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A TRANSDISCIPLINARY FRAMEWORK FOR EFFECTIVE AND RELIABLE CONTINUUM OF CARE

Authored by

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TABLE OF CONTENTS

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A TRANSDISCIPLINARY FRAMEWORK FOR EFFECTIVE AND RELIABLE CONTINUUM OF CARE

ABSTRACT

Global healthcare systems, with their plurality of structures and management arrangements among several unrelated organizations with various goals, information sources, and payment models, are ill-equipped to handle the complex current environment in which their patients live. External environmental shocks to human health, such as pandemics and climate events, have highlighted the need for effective tools that better identify and address health disparities and call attention to underperformance throughout the healthcare system. A Transdisciplinary Framework for a continuum of care can provide a structured approach that integrates the healthcare ecosystem, networks, technologies, enablers, and governance functions for current and future considerations. It may be customized based on local priorities, capabilities, and constraints to provide effective and reliable services across the continuum of care. The evolving healthcare landscape will likely involve a combination of AI-enhanced community-based care, outpatient services, and traditional hospital care. Healthcare systems will need to adapt and integrate these technologies thoughtfully to ensure a comprehensive and patient-centered approach across the continuum of care.

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1. INTRODUCTION TO THE CONTINUUM OF CARE

Technology plays a crucial role in addressing society's most essential needs, such as the goal of providing equitable healthcare for all. Technology innovations are changing our world through many means: pervasive computing, communications and broadband connectivity, satellites, worn sensors, Internet of Things (IoT), smart homes, data fusion, machine learning and artificial intelligence (ML/AI), edge computing, large language models (LLM), digital twins, extended/augmented reality (XR/AR), robotics, telehealth, hospital at home, accessibility, automation and much more. Smart technological innovations using human-centered and sound human factors approaches can significantly improve the quality of life.

Designing and delivering to the continuum of care aims to support citizens' wellness goals as we restore health status, avoid functional decline, promote longevity and healthy aging, and strive to optimize societal resilience. ***Continuum of care refers to the practice of providing consistent and coordinated health care for a patient over a period of time and across the spectrum of care.*** As a person's needs change over time, the continuum of care evolves and will vary based on their changing needs. It should deliver safe care, reduce overall care costs, and optimize health system performance.

In some healthcare systems, healthcare organizations are diverse, with a plurality of structures and management arrangements, and are not necessarily under one management structure. (e.g., not vertically integrated). In such cases, the continuum of care depends on formal or informal connections among several unrelated organizations with various goals, information sources, resources, and payment models. In turn, these organizations may not have a duty to collaborate or coordinate or may need (financial) incentives to collaborate for a common goal involving the patient's healthcare outcomes. Many of these organizations may use the information to limit patient movement to another care provider, as this may have an impact on revenue income or use of resources: for example, a hospital will withhold lab test reports for infection, including C-diff, hepatitis, osteomyelitis, and MRSA, to transfer a patient to a rehabilitation or nursing home facility—as the benefits of such a transfer do not accrue to the transferring provider but the receiving provider. This has further consequences when diagnosis and treatment are delayed or deferred because the patient is no longer in the facility that conducted the testing, as test results are not transferred. A common concern is that the next facility is not providing a level of care for the diagnosis. However, this is hard to verify when providers and health systems sequester patient information.

A key objective for achieving continuity of care is ensuring that information is transparent and associated implications are available to all stakeholders. Patients and their caregivers can rarely access any of the data

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during a care intervention and have no authority to alter, update, or augment any data, for example, the patient's need for durable medical equipment such as a wheelchair, trapeze, or laboratory test results from the current or prior health encounter. In some health systems, records of these tests can only be obtained through a Records Request, which can take several days. Any such delay in test results can fall outside the useful time frame for continuity of care. All information needs to be available across entities, even when a person has moved to another facility or transitioned to a different level of care in varied geographic settings. Digital health autonomy, facilitated by telehealth and digital patient navigation programs, interventions, and tools (Chan, et al. [1], Fitzpatrick [2]),[1] is a pivotal concept empowering patients to engage in information exchange, enhance care continuity processes, endorse data portability, improve the quality of collaborative datasets among providers and for clinical research, and expedite data integration response times as required.

Understanding the continuum of care requires assessing a big-picture overview of medical services. The continuum of care can encompass the changing healthcare needs throughout a patient's life or focus on a particular health condition. The term commonly describes health care that follows patients over a period of time—from preventive care to treatment for medical concerns, rehabilitation, and maintenance. Each type of service complements others throughout the continuum, making treatment more efficient and effective.

A continuum of care endeavors to knit together elements of several functional activities. FIGURE 1 illustrates the basic structure of a generic continuum of care and demonstrates the essential components, professions involved in each element, and the type of organization that might provide services in that component.

[1] Numbers in brackets correspond to references listed in Section 4.

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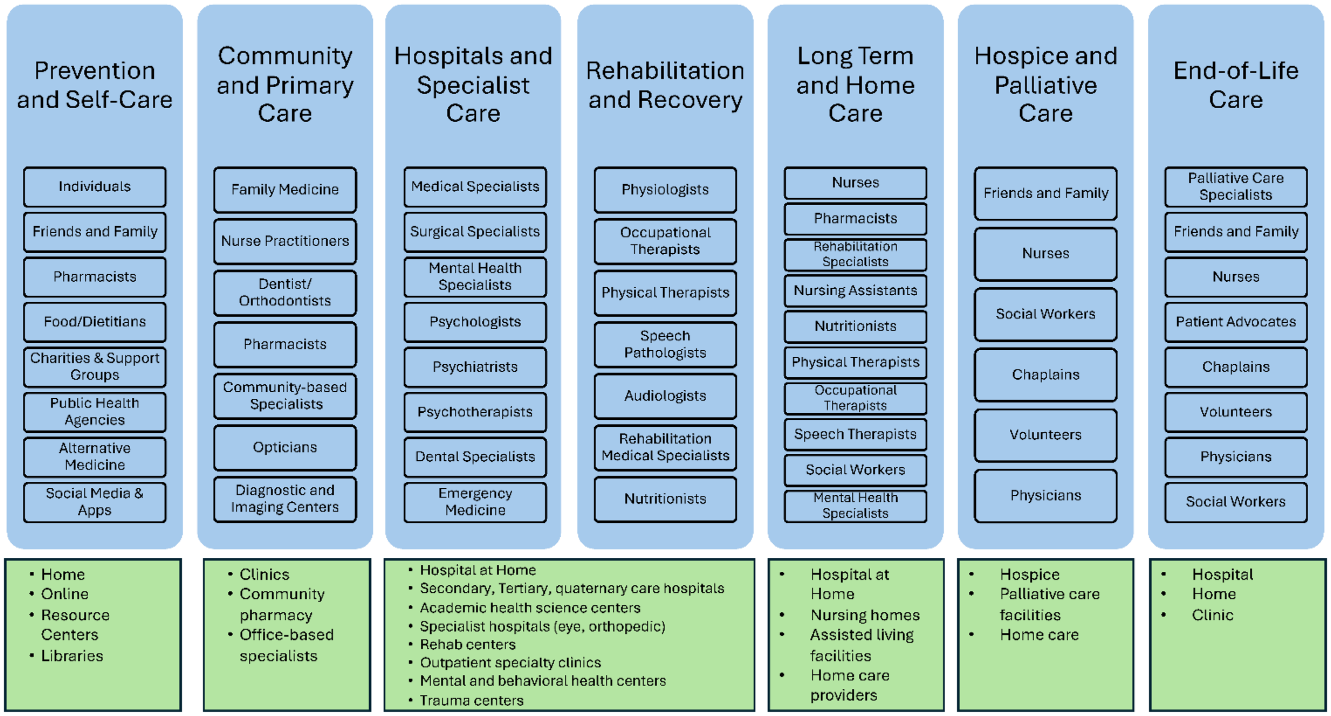
FIGURE 1 Generic Continuum of Care



1.1. PREVENTION AND SELF-CARE

A continuum of care centered on self-care involves disease prevention, health promotion, and public health measures such as population screening and vaccinations. Self-care with patient and/or caregivers supporting and taking on care responsibilities is becoming a critical focus for the continuum of care as advances in treatment increasingly enable self-care (e.g., oral-administered cancer therapies) or novel technologies that support better individual decision-making based on self-monitoring (e.g., wearables).

