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Cancer care pathways across seven countries in Europe: What are the current obstacles? And how can artificial intelligence help?

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ABSTRACT

Background: Cancer poses significant challenges for healthcare professionals across the disease pathway including cancer imaging. This study constitutes part of the user requirement definition of INCISIVE EU project. The project has been designed to explore the full potential of artificial intelligence (AI)-based technologies in cancer imaging to streamline diagnosis and management. The study aimed to map cancer care pathways (breast, prostate, colorectal and lung cancers) across INCISIVE partner countries, and identify bottle necks within these pathways.

Methods: Email interviews were conducted with ten oncology specialised healthcare professionals representing INCISIVE partner countries: Greece, Cyprus, Spain, Italy, Finland, the United Kingdom (UK) and Serbia. A purposive sampling strategy was employed for recruitment and data was collected between December 2020 and April 2021. Data was entered into Microsoft Excel spreadsheet to allow content examination and comparative analysis.

Results: The analysed pathways all shared a common characteristic: inequalities in relation to delays in cancer diagnosis and treatment. All the studied countries, except the UK, lacked official national data about diagnostic and therapeutic delays. Furthermore, a considerable variation was noted regarding the availability of imaging

Abbreviations: ABS, Association of Breast Surgery; AI, artificial intelligence; AIOM, Associazione Italiana Oncologia Medica- Italian; BOCOC, Bank of Cyprus Oncology Centre; CCGs, Clinical Commissioning Groups; CNS, Clinical Specialist Nurse; COVID-19, Coronavirus Disease 19; CT, Computed Tomography; DRE, Digital Rectal Examination; EBUS, Endobronchial Ultrasound; EU, European Union; EUS, Endoscopic Ultrasound; ESMO, European Society of Medical Oncology; ESTRO, European Society of Therapeutic Radiology and Oncology; FIT, Faecal Immunochemical Test; GEC-ESTR, Groupe Européen de Curiethérapie and the European Society for Radiotherapy and Oncology; GOC, German Oncology Centre; GP, General Practitioner; HCPs, Healthcare Professionals; iPAAC, innovative Partnerships for Action Against Cancer; LDCT, Low Dose Computed Tomography; MDT, Multidisciplinary Team; MR, Magnetic Resonance; MRI, Magnetic Resonance Imaging; NCCN, National Comprehensive Cancer Network; NABCOP, National Audit of Breast Cancer In Older Patients; NHS, National Health Service; NICE, National Institute for Health and Care Excellence; PDTAs, Percorsi Diagnostici Terapeutici Assistenziali- Italian. Predefined Diagnostic and Therapeutic Care Pathways- English; PET/CT, Positron Emission Tomography and Computed Tomography; PIS, Patient Information Sheet; PSA, Prostate Specific Antigen; PCWG3, Prostate Cancer Working Group 3; RCT, Randomised Controlled Trial; STP, Sustainability and Transformation Partnership; TWW, Two-Week Wait; US, Ultrasound; UK, United Kingdom.

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and diagnostic services across the seven countries. Several concerns were also noted for inefficiencies/inequalities with regards to national screening for the four investigated cancer types.

Conclusions: Delays in cancer diagnosis and treatment are an ongoing challenge and a source for inequalities. It is important to have systematic reporting of diagnostic and therapeutic delays in all countries to allow the proper estimation of its magnitude and support needed to address it. Our findings also support the orientation of the current policies towards early detection and wide scale adoption and implementation of cancer screening, through research, innovation, and technology. Technologies involving AI can have a great potential to revolutionise cancer care delivery.

Policy summary: This study highlights the widespread delay in cancer diagnosis across Europe and supports the need for, systematic reporting of delays, improved availability of imaging services, and optimised national screening programs. The goal is to enhance cancer care delivery, encourage early detection, and implement research, innovation, and AI-based technologies for improved cancer imaging.

1. Introduction

Cancer is a major global cause of morbidity and mortality [1,2]. In 2020, there were 19.3 million new cancer cases and 10 million cancer deaths worldwide [1]. Factors like population aging and changes in risk factors contribute to the growing burden of cancer [1]. Breast, lung, colorectal, prostate, and stomach cancers are the most diagnosed and cause the highest mortality [1]. In Europe, there were 2.7 million new cancer cases and 1.3 million deaths in 2020, with an economic burden of €199 billion [2,3]. Cancer is expected to surpass cardiovascular disease as the leading cause of mortality, with a 24% increase in mortality rate by 2035 [2,3].

The projected future burden of cancer and its extraordinary diversity reinforce the need for global escalation of efforts to control the disease [1]. Hence, in Europe, several policies have been shaped to tackle cancer burden. Europe's Beating Cancer Plan and the EU Cancer Mission set out the latest approach within the European Union (EU) to cancer prevention, early diagnoses, treatment, care, and survivorship. Cancer management pathways has been an elusive concept lacking a universal consensus. Nevertheless, The Innovative Partnership for Action Against Cancer (iPAAC) has provided a comprehensive definition that encapsulates the essential elements of a patient pathway: "A patient pathway is an evidence-based tool that supports the planning and management of the care process of individual patients within a group of similar patients with complex, long-term conditions. It details the phases of care, guiding the whole journey a patient takes by defining goals and milestones, and supports mutual decision-making by the patient and his/her multidisciplinary care team collaborating in a comprehensive network of care providers" [4].

Despite the great potential that these policy initiatives create at a macro level, it is imperative to be also relevant to the national level, the cancer centre level and at the workforce level. Hence the micro level in introducing such policies also becomes critical in their successful uptake and sustainability. Across the E.U countries, there is a wealth of diversity as well as country-specific inequalities and specificities when it comes to existing cancer pathways. National Cancer Plans are existent in most European countries; however, these are highly dependent on the resources allocated to health by their government. This fact poses by definition a challenge for the effective and efficient implementation of policies developed at a macro level. This study echoes these challenges, and its design was purposively developed to retrieve data from the oncology workforce in relation to the specific characteristics of the cancer pathways in the participating countries.

These policy flagships focus on new technologies, research and innovation as major drivers for change with the contribution of several EU initiatives for investment and funding such as Horizon Europe [2]. INCISIVE, an EU project funded under the programme Horizon 2020 [5]. The project has been designed to explore the full potential of artificial intelligence (AI) based solutions in cancer imaging and diagnosis [5].

