Acute kidney injury occurs in 2 to 3% of CABG patients, with about 1% requiring dialysis. This is thought to result from hypoperfusion, inflammatory responses from cardiopulmonary bypass, and low hematocrit levels. Bleeding during and after CABG is common, often due to anticoagulation for bypass. Transfusions, while necessary, can lead to myocardial depression and increased mortality risk.[27]

Sternal wound complications are a significant concern in CABG patients, with superficial wounds occurring in 2 to 6% and deeper wounds in 0.5 to 5%, increasing mortality risk by 10 to 47%. This is partly due to the loss of blood flow from internal mammary artery branches during harvesting. Patients with diabetes are especially vulnerable to healing issues, highlighting the need for effective perioperative glycemic control.[28]

Pre-Operative Physiotherapy Assessment

Demographic Data

Name

Age/Sex

Address

Contact number

Occupation

Handedness

Height

Weight

BMI

Chief Complaints

Medical History

Surgical History

Personal History

On Observation

Build

Posture

Gait

Deformity

Edema

On Palpation

Tenderness

Edema

On Examination

HR

SPO2

RR

BP

Temp

GCS:

ROM:

MMT:

VAS:

Respiratory Examination

Chest wall appearance: Pectus carinatum / Pectus excavatum / Kyphosis / Scoliosis / Normal

Breathing pattern

H/O cough or sputum

Resp holds

Cough effort

Chest expansion

Diaphragmatic strength

Spirometer

Auscultation

PFT values

Ambulatory Status

Good/Fair/Poor

No. of stair climbed

Sit to stand test

6 MWT

SPPB test score

Use of walking aids

RPE score

NYHA score

Investigations:

HBA1C

CBC

LFT

KFT

Urine R/M

Thyroid profile

ECHO

ECG

CAG

Cardiac biomarkers

Viral markers

Any other investigations

Previous Medications

PT Advice:

1. Pre-op counselling
2. Post-op exercises demonstration
3. Patient's education
4. Post-op precautions

Post Operative Physiotherapy Assessment

Demographic Data (Name/Age/Sex)

Surgical Data

Type of Surgery (On-pump CABG/Off-pump CABG/MIDCAB/TECAB)

POD

Graft Taken

Bed Side Chart Reading

HR

Heart rhythm

SPO2

RR

Mode of ventilation

BP (Invasive BP/Non-invasive BP)

Temperature

GCS

VAS

Investigations

Hb (if <8, careful while ambulating)

ECHO

ABG

Any other Investigations

Sputum (color, frequency, quantity)

On Observation

Patient's appearance/Posture/Positioning in bed

Effect on SOB while moving in bed/talking

Breathing pattern

Signs of distress

Audible wheeze

Chest shape (kyphosis/scoliosis/pectus excavatum/pectus carinatum/barrel chest/Normal)

Calf check (redness, warmth)

CVP

Central Lines

PICC lines

Arterial lines (Radial or Femoral)

Drains (Mediastinal/Pleural)

Any mechanical devices (ECMO/IABP/LVAD/TPI/CRRT/MHD)

Infusion medications

Examination

Type of incision

Length of incision

Chest expansion

Chest Percussion (Hyper resonant/Dull)

Vocal Fermitus

ROM

Edema

Spirometer reading

Chest X-ray Finding

Auscultation

Cough effort

Borg scale

Post Operative Physiotherapy Management

The cardiac rehabilitation (CR) starts generally pre-operatively and otherwise known by pre-habilitation delivered in the presence of a rehabilitation specialist or a cardiopulmonary physical therapist where the patient is worked up for the surgery.[29] When the patient is received in the CTVS-ICU or post-op ICU, the patient is expected to be medically sedated and paralyzed, and kept on ventilator with the most passive mode. Moreover, inotropes are continuously infused to keep the patient hemodynamically stable.[30]

ICU Phase (Pre-extubation)

CR Phase-I starts as soon as the patient comes out of the operation theatre. When the patient is still on the ventilator, the physical therapist starts the rehabilitation by maintaining the bronchial hygiene and triggering the breath on the ventilator. Once the patient starts triggering the breath on regular interval, the ventilator mode is changed to the assistive mode. The physical therapist gradually wean-off the patient from the ventilator and put the patient on T-piece or PS/CPAP trial. When the patient tolerates the T-piece and successfully completes a spontaneous breathing trial (SBT) for at least 30 minutes without getting hemodynamically unstable, extubation is done carefully and put the patient either on NIV or oxygen therapy as needed or as per requirement. Standard protocol for extubation should be followed and nebulisation should be started as per the requirement.[31]

A good ABG report including PF ratio more than 150, hemodynamically stability, low inotropic support, a good GCS score, good/fair cough reflex and chest X-ray are some of the factors that determine if the patient is ready for extubation or not.[32]

ICU Phase (Post-extubation)

After 30 minutes following extubation, the patient is started with rehabilitation session. Allow the patient to assume a semi-fowler's position as it is the most convenient and comfortable position to start the session with. Initiate with deep breathing exercises and proceed with active cycle of breathing exercises (ACBT) and incentive spirometer. Mechanical chest vibrations are choice of treatment in such patients where the cough production is too much and if the patient is not able to expectorate it out. Make the patient do huffing and coughing with splinting so that it does not cause pain at the suture site. ROM exercises are added for the limbs including both lower and upper limbs. Thoracic expansion should be added further after applying the chest binder to support the suture line at the sternal site. Once the inotropes are tapered down to a lower dose, patient should be made to sit bed side in dangled position or on a bed side chair.[33]

In case of any mechanical heart/lung devices such as an intra-aortic balloon pump (IABP) or an extracorporeal membranous oxygenation (ECMO), the limb should be avoided to move where the cannula is inserted as it has the tendency to kink it.[34]

Sit to stand manuever can be performed if there is no contraindication from the anaesthesia team. It will drain out the extra collected fluid in the pleural or mediastinal spaces through the surgical drain tubes. Increase the doses of incentive spirometer and taper down the oxygen support if indicated from the ABG report and peripheral oxygen saturation levels (SPO2).[29]

Step-down Phase

Generally, till POD-3, the patient is expected to be free of oxygen, inotropes, and the surgical tubes, and is shifted to the ward. Patient can be taken out for walk in the hallway with necessary monitor in the presence of his physical therapist. He can start with pedocycle but the target heart rate should not increase beyond the set level that is calculated by the physical therapist as per the patient's condition.[35]

A day before discharge, dynamic exercises for the lower limbs (generally, Dynamic quadriceps exercises) should be incorporated and stair climbing should be taught so that the patient feels more confident to climb any stair after getting discharged. Most

patients do not go for phase-II CR, hence, they should be discharged with home exercise regime, discharge instructions and ergonomic advice.[36]

Psychosocial Consideration

Pre-surgery stress levels are significantly higher than post-surgery stress levels, suggesting that the surgery may help reduce stress. Research indicates that over 80% of patients undergoing CABG experience moderate to severe anxiety.[37]

Depression is linked to the severity of cardiac procedures and underlying heart conditions. Higher rates of depression may be influenced by a lack of specialized support systems in hospitals, as well as the increased occurrence of somatic symptoms in patients undergoing these procedures. Depression levels are significantly higher before surgery compared to after, suggesting that the surgery helped reduce depressive symptoms during the first three weeks of recovery. Three weeks after surgery, when patients are discharged and return home, they often experience a faster recovery, which may contribute to an improvement in their depression levels.[38]

