Novartis MS Innovation Summit

State-of-the-nation analysis of health innovation and digital technologies in MS

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Contents

1 Objectives

Multiple sclerosis (MS) is a chronic, disabling and progressive condition that affects approximately 126,000 people in the UK.[1] The progressive nature of MS and the related functional damage can significantly affect patients' daily activities, quality of life and is associated with high levels of emotional, social and physical implications.[2]

Technological and digital health innovation has the potential to alleviate the burden of disease for people with MS (PwMS), their care givers and the health system, however digital transformation in this sector has not yet been fully realised. In a challenging funding environment with a high demand for services, improvements for technological and digital health innovation may be viewed as a low priority. Across the NHS and third sector there is still huge strides yet to be taken to enable the use of digital technology to meet the complex needs of the MS community.

This state-of-the-nation analysis addresses the current unmet needs in MS, and reviews the existing technology support for PwMS, caregivers and HCPs across the UK, highlighting areas for future direction.

2 Setting the scene

2.1 Vision for digital transformation in the NHS

The NHS Long Term Plan published in January 2019, outlines ambitions for healthcare improvements over the next decade and highlights the importance of technology to enhance patient care. NHSX is responsible for driving digital transformation and leading policy, implementation and change in this area.[3,4]

NHS RightCare (the body involved in improving spending and patient outcomes by analysing patient population data[5]) have reported that improving the use of technology is a key priority for MS, including:[6]

- Sharing protocols across MS teams and providers
- Robust monitoring of disease modifying therapy (DMT)
- Patient self-managing of their condition using digital tools
- Sharing of digital care planning procedures
- Improving data analysis around magnetic resonance imaging (MRI), planning and avoidable hospital admissions

The uptake of data and technology to coordinate care is not widespread across the NHS and many people with MS have not yet benefitted. There is uncertainty and concern about what data can be shared among both patients and professionals, while improvements in computer systems and the ability of different systems to operate together (also known as interoperability) are needed.[7]

The Department of Health has also set out the ambition that all care records will be digital real-time and interoperable (i.e. allowing information held in one department or system to be readily available to another without significant or expensive development efforts).[8] One

example of technology that the NHS is implementing as part of this is Open Application Programming Interfaces (APIs), which aims to improve interoperability, increase flexibility and system selection to suit different clinical or business functions, and foster an environment of digital innovation.[8]

Broadly speaking, it is up to individual service providers rather than national bodies to adopt new technologies. A survey of 45 NHS Trusts revealed that although the NHS recognises the value of technologies such as artificial intelligence (AI), it is lacking clarity about the strategic direction and implementation for clinical practice.[9] A report from Deloitte UK analysing apps and technological solutions noted that staff, particularly doctors, are reluctant to engage with technology due to concerns regarding the limited evidence on outcomes, including cost savings.[10]

2.2 Unmet needs in MS

For the purpose of this review, an unmet need is defined as “healthcare needs that are not optimally met”. This may include people who have healthcare needs but are not aware of them, or people who have poorer quality treatment than ideally should be the case.[11,12]

Despite the attention afforded by MS in recent years, many unmet needs remain in terms of therapeutics, disability avoidance and outcome measures. More progress is needed not only in basic science, genetics and other factors, but also in understanding patients’ priorities, which may improve their outcomes and quality of life. Further attention also must be given to managing the costs associated with treatment.[13]

A 2015 review addressing the unmet needs of PwMS highlighted the following areas of greatest importance:[13]

- **Diagnosis of MS**
  - Identification of useful tools and biomarkers
- **Treatment of MS**
  - Delaying progression and development of better treatments for progressive MS
  - Providing neuroprotection
  - Delaying or avoiding disability
  - Reduction of active symptoms more effectively
  - Individualisation of treatment
- **Management of PwMS**
  - Improvement of adherence to current medications
  - Prevention or amelioration of the adverse effects (AEs) of current medications
  - Detection and management of comorbidities including muscle stiffness and spasms, and vision problems
  - Obtaining better measurements of functional outcome
  - Emotional support for patients and caregivers