In addition, screening for a variety of conditions and diseases is an area of opportunity for wellness in a continuum of care. For example, screening for vision, color vision, hearing, neurological conditions, motor conditions, and more should be easy and routine. Screening and early intervention can benefit the individual, family, community, and everybody locally and globally.

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1.2. COMMUNITY AND PRIMARY CARE

Abundant evidence demonstrates that strong primary care systems should be the individual's first port of call when some treatment is needed. Over 80% of care system activity sits within this area and includes general medical, dental, and nurse practitioners, physiotherapists, pharmacists, nutritionists, and other resources directly accessible to the individual. This usually includes access to psychotherapies and mental health services. Complementary and alternative care includes chiropractic and osteopathic medicine, Traditional Chinese Medicine, and Ayurvedic medicine in India, each formally established in these countries' care systems.

From a quality and effectiveness perspective, primary care is the "gatekeeper" for referrals to more specialist care providers in the highest-ranked health systems. In other, more costly systems, individuals have direct access to specialists, who could be seen as functioning in a primary care way or by avoiding potential hospital access. Once a person is diagnosed, care is usually managed by these providers. These people are invariably located in the local community, easily accessible by public transport, and have connections to community support groups and services. Generally, this accounts for about 14% of expenditure within healthcare systems (OECD [3]).

1.3. HOSPITALS AND SPECIALIST CARE

Hospitals exist as an organizational arrangement for co-locating a mix of expertise to ensure easy and speedy access to diagnosis and treatment. Hospitals and specialist care focus on diagnosis and treatment that cannot be done within the community and primary care. While the most familiar medical professions are here, such as surgeons, cardiologists, or oncologists, it also includes specialist therapies (audiology, speech pathology, physiotherapy, occupational therapy) and specialist diagnostic and treatment support (imaging and laboratories), a great many of which do not need to be co-located in hospitals. Many specialists focus on very complex conditions (super specialists). These are found in tertiary or quaternary hospitals and academic health science centers, not community or secondary care hospitals.

As medical technologies evolve, this can change, leading to the "unbundling" of hospitals and specialists' services toward the community setting (Tremblay and Walsh [4]). Examples include shifting from inpatient elective care to day case care to achieve same-day discharge, cataract surgery, and hernia repair. For instance, society can only speculate how robotic surgery, stereotactic radiosurgery, or theranostics may unbundle monolithic treatment models.

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1.4. REHABILITATION AND RECOVERY CARE

A separate area of the care continuum focuses on what follows specialist care or hospitalization. This is where individuals receive rehabilitation to restore function and other support for “activities of daily living.” An example is cardiac rehabilitation, which should ideally follow immediate hospital discharge after a heart attack. It is its own continuum of care with diet management, weight control, and physical activity, often in a community setting.

Complex rehabilitation for head injuries, for instance, involves occupational therapy and psychologists for cognitive behavioral therapy, and stroke rehabilitation needs specialists in swallowing disorders.

Physiatry and ongoing rehabilitation for people with paralysis, hemiparesis, mobility, and other issues will continue and, at times, restore function and prevent loss of function. Currently, many parameters must be met for patients to qualify for specific therapies; with the continuum of care of the future, including telemedicine and digital presence, many more people can benefit from these essential rehabilitation therapies.

1.5. LONG-TERM CARE

For long-term conditions, where there is a loss of physical function (frailty), there is a range of settings, from the home to specialist nursing resources, to support maintaining independence for as long as possible. However, life expectancy in nursing homes averages about two years. Apart from those results, the options are hospice or palliative care (ONS [5]), but they also vary by the individual’s age.

1.6. HOSPICE AND PALLIATIVE CARE

This focus is on providing emotional and physical support and comfort and often pain relief for individuals with severe and life-ending conditions. New models in hospice care include treatment for the condition in addition to emotional and physical support and comfort in pain relief. Over the past few years, Medicare has demonstrated success in providing care at the same time as hospice, with improved outcomes for many people who live a longer and better quality of life.

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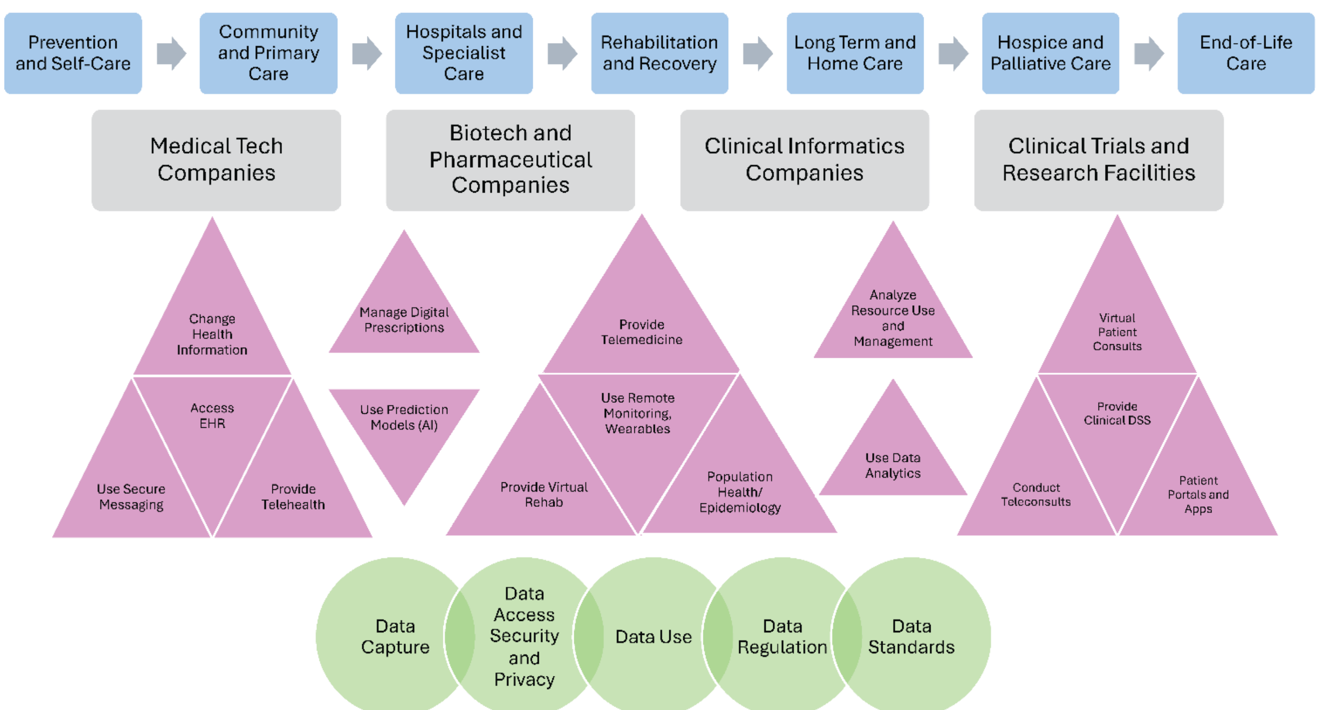
1.7. END-OF-LIFE CARE

End-of-life care/hospice care focuses on a person's quality of life as they near the end of life. A team of healthcare professionals works together to manage symptoms, distress, spiritual issues, and arrangements for the end of life. In most countries, this includes do-not-resuscitate orders and living wills and, in a few, providers of euthanasia (assisted dying) and non-resuscitation.

