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## Chapter 21

# Applied Healthcare Science: Bridging Theory, Technology, and Public Health Practice

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## Abstract

Applied healthcare science integrates biomedical knowledge, clinical expertise, engineering systems, digital technologies, and public health strategies to improve patient care and population health outcomes. This chapter synthesizes evidence from biomedical science, healthcare informatics, digital medicine, biomedical engineering, rehabilitation sciences, and public health systems literature to explore the interdisciplinary foundations of applied healthcare science. The chapter examines evidence-based medicine, translational science, systems biology, telemedicine, health informatics, artificial intelligence (AI), and precision medicine within contemporary healthcare systems (Sackett et al., 1996; Collins, 2011).

Special emphasis is placed on healthcare scalability, healthcare equity, disease surveillance, interoperability, and digital transformation from a public health policy perspective (Institute of Medicine, 2001). Integrated figures, workflow models, and tables demonstrate the relationships between diagnostics, healthcare technologies, AI ecosystems, clinical workflows, and population health management. Ethical considerations, including data privacy, algorithmic bias, resource allocation, cybersecurity, and AI governance, are critically discussed (Rosenbaum, 2019; Emanuel et al., 2020). Future perspectives include predictive analytics, wearable technologies, robotic-assisted care, and integrated global health information systems (Topol, 2019).

Applied healthcare science ultimately represents the convergence of science, engineering, technology, and healthcare governance, enabling evidence-driven, technology-enabled, and population-centered healthcare systems.

**Keywords:** Applied Healthcare Science, Biomedical Science, Healthcare Informatics, Telemedicine, Artificial Intelligence in Healthcare, Precision Medicine.

## 1. Introduction

Healthcare systems worldwide are increasingly dependent on the integration of biomedical science, engineering technologies, digital systems, and public health policy. Applied healthcare science serves as the operational framework for translating scientific discoveries into real-world healthcare delivery (Institute of Medicine, 2001).

Unlike purely theoretical biomedical sciences, applied healthcare science emphasizes implementation, systems integration, diagnostics, rehabilitation, and healthcare management (Porter, 2010). From a public health policymaker's perspective, the challenge is not merely innovation, but the equitable scaling of innovation across healthcare systems and populations (Farmer, 2003).

**Applied healthcare science, therefore, bridges:**

- Clinical medicine
- Engineering and technology
- Public health systems
- Healthcare administration
- Population-level prevention strategies

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The integration of public health systems and clinical medicine is increasingly essential for addressing complex global healthcare challenges and strengthening healthcare resilience (Fineberg, 2012). Modern healthcare systems increasingly depend on interdisciplinary integration to support evidence-based care and population-level disease management. The rapid evolution of health technologies such as AI-assisted diagnostics, wearable monitoring systems, telemedicine platforms, and electronic health records (EHRs) has transformed healthcare delivery into an increasingly data-driven ecosystem (Topol, 2019).

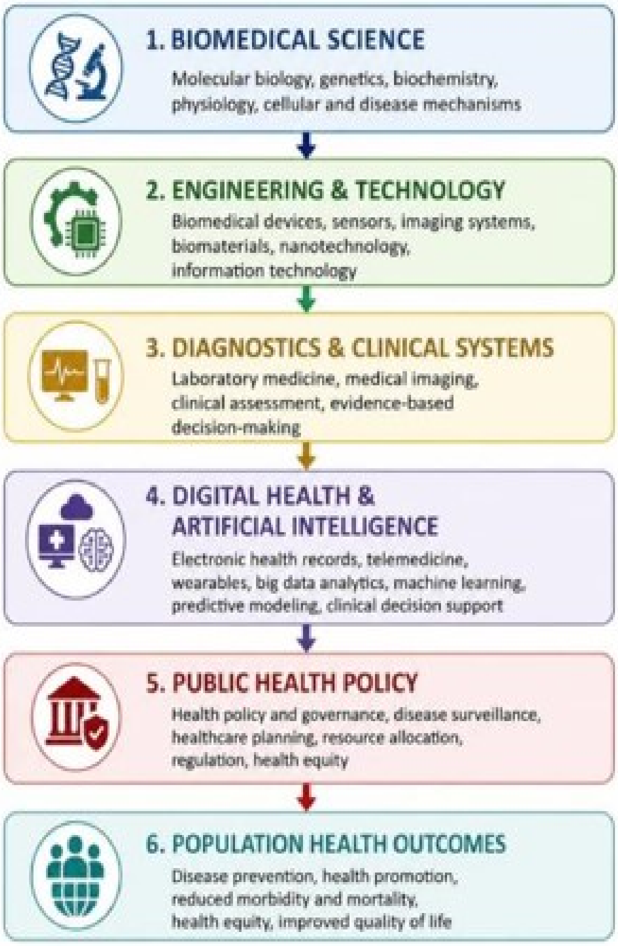

**Figure 1:** Integrated Applied Healthcare Science Framework

Figure 1 presents the conceptual framework of applied healthcare science, illustrating the integration of biomedical science, engineering systems, diagnostics, digital technologies, and public health policy into population-centered healthcare outcomes.

**Source:** Conceptual framework developed based on the Institute of Medicine (2001), Topol (2019), and Shortliffe and Cimino (2014).

## 2. Applied Health Science: Scope and Systems Integration

### 2.1. Definition and Focus

Applied healthcare science applies scientific knowledge, engineering systems, research methodologies, and digital technologies to improve patient outcomes and healthcare efficiency. It acts as a bridge between clinicians, biomedical engineers, data scientists, researchers, policymakers, and healthcare administrators (Shortliffe & Cimino, 2014).

Core objectives include:

- Disease diagnosis and monitoring
- Therapeutic intervention support
- Population health management
- Healthcare systems optimization
- Healthcare technology integration

Modern healthcare systems increasingly rely on interdisciplinary collaboration involving laboratory scientists, radiologists, rehabilitation specialists, informaticians, biomedical engineers, and epidemiologists (Frieden, 2017).

### 2.2. Core Disciplines in Applied Health Science

**Table 1:** Core Disciplines and Healthcare Applications

| Discipline | Primary Function | Public Health Contribution |
|---|---|---|
| Medical Laboratory Technology | Diagnostic testing | Disease surveillance |
| Medical Imaging | Radiological diagnostics | Early disease detection |
| Biomedical Engineering | Medical device systems | Healthcare infrastructure |
| Health Informatics | Data management | Policy planning |
| Public Health | Epidemiology | Population health |
| Nutrition Science | Dietary interventions | Chronic disease prevention |
| Rehabilitation Sciences | Functional recovery | Disability reduction |

**Note:** The table summarizes the major interdisciplinary domains of applied healthcare science and their contributions to healthcare delivery and public health systems.