Anxiety is a significant concern for patients before undergoing CABG. Research suggests that the waiting period before surgery can increase anxiety levels. Additionally, being identified as a candidate for heart surgery may negatively affect patients' functional and psychological well-being. By assessing preoperative anxiety as part of the surgical preparation, nursing interventions can be designed to help reduce postoperative discomfort.[39,40]

Patient's Safety & Precautions After CABG Surgery

- Do not lift any heavy weights more than 10 pounds up to 8 weeks
- Do not bend forward or lean
- Head propped up lying in bed at least 30-40 degrees
- No side turning allowed in bed
- Limb elevation while sitting on chair
- No lower height sitting
- Limited water intake and salt restriction
- Do not touch sutures with stinky or bear hands
- Only Sponge bath allowed till further order by the surgeon
- Chest binder usage for at least 6-8 weeks
- Only western toilet seats allowed
- Do not pass stools forcefully

- Sit and rest when feel any exertion
- Monitor Vitals (Oxygen, BP, HR) regularly
- Keep a check on Sugar levels daily
- Strict diet intake as prescribed by the dietician

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EVIDENCE-BASED PRACTICE IN PHYSIOTHERAPY

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Introduction to Evidence-Based Practice

Evidence-based practice, or EBP, has become a crucial part of modern physical therapy, emphasising the use of professional expertise, patient preferences, and the best available research data to guide treatment decisions. This approach is not only scientifically validated but also ensures that physiotherapy treatments are tailored to each patient's needs, improving patient satisfaction and outcomes(Maher *et al.,* 2001). EBP is based on the systematic evaluation of research findings to determine the appropriateness, safety, and effectiveness of therapeutic techniques. By relying on solid data, physiotherapists may avoid outdated or ineffective treatments, focus on tried-and-true methods, and stay on the forefront of medical innovations. Physiotherapy's incorporation of EBP fosters critical thinking, continuous professional development, and clinical practice integration(Olsen *et al.,* 2013).

Evidence-Based Practice (EBP) in physiotherapy involves the integration of: Clinical Expertise + patient Values + Best Available Evidence = Evidence-Based Practice

- **Clinical Expertise**: The clinician's own experience and skills.
- **Patient Values**: Consideration of patient preferences, concerns, and expectations.
- **Best Available Evidence**: Utilizing the most relevant and rigorous research findings.

Importance: EBP improves patient outcomes by ensuring that clinical decisions are informed by the best evidence, enhancing the quality of care and promoting accountability

Early Practices:

● **Early 20th Century Origins:**

Manual treatments and electrotherapeutic modalities were the first forms of physiotherapy (Moseley *et al.,* 2002).

● **Scientific Inquiry's Emergence (1960s–1980s):**

As healthcare changed, scientific research and methodical approaches to assessing treatment efficacy became increasingly important.

What Constitutes Evidence(Wissing *et al.,* 2025)?

1. **Research Evidence**
    - **Clinical Trials**: Randomized controlled trials (RCTs) are considered the gold standard in research. They provide high-quality evidence by comparing interventions in a controlled environment, allowing for clear conclusions about effectiveness.
    - **Systematic Reviews and Meta-Analyses**: These synthesize findings from multiple studies to provide comprehensive insights.(Clini *et al.,* 2024) Systematic reviews evaluate the quality of the included studies, while meta-analyses statistically combine results, offering robust evidence on treatment efficacy.
    - **Cohort Studies and Case-Control Studies**: These observational studies help to understand the effects of interventions in real-world settings, though they provide lower levels of evidence compared to RCTs.
2. **Clinical Expertise**
    - This refers to the knowledge and skills that physiotherapists acquire through education, training, and experience (Nilsagård & Lohse, 2010). Clinical expertise allows practitioners to interpret research findings in the context of individual patient needs, making it essential for effective decision-making.
3. **Patient Values and Preferences**
    - Incorporating patient values is a fundamental aspect of EBP. Understanding what is important to the patient such as their goals, lifestyle, and preferences ensures that treatment plans are personalized and relevant. This aspect acknowledges that treatment adherence improves when patients are actively involved in their care.

Hierarchy of Evidence

SN	Type of evidence	Level of Evidence
1	**Systematic Reviews**:	Highest level, synthesizing multiple studies.
2	**Randomized Controlled Trials (RCTs**	Experimental studies comparing interventions.
3	**Cohort Studies**:	Observational studies following groups over time
4	**Case-Control Studies**:	Comparing individuals with a condition to those without.
5	**Expert Opinions**:	Insights from experienced clinicians, but lower in the evidence hierarchy.

The Value of Evidence in the Practice of Physiotherapy

Improving Patient Outcomes:

Clinical outcomes are enhanced by evidence-based practice. Physiotherapists can choose therapies that have been scientifically proven to be successful by using the best available data, which will improve patient satisfaction and recovery rates.

Reducing Treatment Variability

EBP contributes to care standardisation by offering evidence-based recommendations. This ensures that all patients receive high-quality care regardless of where they seek treatment by reducing differences in treatment techniques across practitioners.

Improving Professional Accountability

Accountability is fostered by evidence-based practice. By using EBP, physiotherapists may defend their treatment decisions and show that their therapies are grounded on the most recent research rather than custom or personal preference. This openness fosters confidence.

Aiding in Clinical Decision

EBP gives physiotherapists the skills they need to evaluate research critically and apply conclusions to clinical settings. This improves decision-making skills, allowing professionals to handle challenging situations and offer the best solutions.

Promoting Lifelong Education

EBP encourages a culture of ongoing education and development. Physiotherapists are encouraged to keep up with the latest findings and research, which promotes an innovative and inquisitive approach in their work.

Types of Evidence Used in Physiotherapy

Experimental Evidence

Evidence from experimental studies, particularly RCTs, is crucial for establishing causality between interventions and outcomes. For example, RCTs may demonstrate the effeciveness of a specific exercise program for patients with knee osteoarthritis.

Observational Evidence

In situations where RCTs are unfeasible or unethical, observational studies such as cohort and case-control studies offer insightful information.(Clini *et al.,* 2024) They may investigate the long-term consequences of a treatment plan in a natural environment, for example, which would advance practical knowledge.

Qualitative Evidence

By documenting patient viewpoints and experiences, qualitative research enhances our comprehension of how interventions impact quality of life. This data is essential for improving the therapeutic alliance and matching treatment to the patient's values.

Principles and Agreement Statements

Evidence-based recommendations for certain conditions are provided by clinical practice guidelines, which were created by expert panels based on systematic studies. For physiotherapists, these principles are vital tools for directing their work.

Professional Opinion

Despite being lower on the evidence ladder, consensus statements and expert opinions can be useful, particularly in new fields with a dearth of high-calibres research. For practitioners, they can offer preliminary direction and advice.

Challenges in Implementing Evidence-Based Practice

Access to Research

Limited access to academic journals and databases can hinder physiotherapists' ability to stay current with the latest evidence. Many practitioners may lack the resources needed to engage with the vast amount of literature available.

Time Constraints

Busy clinical schedules can make it challenging for physiotherapists to engage in the research process, including reading, appraising, and applying evidence to practice. This can lead to reliance on outdated practices.

Lack of Training

Not all physiotherapy programs emphasize research literacy and EBP principles, leaving graduates unprepared to critically appraise literature or implement evidence-based strategies effectively.

Resistance to Change

Some practitioners may be resistant to adopting new evidence-based approaches due to established habits or scepticism about new research findings. Changing long-standing practices requires education, training, and sometimes a cultural shift within organizations.

