NIHR | Innovation Observatory

Newcastle University

A Horizon Scan of Algorithms Used in the Development of Artificial Intelligence (AI)-Enabled Healthcare Technologies

Authors: Imogen Forsythe, Elizabeth Green, Olushola Ewedairo, Andrew Mkwashi

Date: July 2024

Professor Dawn Craig
Director

T: +44(0) 191 208 2259
E: info@io.nihr.ac.uk

www.io.nihr.ac.uk

Table of Contents

1.0 Key Findings

- Among the different types of algorithms, *'supervised learning'*, represented the majority in terms of clinical trial numbers in the UK. These *'supervised learning algorithms'* involve training a model on labeled data, which helps improve accuracy in predicting patient outcomes. This method allows for more reliable and interpretable results, making it easier to validate and implement in real-world healthcare settings.
- Among the supervised learning algorithm types used in AI-based healthcare technologies, neural networks were the most prominent in both the UK and Europe.
- Out of the 77 UK trials using supervised learning, 60 of these didn't specify the specfic algorithm used.
- Within the unsupervised learning and reinforcement learning algorithm categories for both the UK and Europe, we were not able to identify specific algorithm types, with both these categories containing only unknown specific algorithms. Lack of transparency regarding how these technologies work represents a major challenge in increasing clinician, patient and public confidence in AI-based healthcare technologies.
- AI was used in colorectal cancer more than any other condition in Europe with 29 trials identified.
- In the UK AI was most commmonly used in lung cancer with 6 trials being conducted.
- Both the UK and Europe exhibited a similar trend in terms of the top five conditions targeted by these emerging technologies: colorectal cancer, breast cancer, stroke, lung cancer, and heart failure.
- 82% of identifed trials in the UK were funded by non-industry indicating a strong commitment to unbiased research, as non-industry funding typically comes from government bodies, academic institutions, or non-profit organizations.

2.0 Background

There is an exponential growth in the use of artificial intelligence (AI) in clinical practice and in community care settings. AI is a branch of computer science dedicated to developing machines and software that can perform functions usually requiring human intelligence. These functions include learning, reasoning, problem-solving, perception, and understanding language. In the context of healthcare, AI has a vast range of applications including diagnostics, administrative tasks and personalised medicine.(1)

In some technologies, artificial intelligence is incorporated in the form of special subsets, such as deep learning and machine learning. Additionally, these technologies utilise a variety of algorithms that fall within three broad categories: supervised learning, unsupervised learning, and reinforcement learning. Supervised learning algorithms are a subset of machine learning techniques where the model learns patterns from labelled training data. Unsupervised learning algorithms are also a category of machine learning but the algorithm learns patterns from unlabelled data without explicit guidance or labelled outcomes. Reinforcement learning is a branch of machine learning where an agent learns to make decisions by interacting with an environment.(2) Through these interactions, the agent receives feedback in the form of rewards or penalties, aiming to maximize cumulative rewards over time by learning optimal strategies or policies.(2) Some technologies also use a combination of both supervised and unsupervised learning algorithms, also known as semi-supervised learning.

Previous research in this field has primarily focused on analysis of existing literature of AI-based healthcare technologies in the form of scoping and systematic reviews.(3-5) A scoping review by Sharma et al. focused on how AI is being implemented in clinical practice through analysis of thousands of articles from databases such as PubMed.(3) However, as these types of reviews are retrospective and focus on existing literature, they are unable to provide insight into the development landscape of AI based health technologies.(3) There is a glaring gap in current research on AI-based technologies in healthcare, which involves the examination of the specific algorithms being used in these technologies and their application in specific conditions. There is also a gap in the research of how AI-based healthcare technologies are funded.

A horizon scan of AI-based technologies in healthcare using clinical trial data is undertaken in this report in order to offer insight into the current landscape and development trends in this area. This is accomplished by examining the specific algorithms being used and the specific conditions under which AI-based technologies are being utilised. Furthermore, this report will examine funding sources for development of AI-based healthcare technologies. Understanding current and future development trends in AI-based healthcare technologies can provide useful insights for researchers, policymakers, and funding bodies.

By providing a comprehensive analysis of development trends, this report will also aid healthcare decision-makers in facilitating the rapid implementation of AI-based healthcare technologies as they become available.

2.1 Aims

- Provide an overview of AI-based healthcare technologies currently being developed for use in the healthcare sector, in response to inquiries from stakeholders.
- Identify specific algorithms being used in these technologies.
- Provide an analysis of the application of AI-based health technologies in specific conditions.
- Provide an overview of the funding landscape in the development of AI-based healthcare technologies.

3.0 Methods

The methodology employed for this report was derived from our previous report; Horizon Scanning Report: An Investigation into the Development of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) – Enabled Healthcare Technologies.

3.1 Information sources and search strategy

The Clinical Trials Registry: clinicaltrials.gov was searched for relevant trials published between August 2020 to August 2023. ClinicalTrials.gov is a registry of clinical trials managed by the US National Institute of Health (NIH). The database offers details on over 350,000 trials funded both by private and public organisations across 219 countries. Horizon scanning methodologies developed by the IO were used to identify the future trend of AI based technologies in the healthcare system, published within the specified dates, and this search produced 4,988 clinical trials. Of the 4,988 trials, 2060 were included and 2,928 excluded based on the criteria detailed below:

Inclusion criteria:[(1)]

• Meet the criteria for being a regulated medical device, digital health technology, or diagnostic as defined by the two new EU regulations (EU Regulation 2017/745 on medical devices (MDR) and EU Regulation 2017/746 on in vitro diagnostic medical devices (IVDR))

• Clinical trial record uses keyword phrases specific to AI e.g., “deep learning”

• One or more collaborators specialise in AI, AND a relevant technology

• A technology is described as ‘intelligent’ AND a secondary source confirms AI

• Significant computation is involved (big-data) AND a secondary source confirms AI

• Machine learning methodology is described, i.e., ‘training’ an algorithm with (big) data

• Data is being gathered with the stated intention to apply machine learning

• Existing AI (e.g., apple smart-watch) is being tested for clinical use

• A novel AI is in development for direct patient health impact, diagnostic use or support, or risk assessment/risk mitigation at the individual level.

