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Learning health systems 2.0: Future-proofing healthcare against pandemics and climate change

A White Paper

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FURTHER INFORMATION

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Table of Contents

The need for a Learning Health System approach to future crises: The case for Learning Health Systems 2.0 4

Learning Health Systems 2.0: future proofing healthcare against pandemics and climate change 6

Search 1: Next generation Learning Health Systems – new models, frameworks and iterations ... 6

Key findings from search 1 12

Search 2: "Systems dynamics" modelling in health systems: Primary care and/or Emergency departments and/or hospitals 13

Key findings from search 2 15

Search 3: Pandemics and Learning Health Systems 16

Key findings from search 3 28

Search 4: Climate change, preparedness, and Learning Health Systems 29

Key findings from search 4 29

Search 5: Emergency departments and Learning Health Systems 30

Key findings from search 5 33

Search 6: Primary care and Learning Health Systems 34

Key findings from search 6 44

Discussion 45

Conclusion 45

References 46

The need for a Learning Health System approach to future crises: The case for Learning Health Systems 2.0

The world is changing fast; so fast that many people are increasingly feeling that it is out of control. We have conducted research which shows that anxiety and depression are at record levels (Ellis et al., 2022; Zurynski, Ellis, et al., 2022). COVID-19 has had a massive effect on populations throughout the world (Braithwaite et al., 2021). Other pandemics seem much more likely in the near future (Baker et al., 2022). We are not on a pathway to meet the United Nations' target of maintaining world temperatures below 1.5 degrees Celsius (Meinshausen et al., 2022). The war in Ukraine, as terrible as that is, may be the harbinger of other existential threats brought on by impending or latent conflict between belligerent countries. China and America are not only in disagreement on many issues, but do not even have a meeting of minds about how the world can be improved. Inflation, cost of living pressures, and levels of inequity both within and across countries are proving to be sticky problems that are not easily solved. In short, the world is facing problems on multiple fronts, and there are no magic wands.

While we cannot solve all of these wicked problems, we can aim to affect change in our own area of interest: health systems improvement for the benefit of patients and populations (Braithwaite, Hibbert, et al., 2018; Braithwaite et al., 2020; Zurynski, Herkes-Deane, et al., 2022). Here, we aim to design solutions for providers to create higher quality and safer care for patients. We have produced work over several decades, designed to provide evidence-based solutions, including work with 152 countries (Braithwaite, Mannion, Matsuyama, Shekelle, Whittaker, & Al-Adawi, 2018a, 2018b). Through our research we have sought to strengthen health policy and reform initiatives, enhance the intelligence available to Ministries and government, undergird through studies and research the governance, leadership, and management of health systems (Braithwaite et al., 2023; Clay-Williams et al., 2017), and support clinicians on the ground who strive to deliver high quality care to patients. We have also carefully documented the changing involvement of patients in healthcare, who are no longer passive recipients of the care provided to them, but intrinsically involved in its co-production (Churruca et al., 2021; Sarrami-Foroushani et al., 2014a, 2014b).

We have also published studies in multiple other areas, looking at, for example: how to build better Learning Health Systems (Ellis et al., 2022; Pomare et al., 2022; Zurynski et al., 2020); examining strategies to cope with COVID-19, and, by implication, future pandemics (Braithwaite et al., 2021; Tartaglia et al., 2021); and strengthening health systems so they are better prepared for increasing numbers of patients associated with climate change (Braithwaite et al., under review; Braithwaite, Zurynski & Smith., In press). Now, we want to go further, and bring these wide-ranging study areas together. We seek to put forward the case for Learning Health Systems 2.0 (LHS 2.0). Health systems which are effective at learning (or, LHSs 1.0) can use data well, and skilfully embed knowledge into daily clinical practice and decision making of both health providers and patients. LHSs 2.0 go further: they are accomplished at marshalling information, data, and intelligence, and will also be prepared for future pandemics, and the crises and pressures induced by climate change that will increasingly affect the provision of high-quality care.

In what follows we present a series of literature searches of topics germane to this issue, conducted on 10 February, 2023 in the electronic database PubMed. These searches were designed to shed light on the question: *how can healthcare organisations be strategically enabled to become next-generation Learning Health Systems*? Our label for these next generation systems, *LHS 2.0*, signifies that they are health systems that are adept at continually improving quality, safety and patient outcomes by harnessing data in adroit ways. But it also signifies that they are future-proofing their

services against the additional levels of care that are and will be imposed on them by pandemics and climate change. These are the searches:

1. Next generation Learning Health Systems – new models, frameworks and iterations.
2. "Systems dynamics" modelling in health systems: Primary care and/or Emergency departments and/or hospitals.
3. Pandemics and Learning Health Systems.
4. Climate change, preparedness, and Learning Health Systems.
5. Emergency departments and Learning Health Systems.
6. Primary care and Learning Health Systems.

After presenting the information we obtained from each of the searches, we move to a brief interpretation of them. Then, we consider the implications of this work for creating LHSs 2.0.

Learning Health Systems 2.0: future proofing healthcare against pandemics and climate change

Search 1: Next generation Learning Health Systems – new models, frameworks and iterations

We open our examination of LHSs in the context of pandemics and climate change by looking for work which extends the original definition of an LHS from the Institute of Medicine/National Academy of Medicine. This might give the study insights into how LHSs are being advanced, reconceptualised, or used in new ways.

PubMed searches executed on 10/02/2023.
Search terms: ("Learning Health System*") AND (innovation); ("Learning Health System*") AND (updat*); ("Learning Health System*") AND (novel)
Limits: Published in the last 5 years (i.e., from 10/02/2018)
Results: 182 results, 17 results and 44 results returned for each respective search. All results were title screened and relevant title/abstracts (n=3) are included below. Three additional papers that were relevant to this topic were found in other searches and are also included below.

Anderson, J. L., Reamey, R. A., Levitan, E. B., M Asif, I., S Aswani, M., Fletcher, F. E., G Hall, A., Kennedy, K. C., Long, D., Redden, D., Tunagur, A., Wasko, M., Willig, J., Wyatt, M., & Mugavero, M. J. (2021). The University of Alabama at Birmingham COVID-19 Collaborative Outcomes Research Enterprise: Developing an institutional learning health system in response to the global pandemic. ***Learning Health Systems*****, *6*(2), e10292. https://doi.org/10.1002/lrh2.10292**

Introduction: As a local response to the COVID-19 global pandemic, the University of Alabama at Birmingham (UAB) established the UAB COVID-19 Collaborative Outcomes Research Enterprise (CORE), an institutional learning health system (LHS) to achieve an integrated health services outcomes and research response.

Methods: We developed a network of expertise and capabilities to rapidly develop and deploy an institutional-level interdisciplinary LHS. Based upon a scoping review of the literature and the Knowledge to Action Framework, we adopted a LHS framework identifying contributors and components necessary to developing a system within and between the university academic and medical centers. We used social network analysis to examine the emergence of informal work patterns and diversified network capabilities based on the LHS framework.

Results: This experience report details three principal characteristics of the UAB COVID-19 CORE LHS development: (a) identifying network contributors and components; (b) building the institutional network; and (c) diversifying network capabilities. Contributors and committees were identified from seven components of LHS: (a) collaborative and executive leadership committee, (b) research coordinating committee, (c) oversight and ethics committee, (d) thematic scientific working groups, (e) programmatic working groups, (f) informatics capabilities, and (g) patient advisory groups. Evolving from the topical interests of the initial CORE participants, scientific working groups emerged to support the learning system network. Programmatic working groups were charged with developing a comprehensive and mutually accessible COVID-19 database.

Discussion: Our LHS framework allowed for effective integration of multiple academic and medical centers into a cohesive institutional-level learning system. Network analysis indicated diversity of institutional disciplines, professional rank, and topical focus pertaining to COVID-19, with each center leveraging existing institutional responsibilities to minimize gaps in network capabilities.

Conclusion: Incorporating an adapted LHS framework designed for academic medical centers served as a foundational resource supporting further institutional-level efforts to develop agile and responsive learning networks.

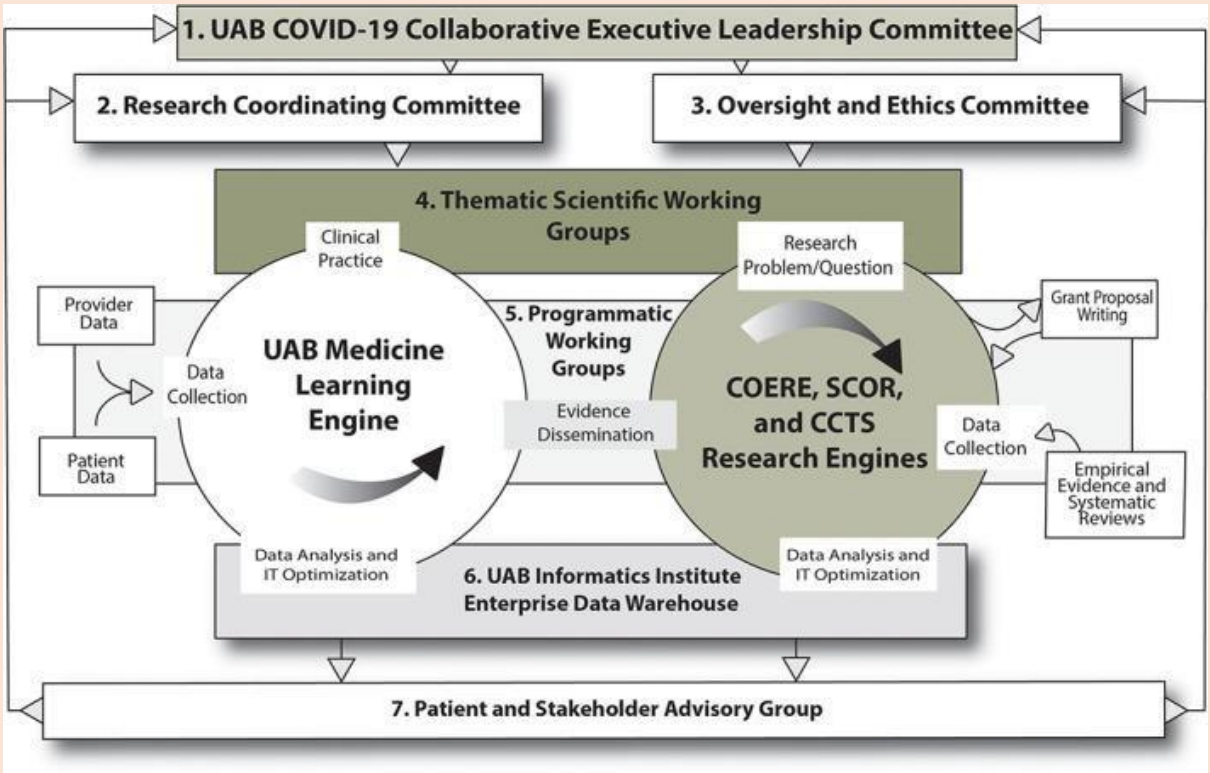

Figure from Anderson JL, Reamey RA, Levitan EB, et al. The University of Alabama at Birmingham COVID-19 Collaborative Outcomes Research Enterprise: Developing an institutional learning health system in response to the global pandemic.

Allen, C., Coleman, K., Mettert, K., Lewis, C., Westbrook, E., & Lozano, P. (2021). A roadmap to operationalize and evaluate impact in a learning health system. *Learning Health Systems*, *5*(4), e10258. https://doi.org/10.1002/lrh2.10258

Background: Many health systems invest in initiatives to accelerate translation of knowledge into practice. However, organizations lack guidance on how to develop and operationalize such Learning Health System (LHS) programs and evaluate their impact. Kaiser Permanente Washington (KPWA) launched our LHS program in June 2017 and developed a logic model as a foundation to evaluate the program's impact.

Objective: To develop a roadmap for organizations that want to establish an LHS program, understand how LHS core components relate to one another when operationalized in practice, and evaluate and improve their progress.

Methods: We conducted a narrative review on LHS models, key model components, and measurement approaches.

Results: The KPWA LHS Logic Model provides a broad set of constructs relevant to LHS programs, depicts their relationship to LHS operations, harmonizes terms across models, and offers measurable operationalizations of each construct to guide other health systems. The model identifies essential LHS inputs, provides transparency into LHS activities, and defines key outcomes to evaluate LHS processes and impact. We provide reflections on the most helpful components of the model and identify areas that need further improvement using illustrative examples from deployment of the LHS model during the COVID-19 pandemic.

Conclusion: The KPWA LHS Logic Model is a starting point for future LHS implementation research and a practical guide for healthcare organizations that are building, operationalizing, and evaluating LHS initiatives.

Inputs	Outputs	Outcomes
People & partnerships	Environmental scanning	Knowledge to action latency
Health information infrastructure	Evidence synthesis & translation	Systematic implementation of evidence-based practices
Prioritization	Data analytics	Systematic elimination of wasteful and ineffective practices
Funding	Design	Population health
Improvement infrastructure	Patient & family engagement	Care experience
Ethics & oversight	Implementation support	Utilization/cost of care
	Evaluation	Work life for care teams
	Dissemination	Equity
	Consultation	Programmatic return on investment

Figure from Allen, C., Coleman, K., Mettert, K., Lewis, C., Westbrook, E., & Lozano, P. (2021). A roadmap to operationalize and evaluate impact in a learning health system.