Strategies for Promoting Evidence-Based Practice

Education and Training

Ongoing professional development and training in EBP should be integrated into physiotherapy education and offered as part of continuing education for practicing clinicians.

Access to Resources

Institutions should provide access to research databases and journals to support physiotherapists in obtaining and applying evidence in their practice.

Collaborative Practice

Encouraging collaboration among healthcare professionals can enhance the sharing of knowledge and resources, fostering a more comprehensive approach to EBP.

Mentorship Programs

Establishing mentorship programs where experienced practitioners guide newer physiotherapists in navigating research and applying EBP can help bridge the knowledge gap.

Creating a Culture of EBP

Physiotherapist should foster a culture that values and prioritizes EBP, encouraging practitioners to seek and implement evidence while supporting research initiatives.

Need for EBP in Physiotherapy

EBP help in improving Patient Outcomes by maintain Consistency in care. It also helps in reduction to harm and reducing ineffective Practices and make treatment options cost effective for patients and improve profession development and lifelong learning for physiotherapist. EBP bridges the gap between research and practice, ensuring safe, effective, and patient-centred care while advancing the profession's reputation and impact. EBP help in the predicting the prognosis of the patients and improve the outcomes.

Critical Appraisal of Evidence About Prognosis in Physiotherapy

Prognosis refers to the forecast of the likely outcome of a condition based on clinical characteristics, interventions, and patient factors. In physiotherapy, understanding prognosis is crucial for informing treatment decisions, setting realistic goals, and advising patients about expected recovery times and outcomes. However, not all prognostic evidence is created equal. Critical appraisal of this evidence is essential to ensure that practitioners can apply the most relevant and reliable information in their clinical practice.

Key Components of Critical Appraisal

1. **Validity**: Assess whether the study measures what it claims to measure. For prognostic studies, this involves evaluating the design, sample size, and methodology.
2. **Reliability**: Examine whether the results can be replicated. A reliable study will yield consistent outcomes under similar conditions.
3. **Relevance**: Consider if the findings apply to the patient population you are treating. This includes examining the characteristics of the study participants and whether they align with your clinical population.
4. **Outcomes Measured**: Identify what outcomes the study reports. Prognostic studies should focus on clinically relevant outcomes that matter to patients.
5. **Bias and Confounding Factors**: Investigate any potential biases in study design or execution that could skew results. This includes selection bias, information bias, and confounding variables.

Steps for Critical Appraisal of Prognostic Studies

Assess Study Design:

Determine the appropriateness of the study design for the research question. Cohort studies are generally more robust for prognosis as they follow patients forward in time.

Evaluate Sample Size:

Larger sample sizes enhance the reliability of findings. Assess whether the study has a sufficient number of participants to detect meaningful differences.

Check for Representative Sample:

Evaluate whether the sample is representative of the larger population you intend to apply the findings to. Look for inclusion and exclusion criteria that may limit generalizability.

Examine Outcome Measures:

Ensure that the outcomes measured are relevant and clinically significant. For example, using functional measures or quality of life assessments is often more informative than purely clinical metrics.

Analyse Follow-Up Period:

A longer follow-up period may provide a more accurate prognosis, especially for chronic conditions. Short follow-ups may miss important long-term outcomes.

Consider Confounding Variables:

Look for adjustments made in the analysis for potential confounding factors (e.g., age, comorbidities) that could impact the prognosis.

Review Statistical Analysis:

Ensure that appropriate statistical methods are used to analyse the data. Check if confidence intervals and p-values are reported to assess the significance of the findings.

Look for Validation:

Determine if the prognostic model or findings have been validated in other populations or settings. External validation enhances the credibility of the evidence.

Application of Prognostic Evidence in Physiotherapy

Setting Realistic Goals:

Understanding prognosis allows physiotherapists to set achievable and relevant goals with their patients. For example, knowing the expected recovery timeline for a specific injury can help in planning rehabilitation.

Informed Consent:

Prognostic evidence enables practitioners to provide patients with informed choices about their treatment options, including the potential risks and benefits.

Resource Allocation:

By understanding which patients are likely to benefit from certain interventions, physiotherapists can allocate resources more effectively, prioritizing patients who are at higher risk of poor outcomes.

Tailored Interventions:

Prognostic evidence can inform the customization of rehabilitation programs. For instance, patients with a higher risk of re-injury may require more intensive monitoring and support.

Challenges in Prognostic Evidence

Variability in Patient Characteristics:

Patient factors such as age, gender, comorbidities, and lifestyle can significantly influence prognosis, complicating generalization of findings across diverse populations.

Limitations of Study Designs:

Prognostic studies often rely on observational designs that may not adequately control for confounding factors, leading to biased results.

Evolving Nature of Evidence:

Prognostic indicators may change over time as new treatments and understanding of conditions develop. Practitioners must stay updated with the latest evidence.

Overreliance on Prediction Models:

While clinical prediction rules can be helpful, they may oversimplify complex patient scenarios. Clinicians should integrate these tools with clinical judgment and individual patient factors.

Current Trends and Future Directions

Integration of Technology:

Telehealth and digital tools are expanding access to EBP, allowing physiotherapists to utilize evidence-based resources remotely.

Patient-Cantered Care:

There is a growing emphasis on involving patients in their care decisions, ensuring treatment aligns with their values and preferences.

Research Opportunities:

Encouraging students and practitioners to engage with current literature and contribute to ongoing research initiatives to further the field.

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Section D: Medical Radio-Technology

BASIC INTRODUCTION TO COMPUTED TOMOGRAPHY

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Abstract:

Tomography, derived from the Greek word "tomos" meaning "to cut," refers to the technique of creating cross-sectional images of the body. A CT scan utilizes an advanced computerized method to collect data and convert it into detailed "slices" or cross-sectional images of the body. Unlike traditional radiography, where X-rays pass through the entire patient, potentially causing blurring due to overlapping structures, CT scans provide clearer and more precise images by focusing on specific slices, allowing for better visualization of internal structures.

Introduction:

Tomo, which means to cut, section, or layer, is the root of the word tomography. It comes from the Greek word tomos, which means to cut. The CT scan uses a very advanced computerized technique to gather data and convert it into "cuts," or cross-sectional slices of the body. [1] In traditional radiography, X-rays are exposed to every part of the patient. As a result, beneath and overhanging objects blur the image of a certain structure within a patient. To get around this, the X-ray tube and film may be moved about an axis through the structure of interest during exposure in order to blur the image of the objects above and below. [2] Tomography is the process of blurring unwanted pictures by moving the X-ray tube and film. Tomography, often known as body section radiography or linear tomography, is the term used to describe slice view or sectional imaging. This imaging method creates a sectional picture of the patient parallel to the tabletop in a plane. [3]

There was limitation on how these cuts could be made with the initial scanners. Slices from all of the early scanners had axial cuts, which resembled the tree's rings as seen through a log's cut edge. Because of this, older scanning technologies were frequently referred to as computerized axial tomography, which is how the popular abbreviation "CAT scan" came to be. Options are available in more than simply the

transverse plane with newer scanning models. As a result, current CT systems no longer use the word "axial" in their names. The term computer-assisted tomography is currently represented by the former acronym, CAT. [4, 5]