2. HEALTHCARE ECOSYSTEM: A TRANSDISCIPLINARY APPROACH

Describing the continuum of care and its components identifies the ecosystem within which health professionals, clinical managers, and care providers operate. FIGURE 2 illustrates the overall structure typical of most healthcare systems, but countries or professions will vary due to their differing regulatory systems and clinical practices.

FIGURE 2 The information value chain within the generic continuum of care



The goal should be to create "scalable modularity" to help ensure that the ecosystem can dynamically adjust to the changing risks, requirements, and locations of care of patients and their caregivers.

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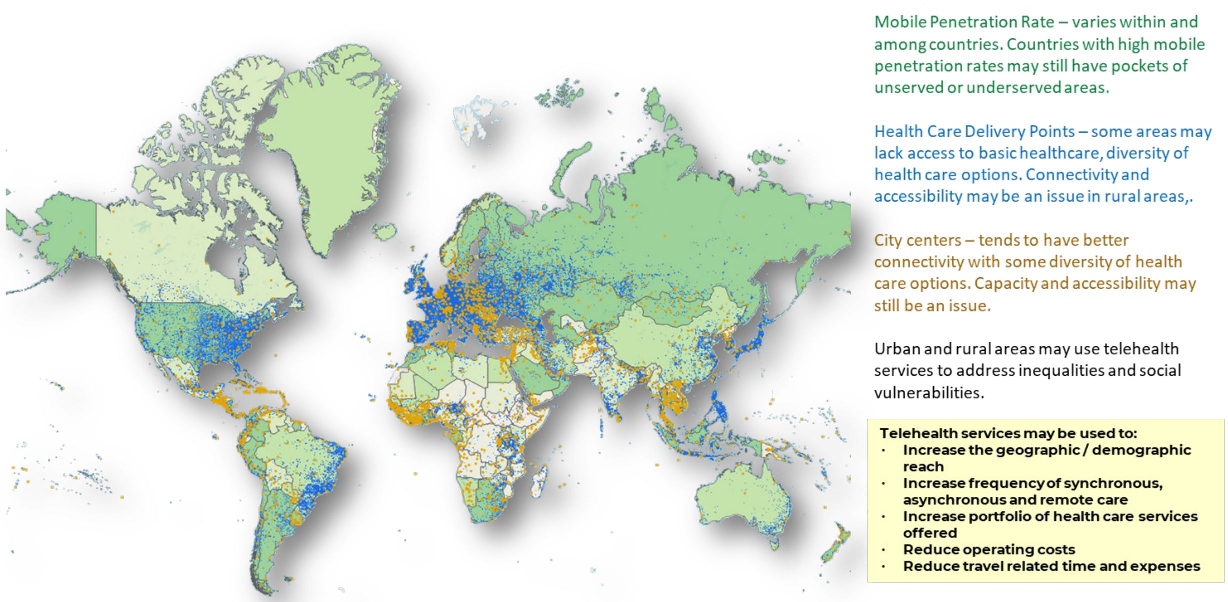
Challenging examples include dealing with emergencies on airplanes or ships, establishing temporary health infrastructures to deal with refugee camps or large-scale migration from conflict zones, evolving needs to support recovery in post-conflict zones (wars, civil unrest) and settings with specific requirements such as the military (e.g., managing combat and pilot fatigue, battlefield injuries) and prisons (e.g., psychological counseling, and mental health).

Several diverse, complex aspects require an alignment for effective continuum of care solutions to achieve these goals. They include building trusting patient and provider relationships, enabling informal care, bridging the digital divide through connectivity and accessibility, healthcare inclusion to mitigate the effects of social and economic inequalities, coordination of services across sectors, accountability, governance, UN SDGs, and so on. Furthermore, there are better models than a one-size-fits-all model for the continuum of care, especially for disadvantaged groups. The map below (FIGURE 3) demonstrates the conceptual approach for global telehealth services with healthcare delivery points, mobile penetration rates, and densely populated city centers. Generally, urban areas tend to have higher availability of healthcare delivery points and wireless and wireline communication networks. This creates opportunities to provide telehealth services to extend healthcare services to marginalized areas and deepen the level of new and existing healthcare services through a combination of synchronous and asynchronous care across geographies.

FIGURE 3 The Conceptual Approach for Global Telehealth Services



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A one-size-fits-all model of the continuum of care works against people who are most in need of care and the most vulnerable. We look to frame the continuum of care with a focus on precision, individualized care, and removing barriers to care. To break down these barriers and address marginalized populations, minorities, aging, chronically ill, and people with multi-morbidities, it will be necessary to address the natural and artificial barriers between social and medical care. Research and systems do not include people with such characteristics. Some examples of the continuum of care-related research in special needs populations and topics include aging and disabled, maternal and infant care, and community pharmacy (Choi and Lee [6]).

The need to safely access care and maintain the continuity of care during the COVID-19 pandemic led to an increase in telehealth adoption and renewed interest in the use of telehealth to bridge systemic gaps in health care and public health (Kalogeropoulos and Barach [7], Domestic Policy Council [8]). Telehealth uses include remote patient monitoring, which positively impacts continuity of care, outcomes, quality of life, and self-care for asthma patients during the pandemic (March, et al. [9]). Telehealth holds the potential to improve access to care for underserved populations and bridge data gaps and asymmetries arising from the underrepresentation of patient populations and communities that exacerbate health disparities. However, many historically marginalized people may have limited internet access or the skills to meaningfully engage with digital health tools.

2.1. TELEHEALTH AND CONTINUITY OF CARE

Virtual care is a multi-component entity. Telehealth has an enabling role in supporting continuity and quality of care with digital health interventions on two conditions. Telehealth emerged as the stimulus for virtual care development and has served as the foundation upon which other critical elements are being built. One such critical element of remote patient monitoring is the ability to monitor patient biometrics accurately and consistently in the home or other settings where the patient spends the overwhelming majority of their time. Telehealth has an enabling role in supporting continuity and quality of care with digital health interventions on two conditions. Telehealth’s ability to support the continuity of care in hospital-at-home (HaH) settings, for chronic disease patients, and during emergencies depends on health systems’ organizational and governance ability to enable connected telehealth and other digital health innovations, with information sharing across jurisdictions and digital health technologies.

There is a need to understand better how relevant data governance principles and concepts can impact the relationships between continuity and quality of care. While there is evidence that telehealth supported the

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continuity of care for some patients during the pandemic, it is unclear how telehealth use impacted the translation of continuity support to quality-of-care sustained improvements (Tierney, et al. [10]).

Regarding scaling and sustainability of a new telehealth paradigm in this context, there is the need to mitigate the risks of digitally vulnerable populations being excluded or not experiencing the same improvements as other more advantaged populations. Evidence shows that relational continuity is essential in telehealth trust and patient uptake (Ladds, et al. [11]). Care continuity, or the extent to which patient care is dispersed or concentrated among clinicians (Haggerty, et al. [12]), is linked to trust in clinicians as a critical determinant of high-quality patient care experiences and has essential implications for telehealth adoption. This is true in terms of both patient and provider engagement and participation in telehealth expanded access to care. The presence of a trusted and functional data ecosystem that supports continuity-connected telehealth services with information sharing is thus a critical adoption and outcomes improvement factor. This is particularly important in the face of evidence that telehealth may deprioritize continuity of care as an adoption factor (Ladds, et al. [11]). In this respect, the benefits of telehealth are marked in HAH settings (IEEE SA [13]). Limited research has been conducted on care continuity for patients with chronic conditions in community health centers that face rigorous continuous improvement expectations and data collection and monitoring that may impact care continuity (Tierney, et al. [10]).