Exclusion criteria:[1]

• Clinical trials using AI in the training and education of health professionals

• Clinical trials using AI to improve health outcomes at hospital level or disaster management level, etc, not at the individual level

• Primary research conducted in the clinical setting

• Patient information/education tools not purposed to improve health outcomes

Search terms used for our initial horizon scan were AI artificial intelligence; machine intelligence; neural network*; deep learning; computational intelligence; natural language processing; learning algorithm; continuous learning algorithm; intelligent device.

3.2 Data extraction

A data extraction form was created in excel which contained the following information: clinical trial ID, study title, brief summary, conditions, algorithm type, intervention categories, funder type, study type, location (broad geographical), country. This was populated from the earlier scan we had undertaken.

In order to provide additional insight following our previous report, we used our original dataset to identify the specific conditions that technologies were in development for, as well as the specific algorithms used within those technologies. Data extraction was completed independently, with queries resolved by a second reviewer.

Conditions:

As part of our previous analysis, we used NICE condition categories to categorise technologies broadly. However, to offer further insights into potential clinical areas of unmet need we extracted information relating to the specific conditions that technologies were being developed for. For UK-based clinical trials, we analysed all trials records for the specific conditions that technologies were being developed for. However, due to time constraints, for clinical trials based in Europe we specifically focused on the top 4 broad conditions identified in our previous report which included; cancer, cardiovascular, respiratory and neurological conditions. The conditions identified were collated and presented in a tabular format.

We did not include trials previously identified as being in development for multiple conditions, due to the breadth of clinical indications they could be used for.

Algorithm Type:

As a result of our initial horizon scan, the algorithms employed within technologies were categorised for analysis to generate a peer-reviewed publication.

Algorithms were classified as either supervised learning, unsupervised learning, reinforcement learning, both supervised & unsupervised learning, and unknown. For the technologies in development in the UK and Europe, we sought to identify the specific algorithm type employed in the technologies. This analysis solely relied on information directly presented in the clinical trial record, and no additional search strategies were employed to identify potentially relevant algorithms not explicitly mentioned within the trial descriptions. The extracted algorithm types were subsequently collated and presented in a visual format.

Funding:

The funding analysis was derived from our previous scan, in which we broadly categorised the funders of the included clinical trials into three groups: non-industry, industry, and both. This information was directly extracted from the clinical trials and recorded in an extraction form. For this scan, we filtered the dataset of the 2,060 included trials to retrieve only those with clinical trial locations in the UK and Europe. The extracted records were then represented in a visual format.

4.0 Results

In this section, we explore the development trends for AI-healthcare technologies using clinical trial data, collected in August 2023. Building on the findings from our original horizon scanning report, we have sought to further understand in greater depth where development is currently focused through extraction of specific conditions, algorithm types and funding sources from our original horizon scanning dataset.

4.1 Conditions and disease areas

In appendix 1, we have provided a comprehensive overview of the specific conditions and disease areas in which novel technologies are currently being developed for the treatment, diagnosis, and management of patients within trials based in the UK and Europe. Our analysis includes technologies at technology readiness 3/4 (initial clinical trials) to technology readiness level 8/9 (late stage clinical trials/post-market surveillance). Therefore, we present findings representing a broad spectrum of technologies.

The largest condition category identified for UK clinical trials was cancer;[1] within this category we identified lung cancer as being the greatest focus of development (n=6), followed by colorectal cancer (n=5) and technologies developed for multiple cancers (n=4) (appendix 1). Lung cancer is the third most common cancer in the UK, responsible for 34,800 deaths every year in the UK.[6,7] Due to the high incidence and mortality rate of lung cancer, it is unsurprising this is a key area of development focus for AI-based technologies. AI-based technologies could be used to expand and enhance cancer screening, aiding early detection and more timely treatment of many cancers, potentially reducing patient morbidity and mortality.[8]

Appendix 1 also highlights cardiovascular conditions as another key area of focus for clinical trials in the UK and Europe. In the same manner as cancer, technologies are currently being developed to address specific diseases that have a significant burden on public health. We identified heart failure as being the main focus of trials within the cardiovascular conditions category in the UK and Europe (n UK = 5, n Europe = 10). There are approximately one million people living in the UK who have heart failure, and these individuals are 2-3 times more likely to suffer a stroke than the average person. 80% of heart failure diagnoses are made while patients are in hospitals, many of the technologies we have identified within our search may aid community screening programmes to detect heart failure earlier, or to aid disease management which may prevent progression.(9)

Our analysis has also highlighted areas of unmet need in the development of AI-based healthcare technologies. Gynaecological conditions, injuries/accidents/wounds and nutritional and metabolic conditions in particular could benefit from greater technology development, as demonstrated by appendix 1. Innovation addressing women's health conditions has historically been overlooked. A recent study identified 51 areas of women's health which could be helped by novel technologies, AI-based technologies may address areas of unmet need such as management of vaginal prolapse and point of care diagnostics for sexually transmitted diseases.(10)

4.2 Algorithm subtypes

Figure 1 depicts the proportion of each algorithm category used within UK clinical trials. Among the different types of algorithms, *'supervised learning algorithms'* represented the majority in terms of trial numbers. The second most common category type was the *'unknown algorithms'*, followed by *'both supervised and unsupervised learning algorithms'*. Among the least used algorithms were *'unsupervised learning algorithms'* and *'reinforcement learning algorithms'*. Currently, there is a greater understanding of supervised learning algorithms, which may explain the fact that this algorithm category constituted the largest portion of technologies used in UK clinical trials. The categorgy of 'both supervised and unsupervised learning algorithms' represented a growing area of interest within AI-based technology development. These algorithms are predominantly employed within deep-learning technologies, these algorithms can also be referred to as 'semi-supervised learning algorithms'.(11) In a large number of trials, the algorithms used within technologies were not mentioned, meaning these trials had to be classified as unknown. Lack of transparency regarding how these technologies work represents a major challenge in increasing clinician, patient and public confidence in AI-based healthcare technologies.

