CANCER INNOVATION CHALLENGE

cancerchallengescotland.com

Transforming the lives of cancer patients with data

Open innovation in data to help Scotland become a world leader in cancer care

Final report January 2022

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Foreword from Scottish Funding Council

To anyone for whom this report is their first introduction to the Cancer Innovation Challenge, I would like to offer the simplest and most important definition of the project; that it was a collaboration to tackle one of the most important health challenges of our time – caring for people with cancer. Its aim was to help the NHS in Scotland use data to refine diagnosis, select treatments and improve the experience for patients.

The idea sprang from the realisation that important benefits for society could come from combining the talent and expertise that had become available through the creation of Scotland's Innovation Centres. The Cancer Innovation Challenge brought together the Data Lab with the Digital Health and Care Institute (DHI) and Precision Medicine Scotland (then called Stratified Medicine Scotland). It received £1 million of funding from the Scottish Funding Council.

As we had hoped, the project benefited from some of Scotland's finest minds and best experts across many areas of research and discovery. It also drew great strength from its involvement of the public and from its engagement with stakeholders in the wider health sector. Vitally, it galvanised companies and organisations to focus on the development of ideas to help in the care of cancer patients.

There are important benefits for society when a range of talent and expertise are brought together in a structured and meaningful way. The Cancer Innovation Challenge has proven this once more and the outputs of this collaboration will go on to change (and save) lives. I hope you enjoy reading of the achievements of the project, laid out in the report which follows. I would like to close by thanking every participant in this work including all those from the NHS, Innovation Centres, academia, industry and patient groups.

Dr Stuart Fancey
Director, Research and Innovation
Scottish Funding Council

Foreword from The Data Lab

Scotland's Innovation Centres are driving innovation across Scotland, bringing strength and depth of expertise and networks in our areas of expertise to drive economic, societal and environmental benefit.

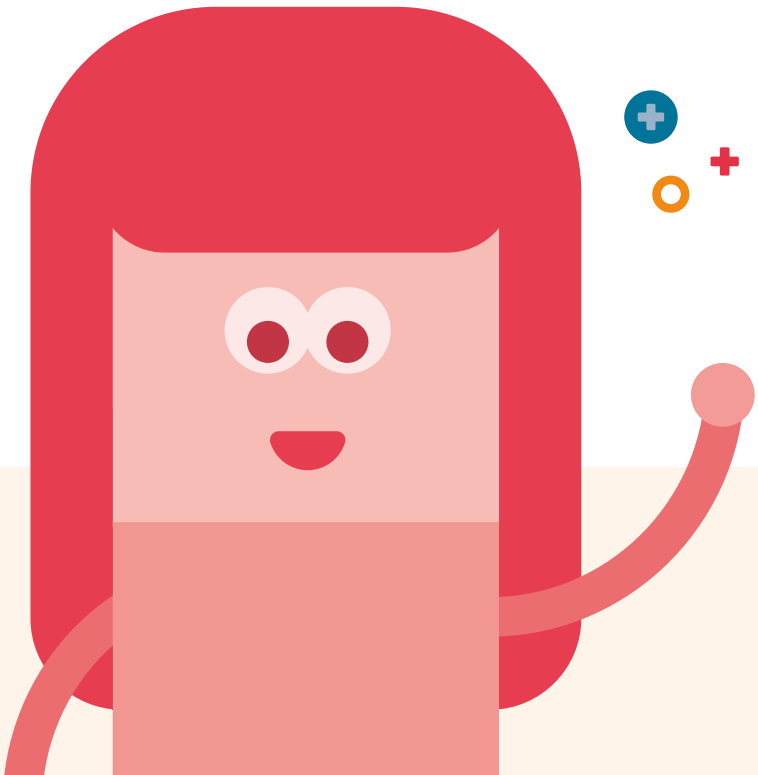
The Cancer Innovation Challenge presented a significant opportunity to tap into the strength of The Data Lab, DHI and Precision Medicine Scotland, bringing our collective experience, networks and support to help address the challenge.

The Innovation Centres were very proud to work on the challenge and bring our collective experience together, enabling new collaborations between companies, NHS and patients. We experienced the difference this made to cancer treatment journeys and the way patients felt connected to their clinical teams more effectively. We saw ground breaking research being used to develop new methods supporting diagnostics.

We are very proud of the achievements of the Cancer Innovation Challenge, the new products developed and implemented helping to improve the cancer journey for many patients. The challenge also delivered a world first in Canon Medical Research Europe's deep learning powered automated RECIST assessment for Mesothelioma.

Building solutions and tackling difficult problems is only really possible when we all work together. It was a privilege to see that throughout the Cancer Innovation Challenge.

Gillian Docherty OBE
CEO, The Data Lab



CANCER INNOVATION CHALLENGE

Launched by the Chief Medical Officer for Scotland on 24 March 2017, the Cancer Innovation Challenge is a £1M project funded by the Scottish Government through the Scottish Funding Council (SFC) to encourage Innovation Centres to work in partnership to help Scotland become a world leading carer for people with cancer.

The project brings together three Innovation Centres, led by The Data Lab in collaboration with the Digital Health and Care Institute (DHI) and Stratified Medicine Scotland (SMS) in addition to various other partner organisations to inspire open innovation in data to improve cancer care.

Two open innovation funding competitions form the core of the Cancer Innovation Challenge. Using the Innovate UK Small Business Research Initiative (SBRI) framework, two-phased funding calls were issued to organisations for:

- New approaches to record and integrate cancer patient reported data; and
- Innovative data science solutions to improve cancer care and outcomes in Scotland

Over a hundred registrations of interest were received and 48 applications were submitted from companies across Scotland, UK and the EU. Eight companies were funded for the Phase 1 feasibility stage and three companies were funded to continue to Phase 2 to develop and evaluate their solution.

Alongside the funding competitions, the Challenge also includes a programme of activities surrounding each work stream and the wider subject of the use of data in healthcare. These events involving industry, the public and a variety of stakeholders in the wider health sector range from public engagement events and hackathons to technical and stakeholder workshops.

The following pages will take you on a journey through all the activity undertaken by the Cancer Innovation Challenge from its inception until its completion in March 2020.

Further detail is available on **cancerchallengescotland.com** (site will be live until March 2024).

Due to COVID-19, this report has been delayed until now.

January 2022

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Contents

New approaches to record and integrate cancer PROMs and PREMs

In addition to saving lives or improving survival, the treatment of cancer aims to improve the quality of life for people who are affected. Quality of life is influenced by most aspects of cancer and its treatment.

Many people are familiar with the symptoms of cancer, side effects of drugs and radiotherapy or complications of surgery, but these can affect people in different ways. Other aspects can also influence quality of life such as the experience of the NHS service, effects on families, personal finances or other psychological and social factors. Once treatment is over, patients often have to deal with physical, psychological and practical changes affecting everyday activities, relationships, work and wellbeing. Some of these changes can pose long term challenges and difficulties.

Many of these 'outcomes' are personal to the individual and are best evaluated by the person themselves, rather than by members of their health care team. Patient reported outcome and experience measures (PROMs and PREMs) have been developed to enable patients' subjective reports and experiences of health, illness and treatment to be measured consistently and accurately.

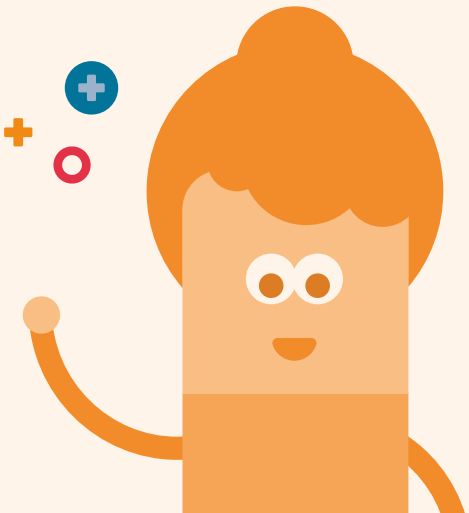
The routine use of PROMs and PREMs offers a real opportunity to improve the relevance and value of NHS cancer care.

- The capture and analysis of PROMs and PREMs across local or national populations of patients, alongside other outcomes such as complication rates, waiting times and survival, in order to improve the quality of NHS care through policy and service design
- The capture and recording of PROMs and PREMs within the clinical record for direct use by a clinician in the care of an individual patient (for example, in the same way as clinicians might use the results of blood tests)

The objective is to enable health care professionals to use PROMs and PREMs alongside clinical data, to understand the difficulties that patients face on a daily basis and to enable the NHS to plan more effective care and interventions across Scotland.

The Cancer Innovation Challenge sought a solution which is accessible from within existing components of the eHealth architecture. The key goal of this challenge was to provide an implementable solution that can directly benefit Scottish patients and is acceptable and desirable for use by patients, clinicians and policy makers.

Five projects were awarded Phase 1 funding for a three month feasibility study which ended in December 2017. Two projects were awarded further Phase 2 funding for the development and evaluation of their solution. Phase 2 commenced in February 2018.



Remote Patient Measures

Docobo's remote monitoring platform, DOC@HOME®, provides the means for the collection and analysis of essential patient related data (vital signs, biomarkers and symptoms) and patient outcome measures (PROMs/PREMs), anywhere, anytime.

Docobo's Cancer Challenge project looked to develop and enhance their offering to support patients undergoing treatment for cancer. NHS Lanarkshire are already having award-winning success with their TCAT project, using the existing DOC@HOME® platform to support lung cancer patients, post chemo treatment.

From their own homes, patients complete the 'SPARC' PROM once a month as part of their post treatment follow-up support. DOC@HOME® has a scheduling engine whereby automated emails/ texts are sent to patients at predefined periods, requesting the online completion of the SPARC PROM.