Enticott, J. C., Melder, A., Johnson, A., Jones, A., Shaw, T., Keech, W., Buttery, J., & Teede, H. (2021). A Learning Health System Framework to Operationalize Health Data to Improve Quality Care: An Australian Perspective. *Frontiers in Medicine*, *8*, 730021. https://doi.org/10.3389/fmed.2021.730021

Our healthcare system faces a burgeoning aging population, rising complexity, and escalating costs. Around 10% of healthcare is harmful, and evidence is slow to implement. Innovation to deliver quality and sustainable health systems is vital, and the methods are challenging. The aim of this study is to describe the process and present a perspective on a coproduced Learning Health System framework. The development of the Framework was led by publicly funded, collaborative, Academic Health Research Translation Centres, with a mandate to integrate research into healthcare to deliver impact. The focus of the framework is "learning together for better health," with coproduction involving leadership by an expert panel, a systematic review, qualitative research, a stakeholder workshop, and

iterative online feedback. The coproduced framework incorporates evidence from stakeholders, from research, from data (practice to data and data to new knowledge), and from implementation, to take new knowledge to practice. This continuous learning approach aims to deliver evidence-based healthcare improvement and is currently being implemented and evaluated.

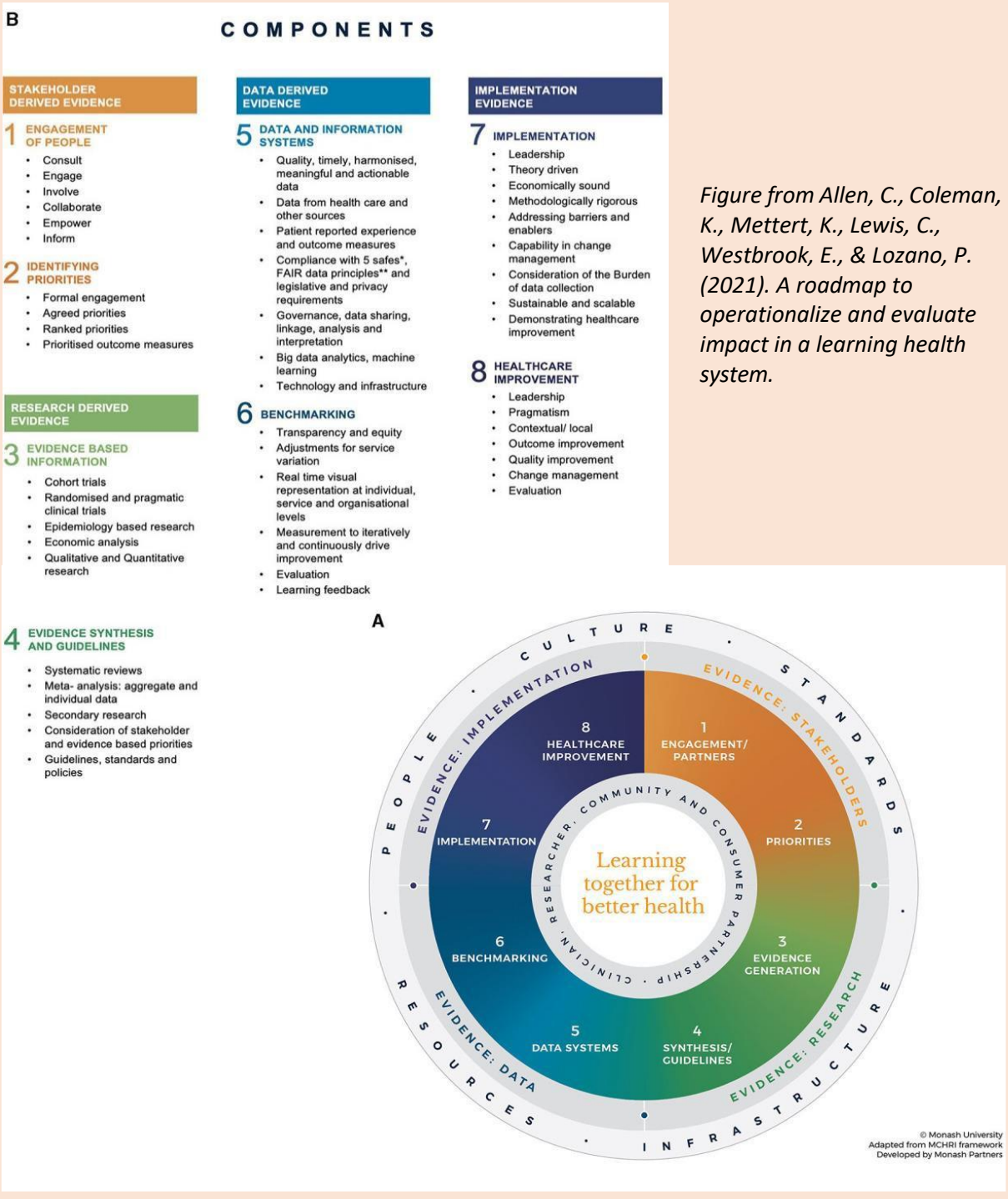

Figure from Allen, C., Coleman, K., Mettert, K., Lewis, C., Westbrook, E., & Lozano, P. (2021). A roadmap to operationalize and evaluate impact in a learning health system.

Walkey, A. J., Bor, J., & Cordella, N. J. (2020). Novel tools for a learning health system: a combined difference-in-difference/regression discontinuity approach to evaluate effectiveness of a readmission reduction initiative. *BMJ Quality & Safety*, *29*(2), 161–167. https://doi.org/10.1136/bmjqs-2019-009734

Abstract not included due to copyright restrictions.

Dash, D., Gokhale, A., Patel, B. S., Callahan, A., Posada, J., Krishnan, G., Collins, W., Li, R., Schulman, K., Ren, L., & Shah, N. H. (2022). Building a Learning Health System: Creating an Analytical Workflow for Evidence Generation to Inform Institutional Clinical Care Guidelines. *Applied Clinical Informatics*, *13*(1), 315–321. https://doi.org/10.1055/s-0042-1743241

Background: One key aspect of a learning health system (LHS) is utilizing data generated during care delivery to inform clinical care. However, institutional guidelines that utilize observational data are rare and require months to create, making current processes impractical for more urgent scenarios such as those posed by the COVID-19 pandemic. There exists a need to rapidly analyze institutional data to drive guideline creation where evidence from randomized control trials are unavailable.

Objectives: This article provides a background on the current state of observational data generation in institutional guideline creation and details our institution's experience in creating a novel workflow to (1) demonstrate the value of such a workflow, (2) demonstrate a real-world example, and (3) discuss difficulties encountered and future directions.

Methods: Utilizing a multidisciplinary team of database specialists, clinicians, and informaticists, we created a workflow for identifying and translating a clinical need into a queryable format in our clinical data warehouse, creating data summaries and feeding this information back into clinical guideline creation.

Results: Clinical questions posed by the hospital medicine division were answered in a rapid time frame and informed creation of institutional guidelines for the care of patients with COVID-19. The cost of setting up a workflow, answering the questions, and producing data summaries required around 300 hours of effort and $300,000 USD.

Conclusion: A key component of an LHS is the ability to learn from data generated during care delivery. There are rare examples in the literature and we demonstrate one such example along with proposed thoughts of ideal multidisciplinary team formation and deployment.

Ramaswamy, R., Ramaswamy, V., Holly, M., Bartels, S., & Barach, P. (2022). Building local decision-making competencies during COVID-19: Accelerating the transition from learning healthcare systems to learning health communities. *Learning Health Systems*, e10337. Advance online publication. https://doi.org/10.1002/lrh2.10337

Introduction: The persisting and evolving COVID-19 pandemic has made apparent that no singular policy of mitigation at a regional, national or global level has achieved satisfactory and universally acceptable results. In the United States, carefully planned and executed pandemic policies have been neither effective nor popular and COVID-19 risk management decisions have been relegated to individual citizens and communities. In this paper, we argue that a more effective approach is to equip and strengthen community coalitions to become local learning health communities (LLHCs) that use data over time to make adaptive decisions that can optimize the equity and well-being in their communities.

Methods: We used data from the North Carolina (NC) county and zip code levels from May to August 2020 to demonstrate how a LLHC could use statistical process control (SPC) charts and simple statistical analysis to make local decisions about how to respond to COVID-19.

Results: We found many patterns of COVID-19 progression at the local (county and zip code) levels during the same time period within the state that were completely different from the aggregate NC state level data used for policy making.

Conclusions: Systematic approaches to learning from local data to support effective decisions have promise well beyond the current pandemic. These tools can help address other complex public health issues, and advance outcomes and equity. Building this capacity requires investment in data infrastructure and the strengthening of data competencies in community coalitions to better interpret data with limited need for advanced statistical expertise. Additional incentives that build trust, support data transparency, encourage truth-telling and promote meaningful teamwork are also critical. These must be carefully designed, contextually appropriate and multifaceted to motivate citizens to create and sustain an effective learning system that works for their communities.

Putting the search in context:
In addition to the search, we included the White Paper of Zurynski et al. (2020). It is the most recent compendium of research on LHSs and added to the original IOM definition.

Zurynski, Y.A., Smith, C.L., Vedovi, A., Ellis, L.A., Knaggs, G.T., Meulenbroeks, I., Warwick, M., Gul, H., Pomare, C., & Braithwaite, J. (2020). Mapping the learning health system: a scoping review of current evidence. A white paper.

The concept of a learning health system (LHS) has been gaining traction for over a decade as we increasingly realise that current health systems are not fit-for-purpose. The Institute of Medicine (IoM; now the National Academy of Medicine) described an LHS as a health system where “science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the care process, patients and families active participants in all elements, and new knowledge captured as an integral by-product of the care experience.”1 In the age of “big data” and artificial intelligence, there is enormous potential to harness the data that health systems generate, such as clinical information from electronic health records (eHRs), imaging, and genomics, to create new knowledge to improve care and health outcomes. With increasing challenges on health systems to deliver high-quality care within fiscal constraints, the LHS as a concept is increasingly being embraced by researchers, funders, managers, and clinicians as a means to embed the capture, analysis, and translation of new knowledge into the practice of healthcare delivery. We

conceptualise an LHS as an ongoing journey rather than a destination – there is always something new to learn to continuously improve health systems. Of course, to advance knowledge on the development, implementation, and sustainability of LHSs we need to know the scope of current knowledge.

Word Cloud from search 1

Key findings from search 1

1. Of the six abstracts included, five were generated from the United States, and one study was contributed from Australia. The additionally included White Paper was generated from Australia.
2. Of the few new frameworks that were developed, most were for use within a particular setting or organisation – that is to say, most new frameworks are context-specific.
3. Two studies looked at developing new methodologies or guidelines to be implemented within an LHS but were not concerned with altering or adding to the original LHS framework proposed by the Institute of Medicine (now, the National Academy of Medicine).
4. The Australian Institute of Health Innovation's Learning Health System group at Macquarie University (Zurynski et al., 2020) extended the IoM's original definition by adding a new element to the four existing elements (science and informatics, patient-clinician partnerships, incentives, and continuous learning culture): structure and governance (the National Academy of Medicine/Zurynski- Braithwaite model.
5. One study expanded the LHS to a 'local learning health community' (LLHC), which included input from stakeholders working in schools, hospitals, health departments, and community organisations with the purpose of monitoring COVID-19.
6. Most studies continue to use the original LHS framework that was developed by the Institute of Medicine (Now the National Academy of Medicine).

Search 2: "Systems dynamics" modelling in health systems: Primary care and/or Emergency departments and/or hospitals

Next, we examine systems dynamics models of LHSs, and reflect on how, or the extent to which, LHSs are being modelled in a sophisticated way. Systems dynamics models are computer representations of systems and each of their composite parts. They help describe the interaction of these parts and how they change over time in response to other agents and features of the environment (Auchincloss & Diez Roux, 2008). We are especially interested in systems dynamics models of health care settings on the front lines of care that are most likely to deal with climate- or pandemic-affected populations of patients – namely, emergency departments (EDs) and primary care. Our intention is to build on any extant systems dynamics models.

PubMed searches executed on 10/02/2023.
Search terms: ("systems dynamics") AND ("primary care"). No limits.
Results: two results, screened for relevance. None included.
("systems dynamics") AND ("emergency department"). No limits.
Results: one result, screened for relevance. Not included.
("systems dynamics") AND (hospitals). No limits.
Results: 29 results, all screened for relevance. Three studies included.
Studies were included if they discussed or used systems dynamics methodologies in one of the following: primary care, emergency departments or hospitals.

Piñero, J. C. M., Díaz, A., & Vela, J. S. M. (2021). Saturación del servicio de urgencias en la ciudad de Bogotá: una comprensión sistémica del problema [Overcrowding of emergency services in the city of Bogotá: a systemic understanding of the problem]. *Ciencia & Saude Coletiva*, *26*(suppl 2), 3609–3622. https://doi.org/10.1590/1413-81232021269.2.27302019

Emergency overcrowding is often associated with issues of inefficiency in care. However, this work focuses on another relevant aspect, namely care of non-urgent patients. In order to understand the dynamics associated with this aspect, a conceptual model of systems dynamics is constructed, based on the characterization of users and their decision criteria. A descriptive study was conducted based on a structured survey; additionally, binomial logistic regression and analysis of variance were used to estimate probability of emergency department visits and to define differences among users. The following criteria are relevant: service effectiveness, availability of medications and exams, and proximity to the emergency center. The waiting time is more significant for pediatric patients and the availability of medications and exams is also more prevalent for middle-income users; the latter attributes less importance to cost compared to low income. The model shows that resources create a virtuous or a vicious cycle of users waiting for care in both emergency and priority care (PC) centers. The proposal suggested is for segregation for pediatric users in PC centers and the promotion of user confidence in alternative options to emergency centers.

