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New and emerging technologies for the diagnosis and monitoring of chronic obstructive pulmonary disease: A horizon scanning review

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Abstract

There is a need for straightforward, novel diagnostic and monitoring technologies to enable the early diagnosis of COPD and its differentiation from other respiratory diseases, to establish the cause of acute exacerbations and to monitor disease progression. We sought to establish whether technologies already in development could potentially address these needs. A systematic horizon scanning review was undertaken to identify technologies in development from a wide range of commercial and non-commercial sources. Technologies were restricted to those likely to be available within 18 months, and then evaluated for degree of innovation, potential for impact, acceptability to users and likelihood of adoption by clinicians and patients with COPD. Eighty technologies were identified, of which 25 were considered particularly promising. Biomarker tests, particularly those using sputum or saliva samples and/or available at the point of care, were positively evaluated, with many offering novel approaches to early diagnosis and to determining the cause for acute exacerbations. Several wrist-worn devices and smartphone-based spirometers offering the facility for self-monitoring and early detection of exacerbations were also considered promising. The most promising identified technologies have the potential to improve COPD care and patient outcomes. Further research and evaluation activities should be focused on these technologies.

Keywords

Chronic obstructive pulmonary disease, diagnosis, monitoring, new technology, horizon scanning

Introduction

Chronic obstructive pulmonary disease (COPD) is the third leading cause of death globally and presents a significant burden to patients, carers and health services worldwide.[1,2] More than 1.5 million adults are known to be diagnosed with COPD in England and Wales, and a further 3 million adults are estimated to be living with undiagnosed COPD.[3,4] Improving the care and outcomes for people with COPD is a priority for the National Health Service (NHS) in England, which aims to reduce premature mortality from respiratory disease, avoid unnecessary hospital admissions and improve the quality of life and support for patients with long-term conditions and their carers.[5] However, several current issues remain in the diagnosis and monitoring of COPD, some of which could be resolved by technological developments or novel disease biomarkers.

Several authors have noted limitations in the use of spirometry to diagnose COPD due to differing

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guidelines as to what constitutes COPD, difficulties in technique encountered by frail or cognitively impaired patients, and a lack of awareness and knowledge in primary care leading to delayed diagnosis, especially in non-smoking subgroups.[6–9] In addition, some commentators have proposed a need for improved diagnostic criteria where asthma and COPD coexist, observing that non-specialist clinicians frequently find it difficult to both diagnose and manage this situation,[8,10,11] whilst others consider that additional emphasis should be placed on early detection.[9,12,13] There is an unmet need for simple, accurate testing approaches that would enable early diagnosis and differentiation from other respiratory diseases.[13] As part of the ongoing care of COPD, patient self-monitoring is increasingly being recognized as beneficial, with evidence indicating this may improve health-related quality of life and the recognition and management of acute exacerbations,[14,15] and self-monitoring is recommended in guidelines from the National Institute for Health and Care Excellence (NICE).[2] However, the most effective approach to self-management in COPD is not known.[14] Finally, several commentators identify the need to determine the cause of acute exacerbations as a research need; this would allow treatment to be tailored to the underlying pathology.[16,17] Correspondingly the NICE Database of Uncertainties about the Effects of Treatments includes questions about the appropriate use of corticosteroids and antibiotics for the management of acute exacerbations of COPD.[18,19] As only around half of exacerbations are associated with a bacterial infection and a only a third of exacerbations demonstrate eosinophilic inflammation, the use of these agents may expose many patients to significant adverse effects and the potential development of antibiotic resistance for no apparent benefit.[20,21] There is an unmet need for novel diagnostic or monitoring approaches, particularly those available at the point of care, to establish the cause of acute exacerbations and to monitor the progression of the disease.