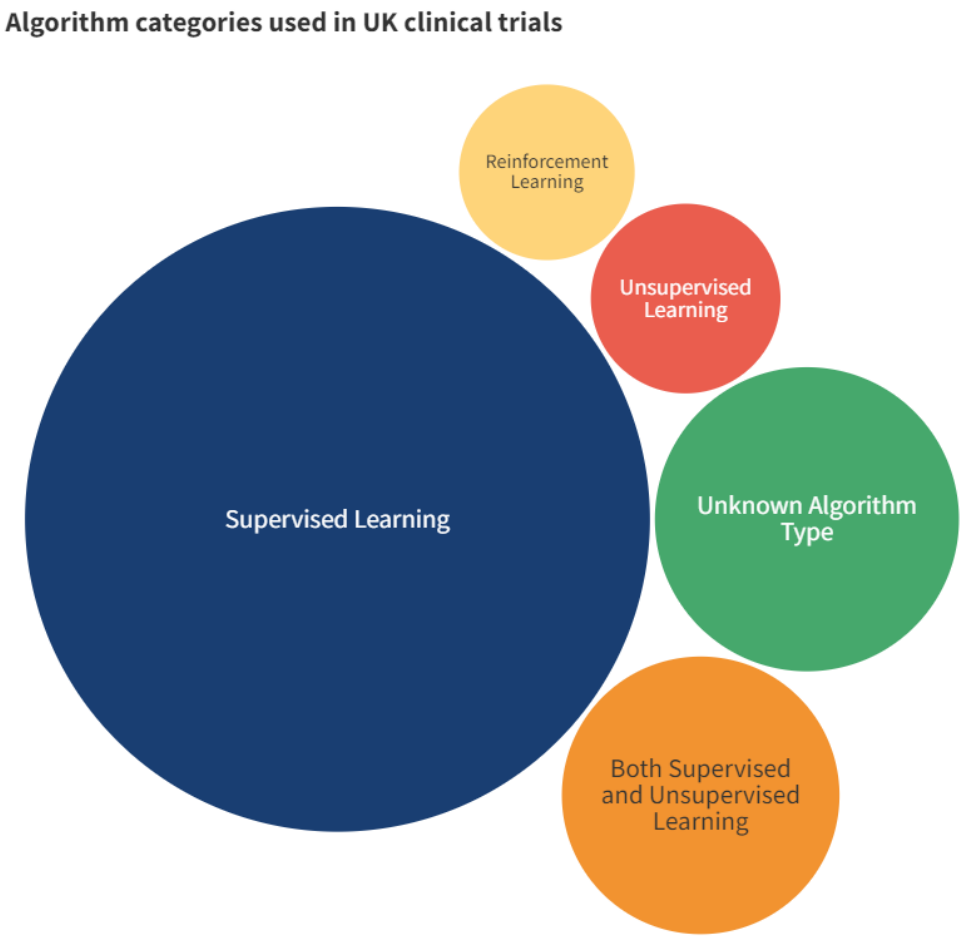

Figure 1- Visual representation of proportion of algorithm categories used in technologies in UK-based clinical trials

Further analysis has revealed that while many developers will provide basic information regarding broad categories of algorithms, there is less transparency regarding specific algorithms used within AI-based healthcare technologies. Many of the trials contained no information regarding specific algorithm types used, meaning these technologies were classified as unknown in such instances. Figure 2 illustrates the specific algorithms used within the supervised learning algorithms category for UK based clinical trials. Among the known algorithm types used in AI-based healthcare technologies, neural networks are one of the most prominent (figure 2). Additionally, developers are exploring the use of support vector machines and combinations of algorithms.