1.1. An overview about the INCISIVE project

INCISIVE [5,42,43,44] is an EU Horizon 2020 funded project spanning 9 European countries. It aims to develop and validate an AI-based toolbox to enhance the accuracy, sensitivity, specificity, interpretability, and cost-effectiveness of cancer imaging methods [5]. The project focuses on breast, prostate, lung, and colorectal cancers, which are among the most prevalent cancer types [1,6]. The INCISIVE project aims at introducing a change in the existing cancer management pathways of these cancer types in the participating countries. As the AI-based toolbox has been designed to deliver a variety of inference services its impact potentially has effects across the cancer continuum.

Given the variability in cancer management pathways across different countries, it is crucial to investigate and analyse these pathways (e.g., how are these deployed in everyday clinical practice, diversities from internationally established guidelines) within the collaborative framework of projects like INCISIVE. This study aims to map the existing cancer care pathways across the INCISIVE partner countries, identifying commonalities, differences, and areas for improvement in utilizing imaging for cancer diagnosis and follow-up. Retrieving data from the oncology workforce who will be utilising the AI-based toolbox is essential to understand the ways to optimally (e.g., without the need to plan extra time and in a way that it is seemingly incorporates in daily practice) introduce it in their practice. The consortium does not seek a one-fits-all approach to this technological solution, but rather a toolbox that allows for personalised variations (i.e., allowing for variability, adjustments) according to the specificities of the cancer centres where it will be implemented. The findings will ultimately inform the application of INCISIVE's AI-based technology in supporting these pathways and improving patient outcomes. Additionally, the study aims to uncover obstacles (e.g., limited specialisation) and similarities (e.g., patients point of contact for diagnoses) within the pathways to maximize the applicability of INCISIVE outcomes across diverse care contexts. In the European context, the data that were retrieved can also support the efficient mobility of European citizens. They provide a scope of existing pathways allowing them to reach an informed decision on where they wish to undergo their diagnosis procedures, treatment, and care. These data can prospectively also form the basis of a wider European tool that tracks inequalities such as the one introduced by the European Cancer Organisation – the Cancer Pulse (https://www.europeancancer.org/pulse).

2. Materials and methods

This is a qualitative study that forms a part of the user requirement definition of the INCISIVE (https://incisive-project.eu/) project [5].

2.1. Study design

A qualitative research approach employing email interviews was used. This phase was conducted across seven partner countries of INCISIVE: Greece, Cyprus, Spain, Italy, Serbia, the United Kingdom (UK) and Finland.

Email interviews proved ideal for the current study amidst the COVID-19 pandemic, addressing both financial constraints and geographical barriers that hindered in-person interviews [7–10]. This method offered several advantages: asynchronous communication allowed participants to respond at their convenience, promoting reflective responses [7], data quality comparable to traditional methods [11–13], streamlined transcription [14], suited electronically responsive participants [15,16], and provided flexibility in participant selection [17]. While probing can be limited in email interviews in general [10], the research team ensured the capture of all the required information from participants via follow-up emails when additional information or clarifications were needed.

2.2. Participants and recruitment

A purposive sampling strategy based on the knowledge of the project's consortium was used to recruit participants. This involved recruiting oncology specialised healthcare professionals (HCPs) representing participating centres (i.e., specialised cancer centres/hospitals) from the partner countries to identify the current clinical pathways for cancer management in each country.

2.3. Data collection tool

The research team developed an interview topic schedule (Appendix A) consisting of 29 questions. The interview schedule was developed based on the study aims in coordination with the project consortium. The schedule aimed to guide data collection and explore the care pathway in each country. The questions covered various aspects of cancer management, including referral pathways, guidelines used, national screening programs, diagnosis procedures, imaging methods, healthcare teams involved in patient care, treatment response, post-treatment care, and identification of decision makers and influential bodies in oncology technology investments.

2.4. Data collection

Data collection took place from January to April 2021. Each partner in the INCISIVE consortium selected one oncology specialized HCP to participate in the email interview on behalf of their institution. The goal was to have a diverse representation of perspectives and experiences within the consortium. The research team provided the participants with the necessary documents, including the participant information sheet, consent form, and interview questions. Participants were asked to provide their informed consent and answer the questions. A total of ten email interviews were conducted, with three participants from Greece, two from Italy, and one each from Spain, the UK, Serbia, Finland, and Cyprus. Spain focused specifically on the prostate cancer care pathway due to the partners' specialization in this area. The interviews were conducted in English, eliminating the need for translation.

2.5. Data analysis

A descriptive analysis was carried out to explore differences and similarities in the cancer care pathways across the seven countries. Content analysis [18] was conducted to identify themes in the data, in conjunction with comparative research [19]. Data was entered into Microsoft excel spreadsheet to allow content examination and comparative analysis.

2.6. Ethical considerations

All methods were performed in accordance with the Declaration of Helsinki and has been approved by Kingston University (KU) Research Ethics Committee. The ethical approval was obtained for this study on 25th November 2020 (Reference No. 2687).

3. Results

3.1. Mapping cancer care pathway

Figs. 1, 2, 3 and 4 illustrate the current care pathways for breast, prostate, lung, and colorectal cancers, respectively in the investigated countries.

3.2. Analysis of the email interviews

In this section, the identified themes related to cancer care across different countries are compared.

- **Theme 1: Inconsistent Rollout of National Screening Programs**

This theme emphasizes differences in how cancer screening programs are provided and implemented across the different countries (Table 1: Cancer Screening Programs), which can lead to discrepancies in patient access and care quality. Cancer screening programs in all countries are nationally implemented, except for Italy, which employs regional implementation. Breast cancer screening, targeting asymptomatic women aged 50–69, is implemented in all countries, although it is loosely established in Greece. Cyprus is the only country with a national prostate cancer screening program for asymptomatic men aged 50–70. There are no established screening programs for Lung cancer in these countries, except for ongoing trials in Serbia and the UK and a recent decision to launch screening in Finland. The UK and Serbia have established national colorectal cancer screening programs, while Finland has a pilot project, and Italy manages regional screening for people aged 50 and above. Moreover, within Italy, most regions offer complimentary periodic mammograms and cervical smear tests, as well as HPV testing, for women in specified age groups, typically ranging from 45 to 70 years. Additionally, in certain Italian regions, individuals aged 50 and above have the option to undergo colonoscopy every five years.