A linear tomography system consists of an X-ray tube, detectors, and a stiff rod that rotates around a fixed fulcrum. The detectors move in the opposite direction when the tube moves in one orientation. The film is placed in a tray beneath the X-ray table, allowing it to move without disturbing the patient. The fulcrum is the single stationary point in the system. The tomography angle is the amplitude of the tube's journey measured in degrees. The patient's plane of interest is located at the fulcrum and is the sole one in crisp focus. All locations above and below the plane are blurry. [5]

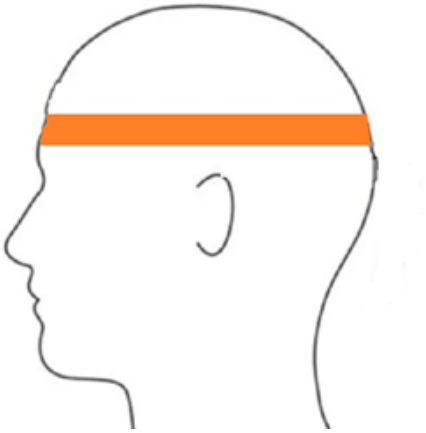


Figure 1.1: The thickness of the cross-sectional is represented as z-axis

Computed Tomography

CT is a type of tomography that uses a computer to mathematically reconstruct a plane or slice. It produces images in transaxial section, which is perpendicular to the axis of rotation of the X-ray tube. Sir Godfrey N Hounsfield developed the computed tomography scanner in 1970, originally known as computerized axial tomography (CAT). The first commercial equipment was created in 1973 to investigate the head, but eventually expanded to scan the entire body in 1975. In 1979, G. Hounsfield and Alan M Cormack received the Nobel Prize for their discovery. In 1963, Alan Cormack developed a laboratory model for image reconstruction. [2,3]

Computed tomography utilizes a computer to process information gathered from x-ray beams passing through an area of anatomy. The images generated are cross-sectional. The common analogy of a loaf of bread can help visualize CT. Imagine the patient's body as a loaf of bread, with each CT slice representing one slice. The bread

crust represents the patient's skin, while the white piece represents their interior organs. [4, 5] Only the portions of the anatomy imaged at a specific level are displayed on the individual CT slice. Parts of the lung, mediastinum, and ribs, for instance, would be visible on a scan performed at the level of the sternum, but not the kidneys or bladder. A solid understanding of anatomy is necessary for computed tomography, especially the placement of each organ in relation to the others. [6]

Each computed tomography (CT) slice defines a unique plane within the patient's anatomical framework. The dimensionality of this plane is denoted as the Z axis. The Z axis dictates the dimensional thickness of the slices. The operator selects the thickness of the slice from the options provided by the particular scanner. The selection of a specific slice thickness constrains the x-ray beam so that it penetrates solely through this designated volume; consequently, scatter radiation and the superimposition of adjacent anatomical structures are significantly reduced. The restriction of the x-ray beam in this fashion is facilitated by mechanical apparatus resembling small shutters, known as collimators, which adjusts the opening in accordance with the operator's predetermined selection. [6, 7]

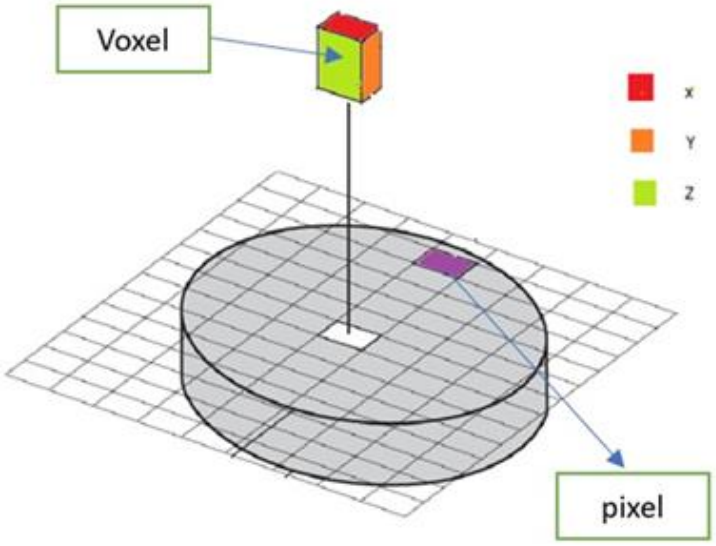


Figure 1.2 Data shown in sectional elements

The data constituting the CT slice are further sections into discrete elements: the width is represented by X, while the height is represented by Y (Fig. 1.2). Each of these two-dimensional squares is classified as a pixel (picture element). A collection of thousands of pixels unites to produce the CT image that is portrayed on the CT monitor. When the Z axis is incorporated into consideration, the resultant structure is a cube

rather than a mere square. This three-dimensional entity is referred to as a voxel (volume element). [7]

A matrix represents the grid constructed from the rows and columns of pixels. In the context of CT imaging, the most prevalent matrix size is 512. This dimension corresponds to 512 rows of pixels extending vertically and 512 columns of pixels extending horizontally. The total number of pixels within a matrix is determined by the product of the count of rows and the count of columns, resulting in 512 × 512 (262,144). Given that the external perimeter of the square remains invariant, an increased matrix size (for instance, 1,024 in contrast to 512) will encompass smaller individual pixels. Each pixel conveys information that the system gathers throughout the scanning operation [7, 8, 9].

Beam attenuation

The anatomical structures depicted in a computed tomography (CT) image are illustrated through a spectrum of gray shades (fig 1.3). The genesis of these gray shades is predicated upon fundamental principles of radiation. An x-ray beam comprises bundles of energy referred to as photons. [8] These photons may either traverse through or be redirected (i.e., scattered) by a particular structure. An alternative consideration is that the photons could be absorbed by a particular structure to differing extents, dependent on the intensity (mean photon energy) of the x-ray beam and the inherent properties of the structure encountered. The extent to which a beam is attenuated is a phenomenon commonly characterized as attenuation [2-8].

In traditional film-screen radiography, the x-ray beam penetrates the patient's body and subsequently exposes the photographic film. Similarly, in computed tomography (CT) imaging, the x-ray beam penetrates the patient's anatomical structures and is subsequently captured by detectors. The computational system then processes this data to construct the CT image. In both modalities, the quantity of x-ray photons that successfully penetrate the body dictates the corresponding gray shades represented in the image [7-9].

Conventionally, x-ray photons that pass through objects without obstruction are depicted as a black region on the image. These regions are habitually referred to as exhibiting low attenuation. In stark contrast, an x-ray beam that is entirely absorbed by an object remains undetectable; the corresponding area on the image appears white. [8] An object with a pronounced capacity to absorb a significant portion of the x-ray beam

is typically classified as exhibiting high attenuation. Regions of intermediate attenuation are illustrated by a range of gray shades.[9, 10]

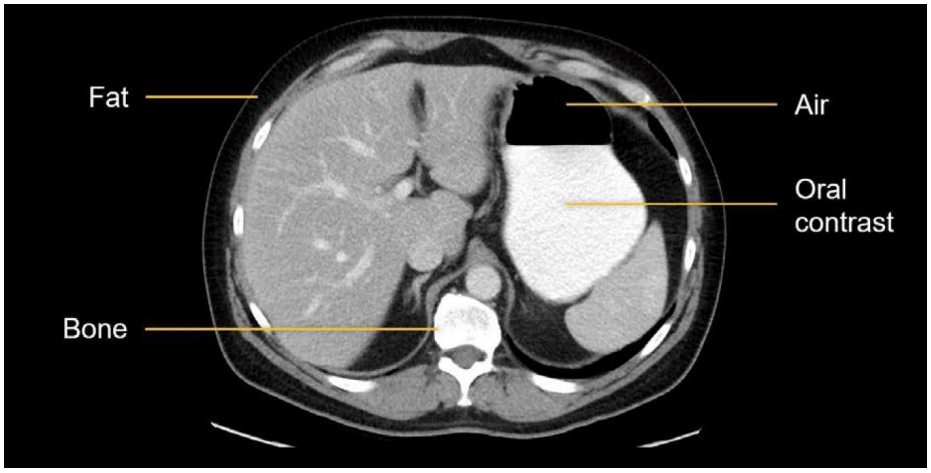


Figure 1.3: Cross sectional image of abdomen showing different shades according to the densities and degree of attenuation.