Measures of continuity are essential from the ecosystem perspective to assess proximal outcomes supporting evidence-based adoption and reimbursement. Utilization indices, for instance, are efficient methods of measuring longitudinally and are often used as an alternative means of describing continuity (Bohnhoff, et al. [14]). Measures of patient-reported outcomes and quality of life provide critical evidence and function as a structural element for data ecosystems that enable connected and collaborating telehealth innovation to address digital inequity and platform-induced community underrepresentation. To this end, a standards-based governance framework that enables data recycling and sharable insights is critical (Kalogeropoulos, et al. [7], [15]). To facilitate agility in designing and adapting tools to uses that support continuity of care, fitting clinical study methodologies must be further developed (Liu, et al. [16]).

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2.2. TRANSDISCIPLINARY FRAMEWORK

2.2.1. CONCEPTUAL VIEW

It is essential to have a framework that includes a comprehensive transdisciplinary approach to the integrated healthcare ecosystem, networking capabilities, and governance functions that can address local priorities, capabilities, and constraints. This transdisciplinary framework can contextually and practically align the needs of healthcare providers and patients, communications, health IT networks and technologies, and governance functions for current and future objectives.

Conceptually, the transdisciplinary framework for the continuum of care includes the healthcare ecosystem with several related ecosystem stages. Each stage may represent closely related healthcare service or industry groups that address prevention and self-care, community and primary care, hospitals and specialist care, rehabilitation and recovery, long-term and home care, hospital and palliative care, and end-of-life care. This ecosystem and associated stages are aligned through a supply chain approach that describes the relationships and intra-ecosystem alignments across the different stages, e.g., patients, and provides traversing forwards or backward along the ecosystem stages from remote patient monitoring to ambulatory care to hospital care.

Networks, technologies, and enablers are added to this transdisciplinary framework to provide end-to-end visibility and information flow for synchronous and asynchronous care. A telecommunications framework can align the healthcare ecosystem with information flow for access, service delivery, patient and provider operations support, healthcare facility hubs, and interoperability among different provider networks.

Governance functions are aligned with the flow of health services and information through different time horizons, i.e., a long-term strategic view, a near-term tactical view, and a present or historical trending operations view. Healthcare policies and pilot programs may be developed to address target healthcare key performance indicators (KPIs), healthcare delivery to marginalized communities, data governance models, etc.

The conceptual healthcare transdisciplinary framework (Mangra, et al. [17]), shown in FIGURE 4, can be integrated with other ecosystems, such as public safety or agriculture, to create smart community scenarios for smart cities and rural development [18].

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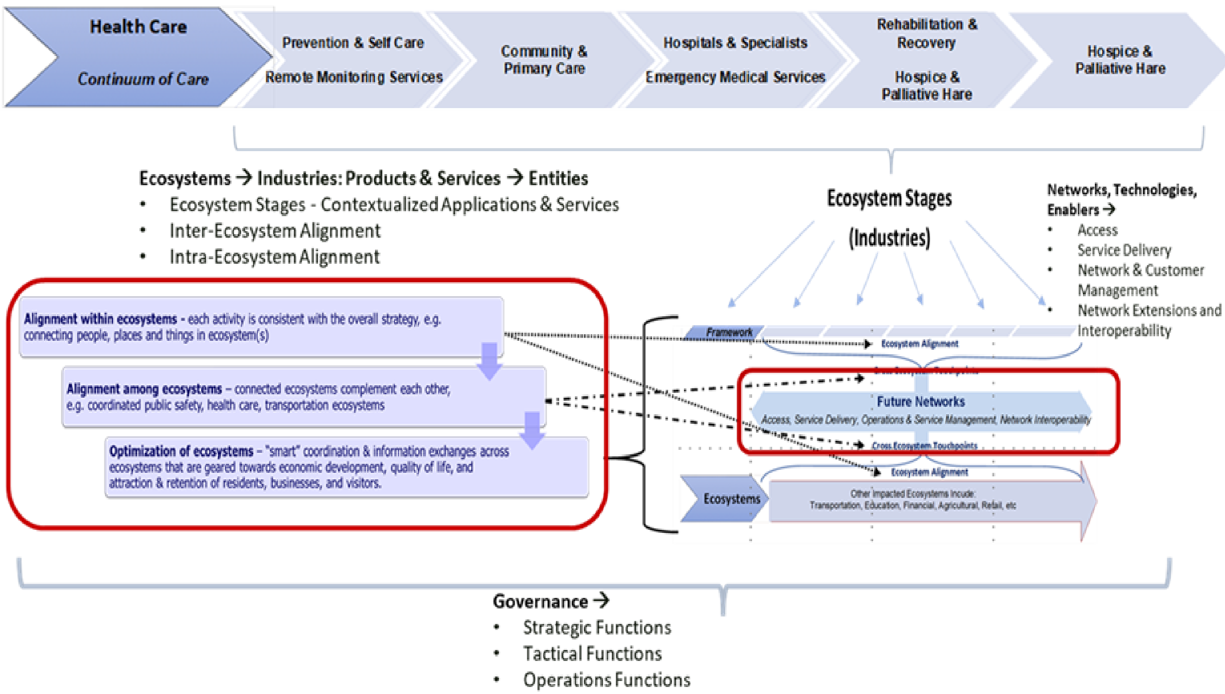
FIGURE 4 Conceptual Transdisciplinary Framework alignment view showing the healthcare ecosystem stages for the continuum of care, networks and technologies, and governance function alignments



2.2.2. COMPREHENSIVE ARCHITECTURAL VIEW

FIGURE 5 shows the comprehensive architectural view of the transdisciplinary framework. It shows the cyber-physical drivers for healthcare service delivery, including new healthcare products and services, communications networks and architecture needed for information flow, and governance objectives to improve the range and depth of healthcare services along the continuum of care. It can be used to operationally extend healthcare services across healthcare infrastructure and facilities, shown in blue; networks and high-level architecture interoperability in green; and governance objectives in red, around the periphery.

This view can be used for initial stakeholder engagements on priorities, capabilities, and constraints. Detailed discussions on healthcare facilities, terrestrial and non-terrestrial wired and wireless communications networks, health IT systems, and governance functions, such as policies to address strategic, tactical, and operational needs, may follow a structured approach. Enablers like blockchain, security, artificial intelligence, and machine learning may be used across healthcare services, networks, and governance functions.