**Source:** Adapted from Shortliffe and Cimino (2014), WHO (2020), and Bronzino (2015).

As shown in Table 1, applied healthcare science encompasses multiple interconnected disciplines that collectively support healthcare delivery and public health systems.

## 3. Discipline-Specific Applications

### 3.1. Medical Laboratory Technology (MLT)

Medical laboratory technology plays a central role in disease diagnosis, surveillance, and treatment monitoring. Clinical laboratory scientists analyze blood, tissue, and biological fluids using automated diagnostic systems and molecular testing platforms. (WHO, 2020)

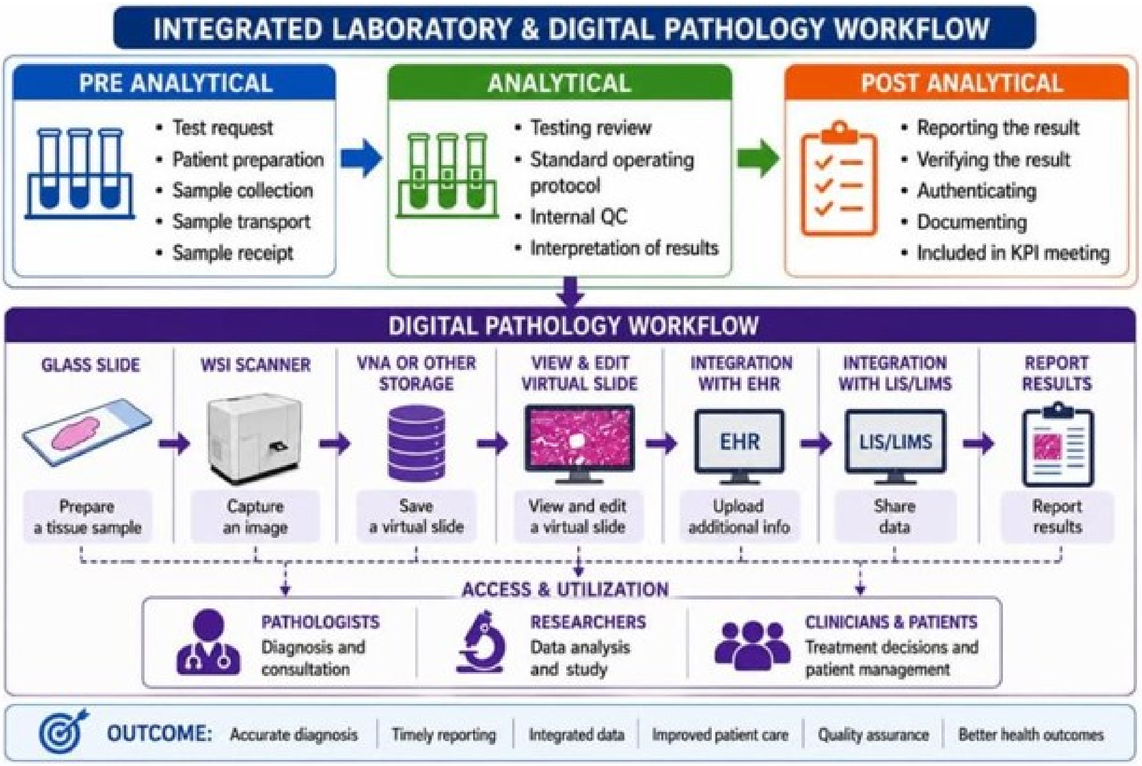

**Figure 2:** Medical Laboratory Technology Workflow

Figure 2 illustrates specimen collection, laboratory analysis, result interpretation, and reporting within integrated laboratory medicine systems.

**Source:** Adapted from WHO laboratory diagnostic frameworks and CDC infection surveillance systems (CDC, 2021; WHO, 2020).

Laboratory diagnostics form the foundation of evidence-based clinical decision-making and public health surveillance systems. The workflow of medical laboratory technology within modern healthcare systems begins with specimen collection, including blood, tissue, urine, or other biological samples, followed by transportation, preparation, and laboratory analysis using automated analyzers and molecular diagnostic platforms. Laboratory scientists interpret biochemical, hematological, microbiological, and immunological data to generate clinically actionable reports. These diagnostic outputs support evidence-based clinical decision-making and contribute to public health surveillance, infectious disease monitoring, and epidemiological investigations (CDC, 2021). The figure demonstrates how laboratory medicine forms the foundational infrastructure for accurate diagnosis, treatment planning, and healthcare quality assurance.

**Public Health Relevance**

- Infectious disease surveillance
- Pandemic response systems
- Cancer biomarker detection
- Antimicrobial resistance monitoring

## 3.2. Medical Imaging Systems

Medical imaging technologies such as radiography, CT, MRI, ultrasound, and PET scans allow non-invasive visualization of anatomical and physiological abnormalities.

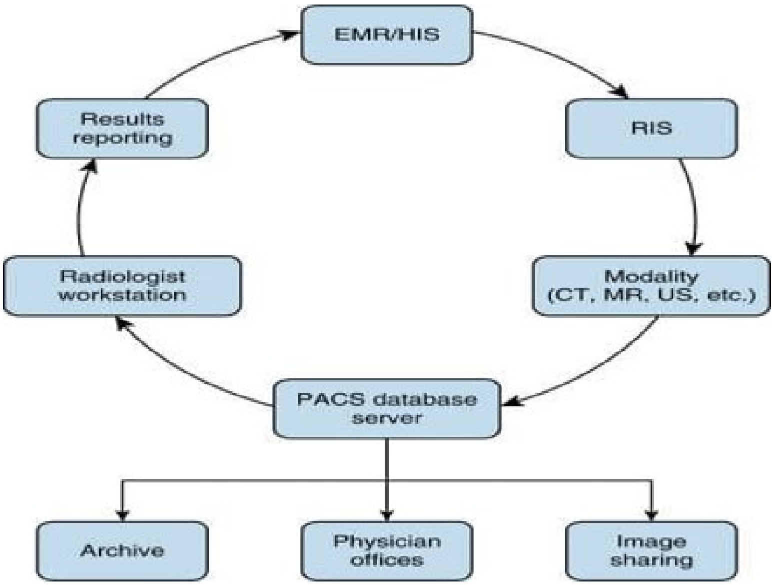

**Figure 3:** Medical Imaging and Diagnostic Workflow

Figure 3 illustrates patient imaging workflows including image acquisition, processing, interpretation, and integration into clinical decision-making systems.

**Source:** Adapted from digital radiology and diagnostic imaging workflow models described by Topol (2019) and Jameson (2018).