3 Technology to address unmet needs in MS within the NHS

3.1 Diagnosis of MS: Improving functional assessments

Identification of useful tools to facilitate and improve management of MS is a key unmet need for PwMS.[13] Improving functional assessments of PwMS may help to speed up diagnosis and monitoring of MS, and free up resources in the NHS. In addition, early intervention and/or delaying disability results in a greater cost effectiveness overall for healthcare systems.[14]

In this area, several technological advances have been identified, particularly within magnetic resonance imaging (MRI) which plays an integral role in both MS diagnosis and monitoring (Table 1).[15]

Molecular biomarkers may also be useful to complement MRI scans.[16] Biomarkers have varying specificity, expense and other challenges for use in daily practice, but technological innovation may assist in the identification of procedures (e.g. lab processes such as tissue microarrays[17], gene expression profiling[18], proteomics and mass spectrometry[19]) and screening processes (e.g. bioinformatics-based methods of interpreting data and validating whether biomarkers have diagnostic, predictive or prognostic value) for PwMS.[13,20]

The biomarkers currently used in clinical practice are:[16]

- **Oligoclonal IgG bands (OCBs)**
  - Up to 90% of PwMS exhibit OCBs in the cerebrospinal fluid (CSF), and the inclusion of OCBs is part of the McDonald criteria for diagnosis of primary progressive MS (PPMS), as well as being predictive of conversion from clinically isolated syndrome (CIS) to MS
- **John Cunningham Virus (JCV) antibodies**
  - As a biomarker for stratifying the risk of progressive multifocal leukoencephalopathy (PML), it is worth noting that ~50% PwMS are JCV antibody seropositive, but <1% are prone to develop PML. Therefore, more specific biomarkers may help to individualise treatment strategies
- **Neutralising antibodies to interferon beta (IFN-β)**
  - ~40% of IFN-β treated patients do not respond to treatment. IFN-β induces an immunologic response by generating neutralising antibodies which may be used to identify non-responders

Table 1. *Identified areas of current research and use of MRI in MS*

Technology	Stakeholders	Function	Method	Availability and usage	References
Hardware (machines)					
Hyperpolarised carbon MRI	University of Cambridge, led by Dr Ferdia Gallagher	Highlights areas of the brain with lesions	Uses radiolabelled carbon-13 pyruvate which is metabolised differently in lesions versus healthy brain tissue	Research use	21–23
Dual-calibrated functional (f)MRI	Cardiff University Brain Research Imaging Centre (led by Prof Richard Wise, Prof John Staffurth and Dr Yulia Hicks	Highlights areas of the brain with lesions with a resolution of a few millimetres	Shows the amount of oxygen that the brain is consuming (CMRO2) which reflects neural activity and can be altered with diseases	Currently focused on glioma, but could be expanded into MS once proof of concept is established	24
		Speeds up data acquisition to ~10 minutes		Would make the technique suitable for clinical use	
Software (computer programmes, image acquisition and analysis etc.)					
Platform for MS-specific regional MRI and Positron emission tomography (PET) analysis	Ixico	Determines validated volumetric image endpoints e.g. eligibility, stratification, safety and efficacy endpoints	Uses proprietary algorithms	Available	25
Icobrain MS	Icometrix	Visualises any white matter abnormalities, brain volume, and tracks changes over time	AI brain imaging software	Approved for clinical use by the FDA	26,27

Job bag: MUL19-E067a
Date of preparation: November 2019

Sensors, software and data analysis	Biogen and Google X collaboration	Tracks disease progression	Tracks patients and their data to understand disease onset, and develop early interventions	In development	28
Integrated Cognitive Assessment (ICA)	King's College London, University of Tehran, and Cognetivity Ltd, London. Led by Seyed-Mahdi Khaligh-Razavi and Chris Kalafatis	Distinguishing normal cognitive function and MS impaired function	A computerised test, which takes a patient ~5 minutes to complete, is self-administered, and language independent	Available, and is being further developed	29