This inconsistent rollout can impact the fair distribution of healthcare services and outcomes. A HCP provided information about their country's national screening programs in the following statement.

> ''*In Italy, the screening programs are in charge to the regional health system (SSR, servizio sanitario regionale), thus the answer is no. However, while there are not regional screenings for lung and prostate cancer, in almost all regions, for defined ranges of aged women (generally 45–70) have free access to periodic mammographic control and cervical smear and HPV testing*'' *(HCP1-Italy)*

- **Theme 2: Lack of Resources**

  The limitations in healthcare resources (infrastructure and personnel) are explained in this theme. The lack of availability of specialised staff and the necessary diagnostic equipment creates unequitable access to care increasing the impact of health inequalities.

  In Finland, imaging and diagnostic services are available in all University hospitals, whereas not all hospitals in Greece have access to imaging services, particularly MRI scanners. In Italy, traditional x-ray and CT scanners are commonly available, but the availability of MRI and PET/CT scanners is more limited. In the UK, some advanced screening techniques like CT scans, bone scans, PET/CT scans, endoscopic ultrasound (EUS), and endobronchial ultrasound (EBUS) are not universally available in all hospitals. Cyprus has limited access to diagnostic and imaging services within public general hospitals. In primary care in Serbia, US is usually available, while mammography is not available in every primary healthcare unit. In

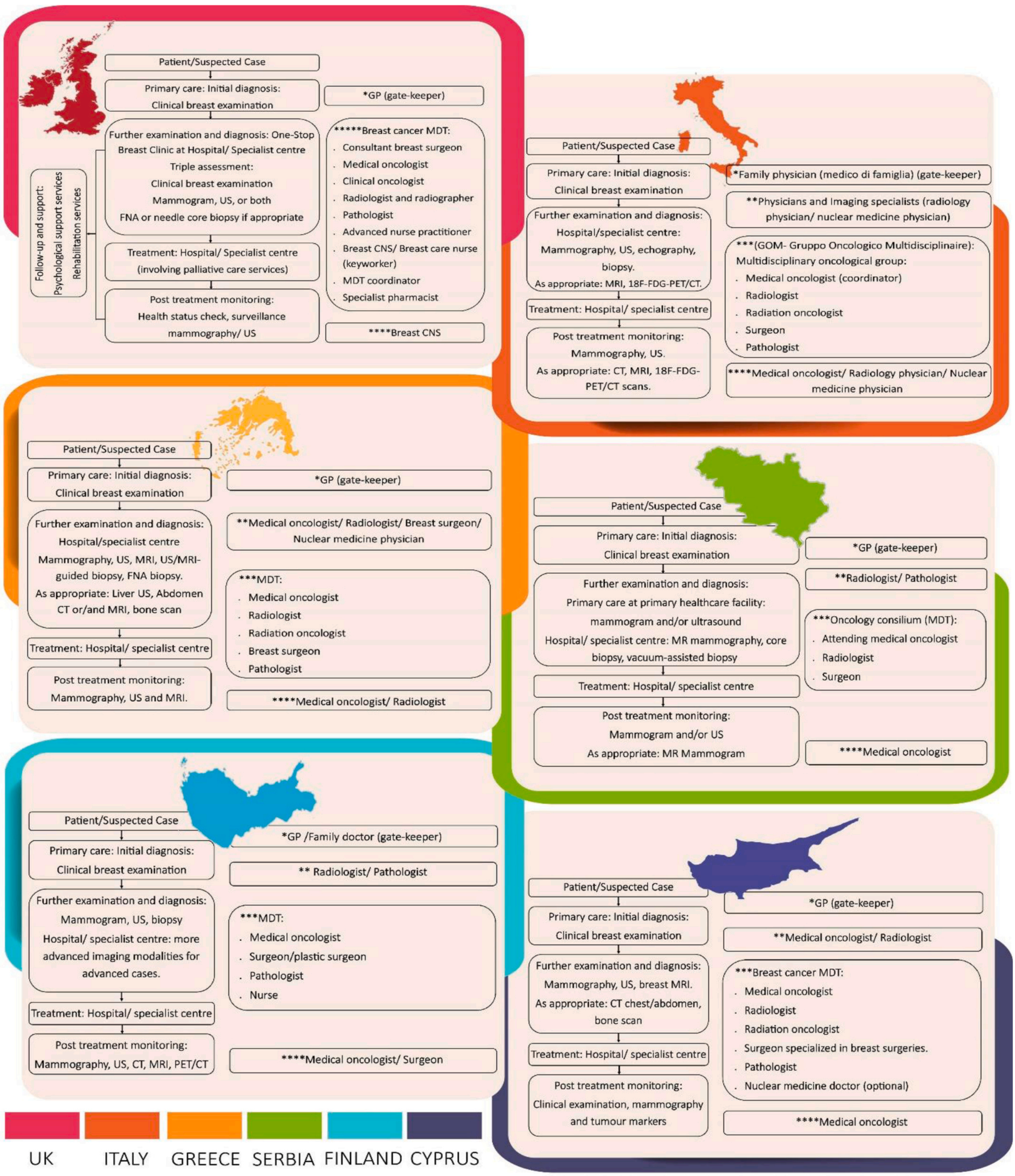

Fig. 1. Breast cancer care pathways in six European countries. * First healthcare professional(s) involved in the care pathway. * *Healthcare professionals involved in further examination and diagnosis including disease staging. * ** Healthcare professionals involved in treatment. * ** * Healthcare professionals involved in post-treatment monitoring. * ** ** Healthcare professionals involved in further examination and diagnosis (including disease staging) and treatment at the same time.