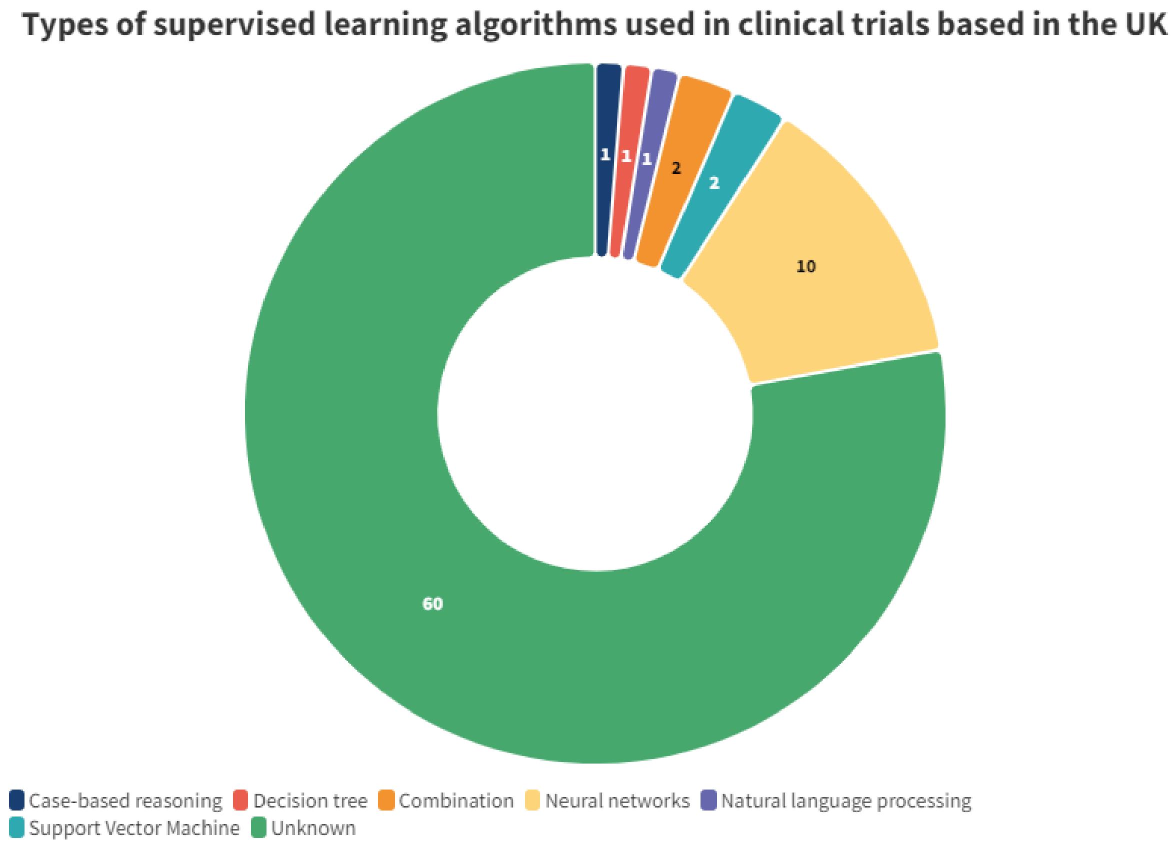

Figure 2 - Number of supervised learning algorithms used in clinical trials based in the UK

Figure 3 visualises the algorithms used within technologies identified as using *'both supervised and unsupervised learning algorithms'*. From the two trials where specific algorithm type was identifiable in this category, these technologies used neural networks and natural language processing algorithms. Similarly to figure 2, figure 3 demonstrates that there a large number of trials where algorithms used within technologies is unknown.

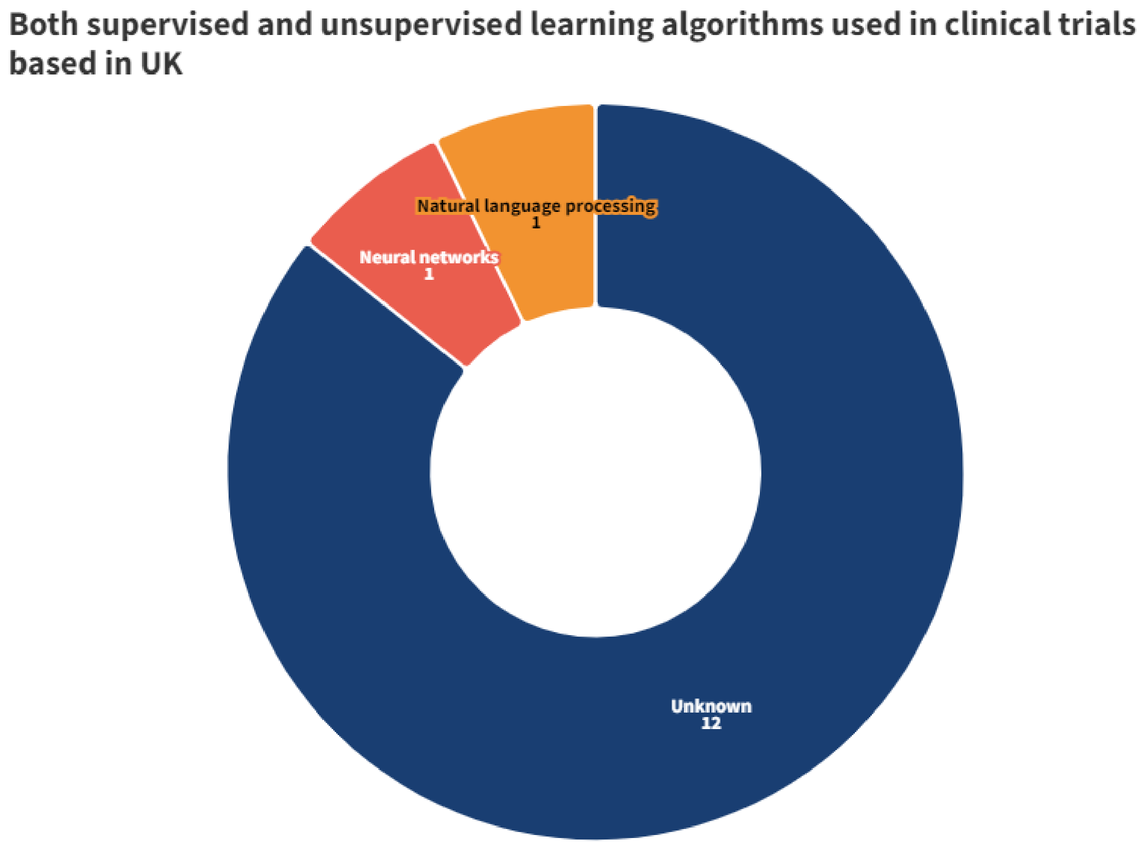

Figure 3 - Number of both supervised and unsupervised learning algorithms used in clinical trials based in the UK

As there were a larger number of trials based in Europe compared to the UK, we were able to identify a larger number of algorithms used within the supervised learning category, this is shown in figure 4. Of the algorithms that were identified from European trials, neural networks was the most common, which may suggest they make up a good proportion of the algorithms used within AI-based healthcare technologies. Figure 4 indicates the breadth of algorithms used within AI-based healthcare technologies, as despite a significant number of unknown algorithm types, we were still able to identify 14 different types of algorithms (or combinations of algorithms) used within technologies in clinical trials in Europe. However, as with the UK clinical trials, a large number did not specify the type of algorithms used within technologies. Within the unsupervised learning and reinforcement learning algorithm categories for both the UK and Europe, we were not able to identify specific algorithm types, with both these categories containing only unknown specific algorithms. This indicates transparency of developers may be a globally widespread problem which must be addressed through rigrous regulation and updating legal obligations of developers to be as transparent as possible to enable public evaluation of technologies.