Job bag: MUL19-E067a
Date of preparation: November 2019

3.2 Diagnosis of MS: Artificial Intelligence

Artificial intelligence (AI) is an area of considerable interest for the NHS. In June 2019, NHS Chief Simon Stevens announced a global call for evidence, i.e. a call for NHS staff and technologists to incentivise the best use of evidence-based AI and machine learning technologies across the NHS[30]. The Department of Health and Social Care invested £250 million into AI for healthcare; notably, diagnostics,[31] with reimbursement reforms to the NHS tariff and other payment systems to incentivise quick and safe adoption.[30] The ultimate aim is for the NHS to become a world leader in AI and machine learning by 2024.[30] From a more fundamental research perspective, the government awarded £17.3 million to the Engineering and Physical Sciences Research Council to support the development of AI and robotics in UK universities.[9]

Diagnosis of MS is complex because there is no single diagnostic experimental method currently used in clinical practice and its signs and symptoms are variable.[32] Decision support systems using AI can facilitate diagnosing the disease. The advantages of such systems include increased reliability, accuracy, consistency, speed, and decreased cost.[32] A 2018 review by Arani et al. stated that intelligent computer systems "have the potential to be applied in clinical practices and research in MS".[33] AI may also be useful in the individualisation of MS treatment, as will be discussed in Section 3.3.

Outside of MS, AI does already have some uses in the NHS. A survey asking 45 NHS Trusts about their use of AI revealed that 43% were investigating the uptake (in particular virtual assistants, speech recognition technology and chatbots) to ease the pressure on healthcare workers.[9] Currently, use of AI in the NHS is sparse, but examples of adoption include:[9]

- A NICE-approved mobile heart monitor (KardiaMobile) that uses AI to detect, monitor and manage atrial fibrillation (AliveCor)
- An algorithm to identify disease from images of the back of the eye (Moorfields Eye Hospital and Google DeepMind)
- An instant triage system to replace 111 (urgent and emergency care service) (Babylon and North Central London Clinical Commissioning Group)
- A holistic care management system to enable individuals and caregivers to select the most appropriate provider to deliver services (IBM Watson and Harrow Council)
- In paediatric medicine, a chatbot that allows children to ask questions about hospital admission (IBM Watson and Alder Hey Children's Hospital)

3.3 Treatment of MS: Individualising treatments

The majority of unmet needs in MS are related to treatment, including increasing efficacy and reducing adverse events (AEs).[13] Since MS treatments are not equally efficacious or tolerable in all patients,[34,35] predicting who would benefit from certain treatments before initiation would aid healthcare professionals (HCPs), healthcare systems and patients by slowing disease progression, improving patient satisfaction, and saving costs.[13]

The July 2018 MS Society report identified that there is a scarcity of longitudinal outcomes data aggregated across the MS population, and inconsistent collection of treatment outcomes at an individual patient level leading to a lack of knowledge about the effectiveness of treatments in various patients. Collection of data, for example through remote technologies and wearables, may help researchers develop new treatments, and inform better prescribing practices.[7]

The report also highlights that currently there are no agreed, robust outcome measures for MS. Short-term and predictive measures tend to be used rather than benchmarks for progression over time. Where data is collected, it is often not visible to planning services to help them best understand and meet the needs of the MS population in a particular area.[7]

Blueteq forms are necessary so that NHS England can see which patients receive disease modifying therapies (DMTs) and in what circumstances. By improving the process of data capture, more relevant information may be gained. Moreover, if other data beyond EDSS is captured, this would aid research into the personalisation of medicines.[7]

The MS register, a data bank of real-world evidence, could provide rich information to commissioners and planners, but currently it only covers a sample of the MS population, and it cannot be used systematically across the country.[7] Raising awareness of the MS register and its value may assist the capture of data, and ultimately aid research and individualisation of treatments.

Until 2017, no studies had been able to predict individual treatment response. However, bioinformatic analyses of large patient cohorts enabled development of a predictive algorithm of future response to MS DMTs based on demographic, clinical and simple paraclinical predictors.[36] The study included a detailed assessment of accuracy and robustness, and resulted in predictive models that will be made available to physicians in the form of a web-based tool, incorporated in the MSBase data entry software, with the aim of providing supporting information to complement the treatment decision process.[36]

More recently, in 2019, Dr Parashkev Nachev and Professor Olga Ciccarelli at UCL, led a study which developed an AI-based method that can predict patients with relapse remitting multiple sclerosis (RRMS) response to treatment, discriminating between pre- and post-treatment changes with higher fidelity than previous methods, however the study only focussed on imaging changes.[37] In the future, the approach may enable:[37,38]

- Guided therapy choice in individual patients
- Detection of treatment success or failure at an earlier timepoint

- Trials of new therapies to be conducted more effectively with small patient cohorts

In the future, research may extend the approach to predicting clinical response to DMTs including cognitive and motor outcomes.[37,38]

A range of molecular biomarkers are under investigation for potential use in diagnostics or predicting treatment response. These are listed in Table 2.