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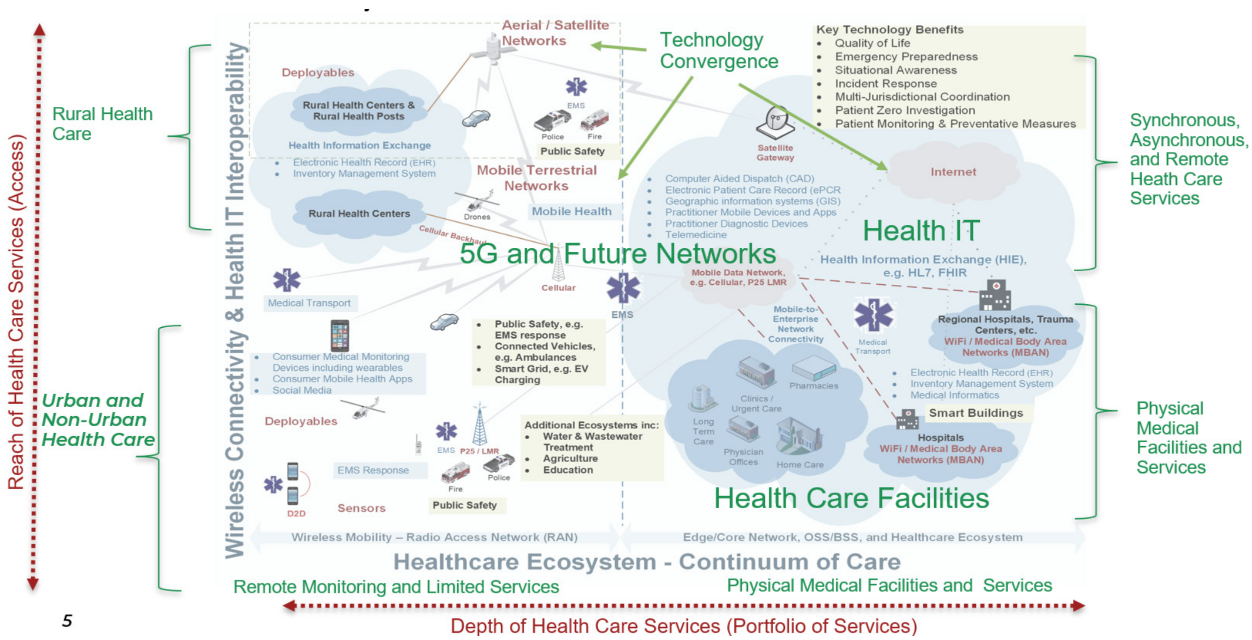
FIGURE 5 Transdisciplinary framework with a comprehensive architectural view showing the cyber-physical drivers for healthcare service delivery, high-level communications networks and architecture needed for information flow, and governance objectives to improve the range and depth of healthcare services along the continuum of care



Several use cases address the delivery of critical medical services in a hospital or medical facility setting where the medical team and the patients are collocated or non-collocated.

2.2.3. COLLOCATED MEDICAL TEAMS AND PATIENTS USING AN INDOOR NON-PUBLIC NETWORK (OR PRIVATE NETWORK)

- **Static—Local:** Use cases in this modality include hybrid operating rooms (OR) that are generally equipped with advanced imaging systems, e.g., fixed C-arms (x-ray generator and intensifiers), CT scans (Computer Tomography), and MRI scans (Magnetic Resonance Imaging). These advanced imaging capabilities are intended for minimally invasive surgery, using duplicate video on additional monitors, eXtended Reality (XR) Assisted Surgery, and Robotic Aided Surgery.

- **Static—Remote:** The World Health Organization (WHO) defines this modality as "the delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities." Use

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cases include emergency care using ultrasound examination and remote interventional support, communication QoS requirement for robotic telesurgery, and mobile specialist practice, e.g., deployable examination rooms on trucks.

2.2.4. NON-COLLOCATED MEDICAL TEAMS AND PATIENTS USING COMBINATIONS OF VPNS, PUBLIC, AND NON-PUBLIC NETWORKS

- **Moving—Local:** This modality requires a highly reliable communication infrastructure as doctors, clinicians, staff, patients, and equipment constantly move in high-stress environments, making life-and-death decisions while complying with regulatory requirements. Use cases include cardiac telemetry inside a hospital or care facility.
- **Moving—Remote:** This modality includes remote health monitoring of patients in their daily lives and monitoring/providing continuous care to injured patients in a moving ambulance as they are transported to the nearest hospital. Use cases include patient monitoring inside ambulances and cardiac telemetry outside the hospital.

Advancements in networks, technologies, and enablers can also help to reduce costs. Cost efficiencies can be realized operationally through a combination of fixed and mobile communications networks, health IT, electronic health records (EHRs), and enablers such as AI/ML that offer coordinated therapies, services, and health analytics for efficient outcomes. The ability to shift health care from hospitals to homes, where applicable, also results in cost reductions.

A transdisciplinary discussion using the comprehensive architectural view may yield requirements needed to support the following:

- **Health Care Services—**Capabilities necessary to support related services offered through a facility or received by a remote or on-premise patient. They may include synchronous and asynchronous care associated with diagnostics, monitoring, treatment, support services, etc.
- **Communications Networks—**Communications and health IT services are delivered through networks, technologies, and enablers. Examples include satellite and other non-terrestrial networks, cellular, WiFi, fixed networks, health IT, including EHRs, evolved residential gateways (5G), holographic communications (6G), ambient communications, IoT, wearables, Telepresence, XR, AI/ML, Robotics, Devices, etc.

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- **Governance—**Strategic, tactical, and operations goals to support health care services and the addressable market, policy development, health care professionals and the labor market, social vulnerabilities, inclusion, scaling, UN SDGs, etc.

2.2.5. DEPLOYMENT VIEW

The conceptual alignment and comprehensive architecture view can be expanded for practical deployment considerations, as shown in FIGURE 6. The percentage of the population over 65 years of age for counties[2] (shaded in red), mobile wireless service area,[3] and the fixed/wireline broadband networks[4] with at least 25 Mbps downlink and 3 Mbps uplink data rates (shaded in green), and the hospitals[5] (shown in blue). There are large areas in the western USA that include a large percentage of the elderly population, lack basic broadband coverage, and are not within proximity to hospitals. There are also similar pockets in the eastern USA. A targeted deployment to provide telehealth services along the continuum of care may include phases specific to local healthcare infrastructures, network capabilities, and governance to bridge the divide. Local implement views can address particular aspects of the deployment plan.

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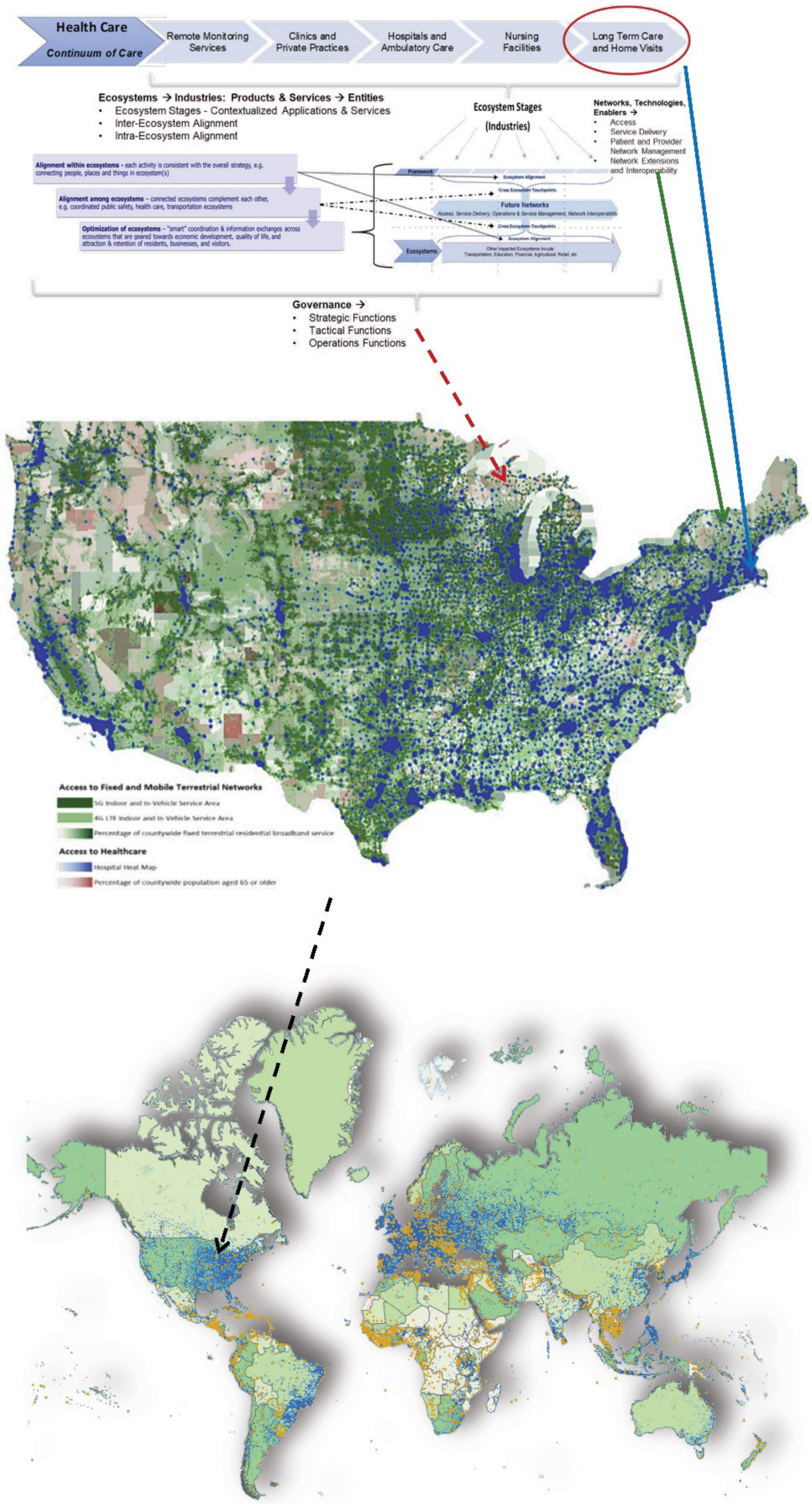
FIGURE 6 Transdisciplinary Framework deployment view showing an addressable market for the CONUS population over 65 years of age (red), wired and wireless networks, fixed broadband connectivity (green), and hospital locations (blue)