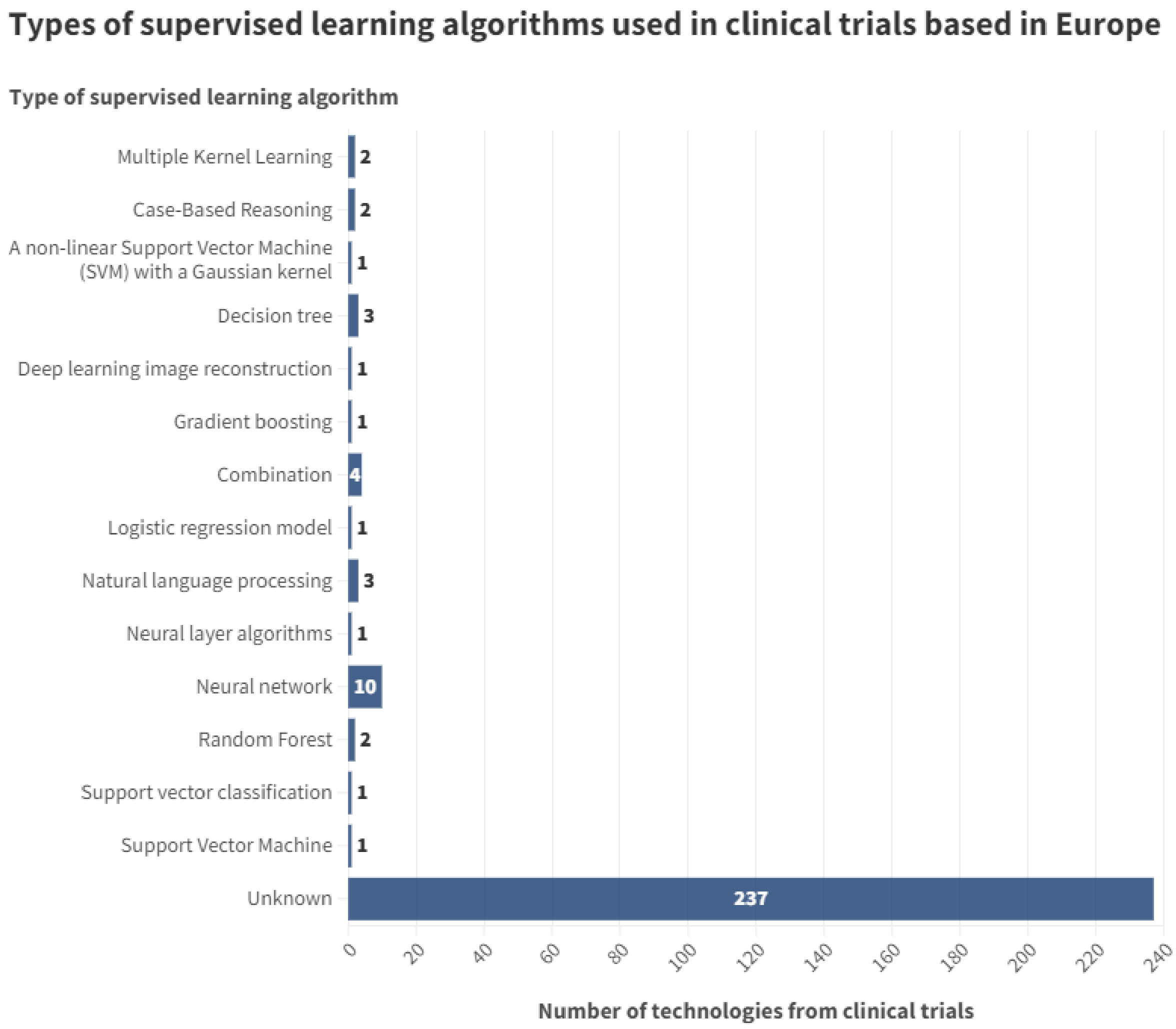

Figure 4 - Number of supervised learning algorithms used in clinical trials based in Europe

4.3 Funding sources for clinical trials

We analysed funding sources for clinical trials focusing on three broad categories; industry funding, non-industry funding or both (combination of industry and non-industry funding). Non-industry funding can include sources such as state funding, charitable organisations and academic institutions. Industry funding can refer to funding from private companies and investors. Figure 5 emphasises the significant role of non-industry funding for clinical trials based in the UK, with 82% of UK trials funded from non-industry sources. As the UK has a state-funded healthcare system, it is perhaps unsurprising that a significant amount of funding from development comes from state/charitable sources. AI-based healthcare technologies are set to transform the NHS, with the establishment of the NHS AI lab in 2019 to support development and deployment of AI healthcare technologies in the NHS.[12] Industry funding can be described as "mile-stone driven", meaning that if development is not progressing rapidly enough contracts may not be renewed or project funding stopped if it is deemed not profitable.[13] Evolving regulatory frameworks and current uncertainty of deployment of AI-based technologies within the NHS may in part, explain the limited industry funding for UK based clinical trials.