Imaging systems support early disease detection and precision diagnostics. Imaging modalities such as X-ray radiography, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and positron emission tomography (PET) enable non-invasive visualization of anatomical and physiological structures. The workflow begins with patient assessment and image acquisition, followed by digital image processing, interpretation by radiologists, and integration into clinical decision-making systems. Medical imaging supports early disease detection, precision diagnostics, emergency care, and population-based screening programs (Topol, 2019). The figure highlights the role of imaging technologies in improving diagnostic accuracy and reducing morbidity and mortality through timely intervention.

**Clinical and Policy Applications**

- Tuberculosis screening programs
- Cancer detection initiatives
- Trauma and emergency care systems
- Maternal and fetal health monitoring

## 3.3. Biomedical Engineering and Medical Devices

Biomedical engineering integrates engineering principles into healthcare systems through the development and maintenance of medical devices and monitoring technologies (Bronzino, 2015). Biomedical engineering applies engineering design principles and technological innovation to develop medical devices, diagnostic systems, and therapeutic technologies that support patient care (Enderle & Bronzino, 2012).

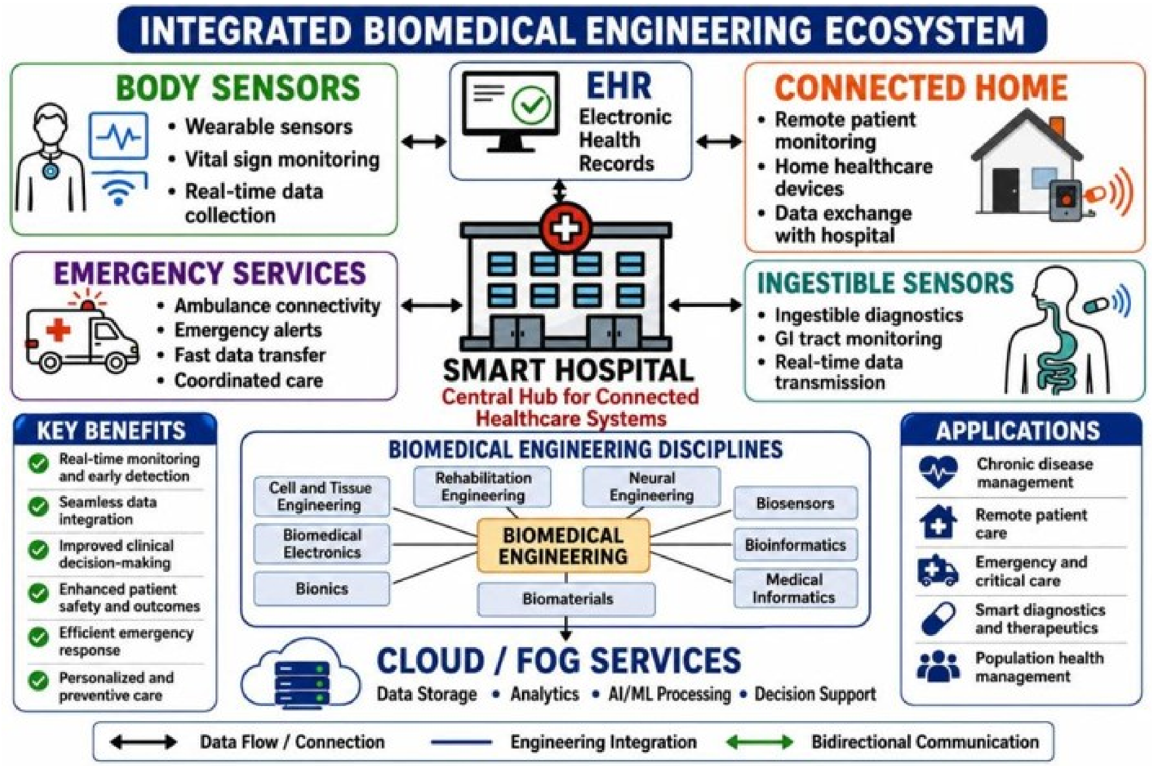

**Figure 4:** Biomedical Engineering and ICU Device Ecosystem

Figure 4 illustrates interconnected ICU technologies including ventilators, infusion pumps, dialysis systems, cardiac monitors, and centralized digital monitoring platforms.

**Source:** Adapted and digitally integrated from biomedical engineering ecosystem models and smart hospital frameworks (Bronzino, 2015; Bates et al., 2003).

Critical care environments depend on interconnected biomedical devices that continuously monitor and regulate essential physiological functions. These devices include ventilators, cardiac monitors, infusion pumps, pulse oximeters, dialysis systems, defibrillators, and bedside multiparameter monitoring systems. Data generated by these devices are transmitted in real time to centralized monitoring platforms, enabling healthcare professionals to rapidly detect physiological deterioration and initiate timely interventions (Bates et al., 2003).

The ICU device ecosystem represents the convergence of biomedical engineering, clinical medicine, and digital technologies, ensuring patient safety, precision monitoring, and advanced life-support management. From a healthcare systems perspective, the integration of smart ICU technologies improves critical care efficiency, reduces medical errors, and supports evidence-based intensive care practices.

### Applications

- Ventilator systems
- Infusion pumps
- Cardiac monitoring systems
- Artificial organ support devices

## 3.4. Artificial Intelligence Ecosystem in Biomedicine

Artificial intelligence (AI) has emerged as a transformative component of modern healthcare systems (Obermeyer & Emanuel, 2016).