The CIC Phase 1 funding allowed Docobo to hold workshops with clinicians and patients, to determine use case requirements to investigate and define suitable new clinician and patient facing features. With the aim for the tool to be used in the wider context of the treatment for cancer, supporting improved patient outcomes and gaining sustainable efficiencies in the delivery of care. In conjunction with these activities, Docobo also investigated the interoperability opportunities for the tool across the wider NHS Scotland systems. With the view to support a scalable, robust and uniform approach to solutions, rather than the historical piecemeal approach.

Currently we are still working in collaboration with NHS Lanarkshire and others, to realise the full potential of using assistive technology to support the delivery of care in a tough and fragmented landscape.

Docobo
towards a better quality of life

docobo.co.uk

@DocoboUK

Phase 1 Project

PROEMS

Openbrolly Health entered the Cancer Innovation Challenge, along with its partners, with a product called PROEMS – a solution for collecting patient reported outcomes and experiences across an entire organisation, such as an NHS board.

It enabled the use of a range of consumer devices to collect data and provide feedback, and offered an opportunity to share best practice and experience across organisations reducing cost.

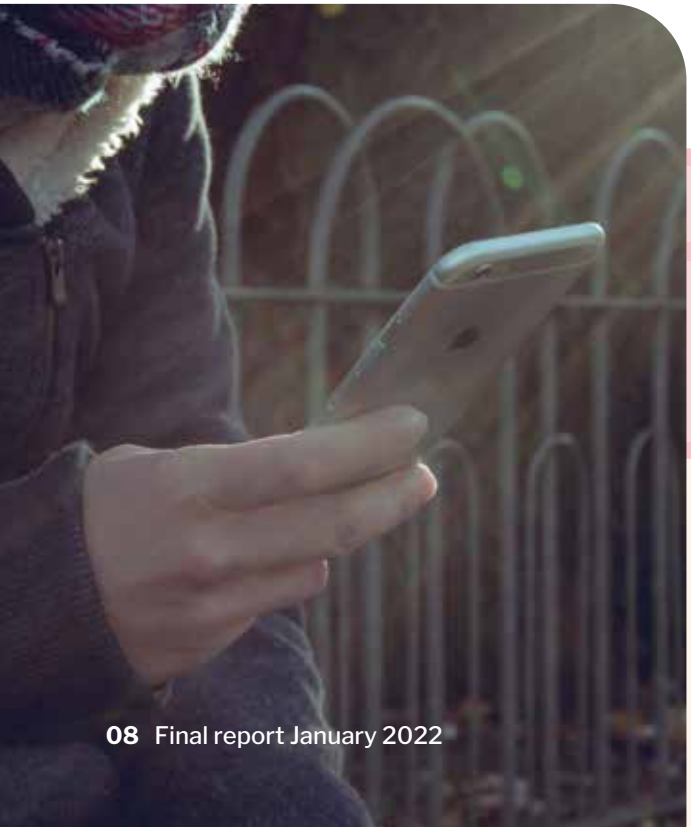
The feasibility study in December 2017 convinced the team of the need for and applicability of the solution. An academic paper has been produced based on subsequent workshops, interviews and mock-ups developed and Openbrolly has used the Business Model Canvas approach to refine the proposal to suit market demand.

Openbrolly has now moved to pilot and test-market PHASE™, a personalised care solution based on PROEMS which supports young people's mental health and well-being. Artificial intelligence is a crucial tool to support people with their holistic well-being: there can be hundreds, perhaps thousands of possible care pathways – from health, to family, to financial issues. Data collection using natural language, as well as traditional forms, allows people to express themselves more effectively.

The next step is moving the PHASE™ pilot into a live environment and standardisation as a commercial product.

openbrollyroc.com

@OpenBHealth



Phase 1 Project

Lifebook: Digital platform for TYA cancer service in Scotland

When Sitekit set out on a project to increase patient-reported data to improve the treatment, care, and personal outcomes for young people with cancer, they found that people wanted to link up information from clinical sources with a personal health record.

Sitekit therefore proposed the integration of PREMs and PROMs with its own electronic personal health record: Lifebook. The Proof of Concept (PoC) created for the Cancer Innovation Challenge focused on integrating Lifebook with PREM 'HowRwe' and PROM 'howRu', created and validated by R-Outcomes.

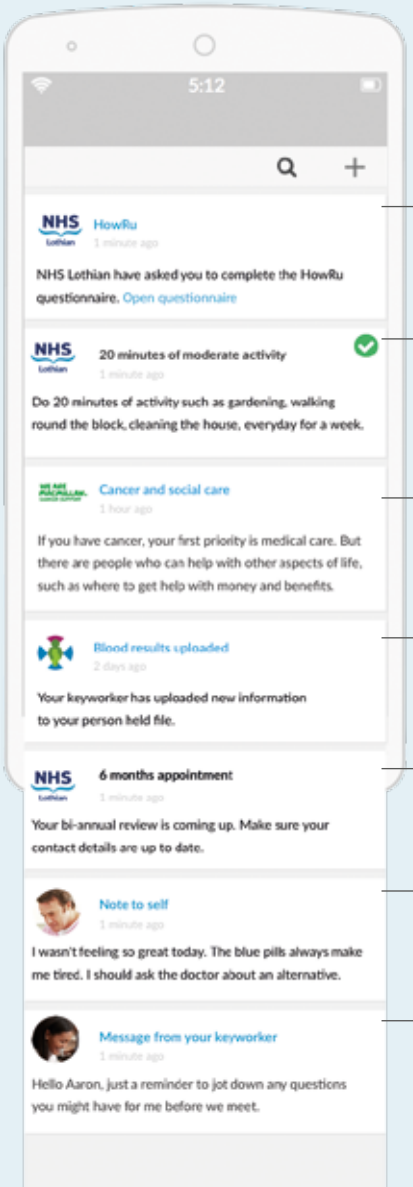
The proposed solution brought together key organisations that are in the process of delivering the (new) Scottish eHealth infrastructure, such as Atos and NHS Greater Glasgow and Clyde, to transfer data between the Person Held File and the Patient Portal.

In addition to PREM/PROM functionality, Lifebook could include copies of health records, information guidance, care plans, notes and messages from health professionals. The PREMs and PROMs would therefore not exist in a silo, but would be part of an integrated digital care plan, controlled by the patient. Feedback on the PoC from key stakeholders, including patients, their families, and IT leads at NHS was overwhelmingly positive.

Since the Cancer Innovation Challenge, Sitekit has developed its own datastore and is involved in several large-scale interoperability projects to enable the infrastructure for connected, untethered personal health records. For instance, Sitekit has added functionality to eRedbook (electronic Personal Child Health Record, running on the Lifebook platform) that enables local health authorities to send digital application forms and questionnaires to parents.

sitekit.net

@Sitekit



Lifebook

PREMs/PROMs
Track your patient's wellbeing and evaluations of their care by inviting them to complete questionnaires.

Care plan
Based on their PREM/PROM data, tailor a care plan to the patient. Motivate patients by showing them progress towards their goals.

Information guidance
Deliver information guidance to the patient based on their position on their care pathway.

Patient health records
Upload copies of important health records to the patient's PHR so that they always have them when needed.

Pathways alerts
Deliver timely reminders of upcoming events on the patient's care pathway.

Notes
Provide patients with the ability to create health notes and share them with health professionals, if desired.

Health professional messages
In-app messages provide your health professionals with a channel to contact their patients.

Phase 2 Project:

New approaches to record and integrate cancer PROMs and PREMs

My Clinical Outcomes

My Clinical Outcomes (MCO) is a health technology platform founded in 2011 to help doctors remotely track patients' quality of life in between clinic visits.

Patient-Reported Outcome Measures (PROMs) are structured clinical surveys that quantify the impact of a condition on a patient's life at a point in time. Using MCO, patients can measure and track PROMs from home and share that information with their doctors remotely. MCO works in any condition and has been in ongoing clinical use and development since 2011 with over 85,000 patients registered to over 1,000 clinicians at numerous hospitals across the UK.

The opportunity for using PROMs to enhance routine cancer care has become more prominent in recent years. A 2017 randomised controlled trial (from Basch et al.) demonstrated a five months survivorship benefit because clinicians could use remotely gathered data to respond to patients' needs faster and more comprehensively than before, helping to prolong chemotherapy, or preventing their health from deteriorating due to other causes.

Soon after this, in late 2017, MCO won phase 1 funding from the 'Cancer Innovation Challenge', to tailor the platform to trial with oncology patients in Scotland.

During this phase, MCO designed and built a working prototype solution that could be feasibility tested with key stakeholders. Patients immediately found MCO easy to use and a value-adding part of their care. One elderly patient at NHS Ayrshire & Arran said that: "It allows a bit more time for you to think about what there is to convey, and it's useful in saving a lot of time for doctors... I think if I could use it anyone could use it!"

A working solution based on the initial prototype was then implemented for haematological cancer patients at University Crosshouse Hospital and long-term funding has since been agreed with the new solution becoming part of the standard chemotherapy pathway to:

- Support the routine clinical care of individual cancer patients
- Improve patient engagement with the cancer service
- Enable more efficient use of clinical capacity and save time
- Identify variation in outcomes and to inform the ongoing improvement of care pathways
- Enhance safety and long-term monitoring of all cancer patients
- Demonstrate the potential for outcomes measurement in Scotland that has led to the implementation of MCO at further health boards in successive phases

Subsequent phases of funding saw MCO deployed in two parallel six month pilot projects starting simultaneously in late 2019. The first was with ovarian cancer gynaecological surgeons and colleagues at NHS Greater Glasgow and Clyde. At the same time, MCO was deployed across the four health boards that make up the South and East Cancer Network (SCAN) in seven clinical conditions. Both pilots were very brief and needed rapid navigation of local governance, design and implementation into clinical pathways but both have been very well received by patients and clinicians and look set to continue to evolve as needs develop beyond the pilots.