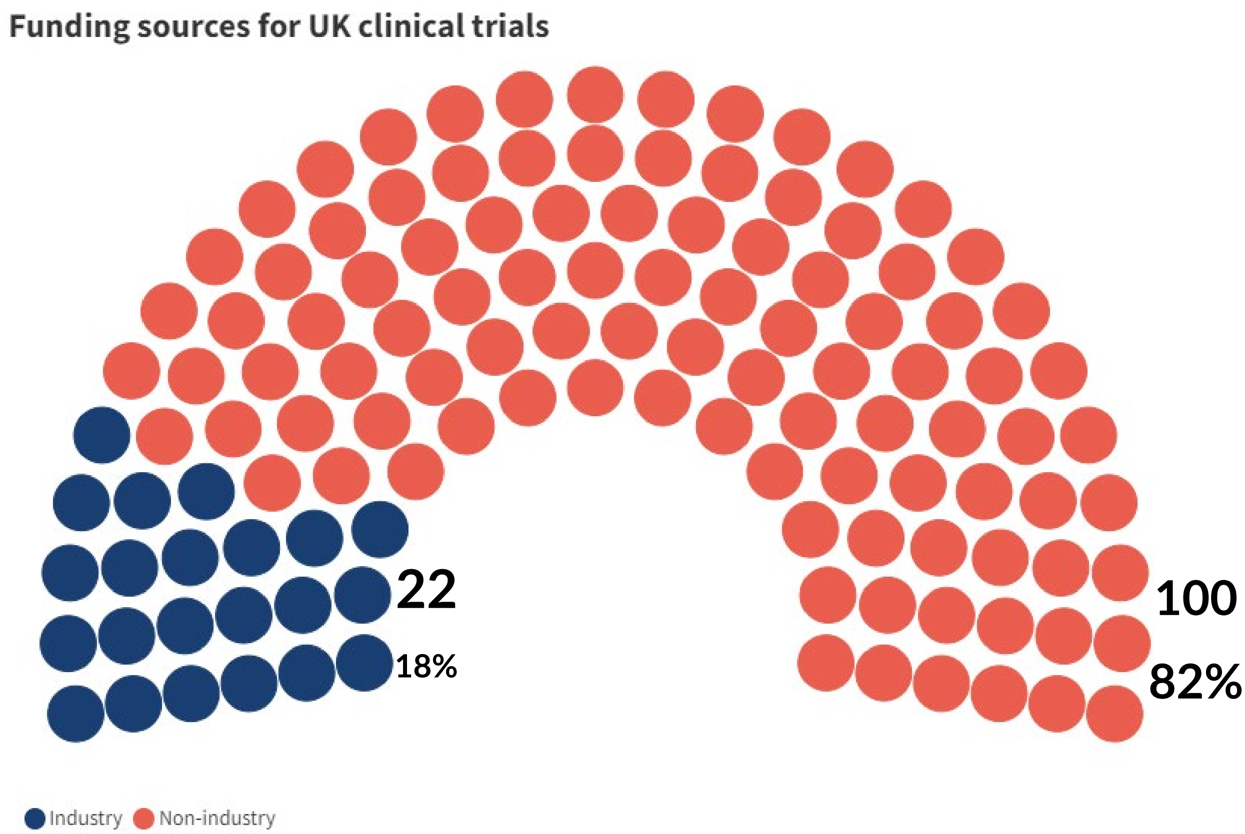

Figure 5- Funding sources for UK clinical trials.

Figure 6 illustrates the differences in funding sources for technologies using different alogirthm types. Whilst figure 6 reflects the evidence of limited industry funding shown in figure 5, figure 6 also highlights that many industry sponsored trials are less transparent about algorithm type used within the technologies they are developing. Two industry funded trials included details of the algorithm type used in their technology, which included neural networks and support vector machine algorithms. The remaining 20 industry funded trials did not provide any details of the alogirthm type, however 83 of the 100 non-industry focused trials also excluded details of algorithm type. This indicates a lack of transparency within research and development in both publically and privately funded trials. Exclusion of key details such as algorithm type hinders public assessment of technologies and reduces confidence in clinical application. Proprietary algorithms may raise social and ethical concerns, with the potential for these algorithms to exacerabate health inequalities through algorithmic bias. An independent report highlighted the need for transparency of algorithm type and how algorithms are used in decision making processes to ensure fair treatment of individuals.[14] However, some developers may be required to keep specific details of algorithms confidential for data security.[15] Additionally, the competitiveness of the development sector for AI healthcare technologies may mean algorithms remain proprietary to maintain a competitive edge.[15] This rationale will be particularly potent in industry funded trials, where development is profit driven.

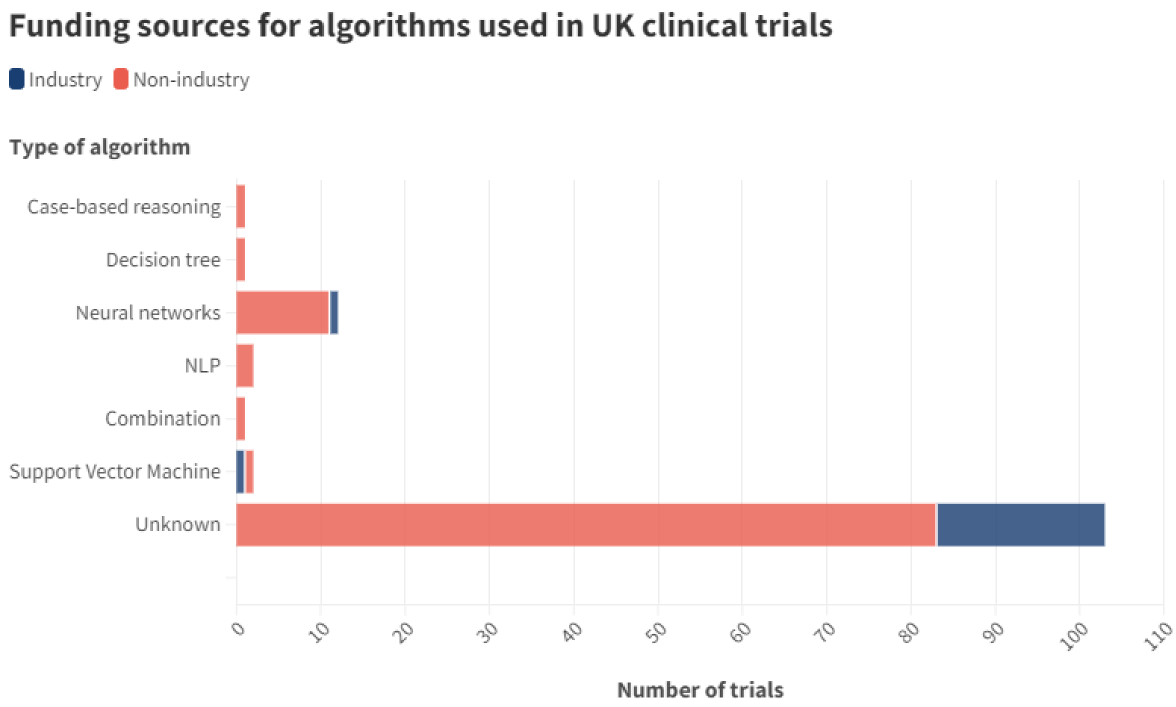

Figure 6 - Graph illustrating the funding sources for technologies in UK clinical trials based on algorithm subtype used in technology.