Horizon scanning systems, or early awareness and alert systems, aim to identify significant health technologies prior to launch that may require further assessment or planning prior to adoption.[22,23] A horizon scanning review uses systematic methods to identify, filter, prioritize and present early information on all new and emerging technologies relevant to the area of interest, however, it does not assess the evidence supporting the identified technologies, validate the claims made about them by developers or comprehensively evaluate the potential impact they may have on clinical care.[24,25] We sought to identify new and emerging technologies already in development for the diagnosis or monitoring of COPD that could potentially address the unmet research and clinical practice needs identified above, and then use the views of clinical experts and patients with COPD to establish which of these technologies could be considered the most innovative, acceptable and likely to make an impact on patients and health services in the future. This horizon scanning review forms part of the National Institute for Health Research Horizon Scanning Research and Intelligence Centre work programme. The full report is available on the Centre's website (http://www.hsric.nihr.ac.uk/news/what-does-the-future-hold-for-copd-diagnostic-and-monitoring-technologies/) and will be used to inform healthcare policymakers, commissioners, researchers, research funders, clinicians and patients about new technologies 'on the horizon' for the management of COPD. Ethical approval was obtained from the University of Birmingham's Internal Ethical Review Committee (reference: IERC2014-5/C1/SF/07).

Methods

Identification and filtration of technologies

Between January and March 2015, potential technologies for the diagnosis and monitoring of COPD were identified by searching relevant online databases and other websites (Table 1) using pre-specified search terms (Table 2) and eliciting suggestions from clinical experts. Initial search findings were filtered to include only those technologies which were new (already licensed/CE marked or launched in the United Kingdom for $\leq$24 months – in the launch, early post-marketing or early diffusion phase) or emerging (in development and expected to be licensed/CE marked in the next 18 months – in late phase clinical trials, prelaunch or pre-marketing phase), and results were further prioritized to include only those technologies that demonstrated, or claimed to demonstrate, some degree of innovation (either a completely novel technology, with no direct comparators already marketed, or a significant development from existing marketed products).

External input

Clinical experts and patients with COPD were recruited as expert external advisors to the review.

Table 1. Search protocol – pre-specified identification sources.

Source name	Website link
Published medical literature	
Medline & Medline in Progress, & EMBASE	Accessed via http://www.elibrary.bham.ac.uk/
PubMed.gov	http://www.ncbi.nlm.nih.gov/pubmed
The Cochrane Library	http://www.cochranelibrary.com/
ZETOC British Library Database	http://zetoc.mimas.ac.uk/
HTA agencies	
AHRQ Healthcare Horizon Scanning System	Status update reports and potential high impact reports via http://www.effectivehealthcare.ahrq.gov/search-for-guides-reviews-and-reports/?pageaction=displayproduct&productid=881
CADTH	http://www.cadth.ca
ECRI Institute	http://www.ecri.org
EuroScan International Network	http://euroscan.org.uk/
NIHR Horizon Scanning Research & Intelligence Centre database	http://www.hsric.nihr.ac.uk/
Clinical trial registries and research funding databases	
ClinicalTrials.gov	http://clinicaltrials.gov/
COPD clinical research network	http://www.copdcrn.org/
Current-controlled trials	http://www.controlled-trials.com/
MRC-funded research	http://www.mrc.ac.uk/research/funded-research/
NIHR Biomedical Research Centres and Units annual dataset (2014)	Not applicable
NIHR Evaluation Trials and Studies Project portfolio	http://www.nets.nihr.ac.uk/projects?collection=netscc&meta_P_sand=Project
UKCRN portfolio database	http://public.ukcrn.org.uk/search/
World Health Organization International Clinical Trials Registry Platform	http://www.who.int/ictrp/en/
Specialist media and commercial research and development databases	
AdvamedSmartbrief	https://www2.smartbrief.com/news/ADVAMED/index.jsp
Clinica	http://www.clinica.co.uk/
Fierce Devices	http://www.fiercemedicaldevices.com/
GlobalData Medical	http://globaldata.com/medical/Login.aspx?ReturnUrl=%2fmedical
MedGadget	http://www.medgadget.com/
Medical News Today	http://www.medicalnewstoday.com/
Regulatory authorities	
USFDA approvals	http://www.fda.gov/newsevents/productsapprovals/default.htm
Specialist journals	
American Journal of Respiratory and Critical Care Medicine	http://www.atsjournals.org/journal/ajrccm
COPD: Journal of Chronic Pulmonary Obstructive Disease	http://informahealthcare.com/loi/cop
European Respiratory Journal	http://erj.ersjournals.com/
Expert Reviews of Respiratory Medicine	http://informahealthcare.com/loi/erx
International Journal of Chronic Obstructive Pulmonary Disease	http://www.dovepress.com/international-journal-of-chronic-obstructive-pulmonary-disease-journal
Thorax	http://thorax.bmj.com/
Professional and patient groups	
American Thoracic Society	http://www.thoracic.org/
British Lung Foundation	http://www.blf.org.uk/Home
British Thoracic Society	https://www.brit-thoracic.org.uk/
COPD Foundation	http://www.copdfoundation.org/
European Lung foundation	http://www.europeanlung.org/en/
European Respiratory Society	http://www.ersnet.org/
Primary Care Respiratory Society	http://www.pcrs-uk.org/
Royal College of Physicians	https://www.rcplondon.ac.uk/