Table 2. *Emerging CSF biomarkers in MS*[39]

Biomarker	Description	Utility
NfL	Axonal protein reflecting inflammation-mediated axonal damage	CSF biomarker of acute axonal damage indicating poor long-term prognosis. Biomarker of DMT-mediated effects on axonal damage
NfH	Axonal protein reflecting acute and ongoing axonal damage	CSF biomarker of accumulated axonal damage in progressive MS. Predictive of more severe EDSS progression and brain atrophy
CHI3LI, CHI3L2, CHIT1	Released from activated astrocytes	Prognostic CSF biomarker of conversion from CIS to MS. Biomarker of inflammation-associated disease activity
sCD14, sCD163, TREM-2	Soluble cell surface receptors	CSF biomarkers of microglia/ macrophage activation. Potential to reflect disease activity and therapeutic response
IgM	Oligoclonal lipid-specific intrathecal antibodies	CSF biomarker of conversion from CIS to MS and a more aggressive disease course. Potential as biomarker for progressive disease patients who may benefit from DMTs

As discussed above, technological innovation may assist in the identification and screening of biomarkers.[13,34]

3.4 Management of MS: Improving patient centricity

Patient-based care puts the patient at the centre of their treatment, care and management and actively involves patients in their healthcare status. Advances in technological innovations may facilitate a patient-centric model of care by helping patients to become more involved in their treatment and management[40], thus alleviating strain on the NHS and improving patient-reported outcomes (PROs).

For patients to use technology and support self-management, a certain level of knowledge, skill and confidence is required to meaningfully participate in their healthcare; this concept is referred to as 'patient activation'.[41] Patients who are more activated are more likely to have a regular source of care, obtain preventative care and are less likely to delay seeking care compared to less activated patients.[41] High levels of activation have been associated with better outcomes, healthy behaviour, adherence to treatments, higher satisfaction and better patient experience.[41] In contrast, less activated patients are almost twice as likely to be re-admitted to hospital within 30 days of discharge than a more activated patient.[7]

Apps are already playing a key role in this shift towards patient-centred care. The 2018 MS Society report recommends that PwMS use digital tools to self-manage their condition where possible.[7] Many apps are available for patients, carers and HCPs which span a range of functions and address several unmet needs.[40,42,43] An extensive list of apps can be found in other references,[40,42,43] however some key examples have been outlined in Table 3.

***Table 3**. Key apps for use by PwMS, carers and HCPs*

App name	Stakeholders	Function	Availability and usage	References
SymTrac	Novartis	Prompts patients to monitor their symptoms and wellbeing over time, helping to identify relapses	Approved on the NHS Health Apps Library, Free to download	40,44
myBETAapp	Bayer	Helps patients and caregivers to track injections and injection-site history	Free to download	40,45
MSBuddy	Healthline Networks Inc	Facilitates discussion and allows patients to share stories and experiences	Free to download	46
My MS Diary	Appxient	Tracks injection sites automatically and manages stock of injections	Free to download	47
MS Energise	University of Bournemouth, Auckland University of Technology, University of Brighton, MS Society	Adaptation of a group-based face-to-face fatigue management programme (FACETS) into a digitised format, particularly to deliver the “homework” element of the programme	In clinical trials	48
Thought Sort	Shift.MS	Helps patients access cognitive behavioural therapy (CBT) to manage emotions and mood	Free to download	49
Basic MS Explorer	Basic Home Infusion Inc	Allows patients to track symptoms, provides reminders for medication,	Free to download	50

