Table 1. Objectives of existing SLR on H4.0

| Reference | Objective |
|---|---|
| Mwanza et al. (2023) | This review assesses the effect of I4.0 on the healthcare systems of low- and middle-income countries. |
| Jose et al. (2022) | The goal of this study is to analyze prior studies on the competencies needed to deploy H4.0 technologies. |
| Sood et al. (2022) | This article gives a scientometric examination of the literature on the use of I4.0 technology in the healthcare industry in the context of COVID-19. |
| Ahsan and Siddique (2022a) | This study examines how I4.0 will affect healthcare systems. |
| Sony et al. (2022) | This study's objective is to evaluate the effect of MCPS on the standard of healthcare service delivery. |
| Sibanda et al. (2022) | This study examines the current status of using I4.0 technologies in maternity healthcare. |
| Alloghani et al. (2022) | This study focuses on articles that discuss theoretical or analytical work for the use of data mining in healthcare analytics. |
| Vassolo et al. (2021) | This study attempts to identify the most prevalent investment methodologies employed and assess prior research on the evaluation of H4.0 technologies in hospitals. |
| Mustapha et al. (2021) | This research intends to examine how I4.0 will affect the healthcare system. |
| Sisodia and Jindal (2021) | This study presents a meta-analytic approach for interpreting, integrating, and critically analyzing I4.0 design principles used in the healthcare industry. |
| Narkhede et al. (2020) | This research intends to present a systematic literature evaluation of cloud computing in healthcare's capabilities, usages, and other difficulties across nations over a time frame. |

Table 2. Article information

| Paper Title | Year | Country | Main Technology |
|---|---|---|---|
| It is in the box! Improving the usability and benefits of surgical safety checklists – A feasibility study | 2021 | USA | Hand gesture sensor |
| Evaluating the experiences of new and existing teledermatology patients during the COVID-19 pandemic: Cross-sectional survey study | 2021 | USA | Tele-dermatology |
| The effects of a digital mental health intervention in adults with cardiovascular disease risk factors: Analysis of real-world user data | 2021 | USA | mHealth app (Happify) |
| Differences in secure messaging, self-management, and glycemic control between rural and urban patients: Secondary data analysis | 2021 | USA | Secure messaging in a web-based patient portal |
| Asthma on the move: How mobile apps remediate risk for disease management | 2016 | USA | mHealth app |
| Health-related quality of life improvements in systemic lupus erythematosus derived from a digital therapeutic plus tele-health coaching intervention: Randomized controlled pilot trial | 2020 | USA | mHealth app |
| Toward using wearables to remotely monitor cognitive frailty in community-living older adults: An observational study | 2020 | USA | Chest-worn sensor |
| Use of digital health kits to reduce readmission after cardiac surgery | 2016 | USA | Web-based digital health kits (DHK) |
| Usability and feasibility of consumer-facing technology to reduce unsafe medication use by older adults | 2020 | USA | mHealth app |
| COVID-19 pandemic accelerates need to improve online patient engagement practices to enhance patient experience | 2020 | USA | Hospital website |
| Qualitative and quantitative analysis of patient's perceptions of the patient portal experience with open notes | 2019 | USA | Patient portal |
| User engagement and clinical impact of the manage my pain app in patients with chronic pain: A real-world, multi-site trial | 2021 | Canada | mHealth app (MMP) |
| Delivering mental healthcare virtually during the COVID-19 pandemic: Qualitative evaluation of provider experiences in a scaled context | 2021 | Canada | Telehealth (Zoom) |
| Exploring how virtual primary care visits affect the patient burden of treatment | 2020 | Canada | Telehealth (video) |