The quantity of photons that engage with a given object is influenced by the thickness, density, and atomic number of that object. Density is defined as the mass of a substance per unit volume. More succinctly, density can be characterized as the extent to which matter is compacted or concentrated. [10] For instance, a densely packed snowball possesses a greater density than one that is loosely formed. Dense elements, characterized by a high atomic number, contain numerous circulating electrons and substantial nuclei, thereby providing enhanced opportunities for photon interaction compared to elements of lower density. [11]

To gain a deeper understanding of how these physical attributes of an object influence the degree of beam attenuation, one may visualize a singular x-ray photon traversing through an object. The greater the number of atoms in its trajectory (reflecting the object's thickness and density), the heightened probability that an atom within the object will interact with the photon. Similarly, the larger the number of electrons, neutrons, and protons within each atom, the greater the likelihood of photon interaction. Consequently, the incidence of interacting photons escalates with the density, thickness, and atomic number of the object. [4-7]

The extent of the x-ray beam that is scattered or absorbed per unit thickness of the absorber is quantitatively represented by the linear attenuation coefficient, denoted by the Greek letter μ. The linear attenuation coefficient for water, for instance, is roughly 0.18 cm−1 when a 125 kVp x-ray beam is used (the unit cm−1 signifies per

centimetre). This indicates that when the x-ray beam travels through 1 centimetre of water, roughly 18% of the photons are either absorbed or dispersed. [11, 12]

Generations of Computed Tomography

Numerous computed tomography (CT) designs have been thoughtfully crafted to support the gathering of X-ray transmission data intended for image reconstruction. These geometries are frequently referred to as generations. The primary aims of the various generations are (i) the reduction of scanning time and (ii) the simplification of mechanical motion.

1. **First Generation**

The initial generation of CT scanners operates on a rotate/translate mechanism, employing a pencil beam system. This system incorporated two X-ray detectors and utilized parallel ray geometry with sodium iodide (NaI) detectors (Fig 1.4). It underwent linear translation to capture 160 rays across a 24 cm field of view (FOV) and was rotated between translations to obtain 180 projections at 1° intervals. The scanning process required approximately 4.5 minutes per scan, with an additional 1.5 minutes necessary for the reconstruction of a slice utilizing linear measurements totalling 28,800 rays (160 × 180). A significant deviation in signal arises due to the intensified X-ray flux surrounding the cranial region; therefore, the patient's head is positioned against a flexible membrane enveloped in a water bath. The signal from the NaI detector exhibited a protracted decay, thereby influencing the accuracy of measurements. A notable advantage of this system is its superior efficacy in scatter reduction, which remains unparalleled among all generations of scanners. [13, 14]

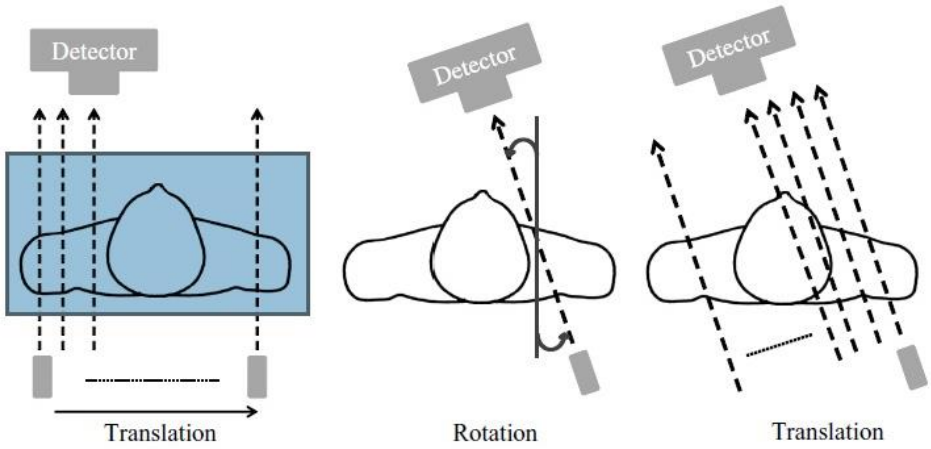


Figure 1.4: First Generation CT showing translate rotate motion with pencil beam geometry

2. Second Generation

The second generation of CT scanners also employs a rotate/translate configuration (Fig 1.5), characterized by a narrow beam geometry (10°). A linear array comprising 30 detectors was utilized to capture an increased volume of data, thereby enhancing image quality (600 rays × 540 views = 324,000). These scanners facilitated larger rotational increments and expedited the scanning process, achieving a minimum scan time of 18 seconds per slice. [15] The utilization of a narrow fan beam enables the detection of a greater amount of scattered radiation.

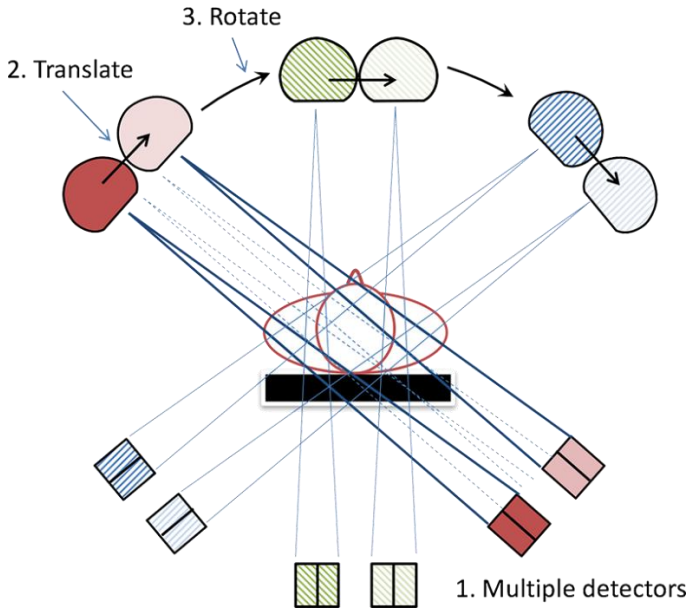


Figure 1.5: 2ND Generation CT showing translate rotate motion with multiple detectors

3. Third Generation

The third generation of scanners adopts a rotate/rotate configuration, featuring a wide beam geometry (Fig.1.6). The number of detectors has experienced a substantial increase, exceeding 800 detectors, and the angle of the fan beam has been augmented to encompass the entirety of the patient. This configuration obviates the necessity for translational motion. The X-ray tube and detector array are mechanically coupled, rotating in unison. Contemporary systems achieve scanning times on the order of less than 0.5 seconds. The third generation scanners engender a scenario in which each detector is accountable for the data corresponding to a ring within the image. Any drift in the signal levels of the detectors over time adversely impacts the attenuation coefficients (μt values) that are back-projected to generate the CT image, thereby resulting in the manifestation of ring artifacts.[5, 15, 16]