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The 2010 FCC Working Paper on Health Care [19] offers some insights that may be helpful for connected care planning. TABLE 1 shows different healthcare delivery settings, functional requirements, and preliminary deployment assumptions.

TABLE 1 Health IT Use Cases and Associated Broadband Requirements from the FCC 2010 Working Paper

Health Care Delivery Setting	Functional Requirements	Key Deployment Assumptions
Solo Primary Care Practice	▪ Supports practice management functions (billing, scheduling, etc.), email and web browsing ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables non-real-time image downloads ▪ Enables remote monitoring	▪ Three total users per doctor for EHR and other general web-based activities ▪ Image files (~10 MB) should download in less than 30 seconds
Small Primary Care Practice (2–4 physicians)	▪ Supports practice management functions (billing, scheduling, etc.), email and web browsing ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables non-real-time image downloads ▪ Enables remote monitoring ▪ Makes possible use of HD video consultations	▪ Three total users per doctor for EHR and other general web-based activities ▪ Two simultaneous high-quality SD video consultations ▪ Image files (~10 MB) should download in less than 30 seconds
Nursing Home	▪ Supports facility management functions, email, and web browsing ▪ Enables remote monitoring of the resident population ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables non-real-time image downloads ▪ Makes possible use of HD video consultations	▪ Five simultaneous users of general facility management and web-based activities ▪ Two simultaneous high-quality SD video consultations ▪ Image files (~10 MB) should download in less than 30 seconds

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Health Care Delivery Setting	Functional Requirements	Key Deployment Assumptions
Rural Health Clinic (~5 practitioners)	▪ Supports clinic management functions (billing, scheduling, etc.), email and web browsing ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables non-real-time image downloads ▪ Enables remote monitoring ▪ Makes possible use of HD video consultations	▪ Three total users per practitioner for EHR and other general web-based activities ▪ Two simultaneous high-quality SD video consultations ▪ Image files (~10 MB) should download in less than 30 seconds
Clinic/Large Physician Practice (5–25 physicians)	▪ Supports clinic management functions (billing, scheduling, etc.), email and web browsing ▪ Enables real-time image transfer ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables remote monitoring ▪ Makes possible use of HD video consultations	▪ Specialty services (e.g., radiology, orthopedics, dermatology) provided ▪ Three total users per practitioner for EHR and other general web-based activities ▪ Large image files (~20 MB) should transfer in less than 10 seconds ▪ Five simultaneous high-quality SD video consultations
Hospital	▪ Supports hospital management functions (billing, scheduling, etc.), email and web browsing ▪ Enables real-time image transfer ▪ Allows simultaneous use of EHR and high-quality SD video consultations ▪ Enables continuous remote monitoring ▪ Makes possible use of HD video consultations	▪ PACS in place for real-time diagnostic imaging ▪ Very large image files (~50 MB) should transfer in less than 5 seconds ▪ Multiple simultaneous high-quality SD video consultations
Academic / Large Medical Center	▪ Same as hospital	▪ Same as hospital, but the scale of demands on the largest medical centers drives exponential bandwidth needs

A revised requirements analysis should be conducted based on the current network capabilities required to support the necessary functions and application requirements to deliver the desired healthcare services. The critical network components include the following:

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- **Access—*How does someone gain access to telehealth services for this stage*?** Connectivity, home health hubs, devices/sensors/wearables, ambient RF services, intuitive user interactions, robotics, etc.
- **Service Delivery—How does one gain/provide telehealth services for this stage? Examples include** analytics, proactive care, scheduled virtual visits, reminders, etc.
- **Patient and Provider Operations Management—How do we manage the overall patient/provider experience? This includes EHR, training, records management, digital literacy, third-party engagements,** including payers, equipment, etc.
- **Health Care Hubs and Interoperability—*How care is handed-off among stages and/or health care providers*?** Ambulances, hospital transports, specialists across the globe, etc.

Network deployment considerations include capabilities for imaging (e.g., 4K or 8K real-time video streaming, compression rates), motion control data streaming, and haptic feedback data streaming capabilities. These requirements include network characteristics such as the following:

- Communication service availability (%)
- Communication service reliability: Mean Time Between Failure (MTBF)
- End-to-end latency (ms)
- Bit rate (Gbps)
- Direction of traffic, e.g., network to device
- Message size (bytes)
- Survival time (ms)
- Mobile device or UE speed, e.g., stationary, mph, km/h
- Number of active devices or UEs, e.g., 1, 10, 100, …
- Service area, e.g., room, floor, building, regional., national

Enablers such as AIML, security, and position determination transcend the healthcare products and services, key network components, and governance functions.

2.2.6. NETWORKS

The network components and functionality depend on the appropriate or needed informatic priorities within and between organizational entities and associated functions for patient care or management. The volume of activity is less important than the purpose of that activity, as small specialist centers may have a considerable need for connectivity with, for instance, a large catchment area of referring general practitioners, perhaps as much as a major hospital also taking referrals.

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Any clinical providers will need to be able to receive and perhaps add images, text, prescribing data, and test results to electronic health records. These records may be viewed as a shared resource accessible on demand by any provider in a location-independent manner. This also addresses the ability to enable location-independent patient care—move the data to the patient, not the patient to the data.

2.2.7. GOVERNANCE

Governance can range from that of individual organizations to the governance of the healthcare system itself. As complex and adaptive, healthcare changes quickly, from hour to hour, as circumstances change. Infrastructure availability (e.g., number of beds, geographical distribution of doctors) creates constraints constantly challenged by real-world events.

Shared priorities create opportunities within networks to significantly uplift system performance.

2.3. HOW STANDARDS AND TECHNOLOGY CAN EXTRACT VALUE AND DELIVER BENEFITS TO THE CONTINUUM OF CARE

2.3.1. METHODICALLY MEASURING CARE OUTCOMES: COLLECTING DATA AND STANDARDIZING RECORDS

There are numerous methods for collecting data for research, hospital, and continuum of care administrative purposes. Observational length of stay and discharge destination data based on standardized medical records are essential to understanding the key drivers of variation in health outcomes. Records can be manually collected from ward and community-based sources, including nursing handover records, paper-based ward and hospital discharge/transfer records, paper-based inpatient medical records, direct observation by experienced personnel, and 24-hour recall of key hospital personnel (e.g., Nurse Unit Manager).