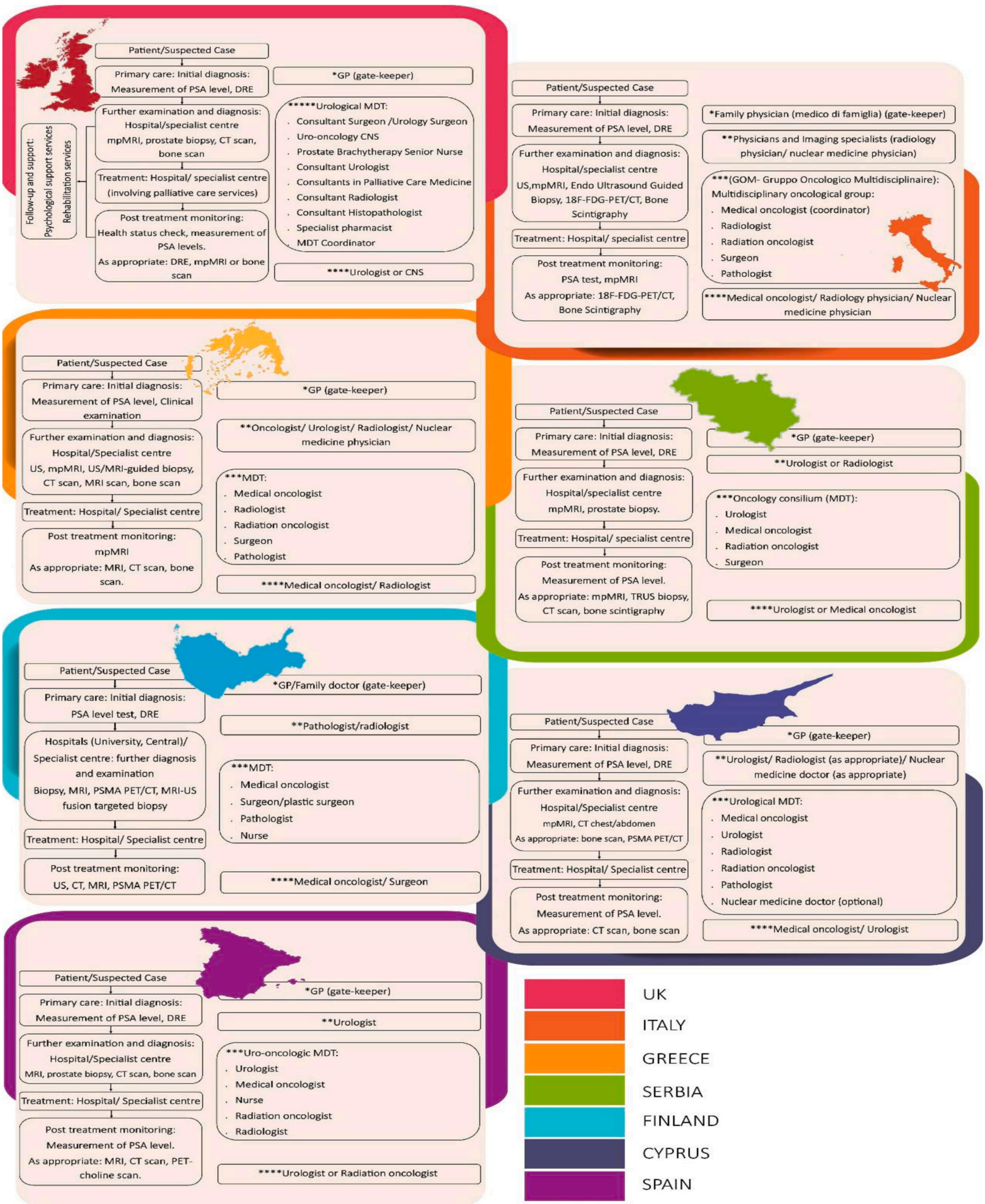

Fig. 2. Prostate cancer care pathways in seven European countries. * First healthcare professional(s) involved in the care pathway. * *Healthcare professionals involved in further examination and diagnosis including disease staging. * ** Healthcare professionals involved in treatment. * ** * Healthcare professionals involved in post-treatment monitoring. * ** ** Healthcare professionals involved in further examination and diagnosis (including disease staging) and treatment at the same time.