Table 2. Search protocol – pre-specified search terms.

Condition and synonyms	Chronic obstructive pulmonary disease
	COPD
	Chronic obstructive airways disease
	COAD
	Chronic obstructive lung disease
	Chronic obstructive respiratory disease
	Chronic airflow limitation
	Emphysema
	Chronic bronchitis
Diagnosis	Diagnosis
	Recognition
	Detection
	Identification
	Test
	Point-of-care test
Monitoring	Monitoring
	Surveillance
	Review
Timeframe	New
	Emerging

Clinical experts were identified from initial scoping and literature searches and the NICE COPD guideline development and review panel. Fifteen clinical experts were contacted via email and asked to act as review advisors, five of whom subsequently agreed, resulting in an expert panel comprising consultant respiratory physicians, a general practitioner with a special interest in respiratory disease and a clinical nurse specialist. Clinical experts were emailed the table of identified technologies and asked to provide their views on each technology's level of innovation, potential for impact (on patients and the delivery of health services), potential barriers to adoption and any further comments. They were also asked to identify any additional relevant technologies or relevant research they were aware of that had not already been identified.

Patients with COPD were identified from the patient advisory group to the existing Birmingham Lung Improvement StudieS (BLISS) research programme.[26] Members of the group were approached using a standard email or letter informing them of the review and inviting them to participate. Three patients subsequently agreed and were sent the table of identified technologies and asked to provide their views on each technology's level of innovation, potential for impact (on patients and the delivery of health services) and acceptability to users, along with any further comments.

Review output

All identified new and emerging technologies for the diagnosis or monitoring of COPD were included in the final report. Clinical expert and patient views were used to identify those technologies that were considered to demonstrate a high degree of innovation and/or a significant potential for impact and adoption by the NHS in England.

Results

Eighty new and emerging technologies for the diagnosis and monitoring of COPD were identified (Table 3, Figure 1). These included 31 biomarkers, 21 telehealth technologies, 6 wearable technologies, 6 imaging technologies, 4 vital sign monitors, 4 questionnaires, 3 spirometers and 5 additional other technologies. Clinical experts and patients provided comments on all identified technologies, providing useful insights into the innovativeness, potential impact, stage of development and probable timeframe for each technology. Of the technologies identified, 25 (31.3%) were considered particularly promising, demonstrating a high degree of innovation and with a significant potential for impact and adoption by the NHS according to expert and patient comments (Table 4).

Wearable technologies

All identified wearable technologies were intended to monitor stable COPD through devices worn either across the chest or on the wrist. Whilst devices monitoring respiratory rate, wheeze, blood oxygenation and/or temperature are already available, several new technologies enabled self-monitoring at home with remote access by clinicians, though the feasibility of multiple clinicians interpreting large volumes of recorded data was questioned. Patients commented that users may be unwilling to wear a 'cumbersome' looking device and were concerned about 'having the restriction of a band around [their] chest'. The wrist-based pulse oximeter and BuddyWOTCH devices could offer alternatives to existing fingertip devices, providing continuous monitoring without limiting movement of the user's hands. In addition, BuddyWOTCH captures physical activity, temperature and heart rate. Both technologies were considered promising, with patients keen to try a more compact, watch style device. Experts considered them 'potentially useful . . . for longer term monitoring . . . in vulnerable groups . . . [and] for pulmonary rehabilitation'.