Retrospective data may be collected via a review of scanned inpatient medical records post-hospital discharge. While this standardized approach has previously been used as a gold standard measure for multiple outcomes, transforming medical records into research data is resource-intensive. An alternative to these traditional methods of hospital data collection has been to extract electronic administrative data. Retrospective hospital administrative data has become a commonly used source of inexpensive and readily available information. Administrative data is not usually explicitly entered for research purposes, with previous literature indicating the use of administrative data in adverse events and coding for billing purposes may result in inaccurate data.

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Despite the importance and frequent reporting of hospital length of stay and discharge destination measures to the community, it is hard to make robust comparisons comparing data collection methods for these outcome measures. With this range of potential data sources and data collection approaches, it is vital to consider the relative completeness and agreement between different data extraction methods. Ensuring the validity of data collection used to inform decision-making around health policy and continuum of care planning is vital.

2.3.2. STRENGTHENING COMMUNICATION, DISSEMINATION, AND FOLLOW-UP

There is a compelling rationale that better communication quality between hospital allied health and primary care practitioners may improve the quality and continuity of patient care. Strengthening communication across the continuity of care via ongoing and effective discharge planning is a routine feature of the best healthcare systems to improve the coordination of services following discharge from the hospital. Discharge communication provides a vital link between hospitals and primary care. It is an essential determinant of positive patient outcomes following hospitalization, helping to facilitate seamless transitions of care between healthcare providers and long-term care in the community. Ineffective communication and information transfer, particularly during transitions of care, has substantial implications for patient safety and continuity of care, patient and healthcare provider comprehension, and satisfaction, and has been directly shown to impact resource use.

2.3.3. ESTABLISHING SUCCESS METRICS AND UNDERSTANDING HOW TO MAKE THESE OUTCOMES BEST-OF-CLASS

The World Health Organization set global priorities in 2018 to promote integrated people-centered health services through collaboration and integration across sectors, settings, providers, and users, using success metrics, yet coordination and timely transfer of information remain significant challenges to optimized outcomes during care transitions. According to the WHO, people-centered care adopts the perspectives of individuals, caregivers, families, and communities relative to people’s comprehensive needs and social preferences rather than individual diseases. A person-centered (or patient-centered) approach allows the person to be seen as a whole, with needs and goals derived from their social determinants of health, basing this care on best-in-class outcomes. Such an approach allows patients to share their health information at the appropriate time with the right person.

A new strategy has been introduced in health care, namely, achieving the best outcomes for the lowest cost and

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thus maximizing value for patients. In value-based care, the essential quality measures are the success outcome metrics that matter to patients. Measuring and reporting outcomes fosters improvement and adoption of best-in-class practices, thus further improving outcomes. Understanding outcomes is central to providing value across the continuum of care and represents an opportunity for redefining patient care using the quadruple aim metrics (Wong, et al. [20]).

2.3.4. VALUE

We know that more care and costly care is often associated with worse outcomes. Value is created by spending the least amount needed to improve the success outcomes of patients with a particular clinical condition over the entire care cycle, which usually involves multiple specialties and care sites. To be successful, an essential aspect of value-based care across the continuum of health services is working as teams (integrated practice units) centered around the patient's clinical condition. As medicine has become more specialized and complex, multidisciplinary communication and trust among the care team are paramount in providing value to patients and their families.

Patient-reported outcomes (PROs) can be primary or secondary endpoints and are increasingly recognized by regulators, clinicians, and patients as valuable tools to collect patient-centered data. PROs provide unique information on the impact of a medical condition and its treatment from the patient’s perspective. Using patient-reported outcomes and success measures is essential to improving clinical care because it enhances the connections among healthcare teams and their patients. Designing and implementing Patient-reported or caregiver-reported outcomes in clinical practice will lead to an understanding of the effects of treatments on outcomes and quality of life (QOL) of patients, a primary way to assess a patient’s QOL.

2.3.5. SYSTEMATICALLY PREVENTING AVOIDABLE HARM TO PATIENTS

Patient harm due to unsafe care is a large and growing global public health challenge and is one of the leading causes of death and disability worldwide. Most of this patient harm is avoidable. Harmful patient incidents are also a significant financial burden for healthcare systems across the globe. The direct consequences of healthcare-related patient harm are estimated to consume 10–15% of healthcare expenditures.

Many gaps in the system still need to be addressed. Strengthening the focus on preventable patient harm can lead to more tangible clinical benefits and improved implementation of patient safety research findings into clinical practice. Patient safety improvement strategies underpinned by a better understanding of the nature of

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preventable patient harm have greater prospects of efficiency (because they are more specific) and implementation (because clinicians are more readily engaged and can readily recognize their value).

2.4. AI AND STANDARDS IN THE CONTINUUM OF CARE

Any technical discussion of standards within a continuum of care will become a barrier when artificial intelligence and machine learning become vital elements.

There is an increasingly high probability that artificial intelligence (machine learning, computational models, prediction models, deep learning, large language models, etc.) will gradually augment and far future replace the rules-based systems we rely on and govern standards development. The replacement will be a system that uses real-time data and analyses, coupled with computational prediction models, to create a dynamic and flexible information environment for healthcare.

Since AI can alter the time and place of decisions (Agrawal, et al.[21]), rules-based systems, which are time- and place-specific, can become obstacles to quality of care and clinical outcomes or even irritants to decision-makers. Indeed, AI could enable better precision in clinical reasoning, personalization of care by eliminating generalized guidelines replaced by data-rich models, and predictive by enabling near-term at least knowledge of the patient's likely progression along this individualized continuum of care (Minor and Rees [22]).

The emerging digital ecosystem will enable precision care and the ability to share clinical information more meaningfully with patients with a “digital twin” or “avatar,” capturing each individual’s unique health status dynamically and personally (Cullis, [23]). Data shadows (Milne, et al. [24]) and digital twins will be the focus or nexus of digital information used by health system decision-makers and individuals. This will also redefine the structure of electronic health record systems and how real-time clinical data is analyzed to create predictions for clinical and personal decision-making; we call this “anticipatory capacity,” which the current rules-based system cannot deal with. Pushing this further, AI has shown the potential to rethink our usual ways of conceptualizing relationships between diseases (Wang, et al. [25]), the typology of cancer tumors (Gardner, et al. [26]), or the discovery of novel digital biomarkers (Cohen, et al. [27]). By positioning individuals within populations, the risk is not merely determined at which point they sit on the epidemiological bell curve but by how individuals will be placed on the evolution of their health journey and within the continuum of care.

Population big data will reveal information about the performance of healthcare systems, such as trends and

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effectiveness of the care of an individual, family, population, and community, and discover other connected features, such as social determinants of health or social vulnerability index (SVI). The proxy of family history might hold far less weight in future healthcare practice because more specific and multidimensional information will provide a more relevant personalized digital twin. Regional, local, microenvironmental, or population data might fill in additional information and indicate relevant common influences on health, including climate and air quality, access to care, culture, practices, and or effectiveness of treatment.

In addition, the healthcare system has a broad and diverse set of resources, supply chains, communications methods, and regulations. Each person might have specific or limited access to the healthcare system due to various factors, including geography, employment, distance to healthcare, insurance coverage, time involved in seeing a doctor, going for a test, or participating in therapy or treatment. Various influences often lead people to seek care that might not be optimal. Private insurance markets may restrict access that will influence avoidable outcomes in universal systems; examples of avoidable barriers here include high deductibles, in-network providers, restricted appointment schedules, formulary medications with weak efficacy, drug-drug interactions, or undesirable side effects.