In the meantime, a supplementary project to design how MCO could be configured and integrated into breast cancer pathways at the Beatson West of Scotland Cancer Centre was funded, with long-term funding since being agreed.

A final grant for MCO to collaborate with the new National Digital Platform (NDP) team on a short exploratory project about how the NDP team might ease the adoption of tools like MCO, including detailing existing barriers to adoption and scale from a technical, governance and operational perspective.

Cancer Innovation Challenge funding concluded in February 2020. The programme has been incredibly beneficial to MCO as a small digital health company helping to spearhead the routine use of PROMs as part of cancer services and leading to significant recognition in Scotland, including:

- Opportunity to take part in a panel discussion at Data Summit 2019 with the Deputy Chief Medical Officer, Dr Gregor Smith, and to meet the First Minister, Nicola Sturgeon
- A presentation at a reception in the Scottish Parliament by Dr Peter Maclean, Director of Cancer Services at NHS Ayrshire & Arran on his experience of working with and using MCO
- Various articles in national newspapers and journals
- Winning the Industry Collaboration Award at the Holyrood Digital Health and Care Awards in February 2020

More broadly, the Challenge has demonstrated the potential of the approach and led to other engagements, including:

1. A project with Macmillan Cancer Support, The Royal College of Radiologists with Imperial College NHS Foundation Trust to remotely monitor pelvic radiotherapy patients for late toxicity that is now in use at 4 NHS Trusts
2. A project with Novartis to help monitor myeloproliferative neoplasm patients using MCO (which has itself led to other engagements in other disease areas)
3. A project with the University Hospitals Sussex to implement MCO across multiple cancer types for use by 29 oncologists and more than 20 allied health specialists in order to remotely monitor patients and target limited resources to hopefully intervene sooner to support quality of life and reduce acute deterioration and unplanned admission. An NHS England case-study has identified that as well as improving quality of life these approaches have the potential to save up to £500,000 per year in cost associated with unplanned care

The formative experience of the Cancer Innovation Challenge was defined by close, collaborative working that was greatly helped by the high profile of the Challenge making it easier to access disparate teams working across disciplines and specialties in the NHS easier.

Dr Maclean said: “I have found the whole experience working with My Clinical Outcomes to have been refreshingly positive. It gives me hope that with the right collaboration an amazing amount can be achieved within an NHS setting that sometimes feels frustratingly sluggish….Their [MCO] clear determination to make the project work gave confidence to the clinical team to imagine what we could do rather than feel restricted to what we usually do. The tenacity shown to overcome challenges such as Information Governance approval for example really took the weight off our shoulders. I am very grateful to MCO for the enthusiasm and personal touch they have brought to this project not to mention their undoubted technical expertise.”

As the Challenge concluded in February 2020, existing users had either found local budget to continue (in the case of NHS Ayrshire and Arran), or were in the process of doing so (in the case of The Beatson, NHSGG&C and SCAN).

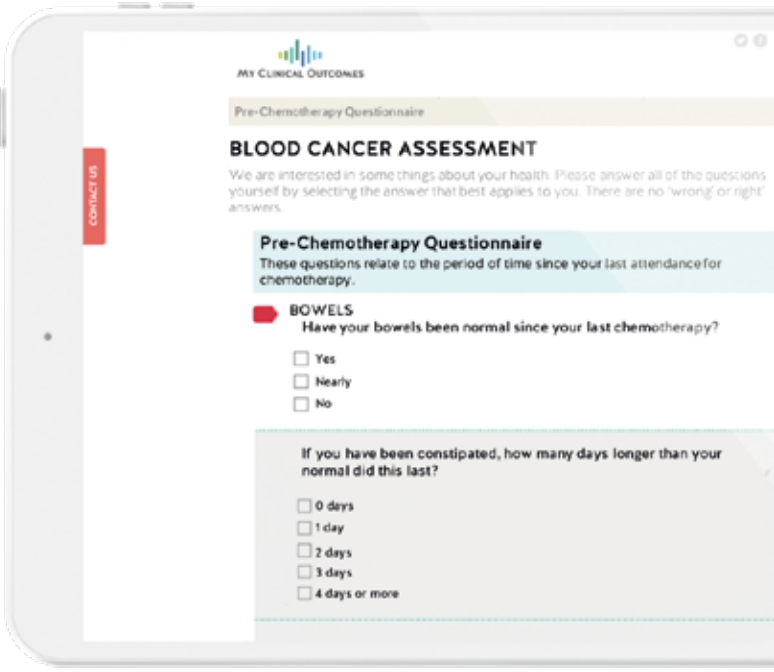
As the COVID-19 pandemic took hold through March 2020, the public was locked down and healthcare services underwent dramatic reorganisation to prioritise acutely unwell patients and also to reduce the risk to immunocompromised patients of contracting COVID-19 in hospital. Routine face-to-face appointments were stopped and remote video consultations became the norm. It quickly became apparent that MCO could be beneficial by supporting remote monitoring, allowing teams to prioritise when patients had a video or telephone call scheduled, and then to make the resulting call more effective and efficient, and focussed on clinical decision-making and planning rather than information gathering.

As interest from teams increased, it became apparent that there wasn’t capacity to have funding conversations; MCO made the offer to develop and roll-out of the platform to whichever teams had need free-of-charge for one year. A contract was put in place with NHSGG&C with the aim that other boards could quickly mirror the governance approvals. During the period, the solution was scaled out to some 23 clinical teams across 8 health boards and 12 cancer types, with more than 100 clinicians engaged in using the platform.

In June 2021, the Scottish Government Cancer Policy Team announced that £500,000 was being made available to consolidate the activity around Cancer PROMs in Scotland over 2 years. At the time of writing (August 2021) the MCO platform remains live and active although there is not as yet any clarity as to how these funds will be allocated or what the strategy will be.

myclinicaloutcomes.com

@MyClinOutcomes



OWise in Scotland

OWise is an award-winning mobile app and website developed to support people with breast cancer and more recently also prostate cancer.

It offers patients a range of self-management tools and personalised information about their medical condition and treatment in one easily accessible place. Also, it offers people a platform through which to track and monitor the side effects of their treatment and how they feel. These data are often referred to as Patient Reported Outcomes, PROs in short.

The objectives of the Cancer Innovation Challenge (CIC) and Px HealthCare (Px stands for Patient Experience), the company behind OWise, have been to increase patients' quality of life, to improve clinical outcomes and to make cancer care more affordable. PROs have the potential to guide patients and their clinicians to a treatment with improved quality of life and a better clinical outcome. Recent studies from the US have shown that an electronic PRO system similar to that featured in OWise not only significantly improved advanced cancer patients' quality of life, but also resulted in less worsening patients' condition and a 5-month increase in overall survival (Basch et al. 2016 and 2017).

During the project, the Px team worked closely with breast cancer patient groups at Maggie's Centres. Through these workshops, they have been able to get an excellent understanding of the needs of those undergoing cancer treatment, in order to meet these in the OWise app. They received great insight into how smart alerts could nudge patients to seek medical support when their side effects exacerbate, rather than have complications aggravate resulting in avoidable hospitalisations.

Norma, a breast cancer patient from Scotland, said: "What I really like about OWise, is that it's easy to use... I use the How Do I Feel Now-function and it tells me to contact the doctor quite frequently. I also read the OWise report. That was so helpful. I now understand what type of breast cancer I have."

In collaboration with NHS Lothian (NHSL) an upgrade of the OWise app and platform was developed, whereby real-time PROs are shared by patients with their hospital. This way, clinicians can easily access, in real-time, insights on patients' PROs directly from within the hospital's electronic health record (EHR) system (TrakCare in Scotland and other EHR systems like Epic and Cerner in other parts of the UK).

Whilst putting patients at the centre of their care, and fully aligned with GDPR, OWise enables patients to give the hospital access to their real-time wellbeing data which they control and can stop again anytime (e.g. when moving to another hospital). Sheila, a breast cancer patient noted: "I used the OWise app to record daily stats throughout my primary diagnosis & treatment. It was invaluable for helping my care team to review any changes in my treatment & effects. It took all my fear away."

Dr Peter Hall, Consultant Medical Oncologist at the Edinburgh Cancer Centre, commented: "Being able to see a timeline that chart's a patient's symptoms from their own perspective, directly within our electronic clinical records is fantastic. OWise definitely improves our ability to understand how cancer and its treatment are affecting a patient."

Phase 2 Project

"OWise enables patients to give the hospital access to their real time wellbeing data..."

Recently, the Px team has worked closely with Prostate Scotland, Maggie's Centres and clinicians of the West of Scotland Cancer Network to develop the OWise platform for prostate cancer patients and their clinicians. As one of the finalists of the Healthier Lives Data Fund, a partnership between Nesta and the Scottish Government, they sought to get a detailed understanding of the how digital technology like OWise can improve patient experience as well as clinical outcomes in prostate cancer. As with its breast cancer work the team embarked on a series of six workshops to co-design a patient-centred, PRO data-sharing, digital tool with prostate patients and their clinicians. Working so closely with people affected by prostate cancer has been incredibly helpful to understand the difficulties that people with the condition face, from the point of diagnosis, all the way throughout treatment. Involving more than 30 prostate cancer patients from a wide range of demographics and backgrounds as well as various clinicians, the OWise prostate cancer app platform has been fully co-designed and tested to address their respective needs.