Muttalib, F., Ballard, E., Langton, J., Malone, S., Fonseca, Y., Hansmann, A., Remy, K., Hovmand, P., & Doctor, A. (2021). Application of systems dynamics and group model building to identify barriers and facilitators to acute care delivery in a resource limited setting. *BMC Health Services Research*, *21*(1), 26. https://doi.org/10.1186/s12913-020-06014-7

Background: Group model building (GMB) is a method to facilitate shared understanding of structures and relationships that determine system behaviors. This project aimed to determine the feasibility of

GMB in a resource-limited setting and to use GMB to describe key barriers and facilitators to effective acute care delivery at a tertiary care hospital in Malawi.

Methods: Over 1 week, trained facilitators led three GMB sessions with two groups of healthcare providers to facilitate shared understanding of structures and relationships that determine system behaviors. One group aimed to identify factors that impact patient flow in the paediatric special care ward. The other aimed to identify factors impacting delivery of high-quality care in the paediatric accident and emergency room. Synthesized causal maps of factors influencing patient care were generated, revised, and qualitatively analyzed.

Results: Causal maps identified patient condition as the central modifier of acute care delivery. Severe illness and high volume of patients were identified as creating system strain in several domains: (1) physical space, (2) resource needs and utilization, (3) staff capabilities and (4) quality improvement. Stress in these domains results in worsening patient condition and perpetuating negative reinforcing feedback loops. Balancing factors inherent to the current system included (1) parental engagement, (2) provider resilience, (3) ease of communication and (4) patient death. Perceived strengths of the GMB process were representation of diverse stakeholder viewpoints and complex system synthesis in a visual causal pathway, the process inclusivity, development of shared understanding, new idea generation and momentum building. Challenges identified included time required for completion and potential for participant selection bias.

Conclusions: GMB facilitated creation of a shared mental model, as a first step in optimizing acute care delivery in a paediatric facility in this resource-limited setting.

Pilar, M. R., Proctor, E. K., & Pineda, J. A. (2020). Development, implementation, and evaluation of a novel guideline engine for pediatric patients with severe traumatic brain injury: a study protocol. *Implementation Science Communications*, *1*, 31. https://doi.org/10.1186/s43058-020-00012-w

Background: Severe traumatic brain injury (TBI) is a leading cause of death and disability for children. The Brain Trauma Foundation released evidence-based guidelines, a series of recommendations regarding care for pediatric patients with severe TBI. Clinical evidence suggests that adoption of guideline-based care improves outcomes in patients with severe TBI. However, guideline implementation has not been systematic or consistent in clinical practice. There is also a lack of information about implementation strategies that are effective given the nature of severe TBI care and the complex environment in the intensive care unit (ICU). Novel technology-based strategies may be uniquely suited to the fast-paced, transdisciplinary care delivered in the ICU, but such strategies must be carefully developed and evaluated to prevent unintended consequences within the system of care. This challenge presents a unique opportunity for intervention to more appropriately implement guideline-based care for pediatric patients with severe TBI.

Methods: This mixed-method study will develop a novel technology-based bedside guideline engine (the implementation strategy) to facilitate uptake of evidence-based guidelines (the intervention) for management of severe TBI. Group model building and systems dynamics will inform the guideline engine design, and bedside functionality will be initially assessed through patient simulation. Using the Promoting Action on Research Implementation in Health Services (PARIHS) framework, we will determine the feasibility of incorporating the guideline engine in the ICU. Study participants will include pediatric patients with severe TBI and providers at three trauma centers. Quantitative data will include measures of guideline engine acceptance and organizational readiness for change. Qualitative data will include semi-structured interviews from clinicians. We will test the feasibility of

incorporating the guideline engine in "real life practice" in preparation for a future clinical trial that will assess clinical and implementation outcomes, including feasibility, acceptability, and adoption of the guideline engine.

Discussion: This study will lead to the development and feasibility testing of an adaptable strategy for implementing guideline-based care for severe TBI, a strategy that meets the needs of individual critical care environments and patients. A future study will test the adaptability and impact of the bedside guideline engine in a randomized clinical trial.

Word cloud from search 2

Key findings from search 2

1. There are few studies in PubMed that use systems dynamics modelling in hospitals or emergency departments. No studies were found that discussed systems dynamics modelling in a primary care setting.
2. This represents an important gap in the evidence base and is a prime area for future research.

Search 3: Pandemics and Learning Health Systems

Next, we move to a search at the intersection of pandemics and LHSs. How and in what ways is the LHS concept being mobilised to tackle COVID-19 or future pandemics?

PubMed search executed on 10/02/2023.
Search terms: (pandemic) AND ("Learning Health System*").
Limits: Published in the last 5 years (i.e., from 10/02/2018)
Results: 65 studies included. All results were title screened and relevant title/abstracts (n=19) are included below.
Screening selection criteria: exclusion based on setting (i.e., a study was set in a learning health system facility but didn't explicitly discuss elements of the LHS), inclusion based on discussion of pandemics, future pandemics, COVID-19 and Learning Health Systems, all health systems, low middle and high income.

Cassidy, C., Sim, M., Somerville, M., Crowther, D., Sinclair, D., Elliott Rose, A., Burgess, S., Best, S., & Curran, J. A. (2022). Using a learning health system framework to examine COVID-19 pandemic planning and response at a Canadian Health Centre. *PloS One*, *17*(9), e0273149. https://doi.org/10.1371/journal.pone.0273149

Background: The COVID-19 pandemic has presented a unique opportunity to explore how health systems adapt under rapid and constant change and develop a better understanding of health system transformation. Learning health systems (LHS) have been proposed as an ideal structure to inform a data-driven response to a public health emergency like COVID-19. The aim of this study was to use a LHS framework to identify assets and gaps in health system pandemic planning and response during the initial stages of the COVID-19 pandemic at a single Canadian Health Centre.

Methods: This paper reports the data triangulation stage of a concurrent triangulation mixed methods study which aims to map study findings onto the LHS framework. We used a triangulation matrix to map quantitative (textual and administrative sources) and qualitative (semi-structured interviews) data onto the seven characteristics of a LHS and identify assets and gaps related to health-system receptors and research-system supports.

Results: We identified several health system assets within the LHS characteristics, including appropriate decision supports and aligned governance. Gaps were identified in the LHS characteristics of engaged patients and timely production and use of research evidence.

Conclusion: The LHS provided a useful framework to examine COVID-19 pandemic response measures. We highlighted opportunities to strengthen the LHS infrastructure for rapid integration of evidence and patient experience data into future practice and policy changes.

McCreary, E. K., Kip, K. E., Bariola, J. R., Schmidhofer, M., Minnier, T., Mayak, K., Albin, D., Daley, J., Linstrum, K., Hernandez, E., Sackrowitz, R., Hughes, K., Horvat, C., Snyder, G. M., McVerry, B. J., Yealy, D. M., Huang, D. T., Angus, D. C., & Marroquin, O. C. (2022). A learning health system approach to the COVID-19 pandemic: System-wide changes in clinical practice and 30-day mortality among hospitalized patients. *Learning Health Systems*, *6*(3), e10304. https://doi.org/10.1002/lrh2.10304

Introduction: Rapid, continuous implementation of credible scientific findings and regulatory approvals is often slow in large, diverse health systems. The coronavirus disease 2019 (COVID-19) pandemic created a new threat to this common "slow to learn and adapt" model in healthcare. We describe how the University of Pittsburgh Medical Center (UPMC) committed to a rapid learning health system (LHS) model to respond to the COVID-19 pandemic.

Methods: A treatment cohort study was conducted among 11 429 hospitalized patients (pediatric/adult) from 22 hospitals (PA, NY) with a primary diagnosis of COVID-19 infection (March 19, 2020 - June 6, 2021). Sociodemographic and clinical data were captured from UPMC electronic medical record (EMR) systems. Patients were grouped into four time-defined patient "waves" based on nadir of daily hospital admissions, with wave 3 (September 20, 2020 - March 10, 2021) split at its zenith due to high volume with steep acceleration and deceleration. Outcomes included changes in clinical practice (eg, use of corticosteroids, antivirals, and other therapies) in relation to timing of internal system analyses, scientific publications, and regulatory approvals, along with 30-day rate of mortality over time.

Results: The mean (SD) daily number of admissions across hospitals was 26 (29) with a maximum 7-day moving average of 107 patients. System-wide implementation of the use of dexamethasone, remdesivir, and tocilizumab occurred within days of release of corresponding seminal publications and regulatory actions. After adjustment for differences in patient clinical profiles over time, each month of hospital admission was associated with an estimated 5% lower odds of 30-day mortality (adjusted odds ratio [OR] = 0.95, 95% confidence interval: 0.93-0.97, P < .001).

Conclusions: In our large LHS, near real-time changes in clinical management of COVID-19 patients happened promptly as scientific publications and regulatory approvals occurred throughout the pandemic. Alongside these changes, patients with COVID-19 experienced lower adjusted 30-day mortality following hospital admission over time.

Payne, P. R. O., Wilcox, A. B., Embi, P. J., & Longhurst, C. A. (2022). Better together: Integrating biomedical informatics and healthcare IT operations to create a learning health system during the COVID-19 pandemic. *Learning Health Systems*, *6*(2), e10309. https://doi.org/10.1002/lrh2.10309

The growing availability of multi-scale biomedical data sources that can be used to enable research and improve healthcare delivery has brought about what can be described as a healthcare "data age." This new era is defined by the explosive growth in bio-molecular, clinical, and population-level data that can be readily accessed by researchers, clinicians, and decision-makers, and utilized for systems-level approaches to hypothesis generation and testing as well as operational decision-making. However, taking full advantage of these unprecedented opportunities presents an opportunity to revisit the alignment between traditionally academic biomedical informatics (BMI) and operational healthcare information technology (HIT) personnel and activities in academic health systems. While the history of the academic field of BMI includes active engagement in the delivery of operational HIT platforms, in many contemporary settings these efforts have grown distinct. Recent experiences during the COVID-19 pandemic have demonstrated greater coordination of BMI and HIT activities that have allowed organizations to respond to pandemic-related changes more effectively, with demonstrable and positive impact as a result. In this position paper, we discuss the challenges and opportunities associated with driving alignment between BMI and HIT, as viewed from the perspective of a learning healthcare system. In doing so, we hope to illustrate the benefits of

coordination between BMI and HIT in terms of the quality, safety, and outcomes of care provided to patients and populations, demonstrating that these two groups can be "better together."

Levin, A., Malbeuf, M., Hoens, A. M., Carlsten, C., Ryerson, C. J., Cau, A., Bryan, S., Robinson, J., Tarling, T., Shum, J., & Lavallee, D. C. (2022). Creating a provincial post COVID-19 interdisciplinary clinical care network as a learning health system during the pandemic: Integrating clinical care and research. *Learning Health Systems*, *7*(1), e10316. Advance online publication. https://doi.org/10.1002/lrh2.10316

Introduction: Coronavirus Disease-2019 (COVID-19) affects multiple organ systems in the acute phase and also has long-term sequelae. Research on the long-term impacts of COVID-19 is limited. The Post COVID-19 Interdisciplinary Clinical Care Network (PC-ICCN), conceived in July 2020, is a provincially funded resource that is modelled as a Learning Health System (LHS), focused on those people with persistent symptoms post COVID-19 infection.

Methods: The PC-ICCN emerged through collaboration among over 60 clinical specialists, researchers, patients, and health administrators. At the core of the network are the post COVID-19 Recovery Clinics (PCRCs), which provide direct patient care that includes standardized testing and education at regular follow-up intervals for a minimum of 12 months post enrolment. The PC-ICCN patient registry captures data on all COVID-19 patients with confirmed infection, by laboratory testing or epi-linkage, who have been referred to one of five post COVID-19 Recovery Clinics at the time of referral, with data stored in a fully encrypted Oracle-based provincial database. The PC-ICCN has centralized administrative and operational oversight, multi-stakeholder governance, purpose built data collection supported through clinical operations geographically dispersed across the province, and research operations including data analytics.

Results: To date, 5364 patients have been referred, with an increasing number and capacity of these clinics, and 2354 people have had at least one clinic visit. Since inception, the PC-ICCN has received over 30 research proposal requests. This is aligned with the goal of creating infrastructure to support a wide variety of research to improve care and outcomes for patients experiencing long-term symptoms following COVID-19 infection.

Conclusions: The PC-ICCN is a first-in-kind initiative in British Columbia to enhance knowledge and understanding of the sequelae of COVID-19 infection over time. This provincial initiative serves as a model for other national and international endeavors to enable care as research and research as care.

van Rensburg, A. J., Petersen, I., Awotiwon, A., Bachmann, M. O., Curran, R., Murdoch, J., Ras, C. J., & Fairall, L. (2022). Applying learning health systems thinking in codeveloping integrated tuberculosis interventions in the contexts of COVID-19. *BMJ Global Health*, *7*(10), e009567. https://doi.org/10.1136/bmjgh-2022-009567

The COVID-19 pandemic reversed much of global progress made in combatting tuberculosis, with South Africa experiencing one of the largest impacts on tuberculosis detection. The aim of this paper is to share our experiences in applying learning health systems (LHS) thinking to the codevelopment of an intervention improving an integrated response to COVID-19 and tuberculosis in a South African district. A sequential partially mixed-methods study was undertaken between 2018 and 2021 in the district of Amajuba in KwaZulu-Natal. Here, we report on the formulation of a Theory of Change, codesigning and refining proposed interventions, and piloting and evaluating codesigned interventions in primary healthcare facilities, through an LHS lens. Following the establishment and

formalisation of a district Learning Community, diagnostic work and a codevelopment of a theory of change, intervention packages tailored according to pandemic lockdowns were developed, piloted and scaled up. This process illustrates how a community of learning can generate more responsive, localised interventions, and suggests that the establishment of a shared space of research governance can provide a degree of resilience to facilitate adaption to external shocks. Four main lessons have been gleaned from our experience in adopting an LHS approach in a South African district, which are (1) the importance of building and sustaining relationships, (2) the utility of colearning, coproduction and adaptive capacity, (3) the centrality of theory-driven systems strengthening and (4) reflections on LHS as a framework.