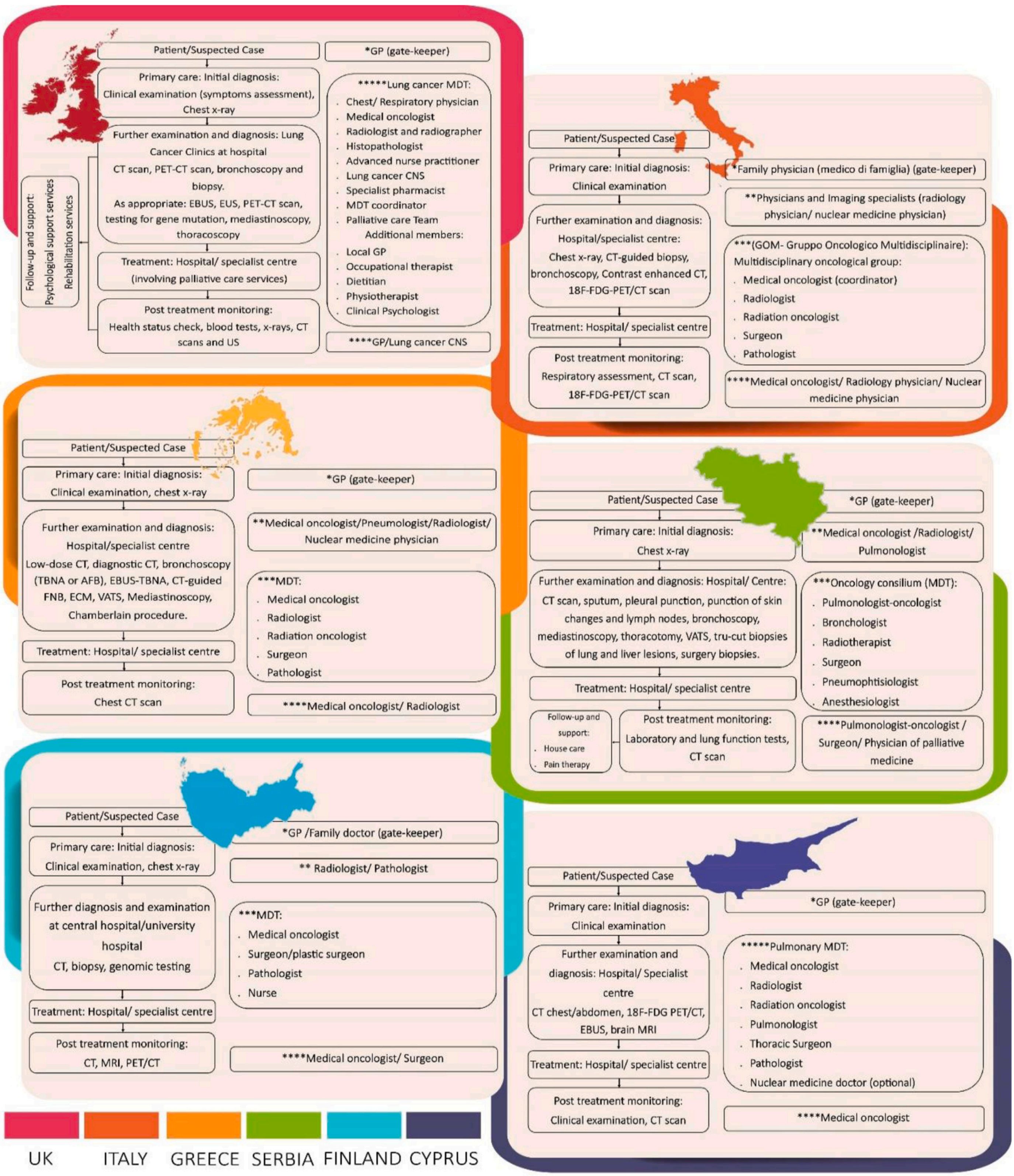

Fig. 3. Lung cancer care pathways in six European countries. * First healthcare professional(s) involved in the care pathway. * *Healthcare professionals involved in further examination and diagnosis including disease staging. * ** Healthcare professionals involved in treatment. * ** * Healthcare professionals involved in post-treatment monitoring. * ** ** Healthcare professionals involved in further examination and diagnosis (including disease staging) and treatment at the same time.

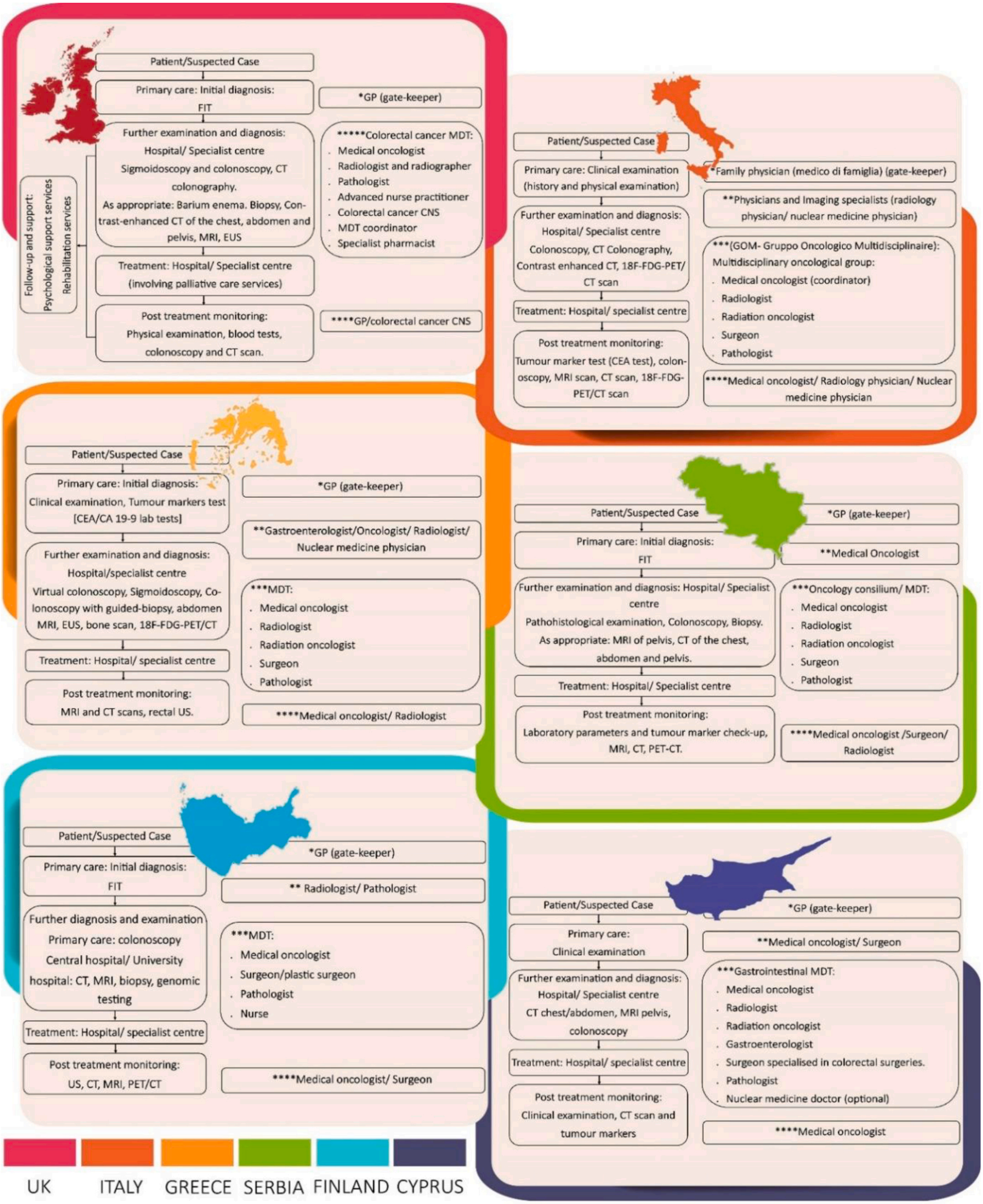

Fig. 4. Colorectal cancer care pathways in six European countries. * First healthcare professional(s) involved in the care pathway. * *Healthcare professionals involved in further examination and diagnosis including disease staging. * ** Healthcare professionals involved in treatment. * ** * Healthcare professionals involved in post-treatment monitoring. * ** ** Healthcare professionals involved in further examination and diagnosis (including disease staging) and treatment at the same time.

Table 1
Cancer Screening Programs.