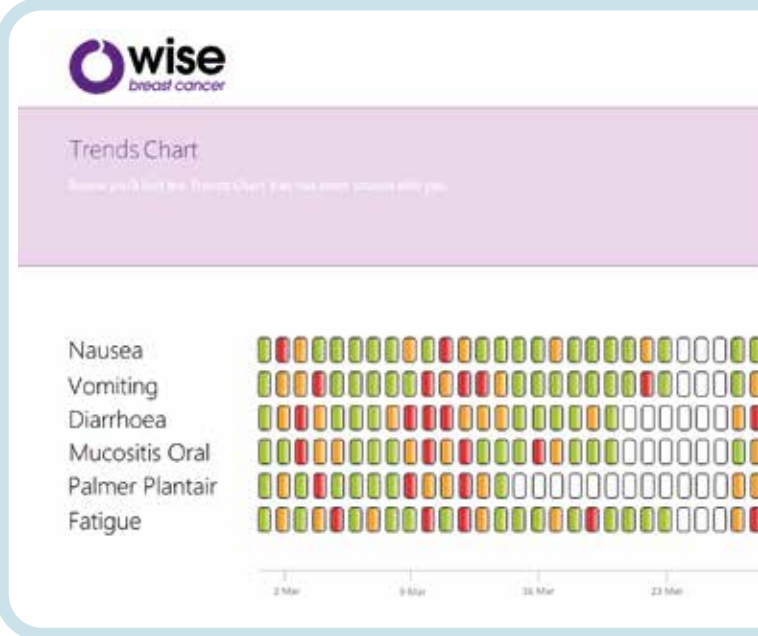
Bruce (74), who was part of the second focus group, said: "It's quite refreshing to meet a company that is so disciplined in their approach to their software product. I was fortunate to be involved in a focus group looking at the various screens and the navigation between them. I found the system simple to understand and operate. This product will be invaluable to anyone wanting to track everything concerning their prostate cancer. OWise is a truly ground-breaking app!".

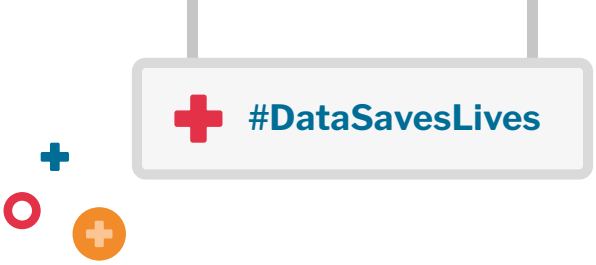
This project led Px HealthCare to win the top prize in the Healthier Lives Data Fund, which not only includes funding to but also Scottish Government support to integrate the OWise prostate cancer app and platform in Scottish hospitals as has been done for breast cancer in NHS Lothian. OWise prostate cancer has been launched in the UK in March 2021. Px is currently expanding the OWise platform to other types of cancer to ensure that all patients can benefit from and improve their outcomes with OWise from the moment of diagnosis throughout treatment and follow up.

owise.uk

@owisebreast

@owiseprostate





Health Board Funding Opportunity

Due to a project underspend as of 2019, a funding opportunity for NHS Scotland Territorial Health Boards to trial the PROMs PREMs Phase 2 solutions for a period of 6 months was made available.

This opportunity was launched in April 2019 and closed in May 2019. Four applications were received and the Strategic Management Board awarded £30k funding each to two successful applications from NHS Greater Glasgow and Clyde and SCAN (South East Scotland Cancer Network), both to trial My Clinical Outcomes for a period of 6 months.

The NHS Greater Glasgow and Clyde project to improve the care of ovarian cancer patients through better collection of patient reported outcome & experience measures kicked off on 3 July 2019.

The SCAN project to implement a regional platform for PROMs and PREMs in cancer care in South East Scotland kicked off on 5 August 2019. Both trials reported in March 2020.

Overall feedback from the two trials was that interest in the recording and use of electronic PROMs in routine cancer care is high but that a six month trial was too short. The SCAN trial achieved the first regional, multi cancer-cohort PROMs data collection in Scotland which was significant achievement in the short timeframe. Both trials committed themselves to further investigate how PROMS can be used to best effect within clinical pathways without creating additional burdens for patients and/or clinicians.

Collaboration with NES National Digital Service

During the discussions taking place in setting up the Health Board Funding Opportunity, the CIC was approached by the NES National Digital Service (NDS) with a proposal for a collaboration.

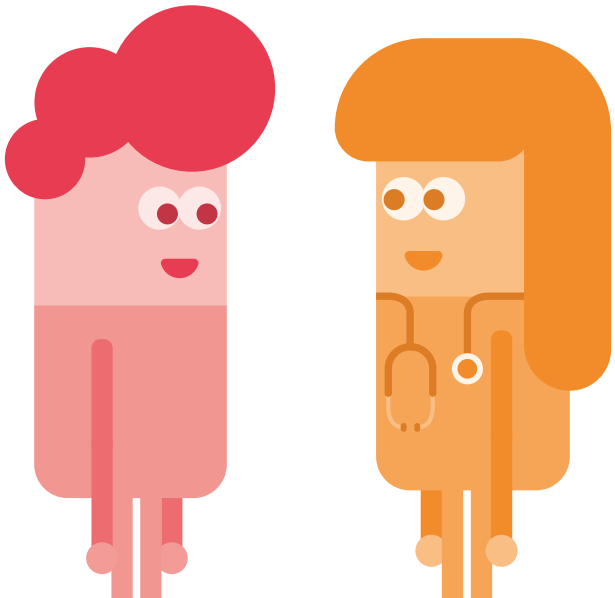
This collaboration was to involve a pilot evaluation of the National Digital Platform (NDP) as a novel route to achieve national deployment of innovative PROMs/PREMs tools.

The NDS proposed to involve the CIC's two validated Phase 2 PROMs PREMs solutions. The Strategic Management Board of the CIC approved this proposal in a meeting in May 2019 with the view that such a collaboration was felt to be of strategic importance to the wider landscape of implementation and scaling of digital innovations in the NHS in Scotland. Work proceeded with My Clinical Outcomes and was completed in February 2020. A final report was submitted in April 2020.

The key learning from this collaboration was on the criticality of procurement strategies that can materially limit the adoption of innovation and translational to enhanced patient care by the NHS. It became clear that forward planning and specialist procurement advice can provide effective mitigation for this risk, whether this is through avoidance of needless SME participation barriers (careless use of defaults on supplier requirements such as years of operation, accounts, liabilities and insurances), or upfront clarity on options to scale product use (thinking beyond the R&D horizon).

Scottish Cancer PROMs Advisory Group

The work of the Cancer Innovation Challenge contributed directly to the setting up of a Scottish Cancer PROMs Advisory Group which has plans to hold its first forum event in early 2022 to bring together efforts to implement the use of electronic PROMs in routine cancer care across Scotland.

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Learning health systems
Heterogeneous data linkage/correlation
Bio/physiological networks/dynamics
Discovery systems
Healthcare process optimisation
Large scale image and text analysis


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We believe in the power of using healthcare data...


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Innovative data science solutions to improve cancer care and outcomes in Scotland

Outcomes for cancer patients in Scotland lag behind those of our Northern European counterparts whilst Scotland has some of the best health service data in the world.

Few other countries have information which combines high quality data, consistency, national coverage and the ability to link data to allow patient based analysis and follow up. This competition asked the question "How can data science be applied to existing NHS Scotland data to improve cancer patient care and outcomes?"

Scotland provides a unique test bed for exploration into innovative technological solutions to accessing large volumes of data pertaining to patients' demographics as well as their pathways to diagnosis, treatment and long term follow up. The intelligent analysis of this wealth of information could be used to deliver benefit at several levels:

- Clinical benefit to individual patients, informing clinical decision making and prognostication
- Clinical benefit to populations, informing vital information on the efficacy of treatment options
- Resource utilisation, informing service delivery, service planning and service development
- Academic benefit of informing high quality research to inform efficacy of current and future treatments
- Economic benefit of driving company growth and inward investment as the Scottish ecosystem leads to rapid commercialisation of medical technologies within a global market

The goal of this challenge was to develop solutions using existing NHS Scotland data to improve cancer patient care and outcomes in Scotland. Proposed solutions should achieve at least one of the following broad objectives:

- Enable analysis of unstructured data (e.g. clinical notes, medical imaging)
- Enable data driven clinical decisions
- Enable data driven service improvement in the NHS
- Enable data driven recruitment for clinical trials
- Enable the adoption of precision medicine approaches

Innovative approaches to these challenges were expected to incorporate data science techniques from fields such as:

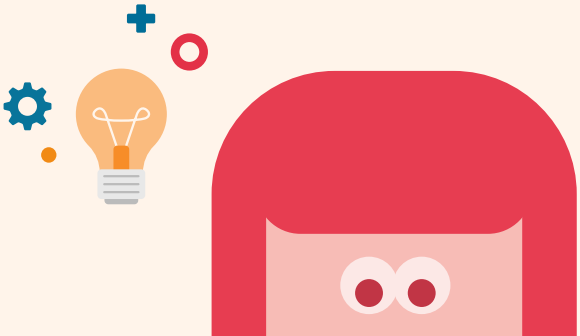
- Predictive analytics
- Visualisation
- Machine learning
- Natural language processing
- Processing of structured and unstructured data

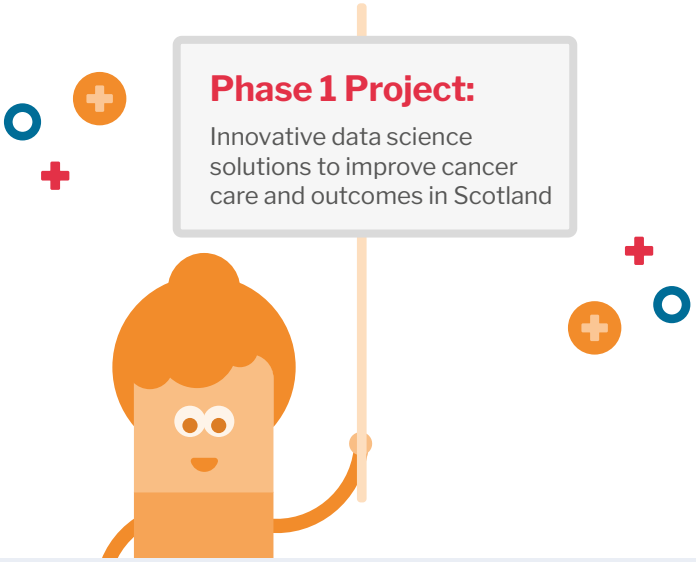
The Cancer Innovation Challenge sought solutions that are well designed, simple and accurate within the confines of a modern healthcare system, respecting clinical confidentiality whilst providing a degree of accuracy which has the confidence of clinicians, patients and health service managers alike.