Table 3. Technologies identified by the review.

Technology type	Technology name	Brief description	Developer	Stage of development
Wearable technologies	WHolter	24 hour ambulatory digital device intended for tracking wheeze and cough.	iSonea Ltd., Israel.	CE marked. FDA approved.
	Breeze@home	Remote monitoring jacket.	Deep Breeze Ltd., Israel.	Estimated launch May 2015.
	Wrist-based pulse oximeter	Wireless, wrist worn, pulse oximeter.	Oxitone Medical Ltd., Israel.	Patent pending. Estimated to reach market by 2015.
	VigilCare	Wireless monitoring device detecting step activity and vital signs remotely in real time.	Agali Technologies, Inc., USA.	Estimated launch October 2017.
	BuddyWOTCH	Wearable smartwatch intended for home monitoring of walking, oxygenation, temperature, chronicle (image capture of medication, food and liquids) and heartrate.	Aseptika Ltd., UK.	Estimated launch October 2019. The Company intends to deliver its first production unit to NHS clinical partners and beta test volunteers by the end of 2015.
	RESpeck	Non-invasive, wireless respiration and movement monitor.	Centre for Speckled Computing, University of Edinburgh, UK.	Pilot trials complete.
Blood biomarkers	Blood eosinophil count	Biomarker to direct corticosteroid therapy during COPD exacerbations.	Glenfield Hospital, UK.	BEAT: COPD study.
	Aα-Val^{360}	Biomarker for the identification of patients with early COPD at risk of progression.	Queen Elizabeth Hospital, UK.	In pilot/feasibility trial.
	CRP point-of-care test	Rapid point-of-care test to direct antibiotic prescribing in exacerbations of COPD.	Cardiff University, UK.	In trial since July 2014, due to publish trial in February 2018.
	Plasma fibrinogen biomarker	Biomarker test to identify individuals at an increased risk of COPD exacerbation.	University of Kentucky, USA.	Qualification Package submitted to the FDA for plasma fibrinogen as a new drug development tool.
	Inflammatory biomarker panel	Inflammatory biomarkers to established predictive factors aiming to improve mortality predictions.	GlaxoSmithKline (GSK) plc.	Test of hypothesis trial (ECLIPSE study).
	CRP, fibrinogen and leukocyte count inflammatory biomarkers	Inflammatory biomarker panel to monitor for exacerbations of COPD.	Copenhagen University Hospital, Denmark.	Test of hypothesis trial.
	PCT	Biomarker test to direct COPD exacerbation treatment.	Holbæk Hospital, Denmark.	Phase IV.
	Serum Procalcitonin	Rapid biomarker test for the diagnosis of a COPD exacerbation.	Ramathibodi Hospital, Bangkok.	Proof of concept study.
	Heat shock protein 27 biomarker	Biomarker test for the diagnosis of early COPD before it is detectable by lung function tests.	University Department of Surgery at MedUni, Vienna.	Test of hypothesis trial.

(continued)

Table 3. (continued)