Country	Types of tumours			
	Breast	Prostate	Lung	Colorectal
UK	National program targeting asymptomatic women aged 50–69.	Opportunistic screening through PSA lab test and clinical examination in men > 45 years of age.	Targeted Lung Health Checks" pilot program operating in 23 centres at the moment for people over 55 who have ever smoked.	National program offered to people aged 60–74 in England, Wales, and Northern Ireland, and people aged 50–74 in Scotland (to be extended to include people aged 50–59 in April 2021).
Greece	Loosely implemented national program with no precise eligibility criteria.	Opportunistic screening through PSA lab test and clinical examination in men > 45 years of age.	No established screening program.	No established screening program.
Serbia	National program targeting asymptomatic women aged 50–69.	No established screening program.	National trial program using LDCT scanning since September 2020 in the northern part of the country.	National program targeting population aged 50–74.
Italy	Regional programs managed under the regional health system.	No established screening program.	No established screening program.	Screening managed under the regional health system and available in some parts of the country for people aged 50 and above.
Finland	National program targeting asymptomatic women aged 50–69.	No established screening program.	Recently decided to launch screening program using LDCT scanning.	Pilot project underway since 2019.
Cyprus	National program targeting asymptomatic women aged 50–69.	National program targeting asymptomatic men aged 50–70.	No established screening program.	No established screening program.
Spain	National program targeting asymptomatic women aged 50–69.	No established screening program.	No established screening program.	No established screening program.

Spain, MRI imaging is available in most specialist centres, though not universally across all facilities. This lack of resources can impact the success of cancer screening programs and timely diagnosis which could reflect in the quality of care provided to patients. This issue was reiterated in the statement shared by one of the HCPs

''The above imaging/diagnostic services are not available in all hospitals, but specialist centres tend to provide the full range of services'' (HCP-3, Greece).

The same HCP also reported that one of the delays in cancer diagnosis is due to lack of human resources.

''There are no national reports of delay in diagnosis. In general, delays may be experienced on an individual basis due to multiple reasons (human resources, etc.*)''. (HCP3-Greece)*

Shortage of human resources in healthcare, leading to delays in cancer diagnosis, can have a profound impact, possibly resulting in late-stage cancer diagnoses, reduced treatment choices and reduced patient outcomes. In contrast, countries with better resource allocation may offer more efficient and timely services.

For more details, refer to supplemental file 1: Lack of resources

- **Theme 3: Delayed diagnosis**

Even though most countries lacked official national data to quantify delays in the pathway, all participants described a concern for a delay in diagnosis which can then delay the start for treatment. In many countries, private healthcare systems offer faster diagnostic routes compared to the national healthcare system. In Italy, there is a growing demand for specialist referrals and diagnostic procedures, although no national reports on diagnostic delays exist. The UK stands out with national cancer audits for various tumour types within the NHS. However, there is a lack of reports regarding the private healthcare system.

It was also noted that COVID 19 had a significant impact on timely cancer services for example in the UK, many women missed mammograms due to COVID-19-related screening program pauses. For prostate cancer, the average time it takes for a man to receive a diagnosis of prostate cancer in England is 56 days following referral far longer than the 28-day target according to the latest national statistics. Delays in lung cancer diagnosis were observed, with an average diagnostic interval of over three months in the North of England, especially for early-stage diseases. Colorectal cancer diagnosis delays affected nearly a third of patients, resulting in a two-month longer wait compared to those without avoidable delays. HCP from Serbia reported that,

''There are no available reports for delay in diagnosis on the national level. It differs between private and national system, since in private healthcare system, diagnostic is usually available at much shorter notice''. (HCP 1-Serbia)

The significant delay in cancer diagnosis may result in unequal access to timely cancer diagnosis and potentially compromise patient outcomes.

For more details, refer to supplemental file 2: Delayed diagnosis

- **Theme 4: Lack of National Audits**

The absence of comprehensive national data audits for cancer care and treatment are covered under this theme. The UK stands out as the only country that keeps national cancer audits for different tumour types within the National Health Service (NHS), providing a valuable source of data on cancer diagnosis and treatment. This lack of national audits makes it tough to monitor and address delays in the healthcare system, hampering quality control and improvement efforts. National audits could help other countries improve accountability and healthcare quality.

''There are usually national cancer audits which report delays for the different tumour types. Nearly a third of bowel cancer patients experience a delay to their diagnosis that could have been avoided. Half of all patients who experienced a delay waited around two months longer to be diagnosed compared with those who did not have an avoidable delay''. (HCP1-UK)

For more details, refer to supplemental file 3: National data and statistics on treatment delays for four tumour types in different countries

- **Theme 5: Two-Tier Health System (Private and Public)**

In this theme, the existence of a parallel private healthcare system alongside the public system is detailed. Even though private healthcare systems provide a solution for those who can self-fund their care, it deepens the health divide and creates further health inequalities.

All the countries under study allow patients to self-refer to specialists for suspected cancer, which is frequently made easier by the private healthcare system. In Greece, self-referral can be done within the national and private healthcare systems. Whereas in Italy, Serbia, Finland, Cyprus, and Spain this is usually done within the private healthcare system where patients would consequently incur most of the charges for diagnostic tests and treatment. Access to diagnostic tests and treatment in the private system may involve higher costs. A referral letter from an NHS GP may still be necessary for patients in the UK who choose to continue with the private healthcare system. In all the nations studied, the private system is frequently regarded as being more effective in terms of quick access to diagnostic services and the initiation of treatment. HCP shared that

'' They can refer directly; it is easier in case of private healthcare system. In the public system, being referred to a specialist or to imaging facility should pass the first filter of the GP unless if there is a direct screening program at specialized health centre''. (HCP 1-Spain)

Overall, the access to healthcare can vary significantly based on an individual's ability to afford private services.

For more details, refer to supplemental file 4: Two-Tier Health System (Private and Public)

- **Theme 6: Role of Multidisciplinary Teams (MDTs)**

In all the seven countries, Multidisciplinary Teams (MDTs) play a critical role in the treatment decision and management of various cancer types, including breast, prostate, lung, and colorectal cancer. These teams may vary slightly in their composition, but they generally consist of core members, such as medical oncologists, radiologists or radiation oncologists, surgeons, and pathologists. Additionally, the inclusion of specialist consultants depends on the specific type of cancer. Nurses and pharmacists are not universally recognized as core members of MDTs across all countries. However, there are exceptions. In the UK and Finland, specialist pharmacists and clinical nurse specialists (CNSs) are considered additional core members of MDTs. In Finland, nurses are part of the MDTs, but pharmacists are not included. Both Italy and the UK have MDT coordinators within their teams. In Italy, the role of the coordinator is typically assigned to the medical oncologist, while in the UK, the MDT coordinator has various responsibilities. HCP reported that,

''There are several multidisciplinary teams. The composition of the teams varies according to the cancer, but often an oncologist, surgeon, plastic surgeon, pathologist. Many times, also nurse is involved. Each doctor is responsible for his or her own responsibilities. The oncologist plans radiotherapy or chemotherapy, the surgeon thinks about the area to be cut, the pathologist tells the histology''. (HCP-1, Finland).