Any solution had to integrate with components of the NHS eHealth architecture. Critically, a key goal was to provide a solution that can be implemented to benefit directly Scottish patients and the wider service.

The ultimate aim of the challenge is to fundamentally change the way data and analytics are used to drive improvement in cancer outcome in Scotland.

Three projects were awarded Phase 1 funding for a three month feasibility study which ended in June 2018. One project was awarded further Phase 2 funding for the development and evaluation of their solution. Phase 2 commenced in July 2018.





Real-time Cancer Data Access - A Milestone for Precision Medicine Delivery in Scotland

Jayex engaged with NHS National Services Scotland (NSS) and NHS Lothian stakeholders for their Cancer Innovation Challenge to work on a project to design and build a Clinical Access Platform (CAP) able to integrate with the national data infrastructure and Scottish Cancer Registry. It complements its functionality through real-time cancer data access for clinicians and policymakers.

Our proof of concept focussed on haematology cancers, as there is a shortfall of this data in the National Registry. We aimed to standardise and migrate existing data collected by clinicians locally over 30+ years - from the outdated, unsupportable system, to the new, cutting edge platform with an innovative structure, mapped to a global data standard.

Working with expert partners Pulse Infoframe Inc., Jayex included modern technology advances to develop a robust and scalable solution assisting in day-to-day clinical management, policymaking, as well as supporting clinical trial recruitment and clinical research. Integrated advanced analytics tools would also enable meaningful data discovery for clinical decision support. With a structure allowing future mapping of genomics and analysis of unstructured data our Platform aimed to also enable adoption of precision medicine approaches.

The platform proposed would be interoperable and scalable, meaning that the investment can be leveraged across all other cancer types, rare diseases and other data types in the future, to eventually deliver a real difference to the lives of cancer patients in Scotland and beyond.

For more information, contact Mel Brola on **m.brola@jayex.com**

jayex.com

@JayexTechnology

Phase 1 Project

Using Machine Learning to Estimate Outcomes in Scottish Cancer Patients

Machine learning is driving revolution across a great number of fields by unlocking the predictive power of large datasets.

Within healthcare, critical clinical decisions rely on analysis and interpretation of various data types, including weight measurements, blood test results, and radiological and pathological findings.

Decisions on cancer treatments in particular require firm evidence and due deliberation, as the considerable side-effects of various therapies have the potential to bring more harm than good to patients.

Sharpe Analytics were working to estimate the life-expectancy of patients suffering from metastatic cancers, using state-of-the-art machine learning techniques and harnessing the power of the entire Scottish Cancer Registry and inpatients data sets.

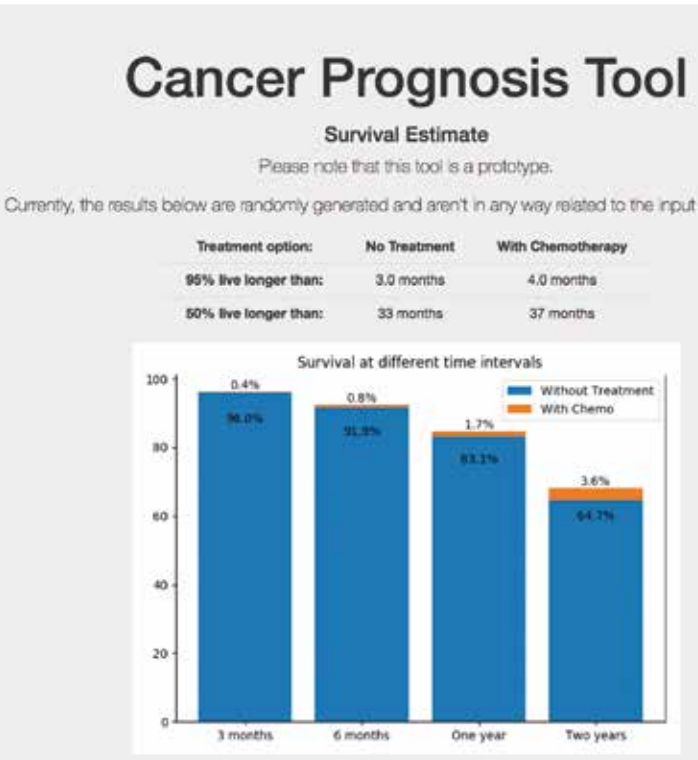
In understanding which factors were and were not important in determining how long a late-stage cancer patient had left to live, we hoped to create a simple tool that would enable doctors and patients to better plan end-of-life treatments and living arrangements.

As part of the Cancer Innovation Challenge's Phase 1, Sharpe Analytics carried out public and patient engagement work that verified the need for improving life-expectancy estimates in these cases. Sharpe were also able to build a prototype tool and create a life-expectancy model based on synthetic data, demonstrating to doctors and patients how our tool would work and gaining valuable feedback.

The team at Sharpe Analytics are currently exploring new avenues of funding their work beyond the Cancer Challenge. For more information, please get in touch with Matt at **matt@sharpeanalytics.com**

sharpeanalytics.com

@sharpeanalytics



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Automatic RECIST measurement in mesothelioma by deep learning

The aim of this Cancer Innovation Challenge project was to automate the measurement of mesothelioma tumour volume and thereby facilitate more accurate assessment of change in mesothelioma tumour size over time, for instance to determine if a treatment (e.g., chemotherapy) was working or not.

The performance of the automated system was evaluated by analysing the agreement between expert human readers and the automated AI system. A smaller comparison was also made between measurement from the new AI system and the current standard for mesothelioma progression on CT scans (known as modified RECIST), which is based on just three corresponding linear measurements on two images.

Working with mesothelioma physician and researcher, Professor Kevin Blyth, from the University of Glasgow, Canon Medical Research developed what was at its time the first fully automated system for measuring the mesothelioma tumour volume on CT, and ultimately the volumetric change during treatment. The system, which is based on deep learning, was trained, optimised and then externally validated using a more comprehensively annotated, and larger set of CT images than any previous semi-automated algorithms developed for this task. This comprised 183 CT scans retrieved from four UK mesothelioma centres. Each CT scan contains ~225 individual images, which were annotated carefully to train the AI to recognise the mesothelioma tumour. For the purposes of our analyses, the 183 scans were split into a training and internal validation set (123 datasets, 80 of which were fully annotated); 108 patients; one centre) and a separate external validation set (60 datasets (all fully annotated); 30 patients; three centres).

In the blinded external validation set, tumour volumes measured by our algorithm were strongly correlated to measurements made on the same images by an expert human reader (validation set $r=0.851$, $p<0.0001$). Agreement, measured by Bland-Altman analysis was also strong between AI and human for these cases (validation set mean bias +31 cm3 ($p=0.182$), 95% limits -345 to +407 cm3). We also showed for the first time in any study, that higher baseline tumour volume, as defined by an AI system without any human input, was associated with shorter survival. Usually in Bland Altman analysis, if the difference between two measurement approaches can be deemed clinically insignificant, the new measurement (the AI algorithm) can be regarded as interchangeable with the old (tumour volume measurements made by an expert human).

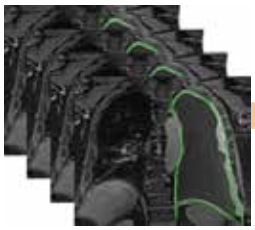
However, this is a complex judgement to make in mesothelioma, since human volume measurements are not routinely performed because of the time involved (2.5 hours per scan) and modified RECIST are therefore used as a surrogate of this. In our study, we found that response to chemotherapy as defined by our AI algorithm agreed with modified RECIST response in 16/30 (55%) validation cases $\kappa=0.284$ (0.026-0.543). However, this is likely to reflect uncertainty regarding the volumetric thresholds for progression and response to treatment, which have yet to be defined reliably. We have received funding for, and are now planning a much larger study to further optimise our AI algorithm and define these thresholds for future clinical use. We expect this to confirm the algorithm developed facilitates reliable and practical volumetric tumour measurement for the first time in mesothelioma. This represents a significant step towards data driven clinical decision support for patients with this condition.