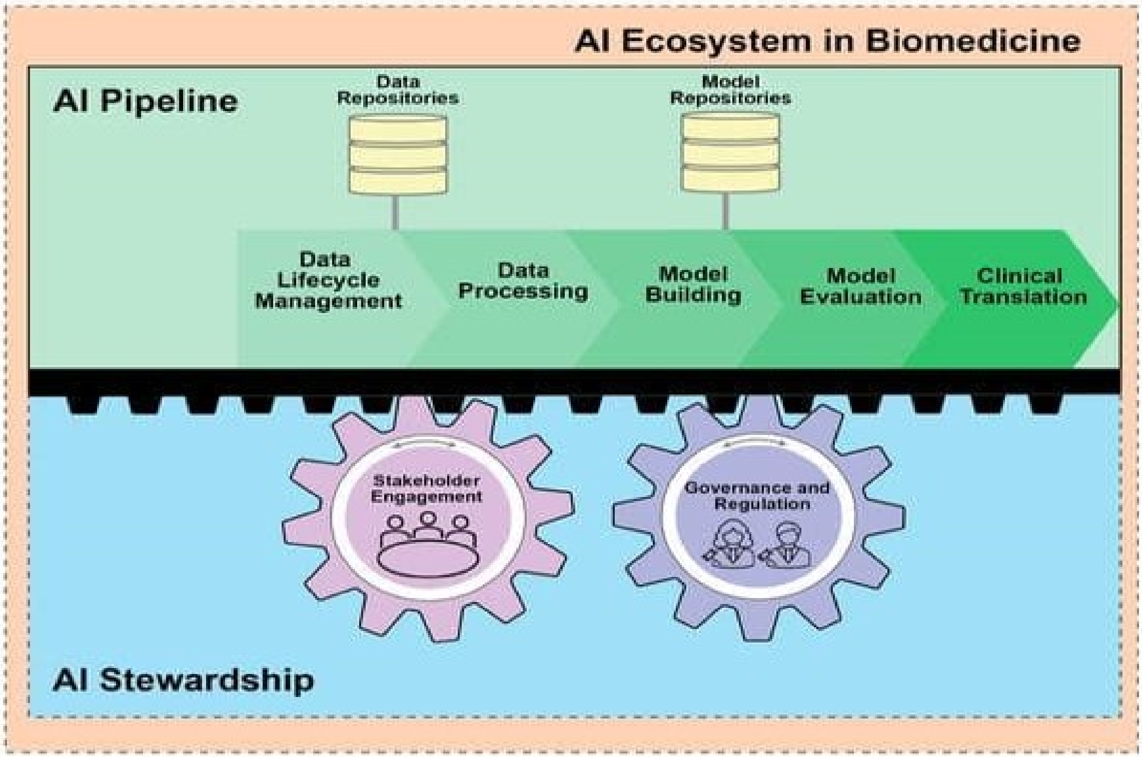

**Figure 5:** Artificial Intelligence Infrastructure in Digital Healthcare

Figure 5 illustrates the interaction of machine learning, natural language processing, electronic medical records, imaging systems, and clinical decision-support systems.

**Source** Adapted from AI-enabled healthcare informatics and digital medicine frameworks (Topol, 2019; Obermeyer & Emanuel, 2016).

AI technologies integrate machine learning algorithms, big data analytics, electronic health records, medical imaging systems, wearable devices, and clinical decision-support platforms to enhance diagnostic accuracy and healthcare efficiency. The ecosystem begins with large-scale biomedical data acquisition from laboratories, imaging systems, genomic databases, and patient monitoring devices. AI algorithms then process and analyze these datasets to identify patterns, predict disease risks, support personalized treatment planning, and automate clinical workflows (Topol, 2019). The figure highlights how AI-driven systems are transforming healthcare by enabling faster diagnostics, predictive healthcare modeling, and population-level disease surveillance while also introducing important ethical considerations related to data privacy, algorithmic bias, and clinical accountability. Deep learning systems have demonstrated diagnostic performance comparable to clinical specialists in selected medical imaging applications, particularly in image-based disease classification (Esteva et al., 2017).

**AI Applications**

- Radiological image interpretation
- Predictive analytics
- Precision medicine
- Robotic-assisted surgery
- Drug discovery

**Ethical Challenges**

- Algorithmic bias
- Data privacy concerns
- Explainability limitations
- Cybersecurity risks
- Regulatory accountability (Rosenbaum, 2019)

## 3.5. Health Informatics and Digital Health

Health informatics combines information science, computer systems, and healthcare technologies to improve healthcare delivery, clinical decision-making, and healthcare data management (Hersh, 2009). Mobile health (mHealth) technologies increasingly support real-time patient monitoring, healthcare accessibility, and digital communication between healthcare providers and patients (Agarwal et al., 2016).

**Figure 6:** Digital Health and Informatics Ecosystem

Figure 6 illustrates interconnected digital health infrastructures, including EHRs, telemedicine systems, wearable technologies, and AI-enabled healthcare analytics.

**Source** Adapted from healthcare informatics and digital health integration models (Shortliffe & Cimino, 2014; Kruse et al., 2018).

The model demonstrates how electronic health records (EHRs), wearable monitoring devices, telemedicine platforms, artificial intelligence algorithms, and health data analytics interact to create a connected healthcare environment. Data generated from patients are processed through digital infrastructures to support clinical decision-making, predictive analytics, and population health management. The figure highlights the transformative role of digital technologies in improving healthcare accessibility, efficiency, continuity of care, and evidence-based policymaking (Kruse et al., 2018). It also reflects the emergence of data-driven healthcare systems in modern public health practice.

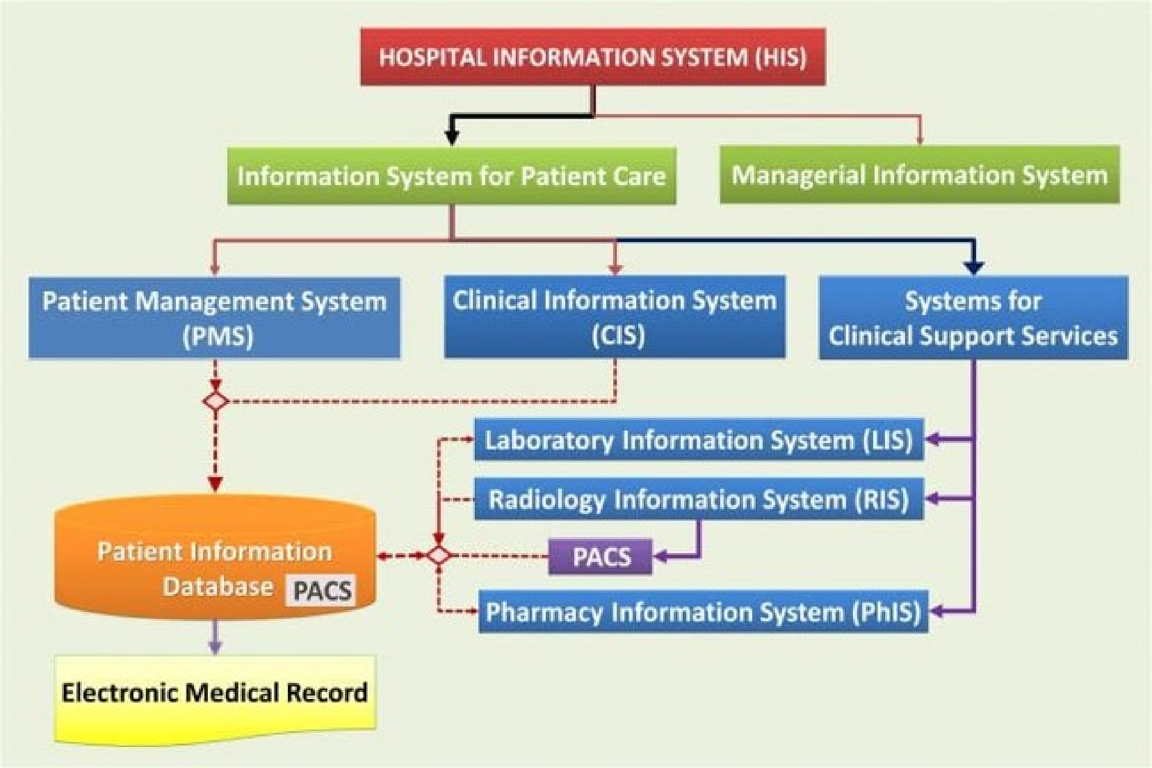

**Figure 7:** Hospital Information System (HIS) Architecture and Integrated Clinical Information Flow

Figure 7 illustrates integration between HIS, LIS, RIS, PACS, pharmacy systems, and EMR infrastructures within healthcare systems.