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| Measuring the effect of healthcare 4.0 implementation on hospitals' performance | 2020 | Brazil | H4.0 |
| Impacts of healthcare 4.0 digital technologies on the resilience of hospitals | 2021 | Brazil | H4.0 |
| Information and communication technologies in emergency care services for patients with COVID-19: A multi-national study | 2021 | Brazil | ICTs |
| Digital technologies: An exploratory study of their role in the resilience of healthcare services | 2021 | Brazil | H4.0 |
| Why #wearenotwaiting-motivations and self-reported outcomes among users of open-source automated insulin delivery systems: Multi-national survey | 2021 | Germany | Automated insulin delivery (AID) system |
| Measuring atopic dermatitis disease severity: The potential for electronic tools to benefit clinical care | 2021 | Germany | mHealth technology |
| Using postmarket surveillance to assess safety-related events in a digital rehabilitation app (Kaia App): Observational study | 2021 | Germany | mHealth app (Kaia App) |
| Postmarketing safety monitoring after influenza vaccination using a mobile health app: Prospective longitudinal feasibility study | 2021 | Germany | mHealth app (SafeVac) |
| Wound image quality from a mobile health tool for home-based chronic wound management with real-time quality feedback: Randomized feasibility study | 2021 | Switzerland | mHealth app |
| User experiences with and recommendations for mobile health technology for hypertensive disorders of pregnancy: Mixed methods study | 2020 | Netherlands | mHealth technology |
| Remote consultations versus standard face-to-face appointments for liver transplant patients in routine hospital care: Feasibility randomized controlled trial of myvideoclinic | 2021 | UK | Telehealth (videoconferencing software) |
| Effects of an innovative telerehabilitation intervention for People with Parkinson's Disease on quality of life, motor, and non-motor abilities | 2020 | Italy | Virtual reality (VR) |
| Design, implementation, and metrological characterization of a wearable integrated AR-BCI hands-free system for health 4.0 monitoring | 2021 | Italy | Augmented reality (AR) |
| A telemedicine service system exploiting BT/BLE wireless sensors for remote management of chronic patients | 2019 | Italy | Wireless sensors |
| BeyondSilos, a telehealth-enhanced integrated care model in the domiciliary setting for older patients: Observational prospective cohort study for effectiveness and cost-effectiveness assessments | 2020 | Spain | Telehealth (BeyondSilos platform) |

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| Blockchain for increased trust in virtual health care: Proof-of-concept study | 2021 | Norway | Blockchain technology |
| Fog computing for healthcare 4.0 environment: Opportunities and challenges | 2019 | India | Fog computing |
| Automatic medical code assignment via deep learning approach for intelligent healthcare | 2020 | China | Deep learning |
| Recommendation system using feature extraction and pattern recognition in clinical care systems | 2019 | China | N/A |
| An interactive voice response software to improve the quality of life of people living with HIV in Uganda: Randomized controlled trial | 2021 | Uganda | Interactive voice response (IVR) |
| Digital health tools and patients with drug use disorders: Qualitative patient experience study of the electronic case-finding and help assessment tool (eCHAT) | 2020 | Australia | eChat |

Table 3. Bundles of H4.0 technologies in the literature

| **Bundles** | **Technology** | **References** |
|---|---|---|
| **Sensing–Communication** | Digital sensors | Boillat and Rivas (2020)<br>Razjouyan et al. (2020)<br>Donati et al. (2019) |
| | Remote patient monitoring | Hamad et al. (2021)<br>Budhwani et al. (2021)<br>Kelley et al. (2020)<br>Damery et al. (2021)<br>Piera-Jiménez et al. (2020) |
| | Blockchain technology | Hasselgren et al. (2021) |
| | IoT | Braune et al. (2021)<br>McElroy et al. (2016) |
| | Messaging | Choy et al. (2020)<br>Meyer (2020)<br>Mishra et al. (2019)<br>Robinson et al. (2021) |
| | mHealth apps | Bhatia et al. (2021)<br>Montgomery et al. (2021)<br>Kenner (2016)<br>Zhang et al. (2021)<br>Holden et al. (2020)<br>Jain et al. (2021)<br>Nguyen et al. (2021)<br>Maintz et al. (2021)<br>Khan et al. (2020)<br>Jongsma et al. (2020) |
| **Processing–Actuation** | Machine/deep learning | Bhatti et al. (2019)<br>Teng et al. (2020) |
| | Augmented reality | Arpaia et al. (2021) |
| | Virtual reality | Isernia et al. (2020) |
| | Fog computing | Kumari et al. (2018) |