Technology type	Technology name	Brief description	Developer	Stage of development
	Endothelial microparticle biomarkers	Biomarker for the identification of smokers with early emphysema.	Weill Cornell Medical College, USA.	Test of hypothesis trial.
	α-2 macroglobulin, haptoglobin, ceruloplasmin and haemopexin biomarkers	Diagnostic biomarker for COPD.	University of Newcastle, UK.	Proof of concept study. Estimated launch January 2018.
	ARHGEF1 (Rio guanine nucleotide Exchange factor 1) biomarker	COPD diagnostic and prognostic biomarker.	Lenimen, USA.	Estimated launch May 2016.
	Autoantibody Antigen Array – COPD	COPD diagnostic and prognostic biomarker.	University of Colorado, USA.	Estimated launch May 2016.
	AlphaKitQuickScreen Device	Point-of-care device intended for the diagnosis of α-1-antitrypsin deficiency.	Grifols, Spain.	CE marked.
	Serum uric acid biomarker	Low-cost biomarker for the prediction of an exacerbation of COPD.	University of Athens, Greece.	Test of concept study.
	Hydrogen sulphide Biomarker	Biomarker for the diagnosis of a COPD exacerbation.	N.R.S.Medical College, India.	Proof of concept study.
	Neutrophil/lymphocyte ratio	A widely available and cost-effective biomarker to determine the cause of an exacerbation of COPD.	Athens Medical School.	Proof of concept study.
Sputum biomarkers	Home use sputum test	Home use test detecting the level of activity of nine respiratory pathogens to provide advance warning of an exacerbation.	Aseptika Ltd., UK.	Phase III trials.
	Sputum rheology	Low-cost, rapid, easy to access and non-invasive biomarker for COPD diagnosis.	TA Instruments, USA.	Technology is already available but is not currently used for this indication.
	Biomarker panel: SP-A, sRAGE, MPO and NGAL	Biomarker panel to diagnose COPD-Asthma overlap.	University of Helsinki, Finland.	Proof of concept study.
	FTIR monitoring	Handheld device using infrared spectroscopy to diagnose and monitor COPD.	Glyconics, UK.	Large validation trial.
Saliva biomarkers	COPDSPOC	Point-of-care biosensor for COPD diagnosis.	University Hospital of North Staffordshire, UK.	Pilot/feasibility trial.
	Saliva CRP and PCT biomarkers	Monitoring biomarker for the detection of an exacerbation of COPD.	University Hospital of North Staffordshire, UK.	Test of concept.
Breath biomarkers	VOC Diagnostic Assay	Immunodiagnostic assay intended for the diagnosis of COPD.	XAir Diagnostics B.V.	Estimated launch April 2016.
	Exhaled VOCs	Breath test for the diagnosis and monitoring of COPD.	Markes International Ltd., UK.	Currently in trial for application of the existing technology for use in COPD.

(continued)

Table 3. (continued)

Technology type	Technology name	Brief description	Developer	Stage of development
	^{13}C-Methacetin Breath Test	Breath test for the diagnosis and monitoring of COPD.	Hadassah Medical Centre, Israel.	Phase II/III trial.
	SpirometrixFenom™ Point-of-care test	Highly sensitive point-of-care test for the diagnosis of COPD and prediction of an acute exacerbation of COPD.	Spirometrix Inc.	Technology is still under development.
	Breath PulmoHealth 'Check' COPD detector	Diagnostic COPD breath test.	Akers Biosciences, Inc., USA.	Estimated CE mark September 2016. Estimated Europe launch December 2016. Estimated USA launch March 2017.
Other biomarkers	Metabolomic Biomarker Assay – COPD	Body fluid or tissue biomarker–based assay intended for diagnosis of COPD.	Biocrates Life Sciences AG, Austria.	Estimated launch May 2017.
	L-Lactate dehydrogenase biomarker	Bronchial aspirate biomarker for the diagnosis of COPD exacerbations.	University Hospital of Split, Croatia.	Proof of concept study.
	Hyaluronic acid and heparin sulphate biomarkers	Bronchial aspirate biomarker for the diagnosis of COPD exacerbations.	University Hospital Basel, Switzerland.	Proof of concept study.
Telehealth technologies	Care Innovations Guide	Online interface for the monitoring and patient education.	Intel-GE Care Innovations LLC., USA.	Estimated launch date May 2011.
	Intel® Health Guide PHS6000	A touch screen, in-home patient device and online management interface for monitoring and patient–doctor communication.	Intel Corporation.	In phase III trial.
	AlereHomeLink	Touch screen device and interface for the monitoring of symptom severity.	Alere Connect, USA.	FDA approved Jan 2014 and CE marked.
	Commander Flex	Interactive home telehealth wireless tablet device intended for patient monitoring.	Cardiocom, LLC., USA.	FDA approved.
	MedVizer T400 Home Health Monitor	Touch screen, tablet device for the monitoring of symptoms, vital signs and for patient education.	Visual Telecommunication Network, Inc., USA.	Phase II trials
	CHROMED monitoring system	Home monitoring system for vital signs and symptoms.	University of Lincoln, UK.	Pilot/feasibility trial.
	eHealth Diary	A digital pen enabling for symptom monitoring.	Phoniro systems, Sweden.	Pilot/feasibility trial.
	i-DSMP (Internet-based Dyspnoea Self-management Program)	An interface enabling the monitoring of symptoms and exercise.	University of California, USA.	Phase II trial.
	Telephone-linked computer–COPD	A computer-based telecommunications system that can monitor, educate and counsel patients.	VA Boston Health Care System, USA.	Phase IV.