The novelty in this challenge was applying AI techniques (deep learning) to the task of mesothelioma measurement. This is a task which, at first, appears daunting with respect to innovating a technical solution – the shape and appearance of the tumour in CT makes more traditional image analysis approaches for fully automated segmentation impossible to deploy with any accuracy. As our research progressed, a key finding was that the unique nature of the tumour played to many of the strengths of deep learning. The variable nature of mesothelioma, both in one subject and between subjects, results in comprehensive annotations which contain a vast amount of complex information with which to train the AI. This data contains the annotator's assumptions, spatial priors, and ultimately an understanding of how the tumour develops. These are relationships which would be difficult to model using traditional image analysis techniques, but such relationships can be extracted and distilled directly from the data by deep learning.

Phase 2 Project:

Innovative data science solutions to improve cancer care and outcomes in Scotland

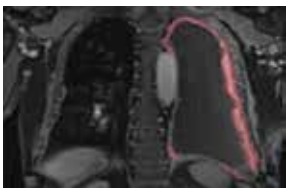
Training data - CT images with corresponding tumour delineations



Using the training data neural network learns to automatically produce segmentation of the tumour

Learning Loop

Deep Neural Network Architecture



This research project has proven to be strategically valuable and created a technical foothold in a field where the commercial deployment of AI techniques has the potential to greatly enhance the level of patient care provided for patients with mesothelioma. With continued investment, we expect projects surrounding mesothelioma measurement by deep learning to remain a prominent theme moving forward. Further, the techniques and methods explored in this project provide expert learning and transferable knowledge (tacit IP) that will be reused in similar image segmentation projects in future. Additionally, a further significant benefit was the fantastic opportunity for publicity – the unique and open nature of the project has resulted in it being one of the go-to topics when sharing our work with other groups. To date, the project has been presented at multiple conferences including Data Talent Scotland, the SINAPSE annual conference and the CDT in Applied Photonics annual conference. It has been the topic of discussion at multiple booths, and the focus of several news articles and television reports, https://www.bbc.co.uk/news/uk-scotland-56734407.

For Canon Medical Research, this project was a first step towards data-driven clinical support in the context of mesothelioma. However, from this project we hope to further develop these approaches as part of the PREDICT-Meso Accelerator Network, which will provide access to at least 1000 CT scans from mesothelioma patients pre- and post-chemotherapy, from multiple UK centres. This access to data will be facilitated by leveraging the infrastructure provided by the recently funded (Innovate UK, £17.5m) National Consortium for Intelligent Medical Imaging (NCIMI), based in Oxford, UK PREDICT-Meso is a global, bedside-to-bench-to-bedside translational programme of mesothelioma research, led by Prof Blyth, which includes this work-flow and is funded by Cancer Research UK (£5m). This initiative involves leaders in mesothelioma research from the UK, Italy, Spain, Belgium, Brazil, Netherlands and the US.

Upon the completion of Phase III, within PREDICT-Meso, it will be possible evaluate the commercial potential of the developed algorithm in the light of a more comprehensive evaluation, utilising data from more centres and wider demographics. The developed algorithm, despite being expertly tuned to the mesothelioma segmentation task, is unlikely to be far enough from prior works to be the subject of IP. As it is the first of its kind, it provides a performance benchmark for further (more task specific) innovation, where IP generation is anticipated.

Since completing phase II, we have successfully presented the technical approach developed at Bioimaging 2020, and published this in extended conference proceedings (Anderson et al, DOI: 10.5220/0008976100640073). In addition, the full clinical results, as summarised here, are currently under review by a high-impact, peer-reviewed scientific journal, with a publication decision expected imminently (Kidd et al). In addition, the two PhD students involved in the project (Owen Anderson (Computing Science) and Andrew Kidd (Clinical Cancer Science) have both completed their studies, with high quality theses expected from both. The development of these two new potential research leaders in the field constitutes a further powerful output for the project.

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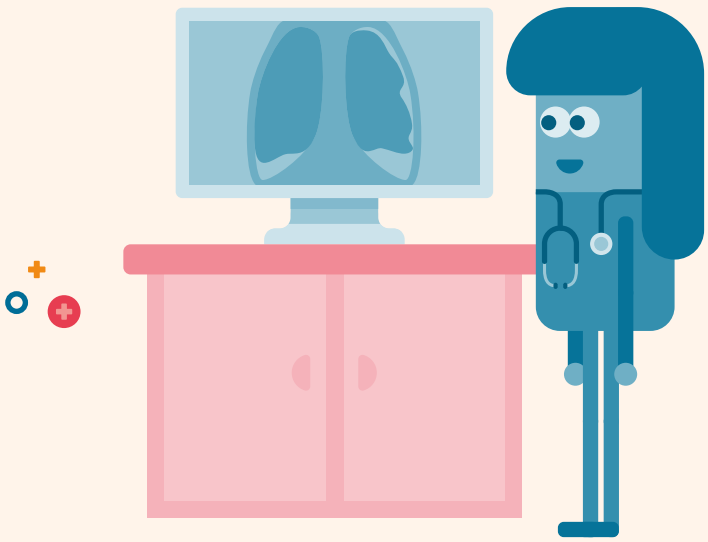


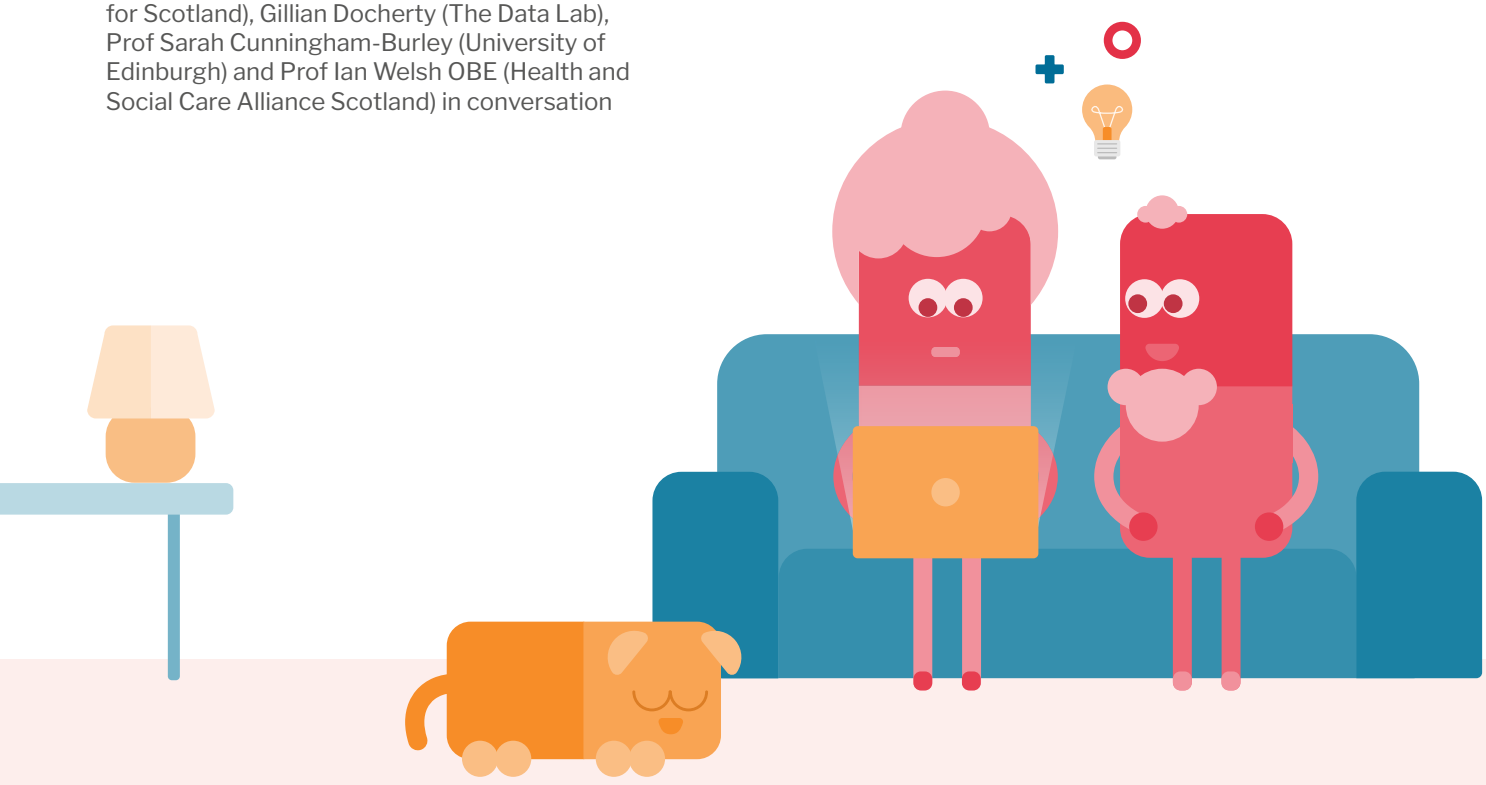
Public Engagement

In addition to the core funding competitions, the Cancer Innovation Challenge has organised various public engagement activities as part of its wider stakeholder engagement programme around the use of data in healthcare.