Table 4. Consolidation of H4.0 implementation barriers and challenges

| References | H4.0 Implementation Challenges | Description |
|---|---|---|
| Boillat and Rivas (2021) | Medical device management | Managing, maintaining, and designing medical devices, applications, and systems to fit various healthcare settings can be challenging. |
| Tortorella et al. (2020b), Kelley et al. (2020), Hasselgren et al. (2021), Mishara et al. (2019), Robinson et al. (2021), Zhang et al. (2021), Maintz et al. (2021), Teng et al. (2020), Isernia et al. (2020), Kumari et al. (2018), Byonanebye et al. (2021) | Technical issues<br>• Internet coverage<br>• Quality of image<br>• Lack of system interoperability<br>• Lack of usability<br>• Internet and system failures<br>• Device malfunctions<br>• Scalability | Technical issues were noted such as issues with the portal, appointments, and the inability to print results. |
| Choy et al. (2020), Kumari et al. (2018) | Privacy and data security | Patients identified privacy breaches and data security as more significant concerns than the cost of healthcare. |
| Tortorella et al. (2020b), Budhwani et al. (2021), Damery et al. (2021), Meyer (2020), Khan et al. (2020) | Social barriers<br>• Digital illiteracy<br>• Poor engagement with technology<br>• Preference for in-person attendance<br>• Smartphone ownership<br>• Remote follow-up dislike | Patients with specific characteristics (e.g., past trauma history, older age, not speaking English as a first language) had more difficulties accessing and navigating the video visit technology and registration processes. |
| Choy et al. (2020) | Physical disabilities of patients | Patients with weak eyesight, for instance, find it hard to use digital technologies. |
| Hasselgren et al. (2021), Jongsma et al. (2020) | Cost<br>• The initial investment for technology implementation<br>• High transaction fees (blockchain) | Varying healthcare regulations and accrediting organizations impose different requirements on hospitals that invest significant efforts to achieve compliance. Such actions are usually capital consuming. |
| Meyer (2020) | Regulations<br>• Regulatory changes<br>• Different regulations across geographies | Patients claimed that the regulations regarding using some digital technologies could be confusing and vary from place to place. |

Table 5. Summary of H4.0 technologies impact on quality measures

| Sensing–Communication Bundle | | | | |
|---|---|---|---|---|
| | **H4.0 Technologies** | **Patient Safety** | **Patient Experience/ Satisfaction** | **Clinical Effectiveness** |
| **Biomedical/Digital Sensors** | Hand gesture sensors (Boillat and Rivas, 2021)<br>Chest-worn sensors (Razjouyan et al., 2020)<br>Wireless sensors (Donati et al., 2019) | • Limit the number of missed elements (Boillat and Rivas, 2021)<br>• Identify modifiable risk factors for cognitive frailty (Razjouyan et al., 2020) | • Reduce the frequent domiciliary or in-hospital visits (Donati et al., 2019) | • Complete digitalizing of processes and sharing clinical information without the time and distance barriers (Donati et al., 2019)<br>• Improve identification of high-risk individuals who develop cognitive frailty or associated adverse health outcomes (e.g., dementia) (Razjouyan et al., 2020)<br>• Ensure going through all the elements guarantees better quality of care (Boillat and Rivas, 2021)<br>• Optimize the chronic patient management processes (Donati et al., 2019)<br>• Enable the care team to remotely assign personalized care plans and monitor distance patients' health status (Donati et al., 2019) |
| **mHealth Apps** | MMP (Bhatia et al., 2021)<br>Happify (Montgomery et al., 2021)<br>mAsthma (Kenner, 2016)<br>Wound Management (Zhang et al., 2021)<br>Brain Buddy (Holden et al., 2020)<br>Kaia App (Jain et al., 2021)<br>SafeVac (Nguyen et al., 2021) | • Highlight overlooked components of disease, risk, and care (Bhatia et al., 2021)<br>• Routine medication use and doctor visits (Montgomery et al., 2021)<br>• Track medical performance (Kenner, 2016)<br>• Improve patient literacy (Zhang et al., 2021)<br>• Stay better informed about medications that may be unsafe (Holden et al., 2020)<br>• Report adverse events (Jain et al., 2021)<br>• Allow feedback which can improve safety (Nguyen et al., 2021) | • Enhance the connectivity between patients and their HCPs (Bhatia et al., 2021)<br>• The apps resulted in positive health outcomes, impacting patients' experiences (Montgomery et al., 2021)<br>• Reduce unnecessary travel to the clinics (Kenner, 2016) | • Decrease in anxiety and pain catastrophizing (Bhatia et al., 2021)<br>• The users experienced significant improvement in subjective well-being and anxiety over time (Montgomery et al., 2021)<br>• Share data and risk patterns with the provider to create new, more refined care practices (Kenner, 2016)<br>• Meaningful improvements when added to usual care, compared with routine care alone (Zhang et al., 2021)<br>• JIT information access, efficient and effective communication channels, and continuous support (Holden et al., 2020) |
| | Tele-dermatology (Hamad et al., 2021)<br>Zoom meetings (Budhwani et al., 2021) | • Easy access to primary care through timely appointments with no booking required (Hamad et al., 2021) | • Reduce time and money (Hamad et al., 2021)<br>• Easier routine follow-up (Damery et al., 2021) | • Virtual visits appeared to improve access to primary care through timely appointments with no booking required and reducing the risk of infection by not |