(continued)

Table 3. (continued)

Technology type	Technology name	Brief description	Developer	Stage of development
	InterSpace: Web-based supported self-management programme	COPD self-management website offering doctor/nurse–patient videoconferences.	University hospitals of Leicester, UK.	Feasibility study.
	ADAPT	Post-discharge-staged telemonitoring programme.	Prince Phillip Hospital, Llanelli, UK.	Pilot trial.
	SmartScope System	A remotely used software application system intended for remote patient monitoring.	Futura Mobile Health, LLC., USA.	Pilot study. Estimated launch May 2016.
	GaitTrack App	A smartphone app used in conjunction with a pulse oximeter to monitor gait, heart rate and blood oxygenation.	University of Illinois, USA.	Pilot study.
	Respiratory virtual clinics	Multidisciplinary virtual clinics between primary and secondary care to monitor patients with COPD.	King's Health Partners Integrated Respiratory Team, UK	Feasibility study completed in 2014.
	mACEWS (mobile Acute Care Early Warning System)	A mobile monitoring solution to detect the early signs of an exacerbation of COPD.	Airstrip Technologies Inc., USA.	No trials found.
	Smart inhaler	Inhaler sensor providing remote monitoring of drug use and therefore prediction of exacerbation.	Propeller Health, USA.	FDA approved. Estimated going to market early 2015.
	Health-e-Connect System	Internet-based patient monitoring system intended for remote nebulizer compressor monitoring.	ALR Technologies Inc., USA.	Estimated launch March 2016.
	CTC-Actiwise	An algorithmic system intended for the early detection of potentially upcoming exacerbations in patients with COPD.	CareTelCom AB, Sweden.	Estimated launch May 2017.
	Semi-automated cough classifier	Daily cough monitoring using ambient sound recording system and a novel semi-automated cough classifier as a marker for exacerbations.	Hull York Medical School, UK.	Pilot study.
	Microsoft@ Kinect™-based telemedicine programme	A Microsoft Kinect-based telemedicine system used in order to monitor patients with COPD.	HUA Txagorritxu, Spain.	Pilot study.
Imaging technologies	PRM™ (Parametric response map) COPD	Software capable of diagnosing COPD types on CT scan.	Imbio, USA.	FDA 510(K) clearance in 2014.
	Mobile SPECTImaging	Imaging sensitive to early changes in COPD and has the possibility of identifying comorbid disease.	Professor Brian Hutton, UK.	Prototype to be installed early 2016.

(continued)

Table 3. (continued)