Job bag: MUL19-E067a
Date of preparation: November 2019

		generates a report on progression, cognition, medication and compliance		
Becare MS Link	BeCare Link	Patients use the app whilst participating in their daily activities. This generates real-time data which is used for EDSS assessment	Free to download	51
Cure MS	BDDevCo	Provides information and research about MS	Free to download	52
Healthstories MS	Jacob Wachsman	Tracks patients' symptoms and shares with friends and caregivers	Free to download	53
Multiple sclerosis virtual education academy	The Wyanoke Group	CME-accredited educational training application for HCPs	Free to download	54
Noteness	Martin Hartl	MS diary app for patients	Free to download	55
MS Topography	S Krieger MD	Aimed at HCPs, creates dynamic visualisations of MS and encourages discussion between patients and HCPs	Free to download	56
MSFocus Radio	Multiple Sclerosis Foundation	Round-the-clock motivation, education and empowerment for patients, via audio content	Free to download	57
My MS-UK	Digital Edition Technology	Provides access to MS-UK bimonthly magazine (single issue, £2.99, 1-year subscription, £14.99)	Free to download	58

Job bag: MUL19-E067a
Date of preparation: November 2019

Multiple sclerosis spotlight	International Medical Press, UCL, Merck KGaA	Aimed at HCPs but suitable for patients, course about optimising treatment of MS using NEDA	Free to download	59
Multiple Sclerosis 101-Treatment and Recovery Tips	BigDave Lab	Provides information about MS and it's symptoms	£2.99	60
Multiple Sclerosis Chat	Kingfish Apps	Allows pwMS to talk with one another, HCPs and carers	Free to download	61
Multiple Sclerosis Messenger	KingfishApps	Allows pwMS to talk with one another, HCPs and carers	Free to download	62
Multiple Sclerosis Support	MyHealthTeams	Social network for pwMS	Free to download	63
Pre-Meet: Multiple Sclerosis	Darin Okuda/Ardireo	Information for patients about what to expect during their MS specialist appointment	Free to download	64
MS Fatigue Fix	Darin Okuda/Ardireo	Information about fatigue for patients, including symptom tracker	£4.29	65
Understanding MRI	Darin Okuda/Ardireo	Information for patients about MRI, and understanding MRI results	£4.99	66
MS Relapse tool	Darin Okuda/Ardireo	Allows patients to evaluate symptoms and estimate probability of relapse	£1.79	67

Pain Solutions: MS	Darin Okuda/Ardireo	Provides information about MS pain and create management strategies	In development	68

In a review by Giunti et al, 2018[42] 30 MS apps were identified (UK-accessible, currently supported also listed in Table 3), with the most recurrent features being patient education, social media and data visualisation. However, the following gaps were noted in these 30 apps:[42]

- For patient education, information was abundant but links to source materials were scarce
- Most (24) lacked a reminder system (notifications that remind PwMS to engage in activities)
- Most (29) lacked connectivity to external sensors (in this case, a Fitbit device) and instead relied on integrated capabilities within the mobile phone
- Most (29) did not offer a remote monitoring system meaning that users could not share their symptoms and lab results with their HCP
- Furthermore, another review noted that few apps have been translated into all languages[40]

3.5 Management of MS: Rehabilitation

Delaying disability, reducing active symptoms, and detection and management of comorbidities are key unmet needs in MS.[13] Physical therapy and rehabilitation help to manage symptom severity in PwMS. These interventions should be tailored to a patient and the degree of disability, with a focus on spasticity, walking, balance, upper limb function and cognition. Technology-aided rehabilitation is now widespread in clinical settings (Table 4) and has recently been proposed as an approach with great potential for restoring motor functions and activities.[69]

Table 4. *Technology-aided rehabilitation available in clinical settings or in development*

Technology	Function	Examples	Availability and usage	References
Virtual reality (VR)	Motor assessment and rehabilitation	Functional electrical stimulation combined with passive robot assistance for arm movement and control Balance training programme Variable compliance joystick as wheelchair input Motor-telerehabilitation programmes	Additional research is needed before clinical use	70
Wearables*	Continuous patient-based monitoring, measurement of objective outcomes and delivery of feedback on daily-life activities	Accelerometers Gyroscopes Multi-sensor systems Infrared devices Force sensors Eye tracking	Further studies are required to assess reliability and accuracy before clinical use	40,71,72
Accelero-meters	Step count measurement to assess activity and function (e.g. gait, balance, fall)	Fitbit Flex StepWatch RT3 Actibelt Actigraph		73
Gyroscopes	Record orientation and movement to identify falls and analyse static balance and gait		Many digital devices already contain gyroscopes	73