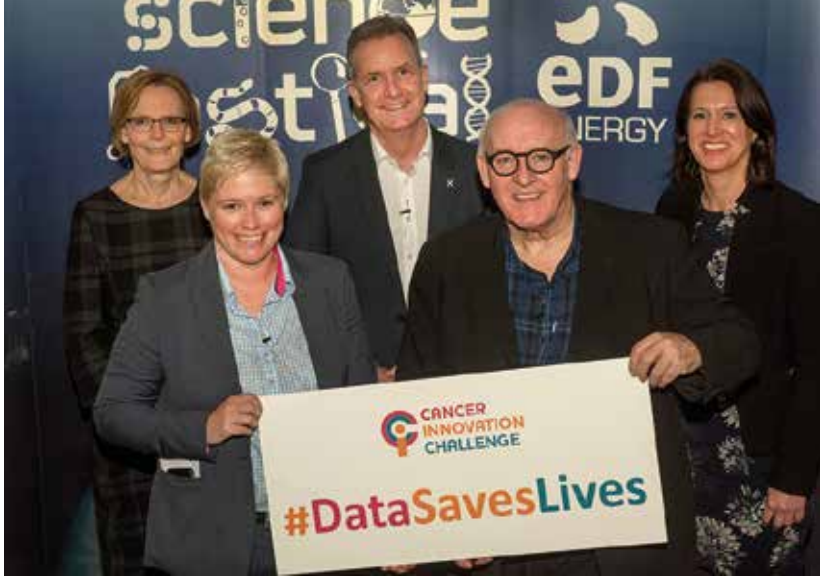
The activities included a show as part of the Cabaret of Dangerous Ideas programme at the Edinburgh Festival Fringe (the world's largest arts festival) in August 2017. Featuring Professors Aileen Keel (Innovative Healthcare Delivery Programme) and David Robertson (University of Edinburgh), ***Dr Data: The Answer to Cancer***, was a live discussion event around the contributions of data science towards cancer research and care.

The Cancer Innovation Challenge held a live panel discussion as part of the Edinburgh International Science Festival programme in April 2018. ***Realistic Medicine, Data and Me*** saw Dr Catherine Calderwood (Chief Medical Officer for Scotland), Gillian Docherty (The Data Lab), Prof Sarah Cunningham-Burley (University of Edinburgh) and Prof Ian Welsh OBE (Health and Social Care Alliance Scotland) in conversation with Dr Brian Robson (Healthcare Improvement Scotland) about the role that innovations in data will play in the delivery of Realistic Medicine.

On 31 May 2018 and 1 June 2018, the Cancer Innovation Challenge joined NHS National Services Scotland (NSS), NHS Scotland, IHDP, SHIL and a host of other organisations in presenting ***Co-Lab(orate)*** at TEDx Youth Glasgow 2018 and TEDx Glasgow 2018. Co-Lab(orate) was a pop up interactive journey through innovations in health and well-being in Scotland and was visited by more than 1000 people over the two days.




BARET OF DANGEROUS IDEAS
RENT SPEAKER AT 1.50PM EVERYDAY! ALL SHOWS £8/£6
4 Aug
MAKING A SIGNBANK WITHDRAWAL
5 Aug
16 Aug
"NO COPYRIGHT, NO PROBLEM?"
With Smita Kheria
17 Aug
FITNESS TO WITNESS*
With Faye Skelton. *Also on THE CABARET OF DANGEROUS IDEAS BY CANDLELIGHT 14th Aug 8.20pm
18 Aug
MEASURING HUMANITY
With Marisa de Andrade
19 Aug
DR DATA: THE ANSWER TO CANCER
With Aileen Keel and Dave Robertson
21 Aug
With Derek Bar
22 Aug
With Rachel Hosker.
CANDLELIGHT 7th Aug 8.20pm
23 Aug
HOW TO REBUILD A LIFE
With Alastair Ager
24 Aug
DON'T THEY?"
With Orla Shortall
25 Aug
SEE 11 AUG FOR TODAYS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CANCER INNOVATION CHALLENGE


TEDx
Glasgow


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Realistic Medicine, Data and Me
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Co-Lab-orate


Do you have an idea to
improve patient care?


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Paul Wheelhouse MSP
er for Business, Innovation and Energy


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CHALLENGE
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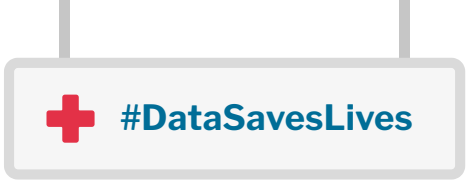
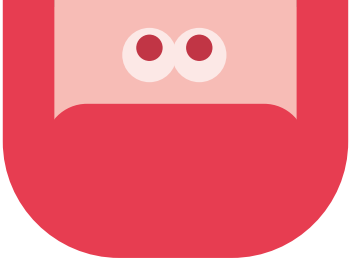




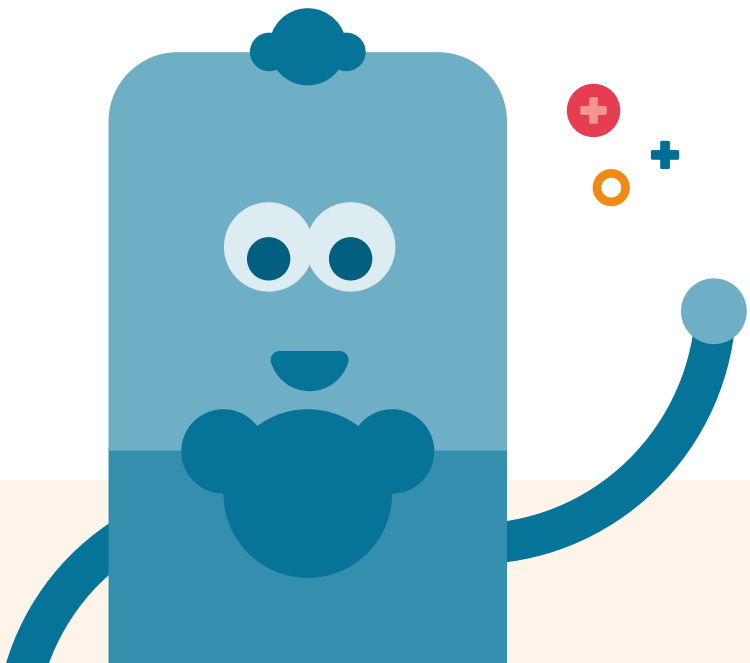
Stakeholder Engagement

The Cancer Innovation Challenge has also organised a series of events aimed at professional stakeholders from the private sector, academia, public sector and the NHS.

The launch of each competition's Phase 1 programme of work included a comprehensive stakeholder engagement workshop. These events invited primary and secondary care clinicians, patients, carers, interested citizens, eHealth professionals, data scientists, academics and other cancer care service providers to engage with and support the successful projects to ensure that they develop the best possible product to improve cancer care and outcomes in Scotland.

A technical workshop was held in October 2017 around the creation of better synthetic data to improve healthcare research. The event brought policy makers, data scientists, the NHS and academics together to kick off a programme of work that is currently still ongoing.

As part of the DataFest18 Fringe programme, the Cancer Innovation Challenge hosted a networking event titled Realising your data-driven healthcare innovation in Scotland. It was an opportunity for entrepreneurs, innovators and SMEs interested in innovating with data in the healthcare space to meet various organisations that can help and support their journey. MSP Paul Wheelhouse (then Minister for Business, Innovation and Energy) opened the event involving Innovate UK, Scottish Enterprise, MediCity, NHS, Scottish Government, Informatics Ventures, Edinburgh BioQuarter, CodeBase, Stratified Medicine Scotland, Digital Health and Care Institute Scotland (DHI) and The Data Lab.






Cancer Data Dive

The Cancer Innovation Challenge's Cancer Data Dive hackathon event took place at CodeBase in Edinburgh from the evening of Thursday 15 June 2017 until the evening of Sunday 18 June 2017.

Working with Product Forge, the aim of the event was to generate ideas around the use of cancer data, encourage cross-disciplinary approaches to innovative data science and if possible, develop prototypes that can inform our the cancer data funding competition that launched in September 2017.

We had 61 participants registered from a myriad of backgrounds including clinicians, designers, software developers, informaticians and data scientists. Over a period of about 72 hours, we had 12 teams present 12 fantastic ideas to a panel of judges and an audience of supporters on the Sunday evening to help improve cancer care in Scotland.

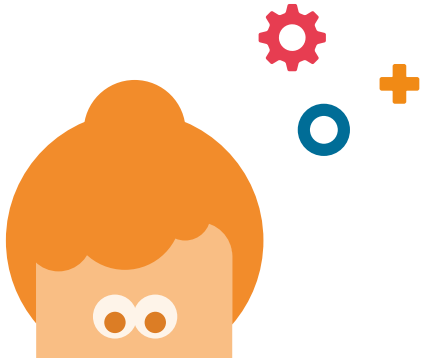
The winning was OIMK with their product Progdict. Progdict uses machine learning to improve prognostication in patients with metastatic cancer to inform and improve advanced care planning i.e. it helps to better answer the question of "how long do I have left?" once you are diagnosed with an untreatable cancer.

The tool enables predicting what time you have left with and without treatment and allows a doctor to discuss the options with patients with better accuracy in terms of indicative timelines.

OIMK went on to become Sharpe Analytics, one of the companies awarded Phase 1 funding in the Cancer Innovation Challenge's innovative data science competition.

In February 2019, the Cancer Innovation Challenge will be partnering with NHS NSS and IHDP for the Digital Health Product Forge, Europe's largest health hackathon.

productforge.io/events/digital-health-product-forge



Exhibiting at the NCRI Conference 2018

The Cancer Innovation Challenge exhibited for the first time at the National Cancer Research Initiative (NCRI) Conference in November 2018.

This flagship cancer research conference took place in Scotland for the first time in 2018 and the CIC saw this as an important platform to communicate the work of the project. An animated film was commissioned along with a series of printed collateral for this exhibition which saw over 1500 delegates attend from the field of cancer research from all over the world. The CIC exhibited along with representatives from all three Phase 2 companies and was a successful endeavour in raising awareness of the projects.

Digital Health Product Forge

The Cancer Innovation Challenge was a lead sponsor (with NSS and IHDP) for Europe's largest health hackathon, the Digital Health Product Forge, in February 2019. Over 160 participants from a myriad of backgrounds (developers, data scientists, clinicians, designers, entrepreneurs etc), and from all over Europe, came together over the 4 days in Edinburgh to develop digital health solutions to improve the future of healthcare for all.