Technology type	Technology name	Brief description	Developer	Stage of development
	CT perfusion scan	Imaging capable of the diagnosis of early COPD and those at risk of disease progression.	University of Edinburgh, UK.	Pilot/feasibility trial.
	Quantitative CT scans	Imaging able to monitor for the likelihood of a COPD exacerbation.	National Jewish Health, USA.	Technology widely available but not widely used for this indication.
	Transthoracic Parametric Doppler/Pulsed Doppler Ultrasound System	A non-invasive and non-imaging ultrasound Doppler and signal processing technology capable of extracting parametric information for the diagnosis of COPD.	EchoSense Ltd., Israel.	Proof of concept study
	Human Lung Regional Ventilation Defect Severity Measured by Fluorine-19 Gas MRI	MRI assessment for the monitoring of COPD disease progression.	Duke University Medical Center, USA.	Phase II trial.
Vital sign monitoring technologies	EverOn™ heart and respiration monitor	Disposable sensor placed under a mattress for the detection of respiratory and heart rate, for the detection of COPD exacerbations.	EarlySense Ltd., USA.	FDA approved and CE marked.
	Respiratory Holter – COPD	A device to detect respiratory rate through QT interval monitoring.	Nicrem S.r.l., Italy.	Preliminary validation stages. Estimated launch February 2018.
	Nonin Bluetooth® Smart Model 3230 Finger Pulse Oximeter	A finger pulse oximeter with Bluetooth Smart wireless technology.	Nonin Medical, Inc., USA.	FDA approved. Launched in 2013.
	Capno-Pulse	A continuous, non-invasive respiratory monitoring device intended for the monitoring of COPD.	Neetour Medical Ltd., Israel.	Estimated launch March 2018.
Spirometry technologies	MySpiroo	Handheld portable spirometer which monitors lung function via a smartphone app.	MySpiroo, Poland.	Expected launch 2015.
	MIR Smart One®	Smartphone-based spirometer, connecting wirelessly to an app.	MIR (Medical International Research), Italy.	Launched November 2014.
	Smartphone spirometer	Smartphone-based spirometer, utilizing global positioning system location and positioning to monitor COPD.	resp.io, USA.	No trials found.
Questionnaire-based technologies	DECAF scoring system	A simple yet effective predictor of mortality in patients hospitalized with an exacerbation of COPD.	North Tyneside General Hospital, UK.	Validation trial.

(continued)

Table 3. (continued)

Technology type	Technology name	Brief description	Developer	Stage of development
	Asthma-COPD Overlap Syndrome Questionnaire	Questionnaire for the diagnosis of COPD where Asthma co-exists.	US GSK Clinical Trials Call Centre, USA.	Phase II trial.
	COPD screening questionnaire	Smoking status and symptom questionnaire for the identification of patients in need for COPD investigations.	Bispebjerg University Hospital, Denmark.	Effectiveness evaluation study.
	DOSE index	Multicomponent index with the potential to predict future outcomes in patients with COPD.	Radboud University Nijmegen, Netherlands.	Validation study.
Other technologies	SPPB	Short walking test for the monitoring of COPD.	Royal Brompton & Harefield NHS trust, UK.	Effectiveness study.
	SonicSense	An ultrasonic sensor for use of COPD monitoring.	The Technology Partnership (TTP), UK.	Prototype stage.
	ResPOC point-of-care testing for respiratory viruses	Point-of-care test to detect viral causes of COPD exacerbations.	Ateknea Solutions, Hungary.	Expected commercial launch 2016.
	HIRA-TAN semi-quantitative PCR	A rapid, accurate, easily performed PCR test to identify causative bacteria in COPD exacerbations.	Saitama Medical University, Japan.	Validation study.
	mPCR	A sensitive, rapid mPCR test for the detection of respiratory viruses from tracheal aspirate and nasal pharyngeal aspirate samples.	All India Institute of Medical Sciences, India.	Proof of concept study.

BEAT: COPD -: Biomarkers to Target Antibiotic and Systemic Corticosteroid Therapy in COPD; USFDA: US Food and Drug Administration; COPD: chronic obstructive pulmonary disease; NHS: National Health Service; CRP: C-reactive protein; PCT: procalcitonin; FTIR: Fourier transform infrared; SPOC: saliva point of care; VOC: volatile organic compounds; MRI: magnetic resonance imaging; DOSE: dyspnoea, obstruction, smoking, exacerbation; mPCR: multiplex polymerase chain reaction; SPPB: short physical performance battery; CT: computed tomography; ResPOC: Respiratory Virus Point-Of-Care; DECAF: Dyspnoea, Eosinopenia, Consolidation, Acidaemia and atrial Fibrillation.