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|---|---|---|---|---|
| **Remote Patient Monitoring** | Videoconferencing software (Kelley et al., 2020; Damery et al., 2021)<br>Telehealth platform (Piera-Jiménez et al., 2020) | • Reduce the risk of infection by not going to a healthcare facility (Budhwani et al., 2021) | | going to a healthcare facility. (Hamad et al., 2021)<br>• Routine medication use and doctor visits (Damery et al., 2021)<br>• Track medical performance, and improve patient literacy (Piera-Jiménez et al., 2020) |
| **IoT** | Automated insulin delivery (AID) system (Braune et al., 2021)<br>Digital Health Kits (DHK) (McElroy et al., 2016) | • Improving management of diabetes-related complications and increasing safety by avoiding hypoglycemia (McElroy et al. 2016; Braune et al. 2021) | • Positive improved sleep quality thanks to technology (McElroy et al., 2016; Braune et al., 2021) | • Highlight the unmet needs of people with chronic diseases (Braune et al., 2021). |
| **Messaging** | Patient portal (Mishra et al., 2019)<br>eChat (Choy et al., 2020)<br>Hospital website (Meyer, 2020) | • Improve understanding (education) and refresh the memory of patients (Mishra et al., 2019; Choy et al., 2020; Meyer, 2020) | • Communicate the situation more effectively (Mishra et al., 2019; Choy et al., 2020; Meyer, 2020)<br>• Reduce experiences of stigma (Mishra et al., 2019; Meyer, 2020) | • Improve self-care thanks to medication adherence (Mishra et al., 2019; Meyer, 2020)<br>• Engage more with healthcare providers (Mishra et al., 2019; Choy et al., 2020) |
| **Processing–Actuation** | | | | |
| **Fog Computing** | Fog computing (Kumari et al., 2018) | • Assist doctors in making smart decisions during an emergency (Kumari et al., 2018) | • Patients can manage current and historical medical history/bills using a mobile application or a web interface which makes their overall experience positive (Kumari et al., 2018) | • Increased collaboration between stakeholders as FC allows patients and medical practitioners to access the data anytime, anywhere (Kumari et al., 2018) |
| **Machine/Deep Learning** | Feature extraction and pattern recognition (Bhatti et al., 2019)<br>Automatic medical code assignment via DL (Teng et al., 2020) | • The system helps providers detect some rare diseases (Bhatti et al., 2019)<br>• Highlight issues in a real-time environment (Bhatti et al., 2019)<br>• Assist management and providers in analyzing the drastic change in chronic diseases (Teng et al., 2020) | N/A | • Improve the quality of health monitoring, disease-trend modeling, and early intervention with evidence-based medical treatment (Bhatti et al., 2019)<br>• Identify causes of diseases (Bhatti et al., 2019)<br>• Establish diagnoses (Teng et al., 2020)<br>• Detect side effects of beneficial treatments (Teng et al., 2020)<br>• Monitor clinical outcomes (Teng et al., 2020) |
| **Augmented and Virtual Reality** | Augmented reality (AR) (Arpaia et al., 2021)<br>Virtual reality (VR) (Isernia et al., 2020) | • Reduce the number of times the operator has to shift attention from the patient to the equipment, thus, fewer medical errors (Arpaia et al., 2021)<br>• Decrease incidents of falling (Isernia et al., 2020) | N/A | • Patients had a positive global cognitive level, memory, positive affect, and mental health results (Isernia et al., 2020; Arpaia et al., 2021) |