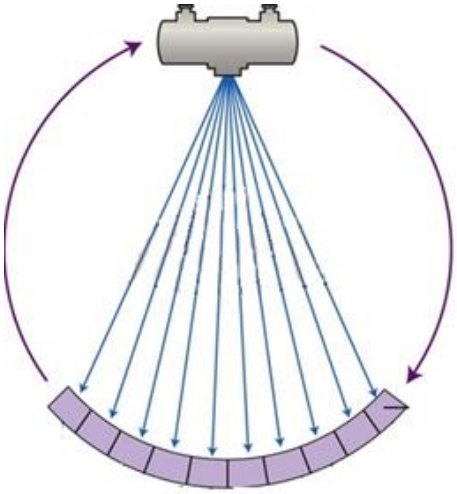


Figure 1.6: 3rd Generation CT- rotate-rotate configuration

4. Fourth Generation

The fourth generation of scanners has been specifically devised to mitigate the occurrence of ring artifacts. This generation features a stationary ring composed of approximately 4,800 detectors, with the X-ray tube required to traverse within this detector array. The continuous rotation enables exceedingly rapid scan times. However, geometrical misalignments between the radius of the detector ring and the origin of the X-ray beam may arise. Additionally, inter-scan delay intervals are present, necessitating the X-ray tube's return to its initial position (home). [15-17] In the third generation, the fan beam geometry positions the X-ray tube as the apex of the fan, whereas in the fourth generation, the individual detector serves as the apex (Fig.1.7).

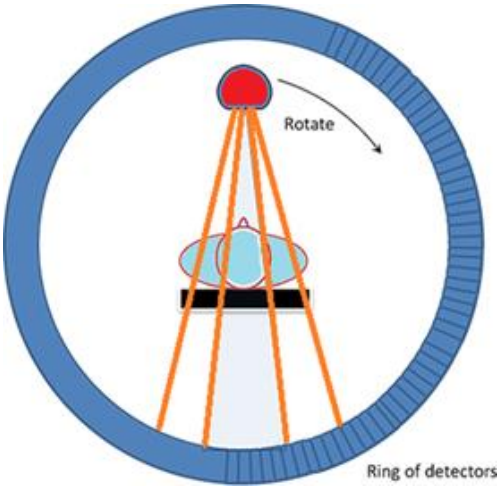


Figure 1.7: 4th Generation CT Scanner showing rotate-stationary configuration

5. Fifth Generation (Electron Beam Computed Tomography-EBCT).

The fifth-generation scanner was created especially for cardiac tomography imaging and is a stationary/stationary equipment. Instead of using a traditional X-ray tube, the patient is surrounded by a huge tungsten arc (210°) that is positioned directly across from the detector ring (fig 1.8). A fast-moving electron beam is deflected and focused along a tungsten target ring in the gantry by use of an electron gun. Multiple image portions can be acquired simultaneously because the detector is likewise shaped like a ring. [18] The pictures can create fast frame rate CT movies of the beating heart with minimal motion artifacts because they are captured at 50ms intervals. The speed at which data is acquired is an advantage. [19]

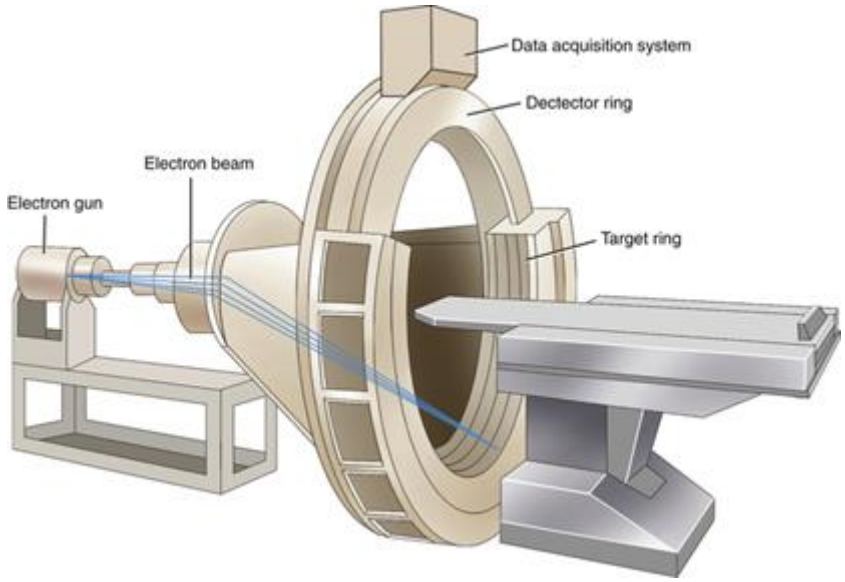


Figure 1.8: 5th Generation CT (Electron beam Computed Tomography)

6. Sixth Generation:

Sixth generation (1990) is equal to third/fourth generation plus slip ring technology and helical motion. The gantry may rotate constantly thanks to a slip ring (fig 1.9), which is a circular contact with sliding brushes. It has faster scan times, higher rotating velocities, and no inertial constraints at the conclusion of each slice. As the table moves, helical CT scanners gather data. With the exception of the time needed to translate the patient table, the overall scan time needed to image the patient can be significantly reduced. It boosts patient throughput and permits the use of less contrast agent. In certain cases, the patient might have the full scan done while being held at breath. It is possible to approximate the acquisition of planar reconstruction data by interpolating raw data from helical scans. [14-18]

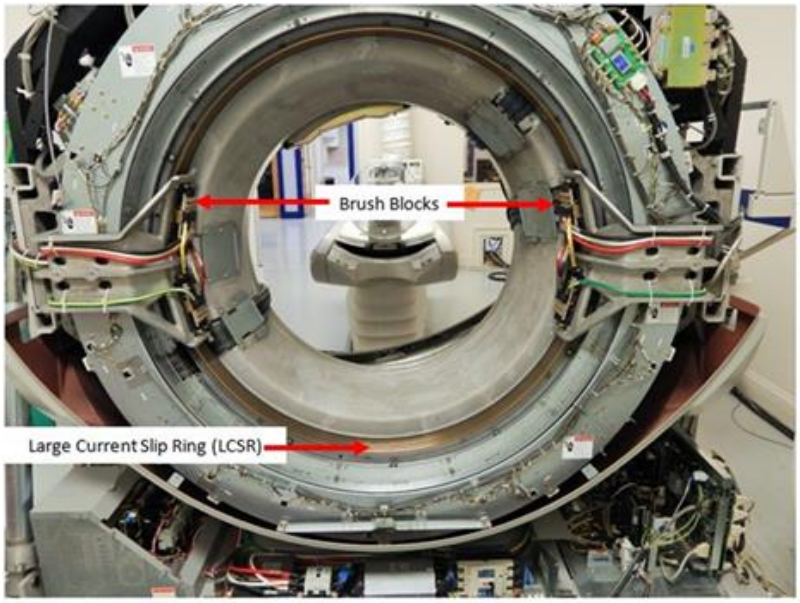


Figure 1.9: Slip Ring Technology used in 6th Generation CT Scanners.