Medications are also subject to manufacturing irregularities, recalls, contamination, etc. Each jurisdiction has different regulations about how patients are informed about whether the medicines they take are impacted and whether the inventory they have in their possession might be involved. With innovative systems, the supply chain can be connected to improve overall population health by tracking lot numbers in patients' hands and handling notifications and replacements as soon as possible. Specific terms of the contract and service agreement might be rendered into an illustration and index of access to healthcare for each person and group of people covered by the plan, improving recognition of gaps and predicting care outcomes. An essential thread in the continuum of care is the transparent flow of information about medicines and implants where quality considerations are a priority.

Treatments for individual conditions will impact future health. For example, treatment of arthritis, asthma, COPD, or IBS can lead to greater vulnerability for other conditions such as bone fractures. Innovative continuity of care systems can track and predict future issues based on prior care. In addition to risk prediction, information must cross professional knowledge domains and specialties to avoid the known silos that affect and limit continuity of care (Tett [28]). Questions at the doctor's office might change from those about family history to a personal history of conditions that might lead to the risk of fractures, for example (Balasubramanian [29]).

Trends were observed in state-related care outcomes during the COVID-19 global pandemic, where specific

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populations (for example, disabled persons and people 65 and older) and geographic regions (for example, Ohio and Florida) were more impacted than others. Alarming trends are seen in maternal mortality and morbidity, where trends in the United States indicate higher maternal mortality and morbidity, whereas global statistics are improving. Including geographic information systems within the digital envelope of a continuum of care would not just integrate information but lead to an improved understanding of determinants and greater treatment precision for individuals.

Transparency, ease of use, and access to accurate information across a complex system of systems—equipment, policies, patients, caregivers, medications—are critical to the continuum of care. State and organizational policies can impact care decisions and outcomes; only in certain jurisdictions can the Sequential Organ Failure Assessment (SOFA) be used for decision-making involving removing patients from respirators, even though SOFA alone is not an appropriate model for COVID-19 care. Some patients may have suffered when healthcare organizations used pulse oximeter devices to erroneously estimate the oxygen saturation in people with darker skin instead of blood gas measurements, even when blood gas measurements, the gold standard, were available. Pulse oximeter devices were used to determine whether patients had severe cases of COVID-19 and whether they qualified for treatment, medications, hospitalization, and respirators. Using the wrong model or device, a poorly functioning device or method, or with the wrong patient, or without enough information could lead to poor healthcare decisions. Standards that improve data and outcomes transparency can provide individual and population information and prediction for care decision-making across the interdisciplinary domains involved.

As technology advances, the interactions between patients and healthcare will be impacted, from monitoring, contacts, and queries to follow-up. In a traditional healthcare encounter, a patient may be asked if they have a family history of diabetes and or breast or colon cancer as a proxy for a decision to rule in screening tests or assist in diagnosis. In some cases, such proxies exclude patients with no family history and no screening from screening and care. As technology and care transform, interactions involving history and risk will be fundamentally different. It will be more apparent that the healthcare system treats an individual in the context of a family or a community. There will be more knowledge of available resources, with more data, effective analysis tools, and capabilities to plan care that is more likely to be effective for the individual in the community.

Big data will reveal access to healthcare and the population's attitude towards healthcare. Are the members of the population likely to seek healthcare? Are they insured? Do they trust the healthcare system enough to follow instructions for care? Do they understand the instructions in their primary language and cultural experience?

Access to healthcare is multidimensional; not only must the care and transitions of care be present and effective,

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but the caregivers and patients must actively engage in the care to benefit. Many of those in need of continuity of care include those who are pregnant or who recently gave birth, infants and children, aging, people with disabilities, people with chronic conditions including asthma, COPD, and diabetes, people with mental healthcare needs, substance issues, and people with acute conditions including cancer. Some people need intensive ongoing care with durable medical equipment and medications, including people with paralysis, hemiparesis, hepatitis, HIV, diabetes, and more. Diverse systems provide care, and transitions can be complicated and confusing. When any part of the system or a transition among systems breaks down, those fragile connections with other parts of the system can leave an individual in harm’s way (Fakha, et al. [30]).

Often, healthcare systems call for navigators or doulas to fill the gap in attempts to implement innovations in continuity of care and associated quality of care. Sadly, this may indicate that the system is not fully equipped to provide continuity of care in an accessible, transparent manner to patients and their informal caregivers. When the healthcare system must rely on such augmented systems, it is fragile and vulnerable to available collaborators, resources, funds, and more. There must be more opportunities to check whether the information being transmitted is accurate or effective.

When budgets are cut, the navigators or doulas may not be available. There is already a trend to revoke the privileges of community oncologists in certain hospitals as the corporations manage the entirety of each case, as has been seen recently in Philadelphia (Otto [31]). Now, oncologists must send their patients to hospitals further away where they have privileges. These healthcare management strategies and structure trends are often transparent to the patient and their informal caregivers. Lack of transparency leads to problems in continuity of care, associated quality of care, and ultimately, outcomes in mortality and morbidity. In a move by hospitals to control the entire case, will communication be improved? Will care options be available to patients?

Big data is available to indicate by population, region, and age the extent to which healthcare is accessible. Systems and innovations in those systems at the points of transition commonly involved in continuity of care may be designed by and for the healthcare system more so than for patients and informal caregivers, leaving gaps in features with less-than-desirable outcomes. Very few patients or informal caregivers are involved in designing or evaluating continuity of care systems.

Often, more entities are involved in care and care transitions than outside single systems used in formal collaborations. These relationships become a challenge when transferring a person to another level of care. It is difficult to achieve any progress for patients and or stakeholders involved in a case for a given patient (plan, care, treatment, tests, records, prescriptions, durable medical equipment, follow-up, rehabilitation, hospital at

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home, long-term care, etc.). The various stakeholders rarely see into one another's systems, and they may be unaware of the systems, processes, and states of the systems. These transitions can introduce delays, lack of information, and complexities. There are many handoffs among healthcare providers in and among facilities, even when a patient is discharged to home. Each interface introduces opportunities for delays and problems. Formal contracts prevent specific care on the same date of service. Frail patients might fall through the cracks during these transitions.

Most urgently, there is a lack of a continuum of care for people who need mental healthcare, and in particular, there is very little care available for children and less insurance coverage, for example, in the United States. More children are on Medicaid than those who are not. Many describe a mental health crisis for children and people of all ages in a time of significant disruption in society. Continuum of care and access to care go hand in hand.

3. CONCLUSIONS

The COVID-19 pandemic has highlighted the need for effective tools to better identify and address health disparities and call attention to underperformance throughout the healthcare system. The potential can reduce the burden and improve care by moving to a digital quality measurement system that provides a continuum of care that captures quality data during care delivery. It can give results and decision support much more rapidly. From the continuum of care, reconceptualization will come new ways of transparently connecting all citizens to information, making healthcare decisions, and conducting transitions among healthcare providers and facilities. This, in turn, can impact how digital data is structured, shared, and created, with an associated need for new standards to achieve ease of use and transparency for an interdisciplinary continuum of care.

While AI and ML have the potential to help healthcare providers and systems become more intelligent, faster, and more efficient in providing care to millions of people worldwide, we should be mindful of the unintended dangers of bias, privacy risks, and loss of trust. Under current concepts of how a healthcare system works, hospitals serve as essential hubs for specialized care, surgeries, critical cases, emergencies, and complex treatments that require advanced medical facilities and expertise. The continuum of care provides a path from hospital-centered to truly community-based patient-centered systems (Tremblay [32]).

The evolving healthcare landscape will likely involve a combination of AI-enhanced community-based care, outpatient services, and traditional hospital care. Healthcare systems will need to adapt and integrate these technologies thoughtfully to ensure a comprehensive and patient-centered approach across the continuum of care.

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A Transdisciplinary Framework can provide a structured approach that integrates the healthcare ecosystem, networks, technologies, enablers, and governance functions for current and future considerations. It may be customized based on local priorities, capabilities, and constraints to provide effective and reliable services across the continuum of care.

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