Table 4. Promising technologies – those considered to demonstrate a high degree of innovation, potential for impact, and potential for adoption by the NHS.

Technology type	Promising technologies
Wearable technologies	Wrist-based pulse oximeter BuddyWOTCH
Biomarker technologies	
Diagnostic	Aα-Val 360 biomarker
	Biomarker panel: SP-A, sRAGE, MPO and NGAL for asthma-COPD overlap syndrome
	FTIR monitoring
	COPD-SPOC sensor
Monitoring	Home use sputum test
To determine the cause of an acute exacerbation	Blood eosinophil biomarker
	CRP point-of-care test
	PCT
Telehealth technologies	Virtual Medical Assistant Version 2.0
	Commander Flex
	MedVizer T400 Home Health Monitor
	ADAPT
	SmartScope System
	Respiratory virtual clinics
Spirometry technologies	MySpi-roo
	MIR Smart One®
	Smartphone spirometer
Questionnaire technologies	DECAF scoring system
	DOSE index
Other technologies	SPPB
	ResPOC point-of-care testing for respiratory viruses
	HIRA-TAN semi-quantitative PCR
	mPCR

FTIR: Fourier transform infrared; SPOC: saliva point of care; COPD: chronic obstructive pulmonary disease; DOSE: dyspnoea, obstruction, smoking, exacerbation; mPCR: multiplex polymerase chain reaction; ADAPT: After DischArge Pulmonary Telehealth; CRP: CRP: C-reactive protein; ResPOC: Respiratory Virus Point-Of-Care; DECAF: Dyspnoea, Eosinopenia, Consolidation, Acidaemia and atrial Fibrillation.

Concerns were expressed regarding the reliability of wrist-based monitoring; however, a potentially large impact could be expected if these devices demonstrated acceptable performance.

Biomarker technologies

Thirty-one biomarker tests were identified and included in the report, the majority based on blood samples. Alternative samples included sputum, bronchial aspirate and innovatively, saliva and volatile organic compounds from breath samples. Most biomarkers were intended for the diagnosis of COPD, but experts dismissed the majority of blood-based diagnostic biomarkers as being too early in development or 'possibly as a research tool' with no demonstrated clinical value, despite some being considered highly innovative. Aα-Val360 was the most promising biomarker in this category, having been proposed as a method to identify patients with early COPD at risk of progression. Experts commented that it was 'highly innovative . . . targeting high risk individuals'. Fourier transform infrared spectroscopic monitoring used sputum to rapidly differentiate COPD from other respiratory conditions and determine the risk of an imminent exacerbation; experts commented that this was 'interesting and if effective then impact and adoption [are] possibly significant'. A further sputum-based biomarker panel to diagnose asthma-COPD overlap was thought to be 'of interest in secondary care clinics', whilst experts considered COPD-saliva point of care (SPOC), a novel saliva-based point-of-care test for the diagnosis of COPD incorporating three biomarkers, to have the 'potential to change practice'.

Several inflammatory blood biomarkers were proposed for the monitoring of COPD for risk of an acute exacerbation. However, fibrinogen and C-reactive protein (CRP) were noted to be 'non-specific indicators of inflammation' and therefore 'unlikely to be much impact or . . . [high adoption]'. In contrast, procalcitonin was thought to be a 'more specific marker of infection'. Researchers claimed it was able to differentiate between a bacterial and nonbacterial cause of acute exacerbations, prompting an expert to state ' . . . a strong chance of high impact (more appropriate exposure to antibiotics) and adoption'. The Home Use Sputum Test may provide advance warning of an acute exacerbation in the community and experts were very positive, commenting 'this would be useful and may help identify pathogens early so treatment can be commenced', and highlighting the potential to 'reduce antibiotic use', though also noting 'identifying a bacterium does not always mean that the cause of symptoms is identified'. Patients commented on its potential to 'reassure patients'. Other technologies aimed to identify the cause of acute exacerbations in order to better direct specific management. Experts commented that the use of peripheral blood eosinophil count as a biomarker to direct corticosteroid