7. Seventh Generation:

The seventh generation produces image data using a multidetector array (MDA), a bigger collimator spacing, and more X-rays (fig 2.0). In a single array scanner, opening the collimator results in a thicker slice but a worse spatial resolution in the slice thickness dimension. Therefore, rather than the collimator, the detector size controls the slice thickness. 20 mm collimator space is provided by a 4 contiguous 5 mm detector array. Four times as many X-rays were detected as with a single 5 mm array. [4, 5, 8, 11] Additionally, the same acquisition may yield slices of 10 mm, 15 mm, and 20 mm. Even if the CT acquisition methodology is more flexible, there are now more parameters. It is more effective for imaging patients; however, the detector pitch must be specified. [12]

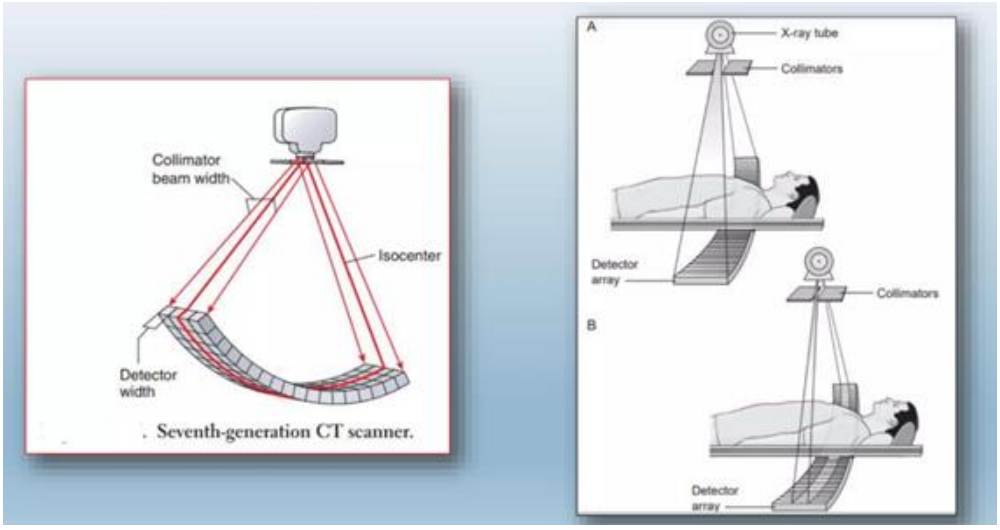


Figure 2.0: Seventh Generation CT with multiple detector array and cone beam

Image Reconstruction Techniques

Image reconstruction is a mathematical process to create an image from acquired raw data.

1. Filtered back projection (FBP) has long been recognized as the conventional reconstruction methodology since the inception of commercial computed tomography. Nonetheless, it may be regarded as antiquated due to the imperative to mitigate radiation exposure while enhancing both spatial and temporal resolution. At diminished image doses, traditional FBP tends to exhibit elevated levels of image noise.

2. Iterative reconstruction (IR) has emerged as a result of technological advancements, providing a means to diminish image noise without sacrificing image resolution, all while maintaining radiation exposure at levels that are as low as reasonably achievable. The majority of imaging scanners implement iterative reconstruction techniques for the process of image reconstruction. [19]

Computed Tomography Numbers

Each pixel is represented on the digital interface as a specific level of brightness. These brightness levels correspond to a spectrum of CT numbers ranging from −1000 to +3000 for every individual pixel. A CT number of −1000 is indicative of air, whereas a CT number of +3000 signifies dense osseous tissue. A CT number of zero is representative of water. Table 1.1 delineates the CT values associated with various biological tissues along with their corresponding x-ray linear attenuation coefficients. The exact CT number attributed to any pixel is inherently connected to the x-ray attenuation coefficient of the tissue encapsulated within the voxel. The extent of x-ray attenuation is influenced by the mean energy of the x-ray beam in conjunction with the effective atomic number of the absorbing material and is quantitatively expressed by the attenuation coefficient. [10-15, 19]

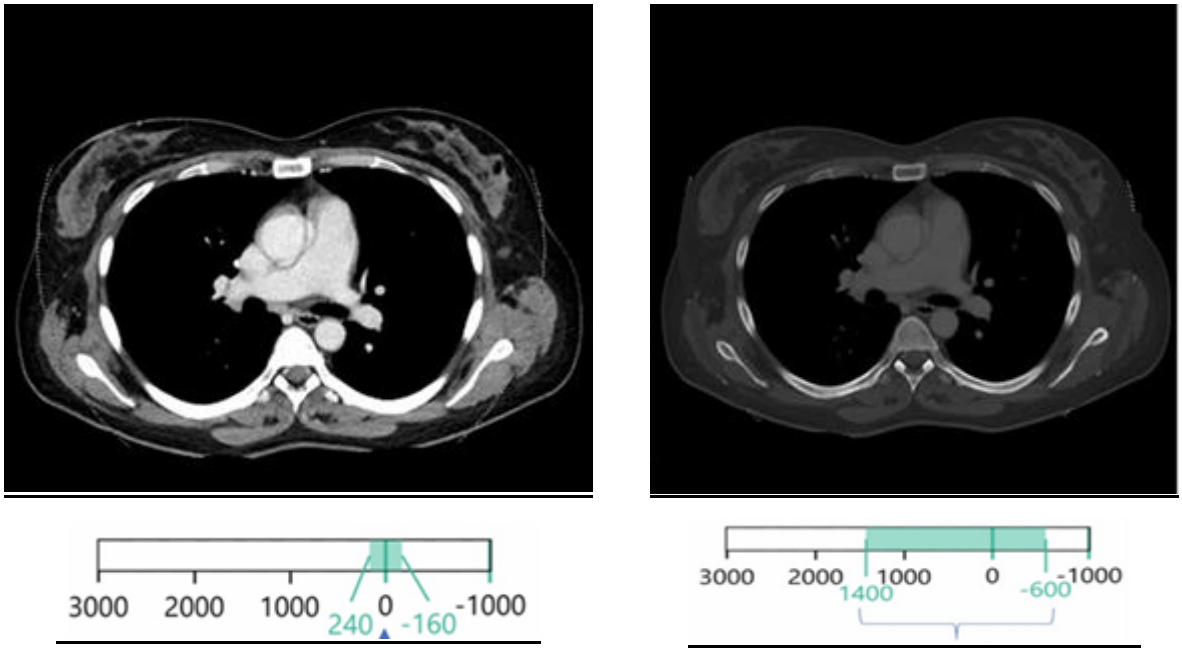
Windowing

Windowing, which is alternatively referred to as grey-level mapping, contrast stretching, histogram modification, or contrast enhancement, denotes the procedure whereby the greyscale component of a computed tomography (CT) image is systematically manipulated through the utilization of CT numbers; this manipulation effectively alters the visual representation of the image to accentuate specific anatomical structures. The luminescence of the image is modified through the

adjustment of the window level. Conversely, the contrast is calibrated via the modification of the window width. [3, 5, 7, 11, 19]

Window level: The window level represents the median value within the spectrum of CT numbers.

Window width: The window width delineates the spectrum of CT numbers that are rendered in varying shades of gray.