Forming 31 teams over 7 tracks, 31 ideas and products were presented on the Sunday evening. Over 60 mentors were involved in the event and guests included Chief Medical Officer for Scotland, Dr Catherine Calderwood, and Minister for Trade, Investment and Innovative, Ivan McKee MSP.

The Cancer Innovation Challenge sponsored track, Data Driven Cancer Care, was one of the biggest tracks at the event with 7 teams choosing to innovate under that theme. The winning team of the track was Team Front End who created a non-web based symptom tracker called TreatMe Net to help detect lung cancer relapse in communities which have limited access to the internet and web based tools.

Plenary panel at DataFest 2019

DataFest 19 was a two week festival of Data Innovation in Scotland from 11 to 22 March 2019 showcasing Scotland's role in data science and artificial intelligence. The year's theme focused on collaboration and doing #DataTogether as a community.

The Cancer Innovation Challenge was delighted to be part of the Data Summit (the two-day flagship international conference held in Edinburgh) line up full of inspirational and thought provoking speakers and sessions covering a wide range of topics.

Hosted by the Deputy Chief Medical Officer for Scotland, Dr Gregor Smith, the Cancer Innovation Challenge panel session on 21 March 2019 was an opportunity to hear about the collaborative stories behind the three Phase 2 companies from the Challenge two years after its launch at Data Summit 2017. The panel included Dr Anne Bruinvels, CEO and Founder of Px HealthCare, Dr Ken Sutherland, President of Canon Medical Research Europe and Dr Tim Williams, CEO and Co-Founder of My Clinical Outcomes. The panel was very positively received and afterwards, the Cancer Innovation Challenge had the opportunity to meet First Minister Nicola Sturgeon and tell her about the great work that the projects were doing.

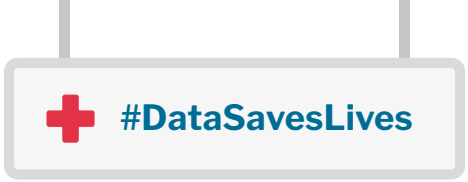
Parliamentary Reception

The Cancer Innovation Challenge were delighted to take part in the The Data Lab's 'Supporting Transformative Projects' event at the Scottish Parliament on Tuesday 21 January 2020.

The event was opened by Clare Adamson MSP, convenor of the Education and Skills Committee and featured Minister for Public Finance and Digital Economy Kate Forbes MSP and CEO of the Data Lab, Gillian Docherty OBE.

The event showcased The Data Lab's work in Scotland to Ministers, MSPs and their staff and provide an opportunity for guests to hear first-hand about The Data Lab's transformative projects such as the Cancer Innovation Challenge.

We were pleased that Dr Peter MacLean, Clinical Director for Cancer Services in NHS Ayrshire & Arran was able to attend and bring to life the work of the Cancer Innovation Challenge through their collaboration with My Clinical Outcomes for their Phase 2 funded project on cancer PROMs.



Finances

The Cancer Innovation Challenge was delivered under budget with £84,539 returned to SFC at the final reporting point in Spring 2020.

Outline expenditure on the project was as follows:

Call management	£2,036
Cancer Data Workstream (including SBRI funding)	£231,744
Communications	£46,253
Computing Hardware/Software	£1,602
Data Dive	£22,236
Events	£35,669
Meetings	£5,864
NDS Project	£6,000
PROMs PREMs Workstream (including SBRI funding)	£412,802
Public Engagement	£2,783
Salary costs + Staff CPD	£148,472
Total Expenditure	**£915,461**

Innovation Centres

The Data Lab, DHI and PMS-IC are all part of the Scottish Funding Council's Innovation Centre Programme, funded by the Scottish government and designed to support transformational collaboration between universities and businesses.

The Data Lab

The Data Lab is Scotland's innovation centre for data science and AI.

Our purpose is to change lives and make Scotland a more productive economy and a sustainable society by transforming the way we use data. We aim to create a thriving, connected society powered by data. We are helping to create a highly skilled workforce and a closely connected business, academic and public sector community to enable Scotland's economy and society to thrive.

Through our hubs in Edinburgh, Glasgow, Aberdeen and Inverness, we harness opportunities, connect people and ideas, and develop knowledge, skills and expertise. We help companies and individuals discover the opportunities that exist with data.

Founded in 2014 as part of Scotland's Innovation Centre programme, The Data Lab is hosted by the University of Edinburgh and funded through the Scottish Funding Council, Scottish Enterprise, Highlands and Islands Enterprise and the Scottish Government.

thedatalab.com

@DataLabScotland

Digital Health & Care Innovation Centre – DHI (formerly Digital Health & Care Institute)

The Digital Health & Care Innovation Centre is a national resource, funded by the Scottish Government and the Scottish Funding Council. We are a collaboration between the Glasgow School of Art and the University of Strathclyde with a focus on innovation in digital health and care to help the people of Scotland live longer, healthier lives while providing sustainable and inclusive growth for our economy. We transform great ideas into real solutions. Our vision is "innovation in digital health and care will help the people of Scotland live longer, healthier lives and provide sustainable and inclusive growth for our economies." We play a pivotal role in supporting collaboration to co-design person-centred digital health and care solutions across service, technical and business innovation. We are shifting the balance of care from a traditional treatment focused model to one that focuses on prevention, detection, post event care and self-management.

dhi-scotland.com

@dhiscotland

Precision Medicine Scotland Innovation Centre (formerly Stratified Medicine Scotland Innovation Centre) - PMS-IC

The Precision Medicine Innovation Centre (PMS-IC) was established by a consortium of partners from four Scottish NHS Health Boards, four Scottish Universities and two industrial partners in informatics: Aridhia Ltd and in genetics with ThermoFisher Scientific Ltd.

PMS-IC's focus is on linking Scotland's domain expertise, data assets and delivery capability to accelerate the adoption of Precision Medicine and changing the way we think about health problems with;

> Better diagnostics and earlier intervention,

> Optimal treatment selection; and

> More effective medicine development

PMS-IC has 3 main objectives:

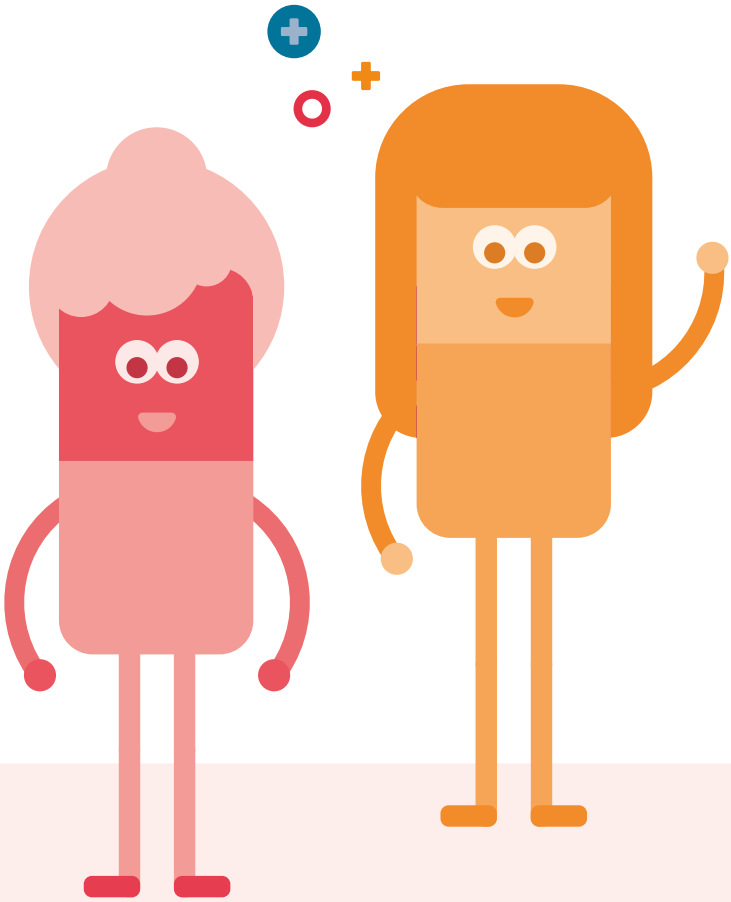
> To enable the effective implementation of precision medicine into the NHS

> To support the Scottish Life Sciences sector

> To develop a pipeline of sustainable exemplar projects

precisionmedicinescotland.com

@PrecisionMedSco




Thank you!

#DataSavesLives

Acknowledgements

Programme Manager

Steph Wright, The Data Lab

Finance Officer

Moira Stewart, The Data Lab

Strategic Management Board

Chair: Professor Andy Mount FRSC, University of Edinburgh

Dr Mary Allison, Citizen Representative

Professor David Cameron, University of Edinburgh and NHS Lothian

Professor George Crooks OBE, Digital Health & Care Innovation Centre

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*Gillian Docherty OBE, The Data Lab

Caroline Forshaw, Patient Representative

Professor Aileen Keel, Innovative Healthcare Delivery Programme (IHDP)

Marian McNeil, Stratified Medicine Scotland Innovation Centre (now Precision Medicine Scotland)

Sally Smith, Golden Jubilee Foundation, NHS GGC

Dr Hester Ward, NHS National Services Scotland (now Public Health Scotland)

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Professor Dave Robertson, University of Edinburgh

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*Simon Malzer, Health and Social Care Alliance Scotland

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*Now moved on from these organisations

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The Cancer Innovation Challenge website will remain live until end of March 2024.