**Source:** Adapted from hospital information system architectures and clinical interoperability models (Bates et al., 2003).

The HIS serves as the central digital framework connecting patient management systems (PMS), clinical information systems (CIS), laboratory information systems (LIS), radiology information systems (RIS), pharmacy information systems (PhIS), and Picture Archiving and Communication Systems (PACS). These interconnected platforms facilitate the collection, storage, processing, and exchange of patient data across healthcare departments. Clinical data generated through laboratory diagnostics, radiological imaging, pharmacy services, and patient monitoring are integrated into a centralized patient information database and electronic medical record (EMR), enabling comprehensive and continuous patient care. The figure demonstrates how health informatics and digital interoperability improve clinical efficiency, reduce duplication of services, enhance diagnostic accuracy, and support evidence-based healthcare delivery (Bates et al., 2003). From a public health and policy perspective, integrated HIS frameworks strengthen healthcare governance, resource management, disease surveillance, and hospital quality assurance systems.

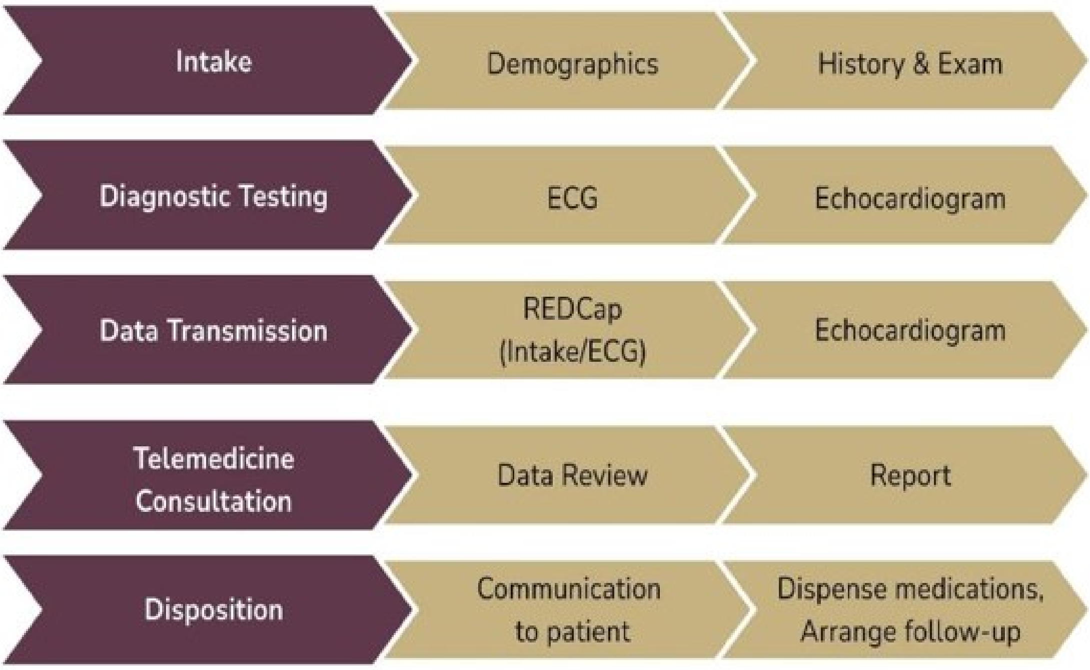

**Figure 8:** Telemedicine-Integrated Clinical Workflow and Patient Management System

Figure 8 illustrates remote patient assessment, diagnostics, teleconsultation, digital reporting, and follow-up care management systems.

**Source:** Adapted from telemedicine workflow frameworks and digital healthcare delivery systems (Kruse et al., 2018).

The workflow begins with patient intake, including demographic registration and collection of medical history and physical examination data. Diagnostic investigations such as electrocardiography (ECG) and echocardiography are subsequently performed and digitally transmitted through integrated data management platforms such as REDCap, enabling secure storage and remote accessibility of clinical information. During the telemedicine consultation phase, healthcare professionals review diagnostic findings, interpret patient data, and generate clinical reports for decision-making. The final stage involves communication of results and treatment recommendations to the patient, including medication dispensing and follow-up planning. This figure demonstrates how telemedicine systems enhance healthcare accessibility, continuity of care, and clinical efficiency, particularly in geographically remote or resource-limited settings (Kruse et al., 2018). From a public health perspective, telemedicine workflows contribute to healthcare decentralization, improved patient outreach, and reduced burden on tertiary healthcare facilities while supporting digital health transformation initiatives. Telemedicine has demonstrated significant effectiveness in chronic disease management, follow-up care, and healthcare accessibility improvement, particularly in rural and underserved populations (Wootton, 2012).

Figure 9 illustrates the integrated ecosystem of artificial intelligence (AI) in biomedicine and clinical decision-making.

**Source:** Adapted from machine learning and natural language processing frameworks in clinical medicine (Topol, 2019; Rosenbaum, 2019).

Artificial intelligence integrates machine learning, natural language processing (NLP), electronic health records, medical imaging, and biomedical datasets to support predictive analytics, clinical decision-making, and personalized healthcare. By analyzing structured and unstructured clinical information, AI systems enhance diagnostic accuracy, automate workflows, and strengthen population health surveillance while raising important considerations regarding data privacy, transparency, and ethical governance.

Digital health systems enable integrated, data-driven healthcare management (Topol, 2019).

## Applications

- Electronic health records (EHRs)
- Telemedicine systems
- AI-assisted diagnostics
- Public health analytics

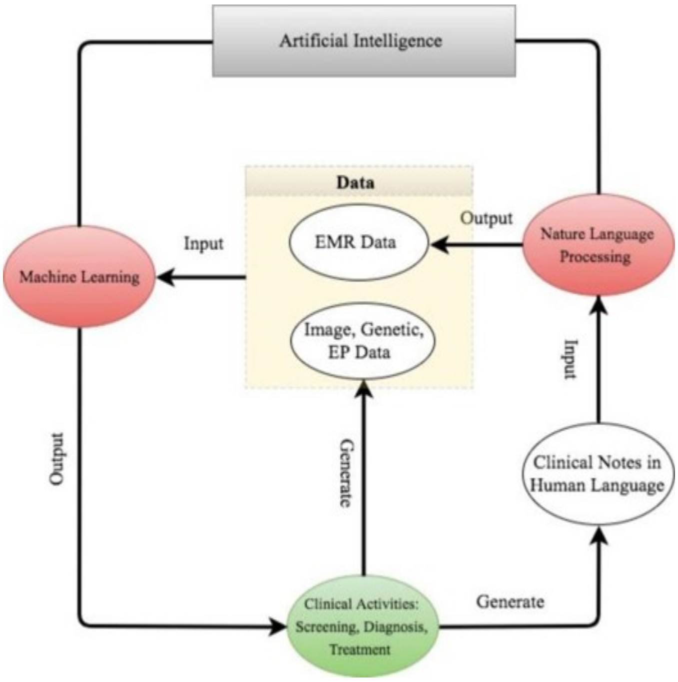

**Figure 9:** Clinical AI Decision-Support Ecosystem

### 3.6. Rehabilitation Sciences and Community Care

Rehabilitation sciences focus on restoring functional ability and improving quality of life in patients with disabilities or chronic illnesses.