Douthit B. J. (2021). The influence of the learning health system to address the COVID-19 pandemic: An examination of early literature. *The International Journal of Health Planning and Management*, *36*(2), 244–251. https://doi.org/10.1002/hpm.3088

Abstract not included due to copyright restrictions.

English, M., Irimu, G., Akech, S., Aluvaala, J., Ogero, M., Isaaka, L., Malla, L., Tuti, T., Gathara, D., Oliwa, J., & Agweyu, A. (2021). Employing learning health system principles to advance research on severe neonatal and paediatric illness in Kenya. *BMJ Global Health*, *6*(3), e005300. https://doi.org/10.1136/bmjgh-2021-005300

We have worked to develop a Clinical Information Network (CIN) in Kenya as an early form of learning health systems (LHS) focused on paediatric and neonatal care that now spans 22 hospitals. CIN's aim was to examine important outcomes of hospitalisation at scale, identify and ultimately solve practical problems of service delivery, drive improvements in quality and test interventions. By including multiple routine settings in research, we aimed to promote generalisability of findings and demonstrate potential efficiencies derived from LHS. We illustrate the nature and range of research CIN has supported over the past 7 years as a form of LHS. Clinically, this has largely focused on common, serious paediatric illnesses such as pneumonia, malaria and diarrhoea with dehydration with recent extensions to neonatal illnesses. CIN also enables examination of the quality of care, for example that provided to children with severe malnutrition and the challenges encountered in routine settings in adopting simple technologies (pulse oximetry) and more advanced diagnostics (eg, Xpert MTB/RIF). Although regular feedback to hospitals has been associated with some improvements in quality data continue to highlight system challenges that undermine provision of basic, quality care (eg, poor access to blood glucose testing and routine microbiology). These challenges include those associated with increased mortality risk (eg, delays in blood transfusion). Using the same data the CIN platform has enabled conduct of randomised trials and supports malaria vaccine and most recently COVID-19 surveillance. Employing LHS principles has meant engaging front-line workers, clinical managers and national stakeholders throughout. Our experience suggests LHS can be developed in low and middle-income countries that efficiently enable contextually appropriate research and contribute to strengthening of health services and research systems.

Ramaswamy, R., Ramaswamy, V., Holly, M., Bartels, S., & Barach, P. (2022). Building local decision-making competencies during COVID-19: Accelerating the transition from learning healthcare systems to learning health communities. *Learning Health Systems*, e10337. Advance online publication. https://doi.org/10.1002/lrh2.10337

Introduction: The persisting and evolving COVID-19 pandemic has made apparent that no singular policy of mitigation at a regional, national or global level has achieved satisfactory and universally acceptable results. In the United States, carefully planned and executed pandemic policies have been neither effective nor popular and COVID-19 risk management decisions have been relegated to individual citizens and communities. In this paper, we argue that a more effective approach is to equip and strengthen community coalitions to become local learning health communities (LLHCs) that use data over time to make adaptive decisions that can optimize the equity and well-being in their communities.

Methods: We used data from the North Carolina (NC) county and zip code levels from May to August 2020 to demonstrate how a LLHC could use statistical process control (SPC) charts and simple statistical analysis to make local decisions about how to respond to COVID-19.

Results: We found many patterns of COVID-19 progression at the local (county and zip code) levels during the same time period within the state that were completely different from the aggregate NC state level data used for policy making.

Conclusions: Systematic approaches to learning from local data to support effective decisions have promise well beyond the current pandemic. These tools can help address other complex public health issues, and advance outcomes and equity. Building this capacity requires investment in data infrastructure and the strengthening of data competencies in community coalitions to better interpret data with limited need for advanced statistical expertise. Additional incentives that build trust, support data transparency, encourage truth-telling and promote meaningful teamwork are also critical. These must be carefully designed, contextually appropriate and multifaceted to motivate citizens to create and sustain an effective learning system that works for their communities.

Anderson, J. L., Reamey, R. A., Levitan, E. B., M Asif, I., S Aswani, M., Fletcher, F. E., G Hall, A., Kennedy, K. C., Long, D., Redden, D., Tunagur, A., Wasko, M., Willig, J., Wyatt, M., & Mugavero, M. J. (2021). The University of Alabama at Birmingham COVID-19 Collaborative Outcomes Research Enterprise: Developing an institutional learning health system in response to the global pandemic. *Learning Health Systems*, *6*(2), e10292. https://doi.org/10.1002/lrh2.10292

Introduction: As a local response to the COVID-19 global pandemic, the University of Alabama at Birmingham (UAB) established the UAB COVID-19 Collaborative Outcomes Research Enterprise (CORE), an institutional learning health system (LHS) to achieve an integrated health services outcomes and research response.

Methods: We developed a network of expertise and capabilities to rapidly develop and deploy an institutional-level interdisciplinary LHS. Based upon a scoping review of the literature and the Knowledge to Action Framework, we adopted a LHS framework identifying contributors and components necessary to developing a system within and between the university academic and medical centers. We used social network analysis to examine the emergence of informal work patterns and diversified network capabilities based on the LHS framework.

Results: This experience report details three principal characteristics of the UAB COVID-19 CORE LHS development: (a) identifying network contributors and components; (b) building the institutional network; and (c) diversifying network capabilities. Contributors and committees were identified from seven components of LHS: (a) collaborative and executive leadership committee, (b) research coordinating committee, (c) oversight and ethics committee, (d) thematic scientific working groups, (e) programmatic working groups, (f) informatics capabilities, and (g) patient advisory groups. Evolving from the topical interests of the initial CORE participants, scientific working groups emerged to support the learning system network. Programmatic working groups were charged with developing a comprehensive and mutually accessible COVID-19 database.

Discussion: Our LHS framework allowed for effective integration of multiple academic and medical centers into a cohesive institutional-level learning system. Network analysis indicated diversity of institutional disciplines, professional rank, and topical focus pertaining to COVID-19, with each center leveraging existing institutional responsibilities to minimize gaps in network capabilities.

Conclusion: Incorporating an adapted LHS framework designed for academic medical centers served as a foundational resource supporting further institutional-level efforts to develop agile and responsive learning networks.

Heys, M., Kesler, E., Sassoon, Y., Wilson, E., Fitzgerald, F., Gannon, H., Hull-Bailey, T., Chimhini, G., Khan, N., Cortina-Borja, M., Nkhoma, D., Chiyaka, T., Stevenson, A., Crehan, C., Chiume, M. E., Chimhuya, S., & Neotree Team (2022). Development and implementation experience of a learning healthcare system for facility based newborn care in low resource settings: The Neotree. *Learning Health Systems*, *7*(1), e10310. https://doi.org/10.1002/lrh2.10310

Introduction: Improving peri- and postnatal facility-based care in low-resource settings (LRS) could save over 6000 babies' lives per day. Most of the annual 2.4 million neonatal deaths and 2 million stillbirths occur in healthcare facilities in LRS and are preventable through the implementation of cost-effective, simple, evidence-based interventions. However, their implementation is challenging in healthcare systems where one in four babies admitted to neonatal units die. In high-resource settings healthcare systems strengthening is increasingly delivered via learning healthcare systems to optimise care quality, but this approach is rare in LRS.

Methods: Since 2014 we have worked in Bangladesh, Malawi, Zimbabwe, and the UK to co-develop and pilot the Neotree system: an android application with accompanying data visualisation, linkage, and export. Its low-cost hardware and state-of-the-art software are used to support healthcare professionals to improve postnatal care at the bedside and to provide insights into population health trends. Here we summarise the formative conceptualisation, development, and preliminary implementation experience of the Neotree.

Results: Data thus far from ~18 000 babies, 400 healthcare professionals in four hospitals (two in Zimbabwe, two in Malawi) show high acceptability, feasibility, usability, and improvements in healthcare professionals' ability to deliver newborn care. The data also highlight gaps in knowledge in newborn care and quality improvement. Implementation has been resilient and informative during external crises, for example, coronavirus disease 2019 (COVID-19) pandemic. We have demonstrated evidence of improvements in clinical care and use of data for Quality Improvement (QI) projects.

Conclusion: Human-centred digital development of a QI system for newborn care has demonstrated the potential of a sustainable learning healthcare system to improve newborn care and outcomes in LRS. Pilot implementation evaluation is ongoing in three of the four aforementioned hospitals (two in Zimbabwe and one in Malawi) and a larger scale clinical cost effectiveness trial is planned.

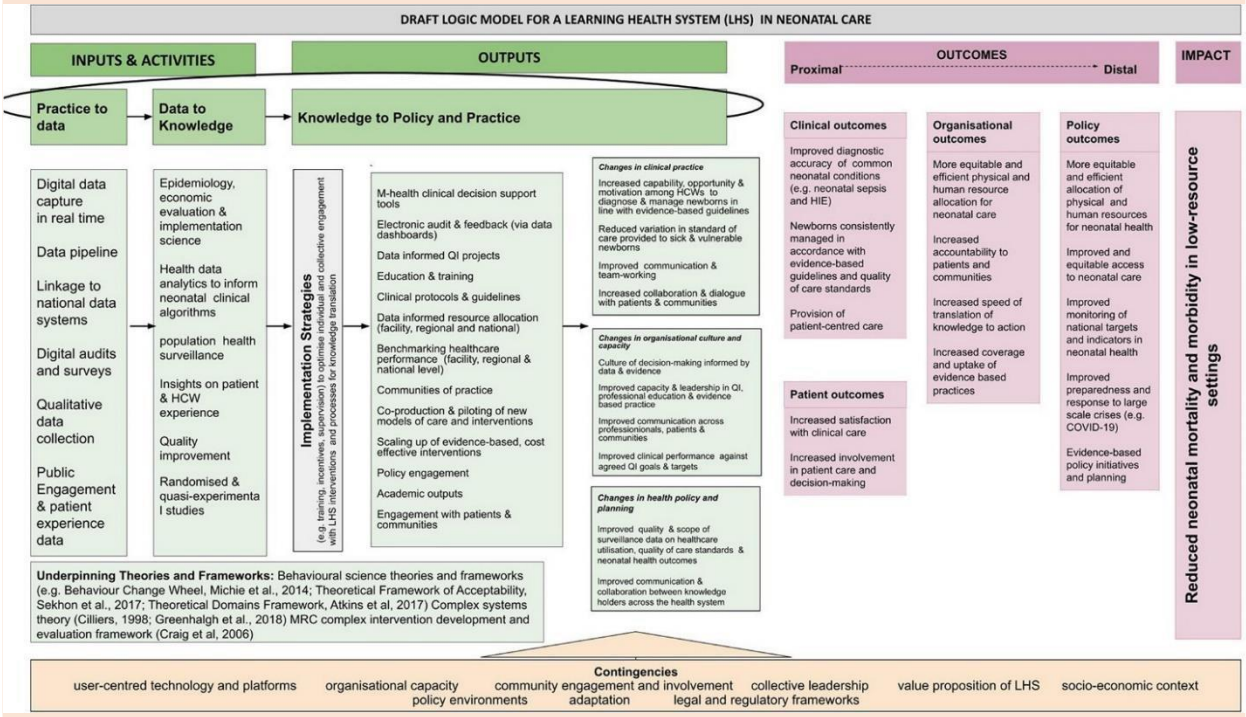

Figure from Heys, M., Kesler, E., Sassoon, Y., Wilson, E., Fitzgerald, F., Gannon, H., Hull-Bailey, T., Chimhini, G., Khan, N., Cortina-Borja, M., Nkhoma, D., Chiyaka, T., Stevenson, A., Crehan, C., Chiume, M. E., Chimhuya, S., & Neotree Team (2022). Development and implementation experience of a learning healthcare system for facility based newborn care in low resource settings: The Neotree.

Romanelli, R. J., Azar, K. M. J., Sudat, S., Hung, D., Frosch, D. L., & Pressman, A. R. (2021). Learning Health System in Crisis: Lessons From the COVID-19 Pandemic. *Mayo Clinic Proceedings. Innovations, Quality & Outcomes*, *5*(1), 171–176. https://doi.org/10.1016/j.mayocpiqo.2020.10.004

The coronavirus disease 2019 (COVID-19) pandemic is the gravest public health crisis that the United States has seen in more than a century. Health care delivery systems are the focal point for interfacing with COVID-19; however, many were and remain unprepared for this or similar outbreaks. In this article, we describe the learning health system (LHS) as an ideal organizing principle to inform an evidence-based response to public health emergencies like COVID-19. We further describe barriers and challenges to the realization of the LHS and propose a call to action for a substantial investment in the LHS, with a focus on public health. Specifically, we advocate for a learning health network that promotes collaboration among health systems, community-based organizations, and government agencies, especially during public health emergencies. We have approached this commentary through the unique lens of researchers embedded within a large, integrated health care delivery system, with direct experience working with clinical and operational units in response to the COVID-19 pandemic.