For more details, refer to supplemental file 5: Multidisciplinary Teams (MDTs).

4. Discussion

This is the first of its kind to comprehensively map the cancer care pathways for breast, prostate, colorectal, and lung cancers across European countries. The themes highlighted both common challenges and variations in cancer care and the healthcare systems of the studied countries, providing valuable insights into the strengths and weaknesses of their respective approaches to cancer diagnosis and treatment.

The study identified three key bottlenecks: diagnostic delays, therapeutic delays, and resource constraints. Regarding the first two bottlenecks, the intervals regarding diagnosis, treatment and follow-up differed between the countries, and all countries indicated faster diagnostic and treatment routes within the private healthcare system compared to the national/public one. Except for the UK, it was difficult to determine the scope of these problems in each country due to the absence of official national statistics on delays in diagnosis and treatment. Research in the UK indicated that 25% of cancer patients had avoidable delays in diagnosis, which increased the diagnostic gap by a median of two months [20].

Cancer diagnosis and treatment delays globally present significant challenges, impacting cancer severity, treatment options, prognosis (including mortality), and patient experience [21,22]. Timely diagnosis is crucial in Europe, as it is associated with improved survival rates, and there is substantial variation in cancer survival rates among European countries, partly due to differences in timely diagnosis [21]. Delays in cancer treatment have adverse consequences on patient outcomes. A comprehensive study examining major cancer types found that even a four-week treatment delay significantly increases mortality risk across surgical, systemic, and radiotherapy treatments [22]. For instance, surgery delays of four weeks result in a 6–8% increase in mortality risk, while radiotherapy for head and neck cancer and adjuvant systemic therapy for colorectal cancer show a 9% and 13% increased mortality risk, respectively [22]. An eight-week delay in breast cancer surgery increases mortality risk by 17%, and a twelve-week delay raises the risk to 26%. Prolonged delays of up to eight or twelve weeks significantly increase the chance of death [22]. Thus, minimizing treatment initiation delays is crucial for improving population-level survival outcomes [22]. The UK was the only country with available data on delays in meeting national standards for diagnosis and treatment. Recent research in the UK indicated that a quarter of cancer patients experienced avoidable delays in diagnosis within one year, with the median diagnostic interval increased by two months [20].

Cancer screening plays a vital role in early detection and improving survival rates [2,3]. Patients diagnosed early, at stages 1 and 2, have the best chance of curative treatment and long-term survival [20,21]. However, the current study highlighted some concerns pertaining the current status of screening programmes across the seven countries. Despite lung cancer being the most fatal cancer in Europe, our study revealed that none of the seven countries examined had established an organized national screening program for this disease, despite strong evidence supporting the effectiveness of screening [3,23,24]. These findings underscore the absence of formal national lung cancer screening initiatives in the studied nations, despite the growing body of research demonstrating the significant benefits of implementing such programs. This finding also stresses the need for National States to implement the latest screening guidelines released by the European Commission [25]. According to these "lung screening programmes should integrate primary and secondary prevention approaches, starting with high-risk individuals. Special attention should be given to the identification and targeting of high-risk profiles, starting with heavy smokers and ex-smokers who used to smoke heavily, and Member States should further research how to reach and invite the target group, as there is no systematic data (documentation) on smoking behaviour" (p22).

Similar gaps were identified for prostate, colorectal, and breast cancers, with limited national screening programs available. From a National State perspective these findings demonstrate the poor investment in such screening programmes across the EU, despite the EU screening recommendations have been made for breast, cervical and colorectal cancer [26]. Optimizing existing cancer screening programs and extending organized population-based screening to other common cancer types, such as lung and prostate cancers, is crucial. Aiming to promote broad screening for colorectal, breast, and cervical cancers, initiatives like the EU Cancer Screening Scheme also take additional cancers into consideration when recommending screening [2]. The study emphasized the need for renewed commitments to cancer prevention, treatment, and care, as reflected in initiatives like Europe's Beating Cancer Plan [2] and the NHS Long Term Plan [27]. These plans focus on increasing early detection, improving the proportion of cancers diagnosed at earlier stages, and enhancing the quality of life for cancer patients and survivors. Digital transformation and innovative technologies, including AI and High-Performance Computing (HPC), are seen as powerful tools to optimize cancer prevention and care [2]. AI has the potential to improve diagnostic accuracy, streamline screening logistics, and address challenges in oncology care such as reliable early detection, accurate tumour classification, and prediction of tumour aggressiveness and recurrence [28–31].

The study also identified that the lack of widespread availability of advanced imaging modalities is a bottleneck in cancer care. AI can play a significant role in workflow improvement [32–34], productivity enhancement, high-quality image production, image interpretation, segmentation, registration, and radiomics analysis. By addressing these aspects, AI can help alleviate workloads and enhance the capabilities of radiologists, radiographers, and other medical imaging staff [32–34].

Several actions can be taken to overcome the bottlenecks found in the clinical cancer pathways. First, implementing standardised national norms and protocols is necessary for enhancing the timeliness of diagnosis and treatment, as well as putting in place reliable data collection mechanisms to track delays. Investment in healthcare infrastructure and resources, such as increasing the availability of imaging modalities and specialist centers, can also help reduce delays and ensure timely diagnosis and treatment.

Second, based on the most recent scientific data, improving and expanding cancer screening programmes can result in early detection and higher survival rates. It is imperative to expand screening programmes to encompass frequent cancer forms that do not currently have organised population-based screening. Advancements in screening technologies, such as blood-based tests and AI-assisted screening, should be considered.

Additionally, combining AI with cutting-edge technology can greatly improve cancer prevention, diagnosis, and treatment. AI can improve the accuracy and efficiency of cancer diagnosis through automated image interpretation, tumor classification, and prediction of tumor characteristics. AI-assisted workflow can streamline radiology services and alleviate workloads. Big data analytics and digitization can improve cancer treatment paths and offer insightful data for personalised medical techniques.