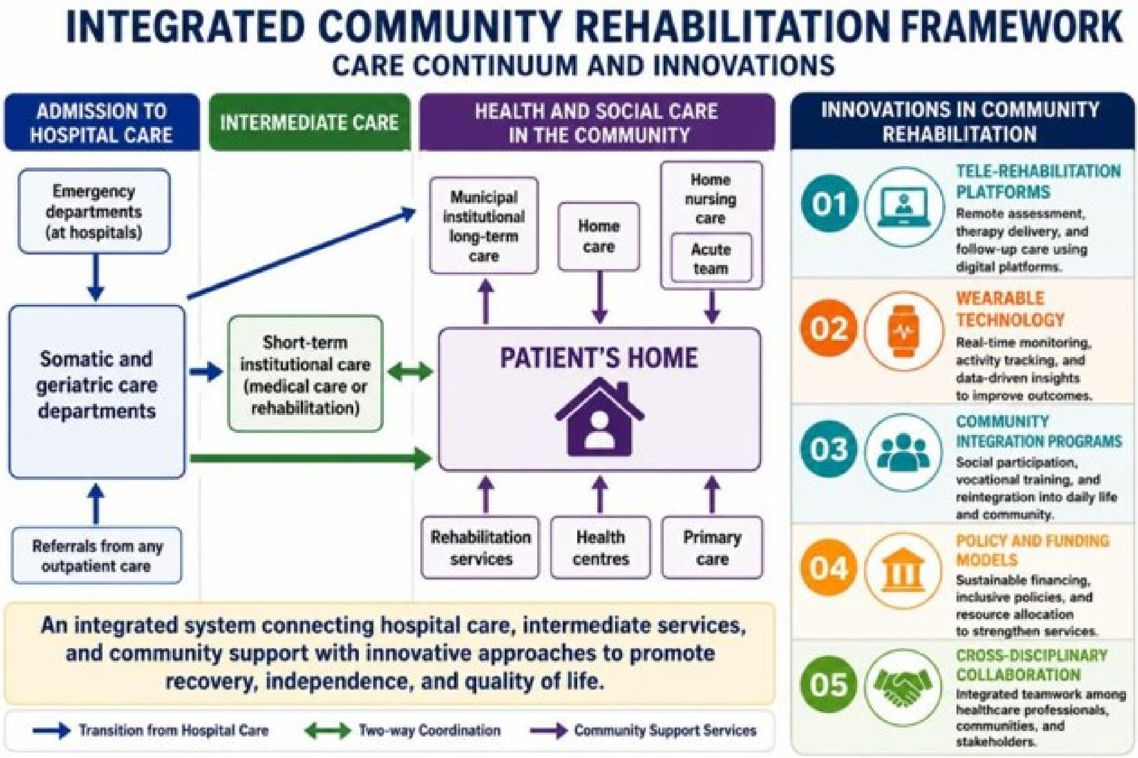

**Figure 10:** Rehabilitation and Community Care Model

Figure 10 illustrates rehabilitation pathways including hospital rehabilitation, physical therapy, occupational therapy, geriatric rehabilitation, and community reintegration.

**Source** Adapted and digitally integrated from WHO rehabilitation frameworks and community healthcare models (WHO, 2017; Stucki & Bickenbach, 2017).

Rehabilitation sciences aim to restore functional ability, independence, and quality of life in individuals affected by injury, chronic illness, disability, or aging-related conditions. The model integrates physical therapy, occupational therapy, geriatric care, neurological rehabilitation, and community reintegration programs. The figure demonstrates how rehabilitation extends beyond hospital-based treatment into long-term community support systems, emphasizing patient-centered recovery and social reintegration. It also highlights the role of rehabilitation in reducing disability burden and improving population health outcomes (Stucki & Bickenbach, 2017).

**Applications**

- Physical therapy
- Occupational therapy
- Geriatric rehabilitation
- Neurological recovery programs

# 4. Theoretical Foundations of Applied Healthcare Science

## 4.1. Evidence-Based Medicine (EBM)

Evidence-based medicine integrates scientific evidence with clinical expertise and patient preferences (Sackett et al., 1996). EBM forms the scientific foundation of applied healthcare science.

## 4.2. Translational Science

Translational science ensures that discoveries move efficiently from laboratory research into clinical practice and population health systems (Collins, 2011).

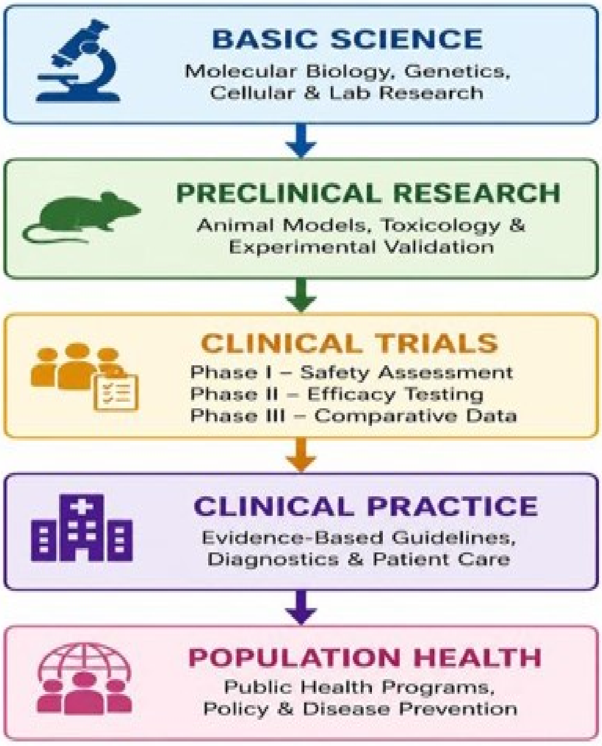

**Figure 11:** Translational Science Pipeline

Figure 11 illustrates the progression of biomedical discoveries from laboratory science to public health implementation.