Allen, C., Coleman, K., Mettert, K., Lewis, C., Westbrook, E., & Lozano, P. (2021). A roadmap to operationalize and evaluate impact in a learning health system. *Learning Health Systems*, *5*(4), e10258. https://doi.org/10.1002/lrh2.10258

Background: Many health systems invest in initiatives to accelerate translation of knowledge into practice. However, organizations lack guidance on how to develop and operationalize such Learning Health System (LHS) programs and evaluate their impact. Kaiser Permanente Washington (KPWA) launched our LHS program in June 2017 and developed a logic model as a foundation to evaluate the program's impact.

Objective: To develop a roadmap for organizations that want to establish an LHS program, understand how LHS core components relate to one another when operationalized in practice, and evaluate and improve their progress.

Methods: We conducted a narrative review on LHS models, key model components, and measurement approaches.
Results: The KPWA LHS Logic Model provides a broad set of constructs relevant to LHS programs, depicts their relationship to LHS operations, harmonizes terms across models, and offers measurable operationalizations of each construct to guide other health systems. The model identifies essential LHS inputs, provides transparency into LHS activities, and defines key outcomes to evaluate LHS processes and impact. We provide reflections on the most helpful components of the model and identify areas that need further improvement using illustrative examples from deployment of the LHS model during the COVID-19 pandemic.

Conclusion: The KPWA LHS Logic Model is a starting point for future LHS implementation research and a practical guide for healthcare organizations that are building, operationalizing, and evaluating LHS initiatives.

Gustavson, A. M., Purnell, A., Adly, M., Awan, O., Bräu, N., Braus, N. A., Bryant, M. S., Chang, L., Cyborski, C., Darvish, B., Del Piero, L. B., Eaton, T. L., Kiliveros, A., Kloth, H., McNiel, E. R., Miller, M. A., Patrick, A., Powers, P., Pyne, M., Rodriguez, I. G., … Shak, J. R. (2022). A Learning Health System Approach to Long COVID Care. *Federal Practitioner: For the Health Care Professionals of the VA, DoD, and PHS*, *39*(7), 310–314. https://doi.org/10.12788/fp.0288

Abstract not included due to copyright restrictions.

Tai-Seale, M., May, N., Sitapati, A., & Longhurst, C. A. (2021). A learning health system approach to COVID-19 exposure notification system rollout. *Learning Health Systems*, *6*(2), e10290. https://doi.org/10.1002/lrh2.10290

Introduction: Digital exposure notification (EN) approaches may offer considerable advantages over traditional contact tracing in speed, scale, efficacy, and confidentiality in pandemic control. We applied the science of learning health systems to test the effect of framing and digital means, email vs Short Message Service (SMS), on EN adoption among patients of an academic health center.

Methods: We tested three communication approaches of the Apple and Google EN system in a rapid learning cycle involving 15 000 patients pseudorandomly assigned to three groups. The patients in the first group received a 284-word email that presented EN as a tool that can help slow the spread. The patients in the second group received a 32-word SMS that described EN as a new tool to help slow the spread (SlowTheSpreadSMS). Patients in the third group received a 47-word SMS that depicted the system as a new digital tool that can empower them to protect their family and friends (EmpowerSMS). A brief four-question anonymous survey of adoption was included in a reminder message sent 2 days after the initial outreach.

Results: One hundred and sixty people responded to the survey within 1 week: 2.33% from EmpowerSMS, 0.97% from SlowTheSpreadSMS, and 0.53% from emails; 29 (41.43%), 24 (41.38%), and 11 (34.38%) reported having adopted EN from each group, respectively. Patient reported barriers to adoption included iOS version incompatibility, privacy concerns, and low trust of government agencies or companies like Apple and Google. Patients recommended that healthcare systems play an active role in disseminating information about this tool. Patients also recommended advertising on social media and providing reassurance about privacy.

Conclusions: The EmpowerSMS resulted in relatively more survey responses. Both SMS groups had slightly higher, but not statistically significant EN adoption rates compared to email. Findings from the pilot not only informed operational decision-making in our health system but also contributed to EN rollout planning in our State.

Vahidy, F., Jones, S. L., Tano, M. E., Nicolas, J. C., Khan, O. A., Meeks, J. R., Pan, A. P., Menser, T., Sasangohar, F., Naufal, G., Sostman, D., Nasir, K., & Kash, B. A. (2021). Rapid Response to Drive COVID-19 Research in a Learning Health Care System: Rationale and Design of the Houston Methodist COVID-19 Surveillance and Outcomes Registry (CURATOR). *JMIR Medical Informatics*, *9*(2), e26773. https://doi.org/10.2196/26773

Background: The COVID-19 pandemic has exacerbated the challenges of meaningful health care digitization. The need for rapid yet validated decision-making requires robust data infrastructure. Organizations with a focus on learning health care (LHC) systems tend to adapt better to rapidly evolving data needs. Few studies have demonstrated a successful implementation of data digitization principles in an LHC context across health care systems during the COVID-19 pandemic.

Objective: We share our experience and provide a framework for assembling and organizing multidisciplinary resources, structuring and regulating research needs, and developing a single source of truth (SSoT) for COVID-19 research by applying fundamental principles of health care digitization, in the context of LHC systems across a complex health care organization.

Methods: Houston Methodist (HM) comprises eight tertiary care hospitals and an expansive primary care network across Greater Houston, Texas. During the early phase of the pandemic, institutional leadership envisioned the need to streamline COVID-19 research and established the retrospective research task force (RRTF). We describe an account of the structure, functioning, and productivity of the RRTF. We further elucidate the technical and structural details of a comprehensive data repository-the HM COVID-19 Surveillance and Outcomes Registry (CURATOR). We particularly highlight how CURATOR conforms to standard health care digitization principles in the LHC context.

Results: The HM COVID-19 RRTF comprises expertise in epidemiology, health systems, clinical domains, data sciences, information technology, and research regulation. The RRTF initially convened in March 2020 to prioritize and streamline COVID-19 observational research; to date, it has reviewed over 60 protocols and made recommendations to the institutional review board (IRB). The RRTF also established the charter for CURATOR, which in itself was IRB-approved in April 2020. CURATOR is a relational structured query language database that is directly populated with data from electronic health records, via largely automated extract, transform, and load procedures. The CURATOR design enables longitudinal tracking of COVID-19 cases and controls before and after COVID-19 testing. CURATOR has been set up following the SSoT principle and is harmonized across other COVID-19 data sources. CURATOR eliminates data silos by leveraging unique and disparate big data sources for COVID-19 research and provides a platform to capitalize on institutional investment in cloud computing. It currently hosts deeply phenotyped sociodemographic, clinical, and outcomes data of approximately 200,000 individuals tested for COVID-19. It supports more than 30 IRB-approved protocols across several clinical domains and has generated numerous publications from its core and associated data sources.

Conclusions: A data-driven decision-making strategy is paramount to the success of health care organizations. Investment in cross-disciplinary expertise, health care technology, and leadership commitment are key ingredients to foster an LHC system. Such systems can mitigate the effects of ongoing and future health care catastrophes by providing timely and validated decision support.

Aryal, D., Beane, A., Dondorp, A. M., Green, C., Haniffa, R., Hashmi, M., Jayakumar, D., Marshall, J. C., McArthur, C. J., Murthy, S., Webb, S. A., Acharya, S. P., Ishani, P. G. P., Jawad, I., Khanal, S., Koirala, K., Luitel, S., Pabasara, U., Paneru, H. R., Kumar, A., … Umrani, Z. (2021). Operationalisation of the Randomized Embedded Multifactorial Adaptive Platform for COVID-19 trials in a low and lower-middle income critical care learning health system. *Wellcome Open Research*, *6*, 14. https://doi.org/10.12688/wellcomeopenres.16486.1

The Randomized Embedded Multifactorial Adaptive Platform (REMAP-CAP) adapted for COVID-19) trial is a global adaptive platform trial of hospitalised patients with COVID-19. We describe implementation in three countries under the umbrella of the Wellcome supported Low and Middle Income Country (LMIC) critical care network: Collaboration for Research, Implementation and Training in Asia (CCA). The collaboration sought to overcome known barriers to multi centre-clinical trials in resource-limited settings. Methods described focused on six aspects of implementation: i, Strengthening an existing community of practice; ii, Remote study site recruitment, training and support; iii, Harmonising the REMAP CAP- COVID trial with existing care processes; iv, Embedding REMAP CAP- COVID case report form into the existing CCA registry platform, v, Context specific adaptation and data management; vi, Alignment with existing pandemic and critical care research in the CCA. Methods described here may enable other LMIC sites to participate as equal partners in international critical care trials of urgent public health importance, both during this pandemic and beyond.

Dash, D., Gokhale, A., Patel, B. S., Callahan, A., Posada, J., Krishnan, G., Collins, W., Li, R., Schulman, K., Ren, L., & Shah, N. H. (2022). Building a Learning Health System: Creating an Analytical Workflow for Evidence Generation to Inform Institutional Clinical Care Guidelines. *Applied Clinical Informatics*, *13*(1), 315–321. https://doi.org/10.1055/s-0042-1743241

Background: One key aspect of a learning health system (LHS) is utilizing data generated during care delivery to inform clinical care. However, institutional guidelines that utilize observational data are rare and require months to create, making current processes impractical for more urgent scenarios such as those posed by the COVID-19 pandemic. There exists a need to rapidly analyze institutional data to drive guideline creation where evidence from randomized control trials are unavailable.

Objectives: This article provides a background on the current state of observational data generation in institutional guideline creation and details our institution's experience in creating a novel workflow to (1) demonstrate the value of such a workflow, (2) demonstrate a real-world example, and (3) discuss difficulties encountered and future directions.

Methods: Utilizing a multidisciplinary team of database specialists, clinicians, and informaticists, we created a workflow for identifying and translating a clinical need into a queryable format in our clinical data warehouse, creating data summaries and feeding this information back into clinical guideline creation.

Results: Clinical questions posed by the hospital medicine division were answered in a rapid time frame and informed creation of institutional guidelines for the care of patients with COVID-19. The cost of setting up a workflow, answering the questions, and producing data summaries required around 300 hours of effort and $300,000 USD.

Conclusion: A key component of an LHS is the ability to learn from data generated during care delivery. There are rare examples in the literature and we demonstrate one such example along with proposed thoughts of ideal multidisciplinary team formation and deployment.

Ros, F., Kush, R., Friedman, C., Gil Zorzo, E., Rivero Corte, P., Rubin, J. C., Sanchez, B., Stocco, P., & Van Houweling, D. (2020). Addressing the Covid-19 pandemic and future public health challenges through global collaboration and a data-driven systems approach. *Learning Health Systems*, *5*(1), e10253. https://doi.org/10.1002/lrh2.10253

Covid-19 has already taught us that the greatest public health challenges of our generation will show no respect for national boundaries, will impact lives and health of people of all nations, and will affect economies and quality of life in unprecedented ways. The types of rapid learning envisioned to address Covid-19 and future public health crises require a systems approach that enables sharing of data and lessons learned at scale. Agreement on a systems approach augmented by technology and standards will be foundational to making such learning meaningful and to ensuring its scientific integrity. With this purpose in mind, a group of individuals from Spain, Italy, and the United States have formed a transatlantic collaboration, with the aim of generating a proposed comprehensive standards-based systems approach and data-driven framework for collection, management, and analysis of high-quality data. This framework will inform decisions in managing clinical responses and social measures to overcome the Covid-19 global pandemic and to prepare for future public health crises. We first argue that standardized data of the type now common in global regulated clinical research is the essential fuel that will power a global system for addressing (and preventing) current and future pandemics. We then present a blueprint for a system that will put these data to use in driving a range of key decisions. In the context of this system, we describe and categorize the specific

types of data the system will require for different purposes and document the standards currently in use for each of these categories in the three nations participating in this work. In so doing, we anticipate some of the challenges to harmonizing these data but also suggest opportunities for further global standardization and harmonization. While we have scaled this transnational effort to three nations, we hope to stimulate an international dialogue with a culmination of realizing such a system.

Symons, T., Zalcberg, J., & Morris, J. (2021). Making the move to a learning healthcare system: has the pandemic brought us one step closer?. *Australian Health Review: a Publication of the Australian Hospital Association*, 10.1071/AH21076. Advance online publication. https://doi.org/10.1071/AH21076

Abstract not included due to copyright restrictions.

Word Cloud for Search 3

Key findings from search 3

1. Of the 19 included abstracts at the intersection of pandemics and LHSs, 10 were empirical studies, seven were theoretical, and two were reviews of the literature.
2. The studies that were included covered 13 countries: the United States, Canada, South Africa, England, Kenya, Zimbabwe, Nepal, Thailand, Pakistan, Sri-Lanka, Spain, Italy and Australia.
3. Study settings included hospitals and medical centres, primary care, large networks such as the US's Veteran's Health Administration, and several online applications and networks.
4. COVID-19 provided an opportunity for organisations to pivot toward operating as an LHS and conduct empirical studies to help evaluate their progress.
5. Putting effort into real-time use of data appeared to have a positive effect within health centres, with one study that reported lower mortality in COVID patients in their medical centre after they started using data as an LHS.
6. Most studies focussed on informatics and data use within their LHS. Few studies looked at organisational culture or the 'human' side of LHSs.
7. An increasing number of low- and middle-income countries are using the principles of an LHS to improve care.
8. Although studies took place during the pandemic, very few examined how the LHS could be used in a pandemic response or how an LHS principles, ideas and concepts can help to prepare health systems for the next pandemic.