*Electronic technology worn on the body or embedded into mobile and portable solutions (e.g. smartphones, watches, bracelets, clothing)

Grip force sensors	Objective measurement of motor function	Gripable (assesses grip strength, hand opening, wrist motions, arm movements and cognition, and wirelessly connects with a mobile app)	Used by several NHS trusts	74
Robotics	Help patients move their limbs	Robot-assisted gait training: grounded end-effectors and exoskeleton devices Upper-extremity robotics and electromechanical devices	Robotics companies developing technology for MS are based in Germany, Switzerland, the US	69
Gaming devices	May enrich rehabilitation and functional recovery	Wii Kinect		69

Job bag: MUL19-E067a
Date of preparation: November 2019

3.6 Technology implemented in adjacent therapy areas

There is significant overlap between MS and other disease areas in terms of unmet needs. Therefore, technology being implemented in adjacent therapy areas may be adaptable for use in MS. Relevant examples for cross-over in technology in adjacent therapy areas which may have the potential to be utilised within MS are shown in Table 5.

Table 5. *Technology in adjacent therapy areas which may be adapted for use in MS*

Technology	Developed by	Usage	Function	Relevance to MS	References
Parkinson's disease (PD)					
KinetiGraph (PKG)	Global Kinetics Corporations (Australia)	Deployed to UK patients by University of Plymouth and University Hospital Plymouth NHS Trust	Wrist-worn PD monitors offer medication reminders and track involuntary movements by patient over 6 days which can be reviewed by HCPs	Similar sensors and approaches could be developed for MS to monitor symptoms and therefore improve patient outcomes	75,76
Fox Insight Wearables	The Michael J Fox foundation (a PD charity)	Clinical study	Smartwatches and an app collect data about motor symptoms in PD to track fluctuations and assist the development of computer programmes to estimate and predict objective measures of PD symptoms	Similar sensors and approaches could be developed for MS to monitor symptoms and therefore improve patient outcomes	77
e-AR	Sensixa (a spin-off from the Hamlyn Centre of Imperial College London)	Research use	A sensor worn behind the ear that monitors PD symptoms, gait, motion and acceleration in 3 dimensions, and user posture	Similar sensors and approaches could be developed for MS to monitor symptoms and therefore improve patient outcomes	78
Deep brain stimulation (DBS)	Multiple	Approved in the UK to treat PD, tremor and other conditions	Advances in DBS could improve efficacy e.g. electrode improvements, reduced size, and development of closed-loop systems	Tremor affects 25–32% of PwMS and NICE supports use of DBS for tremor and dystonia in MS	79–82
Diabetes					

Job bag: MUL19-E067a
Date of preparation: November 2019

Automatic blood glucose monitors	Multiple	Used in the NHS	Blood glucose monitoring in a standardised pattern improves outcomes versus self-monitored blood glucose data (which is often random collection)	Similar systems could improve measurement of patient monitoring and therefore patient outcomes	83,84
Multiple softwares (e.g. Accu-Chek Aviva Expert)	Multiple (Accu-Chek)	Used in the NHS	Software that links patient blood glucose monitoring data to real-time decision support for the patient e.g. automatic insulin dose calculator on the patient's glucometer	Although not directly applicable due to the more standardised dosing of MS DMTs, aspects of this system may increase patient self-management in MS	84
Fully automated physiologic insulin delivery systems	Multiple (including University of Cambridge, UK)	Clinical trials Some patients have created do-it-yourself systems through guidance from online communities (not FDA approved or recommended)	Software and hardware to measure glucose levels and deliver insulin when appropriate	Although not directly applicable due to the different mode of administration of MS DMTs, aspects of this system may increase patient self-management in MS	83,84
Numerous apps	Multiple	Used by many patients and frequently recommended by physicians	Apps which record medication administration, glucose logs and diet. However, >80% have no privacy policies and many actively transmit individual patient data to third parties without obtaining permission from the patient	Could improve the systems already in use for MS to increase patient adherence, and improve monitoring and patient outcomes	84