Soft tissue window- Window level **Bone window- Window width**

Figure 2.1: Windowing

Image Quality

The quality of screen-film radiographic images is articulated through the parameters of spatial resolution, contrast resolution, and noise. These attributes are relatively straightforward to delineate; however, they pose challenges in terms of precise measurement and quantitative expression. As CT images are composed of discrete pixel values, the characterization and quantification of image quality are somewhat more manageable. A variety of methodologies exist for assessing CT image quality, with five principal characteristics being assigned numerical values. These characteristics encompass spatial resolution, contrast resolution, noise, linearity, and uniformity. [12, 18]

Spatial Resolution

When imaging a regular geometric structure characterized by a distinct interface, the resulting image at that interface will exhibit a degree of blurring. The

extent of this blurring serves as an indicator of the spatial resolution of the imaging system and is influenced by several factors. Given that the image of the interface represents a visual interpretation of pixel values, these values may be scrutinized across the interface to derive a quantifiable measure of spatial resolution. Spatial resolution is inherently a function of pixel size: smaller pixel dimensions yield superior spatial resolution. CT imaging systems facilitate the reconstruction of images post-acquisition, followed by postprocessing operations; this represents a formidable approach to enhancing spatial resolution. [20]

Contrast Resolution

The capacity to differentiate one type of soft tissue from another, irrespective of their size or morphology, is referred to as contrast resolution. This domain is one in which multislice helical CT demonstrates exceptional performance. The attenuation of x-rays within tissue is defined by the x-ray linear attenuation coefficient. This coefficient, as previously noted, is contingent upon both the energy of the x-ray and the atomic number of the tissue in question. In the context of CT, the absorption of x-rays by the patient is additionally influenced by the mass density of the anatomical structure being examined.[19, 20]

CT Artifacts

Artifacts are one which not only degrades image quality but leads to wrong diagnosis. The typical artifacts in CT images are:

1. **Motion Artifacts:** Patient movement during CT scanning is often erratic or unpredictable (e.g., a patient's sneeze). Consequently, the image manifests the motion of objects as streaks that align with the direction of movement. The intensity of these artifacts is contingent upon the density of the moving object, with significant disparities in densities relative to the surrounding tissues resulting in more pronounced motion artifacts.
2. **Streak Artifacts:** Streak artifacts arise from the deficiency of transmitted X-rays reaching the detector, presenting as alternating dark and light lines. The origins of streak artifacts are typically attributed to high-density materials such as metallic implants, dental amalgam, and shotgun pellets, among others. The prevalence of streak artifacts escalates in conjunction with motion, and certain CT scanners are equipped with metal correction algorithms to mitigate this phenomenon.

3. **Beam Hardening Artifacts:** Beam hardening artifacts, also referred to as cupping artifacts, originate from the polychromatic nature of the X-ray beam (25–120 keV). As the beam traverses the patient, lower energy photons are absorbed, resulting in an elevation of the mean energy. This phenomenon leads to the hardening of the beam, which, in turn, results in an underestimation of the linear attenuation coefficient (μ) and Hounsfield Units (HU).
4. **Ring Artifacts:** The ring artifact is attributable to mis-calibration or the malfunction of a single detector within the rotating system of a third-generation CT scanner. The malfunction of a designated detector yields erroneous data across each projection, manifesting as a ring in the resultant image. The radius of this ring is contingent upon the specific location of the detector within the array and is virtually eliminated in contemporary CT technology. [9, 17, 18, 20]

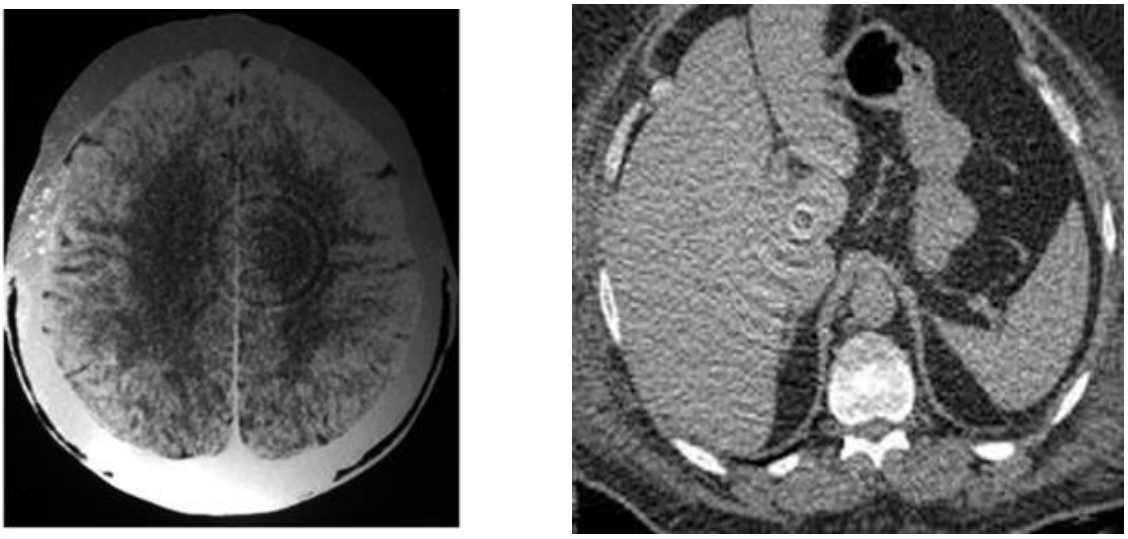


Figure 2.2: 3rd Ring artifact due to malformation of any single detector in third generation CT

5. **Partial Volume Artifacts:** The partial volume artifact arises from the averaging of the linear attenuation coefficient within a voxel that exhibits heterogeneous composition (e.g., the coexistence of bone and soft tissue). This artifact becomes more pronounced with an increase in pixel size and slice thickness, particularly affecting softly rounded structures that are oriented parallel to the CT slice. [20]

Multiple Scan Average Dose

The multislice average dose (MSAD) is quantitatively defined as the average dose, at a specified depth from the surface, resulting from an extensive series of CT

slices (FDA, USA). The estimation of MSAD is achieved through the measurement of (i) CT Dose Index and (ii) dose-length product.

CT Dose Index:

The CT dose index (CTDI) quantifies the radiation dose at either the center or peripheral point of a head or body phantom, derived from a singular scan encompassing seven CT slices in both directions. It is calculated as the integral of the axial dose profile for an individual CT slice, normalized by the slice thickness. The dose is integrated over fourteen slices utilizing a 100 mm ion chamber.

Dose Length Product:

The Computed Tomography Dose Index weighted (CTDIw) does not provide a comprehensive assessment of patient risk, as it fails to consider critical factors such as slice thickness, the total number of slices, and organ sensitivity. Consequently, a term known as the dose-length product (DLP) has been established, which incorporates the assessment of radiation risk. The equation for DLP is expressed as

$DLP = \Sigma CTDIw \times T \times N \times C,$

where N represents the number of slices, T signifies the slice thickness measured in centimeters, and C denotes the exposure measured in milliampere-seconds (mAs). DLP is directly proportional to the aggregate dose of energy administered to the patient. This metric can serve as a valuable indicator of the relative risk associated with Computed Tomography (CT) imaging procedures.[18-20]

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Mr. Harpreet Singh is the Vice Principal of the School of Health Sciences at CT University, Ludhiana, Punjab. With over 21 years of combined academic and industrial experience, Mr. Singh is dedicated to promoting academic excellence and fostering an environment of growth and innovation within the School of Health Sciences. His contributions extend to supporting faculty development, enhancing student experiences, and driving initiatives that contribute to the advancement of health sciences education. In addition to his leadership role, Mr. Singh has numerous publications to his name and holds a patent, showcasing his commitment to both research and practical applications in the field. Through his dedication to educational leadership, he plays a vital role in shaping the future of health professionals at CT University.

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