Search 4: Climate change, preparedness, and Learning Health Systems

Next, we turn to a consideration of LHSs in the context of climate change. Has the LHS model been harnessed to prepare, rather than react, to climate change?

PubMed searches executed on 10/02/2023.
Search terms: (climate change) AND ("Learning Health System*")
Limits: Published in the last 5 years (i.e., from 10/02/2018)
Results: One result, screened for relevance and excluded because of no discussion of climate change.
NB: (climate change) AND (prepar*) AND ("Learning Health System") returned zero results.

Key findings from search 4

1. There were no studies or reports in PubMed found on this topic.
2. We can conclude that our approach, to examine LHS 2.0 as a vehicle to prepare for and cope with additional patients and patient types that are the consequence of climate change, is both a novel undertaking and fertile ground for subsequent work.

Search 5: Emergency departments and Learning Health Systems

Having established the extent of new work and dynamic models and synthesised the literature at the intersection of LHSs and pandemics and LHS and climate change, we now seek to investigate how the LHS concept is being applied to two front-line care providers that will deal with the brunt of the additional care produced by pandemics and climate change: EDs and primary care. First, we searched EDs and LHSs.

PubMed searches executed on 10/02/2023.
Search terms: ("Learning Health System*") AND (“emergency department”) = 24 results, all screened for relevance. Four studies included.
Search terms: (“Learning Health System*”) AND (“emergency room”) = zero results
Search terms: (“Learning Health System*”) AND (“accident and emergency”) = one result, screened and excluded.
Studies were included if they discussed learning health systems in the context of emergency departments.

Brannon, E., Wang, T., Lapedis, J., Valenstein, P., Klinkman, M., Bunting, E., Stanulis, A., & Singh, K. (2018). Towards a Learning Health System to Reduce Emergency Department Visits at a Population Level. *AMIA ... Annual Symposium Proceedings. AMIA Symposium*, *2018*, 295–304.

High utilizers of the Emergency Department (ED) often have complex needs that require coordination of care between multiple organizations. We describe a Learning Health Systems (LHS) approach to reducing ED visits, in which an intervention is delivered to a cohort of high utilizers identified using population-level data and predictive modeling. We focus on the development and validation of a random forest model that utilizes electronic health record data from three health systems across two counties in Michigan to predict the number of ED visits each resident will incur in the next six months. Using 5-fold cross-validation, the model achieves a root-mean-squared-error of 0.51 visits and a mean absolute error of 0.24 visits. Using time-based validation, the model achieves a root-mean-squared error of 0.74 visits and a mean absolute error of 0.29 visits. Patients projected to have high ED utilization are being enrolled in a community-wide care coordination intervention using twelve sites across two counties. We believe that the repeated cycles of modeling and intervention demonstrate an LHS in action.

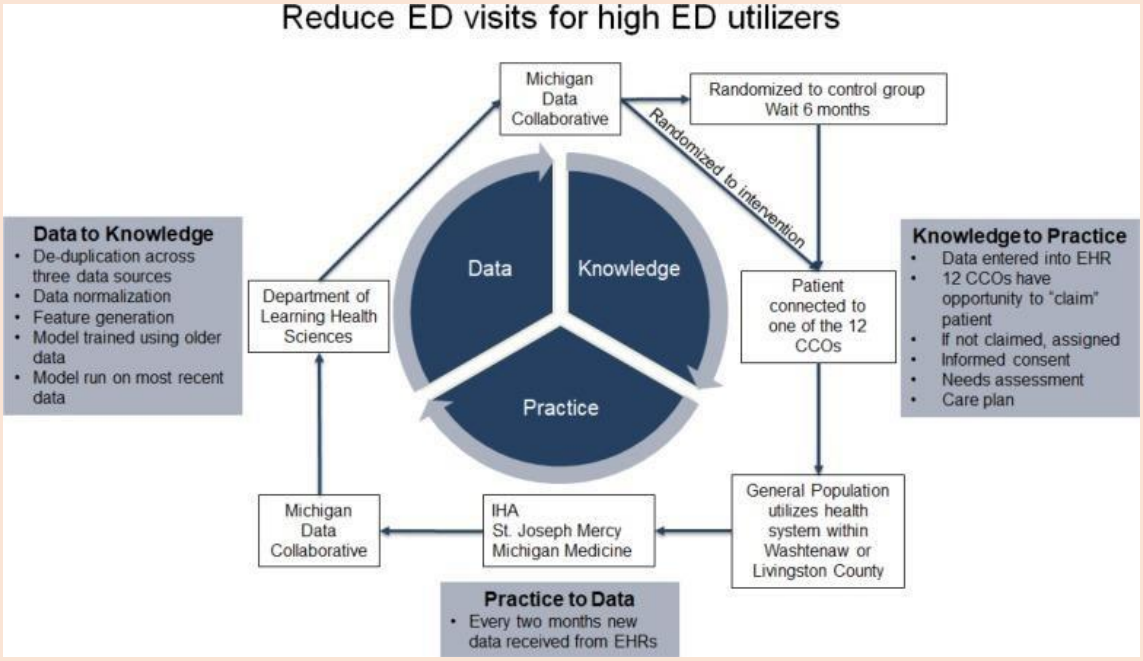

Figure from Brannon, E., Wang, T., Lapedis, J., Valenstein, P., Klinkman, M., Bunting, E., Stanulis, A., & Singh, K. (2018). Towards a Learning Health System to Reduce Emergency Department Visits at a Population Level.

Agarwal, A. K., Hahn, L., Rosin, R., & Merchant, R. M. (2021). Exploring digital methods to capture self-reported on-shift sentiment amongst academic emergency department physicians. The American Journal of Emergency Medicine, 46, 760–762. https://doi.org/10.1016/j.ajem.2020.09.035

No abstract.

Jones, B. E., Collingridge, D. S., Vines, C. G., Post, H., Holmen, J., Allen, T. L., Haug, P., Weir, C. R., & Dean, N. C. (2019). CDS in a Learning Health Care System: Identifying Physicians' Reasons for Rejection of Best-Practice Recommendations in Pneumonia through Computerized Clinical Decision Support. *Applied Clinical Informatics*, *10*(1), 1–9. https://doi.org/10.1055/s-0038-1676587

Abstract not included due to copyright restrictions.

Archambault, P. M., Rivard, J., Smith, P. Y., Sinha, S., Morin, M., LeBlanc, A., Couturier, Y., Pelletier, I., Ghandour, E. K., Légaré, F., Denis, J. L., Melady, D., Paré, D., Chouinard, J., Kroon, C., Huot-Lavoie, M., Bert, L., Witteman, H. O., Brousseau, A. A., Dallaire, C., … Network Of Canadian Emergency Researchers (2020). Learning Integrated Health System to Mobilize Context-Adapted Knowledge With a Wiki Platform to Improve the Transitions of Frail Seniors From Hospitals and Emergency Departments to the Community (LEARNING WISDOM): Protocol for a Mixed-Methods Implementation Study. JMIR Research Protocols, 9(8), e17363. https://doi.org/10.2196/17363

Background:
Elderly patients discharged from hospital experience fragmented care, repeated and lengthy emergency department (ED) visits, relapse into their earlier condition, and rapid cognitive and functional decline. The Acute Care for Elders (ACE) program at Mount Sinai Hospital in Toronto, Canada uses innovative strategies, such as transition coaches, to improve the care transition experiences of frail elderly patients. The ACE program reduced the lengths of hospital stay and readmission for elderly patients, increased patient satisfaction, and saved the health care system over Can $4.2 million (US $2.6 million) in 2014. In 2016, a context-adapted ACE program was implemented at one hospital in the Centre intégré de santé et de services sociaux de Chaudière-Appalaches (CISSS- CA) with a focus on improving transitions between hospitals and the community. The quality improvement project used an intervention strategy based on iterative user-centered design prototyping and a "Wiki-suite" (free web-based database containing evidence-based knowledge tools) to engage multiple stakeholders.

Objective:
The objectives of this study are to (1) implement a context-adapted CISSS-CA ACE program in four hospitals in the CISSS-CA and measure its impact on patient-, caregiver-, clinical-, and hospital-level outcomes; (2) identify underlying mechanisms by which our context-adapted CISSS-CA ACE program improves care transitions for the elderly; and (3) identify underlying mechanisms by which the Wiki-suite contributes to context-adaptation and local uptake of knowledge tools.

Methods:
Objective 1 will involve staggered implementation of the context-adapted CISSS-CA ACE program across the four CISSS-CA sites and interrupted time series to measure the impact on hospital-, patient-, and caregiver-level outcomes. Objectives 2 and 3 will involve a parallel mixed-methods process evaluation study to understand the mechanisms by which our context-adapted CISSS-CA ACE program improves care transitions for the elderly and by which our Wiki-suite contributes to adaptation, implementation, and scaling up of geriatric knowledge tools.

Results:
Data collection started in January 2019. As of January 2020, we enrolled 1635 patients and 529 caregivers from the four participating hospitals. Data collection is projected to be completed in January 2022. Data analysis has not yet begun. Results are expected to be published in 2022. Expected results will be presented to different key internal stakeholders to better support the effort and resources deployed in the transition of seniors. Through key interventions focused on seniors, we are expecting to increase patient satisfaction and quality of care and reduce readmission and ED revisit.

Conclusions:
This study will provide evidence on effective knowledge translation strategies to adapt best practices to the local context in the transition of care for elderly people. The knowledge generated through this project will support future scale-up of the ACE program and our wiki methodology in other settings in Canada.

Trial Registration: ClinicalTrials.gov NCT04093245; https://clinicaltrials.gov/ct2/show/NCT04093245.

Word cloud for search 5

Key findings from search 5

1. Of the four included abstracts, three were for empirical studies, and one was a protocol for a study. Three contributions originated from the United States and one from Canada.
2. All studies focussed on the use of data within the LHS, by either developing predictive models, online platforms, or computerised clinical decision support tools.

Search 6: Primary care and Learning Health Systems

In our final search we looked for literature on LHS applications in primary care. Following this section, we will 'zoom out' to consider what we have learned from this deep dive into our investigation of LHSs and how it illuminates future research interests.

PubMed searches executed on 10/02/2023.
Search terms: ("Learning Health System*") AND (primary care). No limits.
Results: 185 results screened for relevance. 20 studies included.
Search terms: ("Learning Health System*") AND (general practice). No limits.
Results: 50 results screened for relevance. 9 duplicates from previous search, two studies included.
Studies were included if they discussed learning health systems in the context of primary care.
Studies were excluded if they mentioned learning health systems in passing.

Dammery, G., Ellis, L. A., Churruca, K., Mahadeva, J., Lopez, F., Carrigan, A., Halim, N., Willcock, S., & Braithwaite, J. (2023). The journey to a learning health system in primary care: a qualitative case study utilising an embedded research approach. *BMC Primary Care*, *24*(1), 22. https://doi.org/10.1186/s12875-022-01955-w

Background: Healthcare systems may be resilient and adaptive, but they are not fit for purpose in their current state. Increasing threats to health system sustainability have underscored the need to move towards a learning health system in which research and data are used routinely in clinical practice to facilitate system improvement. This study aimed to establish which elements of the learning health system were being realised within a university-based general practice and determine acceptability from staff to embrace further the transition towards a learning health system.

Methods: Semi-structured interviews were conducted with practice staff, including clinical and administrative staff, to determine the current state of the learning health system in the practice. An embedded researcher was placed within the general practice on a part-time basis to investigate the learning health system model. Interviews were transcribed and thematically analysed based on the National Academy of Medicine's framework of learning health systems.

Results: In total, 32 (91%) practice staff were interviewed, comprising general practitioners (n = 15), nurses (n = 3), administrative staff (n = 13), and a psychologist (n = 1). Participants indicated that the practice was operating with several characteristics of a learning health system (e.g., emphasising science and informatics; focusing on patient-clinician partnerships; applying incentives; supporting a continuous learning culture; and establishing structures and governance for learning). These measures were supported by the university-based setting, and resultant culture of learning. Nevertheless, there were areas of the practice where the learning health system could be strengthened, specifically relating to the use of patient data and informatics. Staff generally expressed willingness to engage with the process of strengthening the learning health system within their practice.

Conclusion: Although the idea of a learning health system has been gaining traction in recent years, there are comparatively few empirical studies presented in the literature. This research presents a case study of a general practice that is operating as a learning health system and highlights the utility of using the learning health system framework.

Khanna, N., Klyushnenkova, E. N., Kaysin, A., & Stewart, D. L. (2020). Utilizing the Learning Health System Adaptation to guide Family Medicine Practice to COVID-19 response. *Journal Of Primary Care & Community Health*, *11*, 2150132720966409. https://doi.org/10.1177/2150132720966409

COVID-19 supportive quarantine care in the community is managed by primary care practices. There is no current guidance on how a primary care practice with high volumes of patients screened for COVID-19 can re-configure itself to become responsive to the pandemic. We examined Learning Health System guidance from the National Academies of Science, Engineering and Medicine and adapted it to our primary care practice to create an efficient, effective, adaptive response to the COVID-19 pandemic. We suggest evaluating this response in the future for effectiveness and efficiency.