5.0 Conclusion

This report highlights the lack of transparency regarding algorithms used within AI-based healthcare technologies. The reasons for excluding algorithm details from clinical trial records can be numerous and complex, ranging from cybersecurity and data protection, to maintaining competitive advantage in this expanding market.

However, building trust in AI-based healthcare technologies necessitates a more transparent approach to clinical trial reporting, particularly within open access databases like clinicaltrials.gov. This database serves as a critical resource for potential users, including key healthcare decision makers, who rely on clear and comprehensive information to make informed decisions about adopting these technologies into clinical practice. Greater inclusion of details relating to algorithms employed within AI-based healthcare technologies would allow critical appraisal of the algorithms underpinning AI-based healthcare technologies, which would increase confidence when adopting technologies into clinical practice and inform decisions regarding their role in patient care.

As anticipated, the analysis revealed a greater number of AI-based healthcare technologies in development in Europe compared to the UK for all identified conditions. This is because there were multiple countries in Europe represented in the scan, thereby increasing the overall pool of reported technologies.

Interestingly, both the UK and Europe exhibited a similar trend in terms of the top five conditions targeted by these emerging technologies: colorectal cancer, breast cancer, stroke, lung cancer, and heart failure. This potentially reflect similarilities in public health burdens across the global north, with high prevalence and morbidity/mortality of these conditions in both regions. For example, lung cancer is the third most common cancer in the UK accounting for 13% of all new cancer cases, and the fourth most common cancer in Europe.(7,16) In addition, the prevalence of heart and circulatory diseases in the UK is approximately double that of cancer and alzheimer's disease combined.(9)

Despite blood cancer being the fifth most common cancer in the UK, our scan identified only one trial each in the UK and Europe for this condition. This gap highlights a potential opportunity for developers to explore and contribute to the management of blood cancer.

A key finding of this scan was the dominance of non-industry funding for clinical trials currently under development within the UK and Europe. This observation suggests an opportunity to explore increased private sector involvement in developing AI-based healthcare technologies. Facilitating closer collaboration between industry and academic institutions, alongside the development of public-private partnerships, has the potential to contribute to advancements in healthcare outcomes as well as drive continuous innovation in this field.

Overall, there were fewer trials for technologies in development for a wide range of conditions, including brain cancer, pulmonary hypertension, dementia, respiratory failure, and diabetic retinopathy, among others. Our scan has identified numerous areas of unmet need where AI-based technologies could improve outcomes both in the UK and Europe. Addressing these gaps could be facilitated by fostering more public-private partnerships to financially support start-up developers and by investing more in AI research programs at universities. This would encourage and build a growing community of researchers and developers dedicated to implementing AI-based solutions in the UK and European healthcare systems.

Appendix 1: A breakdown of specific conditions targeted by emerging AI technologies in the UK and European trials

Location	Condition Category	Specific Condition	Number of trials
UK	Cancer	Blood Cancer	1
		Breast Cancer	2
		Brain Cancer	1
		Colorectal Cancer	5
		Gastrointestinal cancer	2
		Lung cancer	6
		Multiple cancers	4
		Prostate cancer	2
		Skin Cancer	3
	Cardiovascular	Abdominal Aortic Aneurysm	1
		Atrial Fibrillation	3
		Coronary artery disease	1
		Deep vein thrombosis	1
		Heart Failure	5
		Multiple	3
		Pulmonary hypertension	1
	Neurological	Alzheimer's disease	3
		Amyotrophic Lateral Sclerosis	1
		Delirium	1
		Dementia	1
		Multiple	4
		Parkinson's disease	3
		Stroke	4
	Respiratory	COPD	2
		COVID-19	4
		Multiple	2
		Respiratory failure	1
	Digestive	Barett's oesophagus	2
		Crohn's disease	1
		Gastro-oesophageal reflux	1
		Inflammatory Bowel Disease	3
	Diabetes and endocrinology	Type 1 Diabetes	2
		Diabetic Retinopathy	1
	Ear, Nose and Throat	Dizziness	1
	Eye	Cataracts	1

	Infections	Respiratory infections	1
		Sepsis	2
		Lyme disease	1
	Mental health, behavioural, neurodevelopmental	Multiple mental health conditions	1
		Psychosis	1
	Musculoskeletal	Total Hip Arthroplasty	1
		Osteoporosis	1
	Nutritional and metabolic	Multiple	1
	Sleep	Sleep Apnoea	2
	Urological	Enuresis	1
	Gynaecological	Polycystic ovary syndrome	1
	Injuries/Accidents/Wounds	Accidental Falls	1
		Concussion	1
		Fractures	1
	Kidney	Chronic Kidney Disease	2
		Kidney transplant	1
	Pregnancy and Childbirth	Labour	1
Europe	Cancer	Bladder cancer	5
		Blood cancer	1
		Bone cancer	2
		Brain cancer	3
		Breast cancer	18
		Cervical cancer	2
		Colorectal cancer	29
		Gastric cancer	3
		Head and neck cancer	5
		Liver cancer	5
		Lung cancer	11
		Multiple	6
		Neuroendocrine cancer	1
		Ovarian cancer	1
		Pancreatic cancer	2
		Prostate cancer	7
		Renal cancer	2
		Skin cancer	9
		Solid tumours	3
	Cardiovascular	Abdominal aortic aneurysm	1

		Arrhythmia (Multiple/unspecified)	6
		Atrial fibrillation	9
		Brugada syndrome	1
		Cardiac arrest	5
		Coma	1
		Congenital heart disease	1
		Coronary artery disease	9
		Coronary microvascular disease	1
		Heart disease (multiple/unspecified)	4
		Heart failure	10
		Heart murmur	1
		Hypotension	3
		Multiple	2
		Myocardial infarction	2
		Syncope	1
		Valvular heart disease	1
		Ventricular fibrillation	1
	Respiratory	COVID-19	4
		Dyspnoea	2
		Lung nodules	2
		Multiple	6
		Pulmonary embolism	1
		Respiratory failure	2
	Neurological	Alzheimer's disease	2
		Central Nervous System diseases	1
		Dementia	3
		Encephalopathy	1
		Epilepsy	2
		Essential tremor	1
		Fabry disease	1
		Migraine	2
		Multiple	2
		Multiple sclerosis	6
		Neurodevelopmental disorders	1
		Parkinson's disease	8
		Stroke	12
		Subarachnoid haemorrhage	1