**Source** Adapted from translational medicine frameworks described by Collins (2011) and Woolf (2008).

Translational medicine bridges scientific discovery and healthcare implementation. The process begins with basic scientific research involving molecular biology, genetics, and cellular studies, followed by preclinical investigations using experimental models. Clinical trials subsequently evaluate safety, efficacy, and therapeutic effectiveness before evidence-based interventions are implemented into routine clinical practice. The final stage involves translation into public health systems and policy frameworks to improve population-level outcomes. This figure highlights the critical role of translational medicine in bridging scientific innovation with practical healthcare implementation (Woolf, 2008).

## 4.3. Systems Biology and Precision Medicine

Systems biology enables predictive disease modeling and personalized treatment approaches through the integration of genomics, proteomics, and computational analytics (Hood & Friend, 2011).

Precision medicine integrates genomic information, biomarkers, and patient-specific clinical data to guide individualized therapeutic interventions (Jameson & Longo, 2015).

## 5. Clinical Decision-Making and Healthcare Workflow

Healthcare delivery relies on systematic clinical workflows integrating diagnostics, treatment planning, monitoring, and outcome evaluation.

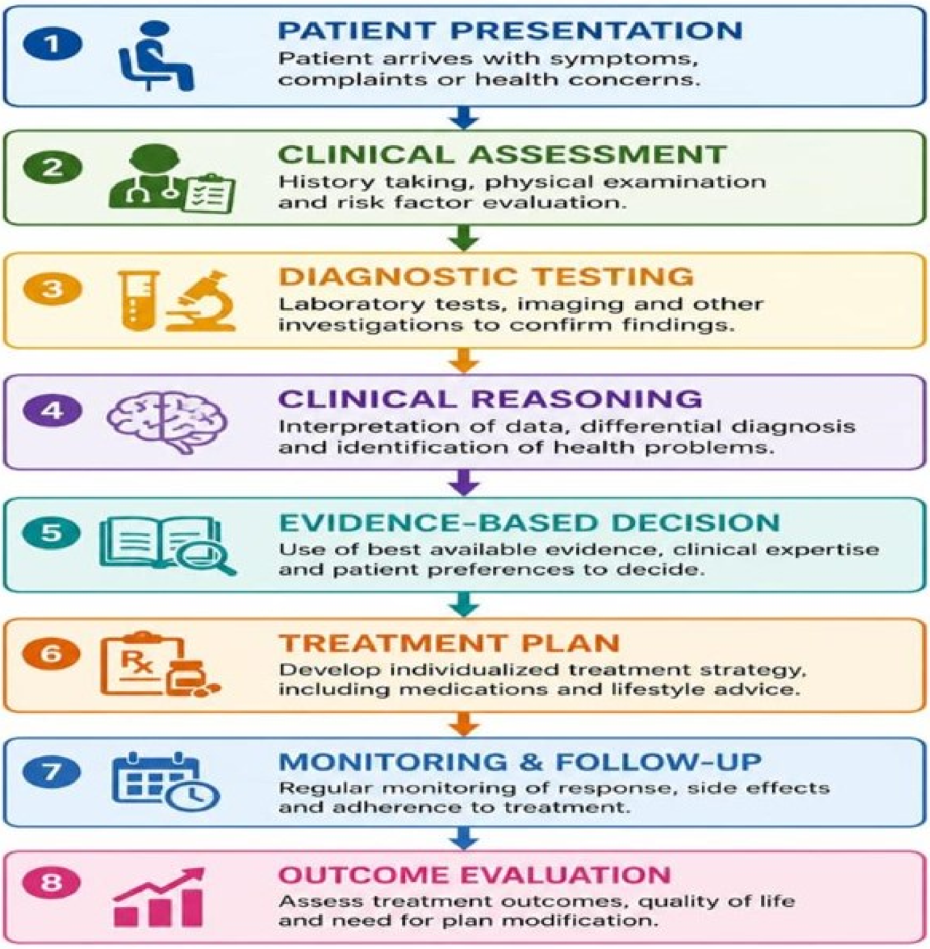

**Figure 12:** Clinical Decision-Making Workflow

Figure 12 illustrates the systematic clinical workflow involved in patient diagnosis, evidence-based decision-making, treatment planning, and healthcare outcome evaluation.

**Source:** Conceptual workflow developed based on evidence-based clinical decision-making frameworks (Sackett et al., 1996; Frieden, 2017).

The figure represents the systematic workflow involved in clinical decision-making and patient management. The process begins with patient presentation and clinical assessment, followed by diagnostic investigations, clinical reasoning, and evidence-based decision-making. Healthcare professionals then formulate individualized treatment plans, monitor patient response, and evaluate clinical outcomes. The cyclical structure of the workflow reflects continuous quality improvement and adaptive patient care. This figure demonstrates the integration of diagnostics, clinical expertise, and evidence-based medicine within healthcare delivery systems (Frieden, 2017).

## 6. Chronic Disease Management

Chronic diseases require integrated diagnostic, therapeutic, and monitoring systems.

**Table 2:** Diabetes Mellitus Management Model

| Stage | Intervention | Clinical Outcome |
|---|---|---|
| Diagnosis | HbA1c Testing | Early Detection |
| Treatment | Medication + Lifestyle | Glycemic Control |
| Monitoring | Continuous Glucose Monitoring | Reduced Complications |

**Note:** The table demonstrates an evidence-based chronic disease management framework integrating diagnostics, therapeutic interventions, and long-term patient monitoring.

**Source:** Adapted from WHO (2020) and Frieden (2017).
As demonstrated in Table 2, evidence-based monitoring significantly improves chronic disease outcomes (WHO, 2020).

## 7. Infection Control and Public Health Systems

Infection prevention remains a fundamental component of healthcare systems and public health policy.