Nash, D. M., Bhimani, Z., Rayner, J., & Zwarenstein, M. (2021). Learning health systems in primary care: a systematic scoping review. *BMC Family Practice*, *22*(1), 126. https://doi.org/10.1186/s12875-021-01483-z

Background: Learning health systems have been gaining traction over the past decade. The purpose of this study was to understand the spread of learning health systems in primary care, including where they have been implemented, how they are operating, and potential challenges and solutions.

Methods: We completed a scoping review by systematically searching OVID Medline®, Embase®, IEEE Xplore®, and reviewing specific journals from 2007 to 2020. We also completed a Google search to identify gray literature.

Results: We reviewed 1924 articles through our database search and 51 articles from other sources, from which we identified 21 unique learning health systems based on 62 data sources. Only one of these learning health systems was implemented exclusively in a primary care setting, where all others were integrated health systems or networks that also included other care settings. Eighteen of the 21 were in the United States. Examples of how these learning health systems were being used included real-time clinical surveillance, quality improvement initiatives, pragmatic trials at the point of care, and decision support. Many challenges and potential solutions were identified regarding data, sustainability, promoting a learning culture, prioritization processes, involvement of community, and balancing quality improvement versus research.

Conclusions: We identified 21 learning health systems, which all appear at an early stage of development, and only one was primary care only. We summarized and provided examples of integrated health systems and data networks that can be considered early models in the growing global movement to advance learning health systems in primary care.

Nash, D. M., Brown, J. B., Thorpe, C., Rayner, J., & Zwarenstein, M. (2022). The Alliance for Healthier Communities as a Learning Health System for primary care: A qualitative analysis in Ontario, Canada. *Journal of Evaluation in Clinical Practice*, *28*(6), 1106–1112. https://doi.org/10.1111/jep.13692

Rationale, aims and objectives: A learning health system model can be used to efficiently evaluate and incorporate evidence-based care into practice. However, there is a paucity of evidence describing key organizational attributes needed to ensure a successful learning health system within primary care. We interviewed stakeholders for a primary care learning health system in Ontario, Canada (the Alliance for Healthier Communities) to identify strengths and areas for improvement.

Method: We conducted a qualitative descriptive study using individual semistructured interviews with Alliance stakeholders between December 2019 and March 2020. The Alliance delivers community-governed primary healthcare through 109 organizations including Community Health Centres (CHCs). All CHC staff within the Alliance were invited to participate. Interviews were audio-recorded and transcribed verbatim. We performed a thematic analysis using a team approach.

Results: We interviewed 29 participants across six CHCs, including Executive Directors, managers, healthcare providers and data support staff. We observed three foundational elements necessary for a successful learning health system within primary care: shared organizational goals and culture, data quality and resources. Building on this foundation, people are needed to drive the learning health system, and this is conditional on their level of engagement. The main factors motivating staff member's engagement with the learning health system included their drive to help improve patient care, focusing on initiatives of personal interest and understanding the purpose of different initiatives. Areas for improvement were identified such as the ability to extract and use data to inform changes in real-time, better engagement and protected time for providers to do improvement work, and more staff dedicated to data extraction and analysis.

Conclusions: We identified key components needed to establish a learning health system in primary care. Similar primary care organizations in Canada and elsewhere can use these insights to guide their development as learning health systems.

Nash, D. M., Rayner, J., Bhatti, S., Zagar, L., & Zwarenstein, M. (2022). The Alliance for Healthier Communities' journey to a learning health system in primary care. *Learning Health Systems*, *7*(1), e10321. https://doi.org/10.1002/lrh2.10321

Introduction: The Alliance for Healthier Communities represents community-governed healthcare organizations in Ontario, Canada including Community Health Centres, which provide primary care to more disadvantaged populations.
Methods: In this experience report, we describe the Alliance's journey towards becoming a learning health system using examples for organizational culture, data and analytics, people and partnerships, client engagement, ethics and oversight, evaluation and dissemination, resources, identification and prioritization, and deliverables and impact.
Results: Many of the foundational elements for a learning health system were already in place at the Alliance including an integrated and accessible data platform. Leadership championed and embraced the movement towards a learning health system, which led to restructuring of the organization. This included role changes for data support personnel, better communication, and dissemination plans, strategies to engage clinicians and other front-line staff, restructuring of committees for more collaborative planning and prioritization of quality improvement and research initiatives, and the development of a new Practice-Based Learning Network for more opportunities to use the data for research and evaluation.
Conclusions: Next steps will focus on continued clinical engagement and partnerships as well as ongoing reflection on the transition and success of the learning health system work.

Jeffries, M., Keers, R. N., Phipps, D. L., Williams, R., Brown, B., Avery, A. J., Peek, N., & Ashcroft, D. M. (2018). Developing a learning health system: Insights from a qualitative process evaluation of a pharmacist-led electronic audit and feedback intervention to improve medication safety in primary care. *PloS One*, *13*(10), e0205419. https://doi.org/10.1371/journal.pone.0205419

Introduction: Developments in information technology offer opportunities to enhance medication safety in primary care. We evaluated the implementation and adoption of a complex pharmacist-led

intervention involving the use of an electronic audit and feedback surveillance dashboard to identify patients potentially at risk of hazardous prescribing or monitoring of medicines in general practices. The intervention aimed to create a rapid learning health system for medication safety in primary care. This study aimed to explore how the intervention was implemented, adopted and embedded into practice using a qualitative process evaluation.

Methods: Twenty two participants were purposively recruited from eighteen out of forty-three general practices receiving the intervention as well as clinical commissioning group staff across Salford UK, which reflected the range of contexts in which the intervention was implemented. Interviews explored how pharmacists and GP staff implemented the intervention and how this affected care practice. Data analysis was thematic with emerging themes developed into coding frameworks based on Normalisation Process Theory (NPT).

Results: Engagement with the dashboard involved a process of sense-making in which pharmacists considered it added value to their work. The intervention helped to build respect, improve trust and develop relationships between pharmacists and GPs. Collaboration and communication between pharmacists and clinicians was primarily initiated by pharmacists and was important for establishing the intervention. The intervention operated as a rapid learning health system as it allowed for the evidence in the dashboard to be translated into changes in work practices and into transformations in care.

Conclusions: Our study highlighted the importance of the combined use of information technology and the role of pharmacists working in general practice settings. Medicine optimisation activities in primary care may be enhanced by the implementation of a pharmacist-led electronic audit and feedback system. This intervention established a rapid learning health system that swiftly translated data from electronic health records into changes in practice to improve patient care. Using NPT provided valuable insights into the ways in which developing relationships, collaborations and communication between health professionals could lead to the implementation, adoption and sustainability of the intervention.

Steiner, J. F., Shainline, M. R., Bishop, M. C., & Xu, S. (2016). Reducing Missed Primary Care Appointments in a Learning Health System: Two Randomized Trials and Validation of a Predictive Model. *Medical Care*, *54*(7), 689–696. https://doi.org/10.1097/MLR.0000000000000543

Abstract not included due to copyright restrictions.

Pestka, D. L., White, K. M., DeRoche, K. K., Benson, B. J., & Beebe, T. J. (2022). 'Trying to fly the plane while we were building it'. Applying a learning health systems approach to evaluate early-stage barriers and facilitators to implementing primary care transformation: a qualitative study. *BMJ Open*, *12*(1), e053209. https://doi.org/10.1136/bmjopen-2021-053209

Objective: A learning health system (LHS) uses data to generate evidence and answer questions required to continually improve system performance and patient care. Given the complexities of practice transformation, an area where LHS is particularly important is the study of primary care transformation (PCT) as PCT generates several practice-level questions that require study where the findings can be readily implemented. In May 2019, a large integrated health delivery system in Minnesota began implementation of a population management PCT in two of its 40 primary care clinics.

In this model of care, patients are grouped into one of five service bundles based on their complexity of care; patient appointment lengths and services provided are then tailored to each service bundle. The objective of this study was to examine the use of a LHS in PCT by utilising the Consolidated Framework for Implementation Research (CFIR) to categorise implementation lessons from the initial two PCT clinics to inform further implementation of the PCT within the health system.

Design: This was a formative evaluation in which semi structured qualitative interviews were carried out. Observational field notes were also taken. Inductive coding of the data was performed and resultant codes were mapped to the CFIR.

Setting: Two suburban primary care clinics in the Twin Cities, Minnesota.

Participants: Twenty-two care team members from the first two clinics to adopt the PCT.

Results: Seventeen codes emerged to describe care team members' perceived implementation influences. Codes occurred in each of the five CFIR domains (intervention characteristics, outer setting, inner setting, characteristics of individuals and process), with most codes occurring in the 'inner setting' domain.

Conclusions: Using an LHS approach to determine early-stage implementation influences is key to guiding further PCT implementation, understanding modifications that need to be made and additional research that needs to occur.

Liyanage, H., Liaw, S. T., Jonnagaddala, J., Schreiber, R., Kuziemsky, C., Terry, A. L., & de Lusignan, S. (2019). Artificial Intelligence in Primary Health Care: Perceptions, Issues, and Challenges. *Yearbook of Medical Informatics*, *28*(1), 41–46. https://doi.org/10.1055/s-0039-1677901

Background: Artificial intelligence (AI) is heralded as an approach that might augment or substitute for the limited processing power of the human brain of primary health care (PHC) professionals. However, there are concerns that AI-mediated decisions may be hard to validate and challenge, or may result in rogue decisions.

Objective: To form consensus about perceptions, issues, and challenges of AI in primary care.

Method: A three-round Delphi study was conducted. Round 1 explored experts' viewpoints on AI in PHC (n=20). Round 2 rated the appropriateness of statements arising from round one (n=12). The third round was an online panel discussion of findings (n=8) with the members of both the International Medical Informatics Association and the European Federation of Medical Informatics Primary Health Care Informatics Working Groups.

Results: PHC and informatics experts reported AI has potential to improve managerial and clinical decisions and processes, and this would be facilitated by common data standards. The respondents did not agree that AI applications should learn and adapt to clinician preferences or behaviour and they did not agree on the extent of AI potential for harm to patients. It was more difficult to assess the impact of AI-based applications on continuity and coordination of care.

Conclusion: While the use of AI in medicine should enhance healthcare delivery, we need to ensure meticulous design and evaluation of AI applications. The primary care informatics community needs to be proactive and to guide the ethical and rigorous development of AI applications so that they will be safe and effective.

Baynes, C., Adedokun, L., Awoonor-Williams, J. K., & Hirschhorn, L. R. (2022). Learning Health Systems to Bridge the Evidence-Policy-Practice Gap in Primary Health Care: Lessons From the African Health Initiative. *Global Health, Science and Practice*, *10*(Suppl 1), e2200390. https://doi.org/10.9745/GHSP-D-22-00390

The compilation of lessons in this supplement on the Doris Duke Charitable Foundation's African Health Initiative's work in the application of implementation research in primary health care in sub-Saharan Africa reflects the evolution of the discipline that is now increasingly recognized as integral to health systems strengthening.

Sanders, A. M., Golden, R. E., Kolehmainen, C., Brenton, J. K., & Frayne, S. M. (2022). Implementation experience and initial assessment of a rural women's health training program in support of the U.S. Department of Veterans Affairs as a learning health system. *Learning Health Systems*, *6*(4), e10334. https://doi.org/10.1002/lrh2.10334

Introduction: The increasing number of women Veterans receiving health care from the Veterans Health Administration (VHA) has spurred the need for more women's health primary care providers (PCPs) and nurses, including in rural areas nationwide. Here we report on the implementation of a women's health rural workforce training program, demonstrate initial evidence of its effectiveness within VHA as a Learning Health System, and present lessons learned and implications for other workforce training programs.

Methods: The Women's Health Primary Care Mini-Residency for Rural Providers and Nurses (Rural WH-MR) is a mobile VHA training initiative adapted from a national training model. The Rural WH-MR uses asynchronous blended learning paired with in-person hands-on instruction delivered directly at rural VHA sites. Mixed methods evaluation using quantitative data, qualitative interviews, and observational feedback assessed the program's implementation feasibility, fidelity, acceptability, and appropriateness. Longitudinal survey data were used to assess the initial program impact via changes in participating PCP and nurse knowledge, attitudes, practices, and skills (KAPS).

Results: Inclusive of the pilot and fiscal years 2018 and 2019 Rural WH-MR trainings, 181 PCPs, and 320 nurses were trained through 56 training events nationwide. Cumulative survey data using 5-point measures showed high participant satisfaction, achievement of program-specific objectives, and usefulness of training activities to the rural practice of both PCPs and nurses. Both a pre-training and 6-month-follow-up survey were completed by 52 PCPs (32.9%) and 93 nurses (32.2%) and revealed significant sustained improvements in 18 out of 22 KAPS ($p < 0.01$-0.03) areas assessed for PCPs and all 17 KAPS ($p < 0.01$) areas assessed for nurses.

Conclusions: This adapted training program benefitted VHA's rural clinical workforce thereby contributing to the VHA goal of increasing the numbers of rural women Veterans with access to PCPs and nurses with women's health expertise.

Nelson, K., Reddy, A., Stockdale, S. E., Rose, D., Fihn, S., Rosland, A. M., Stewart, G., Denietolis, A., Curtis, I., Mori, A., & Rubenstein, L. (2021). The Primary Care Analytics Team: Integrating research and clinical care within the Veterans Health Administration Office of Primary Care. *Healthcare (Amsterdam, Netherlands), 8 Suppl 1*, 100491. https://doi.org/10.1016/j.hjdsi.2020.100491

By designing and evaluating health system improvements and providing evidence to clinical decision-makers, embedded researchers are a critical part of a Learning Health System (LHS). In this article, we describe the evolution and mission of the Primary Care Analytics Team (PCAT), an integrated research team within the Veterans Health Administration Office of Primary Care. We discuss challenges and strategies for success in working with clinical operations partners and provide recommendations for other Learning Health Systems units embedded in large integrated health care organizations.