		Traumatic brain injury	2

Appendix 2: Glossary

Artificial Intelligence: can be defined as "The design and study of machines that can perform tasks that would previously have required human (or other biological) brainpower to accomplish. AI is a broad field that incorporates many different aspects of intelligence, such as reasoning, making decisions, learning from mistakes, communicating, solving problems, and moving around the physical world".[17]

Machine learning: is a subset of AI using computer algorithms capable of learning by finding patterns in data, which can then be applied to new data to make predictions and provide other useful information.[17]

Deep learning: is subset of machine learning "that uses computational structures known as 'neural networks' to automatically recognise patterns in data and provide a suitable output, such as a prediction or evidence for a decision".[17]

Neural networks: (a computational network which artificially mimics activity of neurons in human brains), which enable learning of complex tasks such as identifying features in images and speech.[17]

Supervised learning: Algorithms which are trained using data previously labelled by subject matter experts (SMEs). The algorithms use labelled data to learn and grow, referring to the labelled data to make predictions about new data. These algorithms require significant input from SMEs to ensure quality, accuracy, and safety. This is achieved by reviewing results generated by AI against the original data. Examples of algorithms in this category include decision tree, random forest, and linear regression algorithms.[2]

Unsupervised learning algorithms: Algorithms which identify patterns/clusters in raw (unlabelled) data to create models and analyse relationships between different datapoints. Examples of algorithms in this category include k-means clustering and Gaussian mixture models.[2]

Both supervised and unsupervised learning algorithms: This category includes algorithms which could either be classified as supervised or unsupervised learning algorithms, or a combination of the two. Examples of algorithms in this category include K-nearest neighbour algorithm and neural networks.[2]

Reinforcement learning algorithms: These algorithms learn through experience based on input from their environment, and subsequent feedback usually in the form of a "reward". These algorithms are not trained from datasets and learn through their experiences within an environment. These algorithms will continue to learn based on signals from the environment until a termination signal is sent. Examples of reinforcement learning algorithms include value-based and policy-based algorithms.[(2)]

References

1 Forsythe I, Green E, Roberts S, Ewedairo O, Sadiq A, Mkwashi A. Horizon Scanning Report: An Investigation into the Development of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) - Enabled Healthcare Technologies. 2023 [cited. Available from: https://www.io.nihr.ac.uk/wp-content/uploads/2023/12/DDD-AI-based-Health-Technologies-Report.pdf

2 Tableau. Artificial intelligence (AI) algorithms: a complete overview. 2024 [cited.

3 Sharma M, Savage C, Nair M, Larsson I, Svedberg P, Nygren JM. Artificial Intelligence Applications in Health Care Practice: Scoping Review. J Med Internet Res. 2022;24:e40238.

4 Abdul NS, Shivakumar GC, Sangappa SB, Di Blasio M, Crimi S, Cicciù M, Minervini G. Applications of artificial intelligence in the field of oral and maxillofacial pathology: a systematic review and meta-analysis. BMC Oral Health. 2024;24:122.

5 Senbekov M, Saliev T, Bukeyeva Z, Almabayeva A, Zhanaliyeva M, Aitenova N, Toishibekov Y, Fakhradiyev I. The Recent Progress and Applications of Digital Technologies in Healthcare: A Review. International Journal of Telemedicine and Applications. 2020;2020:8830200.

6 Cancer Research UK. Cancer incidence for common cancers. 2024 [cited.

7 Cancer Research UK Lung cancer statistics. 2024 [cited.

8 Hunter B, Hindocha S, Lee RW. The Role of Artificial Intelligence in Early Cancer Diagnosis. Cancers (Basel). 2022;14.

9 British Heart Foundation. British Heart Foundation UK Factsheet. 2024 [cited. Available from: https://www.bhf.org.uk/-/media/files/for-professionals/research/heart-statistics/bhf-cvd-statistics-uk-factsheet.pdf?rev=5503842f012d416994618f73f5e76667&hash=B25531514E2326EBAD737D565D969EEA

10 Dixon S, Keating S, McNiven A, Edwards G, Turner P, Knox-Peebles C, Taghinejadi N, Vincent K, James O, Hayward G. What are important areas where better technology would support women’s health? Findings from a priority setting partnership. BMC Women's Health. 2023;23:667.

11 Jiao R, Zhang Y, Ding L, Xue B, Zhang J, Cai R, Jin C. Learning with limited annotations: A survey on deep semi-supervised learning for medical image segmentation. Computers in Biology and Medicine. 2024;169:107840.

12 National Health Service. The NHS AI Lab. 2024 [cited. Available from: https://transform.england.nhs.uk/ai-lab/

13 Boston University. How Is Industry Sponsored Research Different from Government or Foundation Sponsored Research? 2024 [cited. Available from: https://www.bu.edu/industry/2021/08/31/what-makes-industry-sponsored-research-different-from-other-sponsored-research/

14 Centre for Data Ethics and Innovation, Department for Science IT. Review into bias in algorithmic decision-making. Gov.UK; 2020.

15 AI Tool Directory. The Rise of Proprietary AI: A Double-Edged Sword. 2023 [cited.

16 Lung Cancer Europe. LUCE report on lung cancer Lung Cancer Europe; 2016.

17 Defining data science and AI. [cited. Available from: https://www.turing.ac.uk/news/data-science-and-ai-glossary

Acknowledgements and Disclaimers

This study/project is funded by the National Institute for Health Research (NIHR) [NIHRIO/project reference HSRIC-2016-10009]. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

NIHR | Innovation Observatory

Newcastle University

Professor Dawn Craig
Director

T: +44(0) 191 208 2259
E: info@io.nihr.ac.uk
www.io.nihr.ac.uk