Funding and resource allocation for cancer research, technological advancement, and infrastructure improvement must be prioritised in order to support these activities. To advance research and put effective cancer policies in place, cooperation between governments, healthcare providers, academic institutions, and industry players is crucial. Regular monitoring and evaluation of policy outcomes and benchmarking against international standards can help identify areas that require further improvement and ensure the effectiveness of policy interventions.

The role of oncology nurses and pharmacists needs to be explored, evolved, and formalized to optimize cancer care pathways and improve patient outcomes. Oncology nurses play a crucial role in providing holistic care to cancer patients, including administering treatments, managing side effects, and providing emotional support. Therefore, it is essential to enhance the role of oncology nurses by providing advanced training [35] promoting interdisciplinary collaboration [36] and integrating their expertise into decision-making processes [37]. Similarly, pharmacists play a vital role in cancer treatment by ensuring safe and effective medication use, managing drug interactions and side effects [38,39], and providing patient education [40]. Integrating pharmacists as integral members of the cancer care team and formalizing their involvement in treatment decision-making processes can contribute to more efficient and effective cancer care.

5. Strengths and limitations

To our knowledge, this study is the first to explore the clinical pathways for the most prevalent cancer types (breast, lung, colorectal and lung cancer) across different European countries, which is a key strength for this study. However, some limitations do exist, including the small sample size and the possibility of selection bias given that the participants were recruited from large specialised oncology centres, these are typical limitations of qualitative research involving interviews [41]. In addition, it is important to acknowledge that email interviewing, while utilized in this study for its practicality, has its own set of limitations for an exploratory study. One notable limitation is that it restricts probing and gathering of contextual insights. However, the research team ensured to capture all the required information from participants via follow-up emails when additional information/clarifications were needed.

6. Conclusion

This study highlights the widespread delay in cancer diagnosis across Europe and supports the need for, systematic reporting of delays, improved availability of imaging services, and optimised national screening programs. The goal is to enhance cancer care delivery, encourage early detection, and implement research, innovation, and AI-based technologies for improved cancer imaging.

This supports the current policies in Europe that prioritize early detection of cancer through research, innovation, and technology. In this regard, the potential of AI technologies to revolutionize cancer care delivery is particularly promising.

Ethics approval and consent to participate

All methods were performed in accordance with the Declaration of Helsinki and has been approved by Kingston University (KU) Research Ethics Committee. The ethical approval was obtained for this study on 25th November 2020 (Reference No. 2687). Written informed consent was obtained from participants prior the interviews.

Authors contributions

IH, SNG and RK were involved in study design and conceptualisation. IH conducted the research and collected the data. AC, ML, ES, WA, JB, TA were also involved in data collection. Data analysis was completed by IH, SNG and RK. IH was responsible for drafting the initial manuscript. All authors were involved in data interpretation, manuscript writing, and critical review. All authors read and approved the final manuscript.

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Declaration of Competing Interest

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Consent for publication

Not applicable.

Appendix A

Interview schedule for oncology specialised healthcare professionals regarding cancer care pathways

Please describe a patient's journey from diagnosis to post treatment care.

- Section 1: First point of contact in the care pathway:

1. What happens when a person suspects they have cancer? Who do they go to see first? How would that differ between national and private healthcare systems?
2. Can patients self-refer themselves to a specialist or to imaging facilities if they suspect cancer? Is that true for all cancers?

- **Section 2 : National Screening programmes (Please answer these questions separately for each of the following types of cancer: Lung cancer, breast cancer, colorectal cancer, prostate cancer).**

3. Are there any national screening programs in your country? If, yes, please describe.
4. How many patients are approximately detected per year through each screening program?
5. Who is the main gatekeeper for each screening program?

- **Section 3 : Guidelines**

6. Are there any specific guidelines (international, national or local) followed for the management of breast cancer? (Can you please specify)
7. Are there any specific guidelines (international, national or local) followed for the management of lung cancer? (Can you please specify)
8. Are there any specific guidelines (international, national or local) followed for the management of colorectal cancer? (Can you please specify)
9. Are there any specific guidelines (international, national or local) followed for the management of Prostate cancer? (Can you please specify)

- **Section 4 : Diagnosis (Please answer these questions separately for each of the following types of cancer: Lung cancer, breast cancer, colorectal cancer, prostate cancer).**

10. Who is the patient referred to next for further testing/imaging?
11. How long does that usually take?
12. Is any part of the diagnostic procedure done in primary care? If yes, please elaborate.
13. What are the diagnostic tests and images used?
14. Can you please describe each diagnostic method in terms of its success rate and accuracy (if possible, can you please provide an estimation of any false positives or false negatives)?
15. Are the imaging/diagnostic services available in all hospitals or specialist centres?
16. Have you had any national reports of delay in diagnosis? What are the documented reasons? Would that differ between national and private healthcare systems?
17. Have there been any measures/plans put in place to reduce diagnostic delay?
18. How many patients are diagnosed per year in each centre?

- **Section 5 : Treatment (Please answer these questions separately for each of the following types of cancer: Lung cancer, breast cancer, colorectal cancer, prostate cancer).**

19. Once the patient has a diagnosis, what happens next? How long before treatment is started?
20. Have you had any national reports of delay in the start of treatment? Would that differ between national and private healthcare systems?
21. Have there been any measures/plans put in place to reduce treatment delay?
22. Who is responsible for the patient's treatment? Is there a multidisciplinary team? Who are the members of the team? What are their responsibilities?
23. How are patients monitored between cycles?

- **Section 6 : Post-treatment care: patient monitoring**

24. How are patients monitored after end of treatment?
25. What are the follow-up care service available for cancer patients?
26. Who are the healthcare professionals and/or teams involved in patients monitoring post-treatment?
27. Are there any specific monitoring techniques or imaging techniques applied for monitoring patients? (Is this different for different tumour types)

- **Section 7 : Adoption of innovations in the country**

28. Who are the decision makers involved in investing in new technologies (like INCISIVE) in your country?
29. Who are the influencers/ influencing bodies involved in the investment process for new technologies (like INCISIVE) in your country?

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jcpo.2023.100457.

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