McGuire M. J. (2019). Building Learning Health Care Systems in Primary Care. *Quality Management in Health Care*, *28*(4), 252–253. https://doi.org/10.1097/QMH.0000000000000230

No abstract.

Palin, V., Tempest, E., Mistry, C., & van Staa, T. P. (2020). Developing the infrastructure to support the optimisation of antibiotic prescribing using the learning healthcare system to improve healthcare services in the provision of primary care in England. *BMJ Health & Care Informatics*, *27*(1), e100147. https://doi.org/10.1136/bmjhci-2020-100147

Introduction: The learning healthcare system (LHS) underpinned by data analysis and feedback to clinical care providers is thought to improve quality of care. The work aimed to implement an LHS for antibiotic prescribing in primary care in England.

Method: Deidentified patient-level data from general practices were processed and analysed at regular intervals (fortnightly increments). A dashboard application was developed and implemented displaying analytical graphics to give periodic feedback to clinicians, tailored to each clinical site. Benchmarking parameters were established by the analysis of two large national primary care datasets allowing peer-to-peer comparisons. To date, the dashboard is available to 70 English practices.

Conclusions: Successful implementation and uptake of the secure technical LHS infrastructure for the analysis and feedback to clinicians of their antibiotic prescribing demonstrate a great appetite for this type of frequent prescribing review in primary care, combining advanced data analytics with tailored feedback.

Wong, S. T., Johnston, S., Burge, F., & McGrail, K. (2019). Value in Primary Healthcare - Measuring What Matters?. *Healthcare Papers*, *18*(4), 58–67. https://doi.org/10.12927/hcpap.2019.26028

Abstract not included due to copyright restrictions.

Burdick, T. E., Moran, D. S., Oliver, B. J., Eilertsen, A., Raymond, J., Hort, S., & Bartels, S. J. (2022). Transitional Care Management Quality Improvement Methods That Reduced Readmissions in a Rural, Primary Care System. *Journal of the American Board of Family Medicine: JABFM*, *35*(3), 537–547. https://doi.org/10.3122/jabfm.2022.03.190435

Background: Transitional Care Management (TCM) is a reimbursable service designed to minimize hospital readmissions. We describe a multifaceted approach to increase TCM services among 107 primary care providers in a rural catchment area of 4250 square miles.

Objective: The primary objective was to increase use of TCM phone calls, office visits, and billing codes; the secondary objective was to decrease hospital readmissions.

Methods: We utilized a learning health system model, an improvement support team (IST), and a learning collaborative that included webinars and in-person support. The process emphasized user-centered system redesign, coaching, electronic health record (EHR) improvements, and real-time feedback. Analyses included statistical process control charts, box plots, analysis of variance, and t-tests.

Results: The IST engaged stakeholders to design and test TCM workflows and EHR prototypes. This resulted in rapid, iterative improvements and system-wide spread of new processes. In the month following implementation, TCM calls and visits quadrupled and increased during 18 subsequent months. Pragmatically, most discharged patients (95% in a subsample) did not receive both the TCM call and visit, serving as a comparison group. The Readmission rate for patients receiving complete TCM services was 5.0% (n = 101) versus 11.9% for comparators (n = 2103, P = .03). Billing codes increased initially, then returned to baseline.

Conclusions: Our approach led to rapid, sustained scaling of TCM calls and visits in a rural primary care group. Patients who received TCM calls and visits had significantly fewer readmissions. Training of new staff, including PCPs, is required for sustainability. Future research is warranted to increase adoption and evaluate additional outcomes including mortality rates, patient satisfaction, and health care economics.

Campbell, C. M., Murphy, D. R., Taffet, G. E., Major, A. B., Ritchie, C. S., Leff, B., & Naik, A. D. (2021). Implementing Health Care Quality Measures in Electronic Health Records: A Conceptual Model. Journal of the American Geriatrics Society, 69(4), 1079–1085. https://doi.org/10.1111/jgs.17033

Abstract not included due to copyright restrictions.

Sivan, M., Greenhalgh, T., Darbyshire, J. L., Mir, G., O'Connor, R. J., Dawes, H., Greenwood, D., O'Connor, D., Horton, M., Petrou, S., de Lusignan, S., Curcin, V., Mayer, E., Casson, A., Milne, R., Rayner, C., Smith, N., Parkin, A., Preston, N., Delaney, B., … LOCOMOTION consortium (2022). LOng COvid Multidisciplinary consortium Optimising Treatments and servIces acrOss the NHS (LOCOMOTION): protocol for a mixed-methods study in the UK. BMJ Open, 12(5), e063505. https://doi.org/10.1136/bmjopen-2022-063505

Introduction: Long COVID, a new condition whose origins and natural history are not yet fully established, currently affects 1.5 million people in the UK. Most do not have access to specialist long COVID services.

We seek to optimise long COVID care both within and outside specialist clinics, including improving access, reducing inequalities, helping self-management and providing guidance and decision support for primary care. We aim to establish a 'gold standard' of care by systematically analysing current practices, iteratively improving pathways and systems of care.

Methods and analysis: This mixed-methods, multisite study is informed by the principles of applied health services research, quality improvement, co-design, outcome measurement and learning health systems. It was developed in close partnership with patients (whose stated priorities are prompt clinical assessment; evidence-based advice and treatment and help with returning to work and other roles) and with front-line clinicians. Workstreams and tasks to optimise assessment, treatment and monitoring are based in three contrasting settings: workstream 1 (qualitative research, up to 100 participants), specialist management in 10 long COVID clinics across the UK, via a quality improvement collaborative, experience-based co-design and targeted efforts to reduce inequalities of access, return to work and peer support; workstream 2 (quantitative research, up to 5000 participants), patient self-management at home, technology-supported monitoring and validation of condition-specific outcome measures and workstream 3 (quantitative research, up to 5000 participants), generalist management in primary care, harnessing electronic record data to study population phenotypes and develop evidence-based decision support, referral pathways and analysis of costs. Study governance includes an active patient advisory group.

Ethics and dissemination: LOng COvid Multidisciplinary consortium Optimising Treatments and servIces acrOss the NHS study is sponsored by the University of Leeds and approved by Yorkshire & The Humber-Bradford Leeds Research Ethics Committee (ref: 21/YH/0276). Participants will provide informed consent. Dissemination plans include academic and lay publications, and partnerships with national and regional policymakers.

Trial registration number: NCT05057260, ISRCTN15022307.

Petersen, I., Kemp, C. G., Rao, D., Wagenaar, B. H., Sherr, K., Grant, M., Bachmann, M., Barnabas, R. V., Mntambo, N., Gigaba, S., Van Rensburg, A., Luvuno, Z., Amarreh, I., Fairall, L., Hongo, N. N., & Bhana, A. (2021). Implementation and Scale-Up of Integrated Depression Care in South Africa: An Observational Implementation Research Protocol. Psychiatric Services (Washington, D.C.), 72(9), 1065–1075. https://doi.org/10.1176/appi.ps.202000014

Abstract not included due to copyright restrictions.

Phelan, S. M., Bauer, K. W., Bradley, D., Bradley, S. M., Haller, I. V., Mundi, M. S., Finney Rutten, L. J., Schroeder, D. R., Fischer, K., & Croghan, I. (2021). A model of weight-based stigma in health care and utilization outcomes: Evidence from the learning health systems network. Obesity Science & Practice, 8(2), 139–146. https://doi.org/10.1002/osp4.553

Objective: Obesity is stigmatized and people with obesity report experiencing stigmatizing situations when seeking health care. The implications of these experiences are not well understood. This study tests an indirect effects model of negative care experiences as an intermediate variable between obesity and care avoidance/utilization and switching primary care doctors.

Methods: A survey was completed by 2380 primary care patients in the Learning Health Systems Network (LHSNet) Clinical Data Research Network with a BMI >25 kg/m2. Measures included scales assessing stigmatizing situations, perceived patient-centered communication, perceived respect, having delayed needed care, and having looked for a new primary doctor in the past 12 months. Sequential and serial indirect effects of care experiences and respect in the association between BMI and care utilization outcomes was modeled.

Results: The hypothesized model was supported by findings. The associations between BMI and delaying needed care (OR = 1.06, p < 0.001) and attempting to switch primary doctors (OR = 1.02, p = 0.04) was mediated by both stigmatizing situations experienced in a health care context and lower patient-centered communication. Lower perceived respect mediated the association between care experiences and utilization outcomes.

Conclusions: People with higher BMIs may avoid care or switch doctors as a result of stigmatizing experiences and poor communication with doctors. These outcomes may contribute to morbidity in people with obesity if they delay or avoid care for health concerns when symptoms first present.

Blok, A. C., Amante, D. J., Hogan, T. P., Sadasivam, R. S., Shimada, S. L., Woods, S., Nazi, K. M., & Houston, T. K. (2021). Impact of Patient Access to Online VA Notes on Healthcare Utilization and Clinician Documentation: a Retrospective Cohort Study. Journal of General Internal Medicine, 36(3), 592–599. https://doi.org/10.1007/s11606-020-06304-0

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Myers, R. E., DiCarlo, M., Romney, M., Fleisher, L., Sifri, R., Soleiman, J., Lambert, E., & Rosenthal, M. (2018). Using a health system learning community strategy to address cancer disparities. Learning Health Systems, 2(4), e10067. https://doi.org/10.1002/lrh2.10067

Accountable care organizations and health systems have the potential to increase patient engagement in medical care, improve population health outcomes, and reduce costs. Characteristics of highly integrated learning health care systems that seek to achieve these goals have been described in the literature. However, there have been few reports on how health systems, especially those that are loosely integrated, can develop the infrastructure needed to support achievement of these goals. In this report, we describe a learning community strategy that involved forming a coordinating team, a steering committee, and patient and stakeholder advisory committees to address cancer screening and disparities in 2 health systems in southeastern Pennsylvania-Jefferson Health and the Lehigh Valley Health Network. This project engaged diverse patients, health care providers, health system leaders, public and private payers, and other stakeholders in identifying and adapting evidence-based methods to increase colorectal and lung cancer screening in primary care. Here, we describe components of a health system learning community. In addition, we describe activities in which different components of the learning community were engaged. Finally, we explore prospects for using this type of approach to catalyze the development of learning health care systems

Word cloud for search 6

Key findings from search 6

1. Of the 22 abstracts included, 14 were empirical studies, six were theoretical, one was a protocol, and one was a literature review.
2. Most studies were from the United States (n=12) or Canada (n=4). Four studies were from the UK, one was from South Africa, and one was from Australia.
3. All but two of the empirical studies were published in or after 2021.
4. Applications of the LHS within primary care appeared broad. Several Canadian studies explored the progression of a network of primary care organisations (the Alliance for Healthier Communities) as it moved toward becoming an LHS. One study evaluated a dashboard for improving medication safety in primary care, and another study evaluated a general practice setting within an LHS framework. Prediction models for reducing missed primary care models were also described in one study.

Discussion

Most of the literature to date seems to be anchored to the original four-element IoM model of an LHS, which we modified to a five-element framework in 2020. The IoM/Zurynski-Braithwaite modified LHS framework raised the importance of the original IoM cornerstones of an LHS: science and informatics; patient-clinician partnerships; incentives; and a continuous learning culture; and added to these effective structure and governance, all of which, if enabled, support progress along a pathway towards becoming an LHS.

From search 1, we can see there are few new models and frameworks of an LHS, and no radical LHS re-conceptualisation has been documented. That said, idiosyncratic variations of the IoM/Zurynski-Braithwaite framework have appeared. These are typically context-specific, largely applicable to local issues and settings. These types of models or frameworks are relatively anecdotal. Until now, there has been no case advanced for LHS 2.0.

Search 2 revealed, perhaps surprisingly, there has been very little systems dynamics modelling in health care settings, whether at the micro, meso or macro levels, in terms of studying ED or primary care. We think this is a fruitful area for further investigation, and that the studies we uncovered in search 2 provide a starting point to build systems dynamics models of EDs and primary care settings.

Searches 3 and 4 provided insights into the state of the literature at the intersection of LHSs and pandemics, and LHSs and climate change. From search 3, we note that there is encouraging early work on the application of LHS principles to COVID-19-stretched health care organisations and, by implication, to future pandemics. This work is embryonic and points to the need for more research in this area. Search 4 told us that the interface of climate change and LHS is a 'greenfields' area. We could find no relevant studies applying LHS concepts to climate change preparedness.

Searches 5 and 6 showed that research into the application of LHS ideas differs between EDs and primary care settings. There is very little traction on applying LHS ideas to EDs, with only two studies uncovered by search 5, both of which emanated from the US. Again, we see that this is fertile ground for further research. By comparison, there is more work on the application of LHS ideas to general practice, family medicine, or primary care (search 6). But again, this work is at an early stage, and points to a need for further investigation in this area.

Conclusion

All-in-all, the case for LHS 2.0, an LHS that is increasingly better prepared for, and adapting to the pressures of future pandemics and climate change is a strong one, and becoming urgent. We argue strongly for health systems to use LHS frameworks, modelling and principles to manage the challenges thrown up by the current pandemic and the intensification of climate change. The task is for EDs and primary care settings, the key delivery mechanisms on the front lines of care, to be future-proofed against destabilising pandemic- and climate-induced events as they unfold.

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