Job bag: MUL19-E067a
Date of preparation: November 2019

Diabetes Wellness Program	Samsung Electronics America, Inc. and WellDoc®	FDA licensed	An app which connects patient-generated glucose monitoring with automated text message responses, telephone- and web-based health coaching, and reports for the HCP	Similar approaches could be developed for MS to monitor symptoms and therefore improve patient outcomes	85
diasend®	Glooko	Available in the US, Canada, France, Germany	A unified population management system for clinics, including hardware for downloading a range of glucometers, remote monitoring and telemedicine interventions for glycaemic control	Similar sensors and approaches could be developed for MS to monitor symptoms and therefore improve patient outcomes	84,86
Electronic diabetes education	Multiple		Computer- or text-based health coaching to educate patients	Could improve the systems already in use for MS	84

Job bag: MUL19-E067a
Date of preparation: November 2019

4 Conclusions and future directions

This state-of-the-nation gap analysis addresses the current unmet needs in MS, and reviews the existing technology support for PwMS, caregivers and HCPs across the UK, and sought to subsequently highlight poorly served areas and challenges in technology uptake. The findings are summarised in Table 6.

MS treatment and management are the most well-serviced areas in MS digital and health technologies. A wealth of apps are currently available which allow PwMS to track symptoms or emergence of AEs, or connect with peers and their clinicians. The greatest barrier that has been identified to uptake of these apps is patient activation and engagement with technology.

In contrast, the identification and validation of biomarkers is an area with potential for considerable advances over the next few years. This could be as a result of developments in AI and machine learning, or improvements in hardware (for example MRI technology), however, as many of the technologies identified in this area are still at a stage of academic research, it will be a number of years before they reach clinical practice.

Regarding next steps, contacting NHSX would enable accurate determination of the technologies already implemented in MS healthcare by the NHS, as well as any related challenges and opportunities. To identify HCPs across the UK who are defining the future digital and technological landscape, it would be beneficial to contact the researchers and teams identified throughout this report.

The recent interest, willingness and available funds from the NHS to incorporate digital and physical technologies into the diagnosis, treatment and management of PwMS (and other disease areas) is positive, and it is therefore timely to be pursuing this research.

***Table 6**. Gap analysis of health innovation and digital technologies in MS in the UK*

Unmet need in MS[13]	Technology already in use in the UK	Innovative technology	Who is driving these initiatives forward?	Innovations impacting other therapy areas
Diagnosis of MS				
Identifying tools	MRI	Improvements in MRI hardware and software	HCPs, academia, tech companies	
Identifying and validating biomarkers	Bioinformatics	AI	HCPs, academia, pharma	
		Improvements in hardware	Tech companies	
Treatment of MS				
Further delaying progression and developing better treatments for progressive MS	Apps to detect symptoms	Remote monitoring	Pharma, HCPs, tech companies, academia	Apps to collect standardised patient data Systems for clinics and HCPs to make monitoring easier
		Wearables	Tech companies, academia	Sensors to monitor patient movement
Providing neuroprotection	None identified to date			
Delaying or avoiding disability	Gripforce sensors to assess function	VR Robotics	Tech companies, academia	DBS
Reducing active symptoms more effectively	Apps to detect symptoms	Remote monitoring	Pharma, HCPS, tech companies, academia	Systems to monitor patients DBS
		VR	Tech companies, academia	
Individualising treatment		Bioinformatics and AI	Academia, pharma	
Management of PwMS				
Improving adherence to current medications	Apps with reminder systems		Pharma, HCPs, tech companies	Automatic delivery and reminders
Preventing or ameliorating AEs of current medications	Apps to detect AEs	Remote monitoring	Pharma, HCPs, tech companies	
Detection and management of comorbidities		Remote monitoring VR	Pharma, HCPs, tech companies	

Job bag: MUL19-E067a
Date of preparation: November 2019

Obtaining better measurements of functional outcome	Gripforce sensors	Wearables	HCPs, tech companies	Software systems to collect data on patient outcomes
Emotional support for patients and caregivers	Peer support groups (online / apps)		HCPs, tech companies, charities	Patient education apps
Sharing information between HCPs	Online groups Apps		HCPs, tech companies, pharma	

Job bag: MUL19-E067a
Date of preparation: November 2019

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