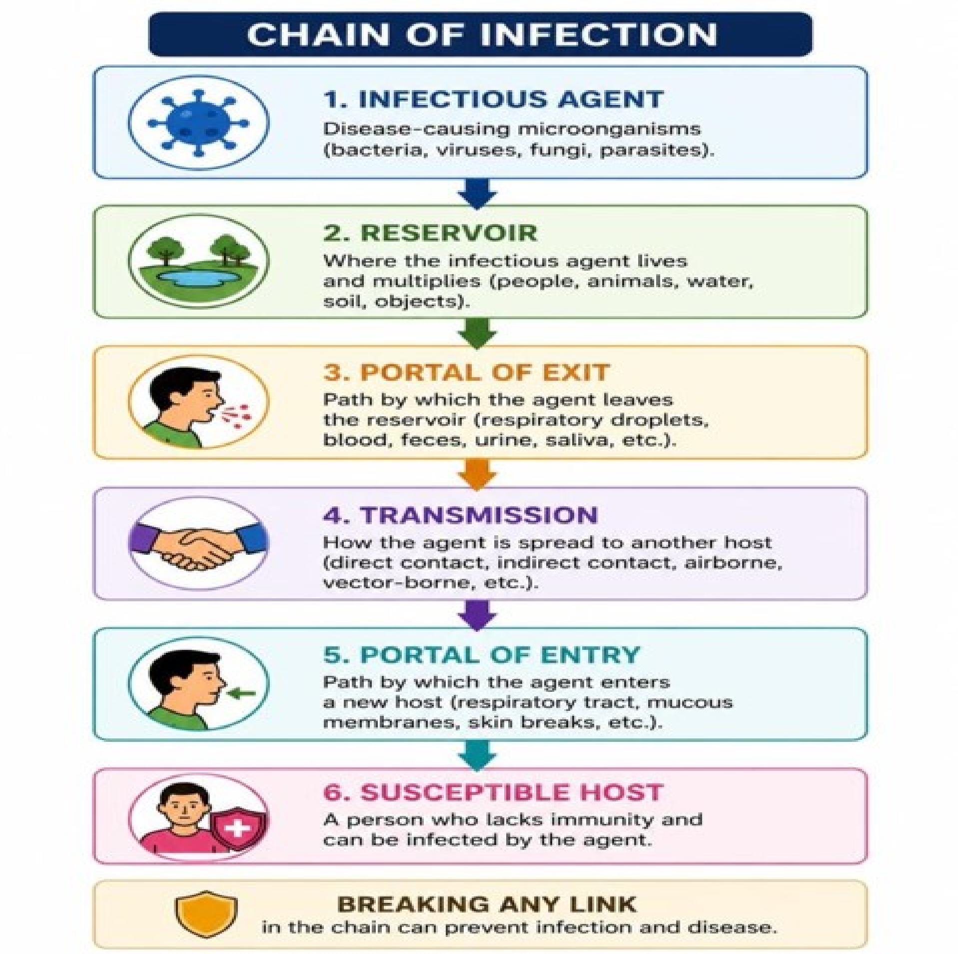

**Figure 13:** Chain of Infection Model

Figure 13 illustrates the epidemiological chain of infection and transmission pathways involved in infectious disease spread.
**Source** Adapted from CDC infection prevention and epidemiological transmission models (CDC, 2021).

Breaking the transmission chain is essential for outbreak prevention and healthcare-associated infection control (CDC, 2021). The model includes six interconnected stages: infectious agent, reservoir, portal of exit, mode of transmission, portal of entry, and susceptible host. Transmission of infectious diseases occurs when all components of the chain remain intact. Public health interventions such as hand hygiene, vaccination, sterilization, isolation procedures, and environmental sanitation aim to disrupt one or more stages within the chain, thereby preventing disease spread. The figure emphasizes the importance of infection control strategies in healthcare settings and public health systems, particularly during outbreaks and pandemics.

## 8. Challenges and Limitations

Despite technological advancements, applied healthcare science faces several limitations and implementation challenges.

**Key Challenges**

- Infrastructure disparities
- Healthcare workforce shortages
- Interoperability limitations
- High implementation costs
- Digital divide in low-resource settings
- AI governance and ethical concerns
- Cybersecurity threats
- Data privacy limitations

Resource-limited healthcare systems may experience difficulty adopting advanced technologies, highlighting the importance of equitable policy frameworks and sustainable healthcare investment (Farmer, 2003).

## 9. Ethical and Policy Challenges

Applied healthcare science raises significant ethical and policy concerns.

### Resource Allocation

Healthcare systems must balance limited resources with increasing population demands (Emanuel et al., 2020).

### Patient Autonomy

Informed consent and patient-centered care remain essential ethical principles (Beauchamp & Childress, 2019).

### Health Inequities

Socioeconomic disparities continue to affect healthcare access and outcomes globally (Farmer, 2003).

### Data Privacy

Digital health systems introduce challenges related to cybersecurity and confidentiality (Rosenbaum, 2019).

### AI Governance

AI systems require ethical oversight regarding transparency, accountability, explainability, and algorithmic fairness (Topol, 2019).

## 10. Policy Implications

Healthcare policymakers must prioritize:

- Digital infrastructure investment
- Interoperability standards
- Workforce development
- AI governance frameworks
- Cybersecurity systems
- Equitable healthcare accessibility
- Telemedicine expansion
- Integrated surveillance systems

Public health systems should integrate digital surveillance, telemedicine services, and AI-assisted healthcare analytics to strengthen healthcare resilience and preparedness (National Academies of Sciences, 2018).AI-assisted diagnostics and personalized medicine are expected to transform healthcare delivery systems worldwide (Obermeyer & Emanuel, 2016). Precision public health approaches increasingly use genomic, epidemiological, and digital health data to improve disease prevention strategies and population health management (Khoury et al., 2016).

## 11. Future Perspectives

Emerging innovations such as digital twins, blockchain-based electronic health records, quantum computing, nanomedicine, and metaverse-assisted healthcare environments are expected to further transform applied healthcare science. These technologies may enable highly personalized, predictive, and decentralized healthcare systems in the future (Topol, 2019; Obermeyer & Emanuel, 2016).

## 12. Conclusion

Applied healthcare science represents a multidisciplinary framework integrating biomedical science, engineering, digital technology, artificial intelligence, and public health systems. Through diagnostics, AI-driven analytics, telemedicine, rehabilitation sciences, and evidence-based clinical workflows, applied healthcare science strengthens healthcare delivery and population health outcomes.

**The future of healthcare will depend on:**

- Interdisciplinary collaboration
- Ethical AI integration
- Equitable healthcare accessibility
- Sustainable healthcare infrastructure
- Evidence-based public health policy

Applied healthcare science therefore, serves as a foundational pillar for modern, technology-driven, patient-centered, and population-focused healthcare systems. As healthcare systems continue to evolve, applied healthcare science will remain central to integrating biomedical innovation, digital technologies, public health systems, and patient-centered care into sustainable and equitable healthcare delivery models worldwide.

**Key Learning Points**

- Applied healthcare science integrates biomedical science, engineering, and public health.
- AI and digital health are transforming diagnostics and healthcare delivery.
- Telemedicine improves healthcare accessibility.
- Biomedical engineering strengthens critical care systems.
- Ethical governance is essential for AI-enabled healthcare.

**Table 3:** Common Abbreviations in Applied Healthcare Science

| Abbreviation | Meaning |
|---|---|
| AI | Artificial Intelligence |
| EHR | Electronic Health Record |
| ICU | Intensive Care Unit |
| HIS | Hospital Information System |
| LIS | Laboratory Information System |
| RIS | Radiology Information System |
| PACS | Picture Archiving and Communication System |
| NLP | Natural Language Processing |
| ML | Machine Learning |

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