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Landscape of cancer biomarker testing in England following genomic services reconfiguration: insights from a nationwide pathologist survey

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ABSTRACT

Aims Cancer diagnostics have been evolving rapidly. In England, the new National Health Service Genomic Medicine Service (GMS) provides centralised access to genomic testing via seven regional Genomic Laboratory Hubs. The PATHways survey aimed to capture pathologists' experience with current diagnostic pathways and opportunities for optimisation to ensure equitable and timely access to biomarker testing.

Methods A nationwide survey was conducted with consultant pathologists from regional laboratories, via direct interviews based on a structured questionnaire. Descriptive analysis of responses was undertaken using quantitative and qualitative methods.

Results Fifteen regional centres completed the survey covering a median population size of 2.5 (1.9–3.6) million (each for n=12). The median estimated turnaround time (calendar days) for standard molecular markers in melanoma, breast and lung cancers ranged from 2 to 3 days by immunohistochemistry (excluding NTRKfus in breast and lung cancers, and PD-L1 in melanoma) and 6–15 days by real-time-PCR (excluding KIT for melanoma), to 17.5–24.5 days by next-generation sequencing (excluding *PIK3CA* for breast cancer). Tests were mainly initiated by pathologists and oncologists. All respondents discussed the results at multidisciplinary team (MDT) meetings. The GMS roll-out was perceived to have high impact on services by 53% of respondents, citing logistical and technical issues. Enhanced education on new pathways, tissue requirements, report interpretation, providing patient information and best practice sharing was suggested for pathologists and other MDT members.

Conclusion Our survey highlighted the role of regional pathology within the evolving diagnostic landscape in England. Notable recommendations included improved communication and education, active stakeholder engagement, and tackling informatics barriers.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Genomics testing is a rapidly evolving cornerstone of cancer treatment, allowing clinicians to offer personalised medicines to patients. In England, the recent implementation of the Genomics Medicines Services has transformed the solid tumour molecular diagnostics pathway.

WHAT THIS STUDY ADDS

⇒ The PATHways survey captured the real-world experience of pathologists involved in biomarker testing and the challenges and opportunities of transition towards expanded and centralised genomic services. Our findings highlight the important role of pathology within this new model.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The recommendations provided by the authors will help clinical teams review and optimise their local genomic testing pathways to ultimately improve patient care.

INTRODUCTION

Over the past decade, transformative advances in genomic sequencing technologies and the corresponding increase in potentially actionable oncogenic targets have facilitated a vast expansion of genomic testing in cancer. Use of technologies such as next-generation sequencing (NGS) and whole-genome sequencing for routine diagnosis and patient management brings great opportunities alongside some challenges. A personalised approach to optimal therapy selection based on molecular markers relies on equitable and timely access to the tests.

The UK has been at the forefront of integrating genomics into routine healthcare following the success of Genomics England's 100 000 Genome Project, which laid the foundation for the National Health Service (NHS) England Genomic Medicine Service (GMS) launched in 2018. Delivery of the GMS is underpinned by consolidation of genomic testing to seven regional Genomic Laboratory Hubs (GLHs) and the publication of a National Genomic Test Directory. This directory specifies the genomic tests commissioned by the NHS, its technology and the patient eligibility criteria.[1 2]

Consolidation of genomic testing requires effective collaboration among multiple stakeholders (figure 1). In optimising diagnostic pathways from pathology through to regional genomic laboratories, there are several technical

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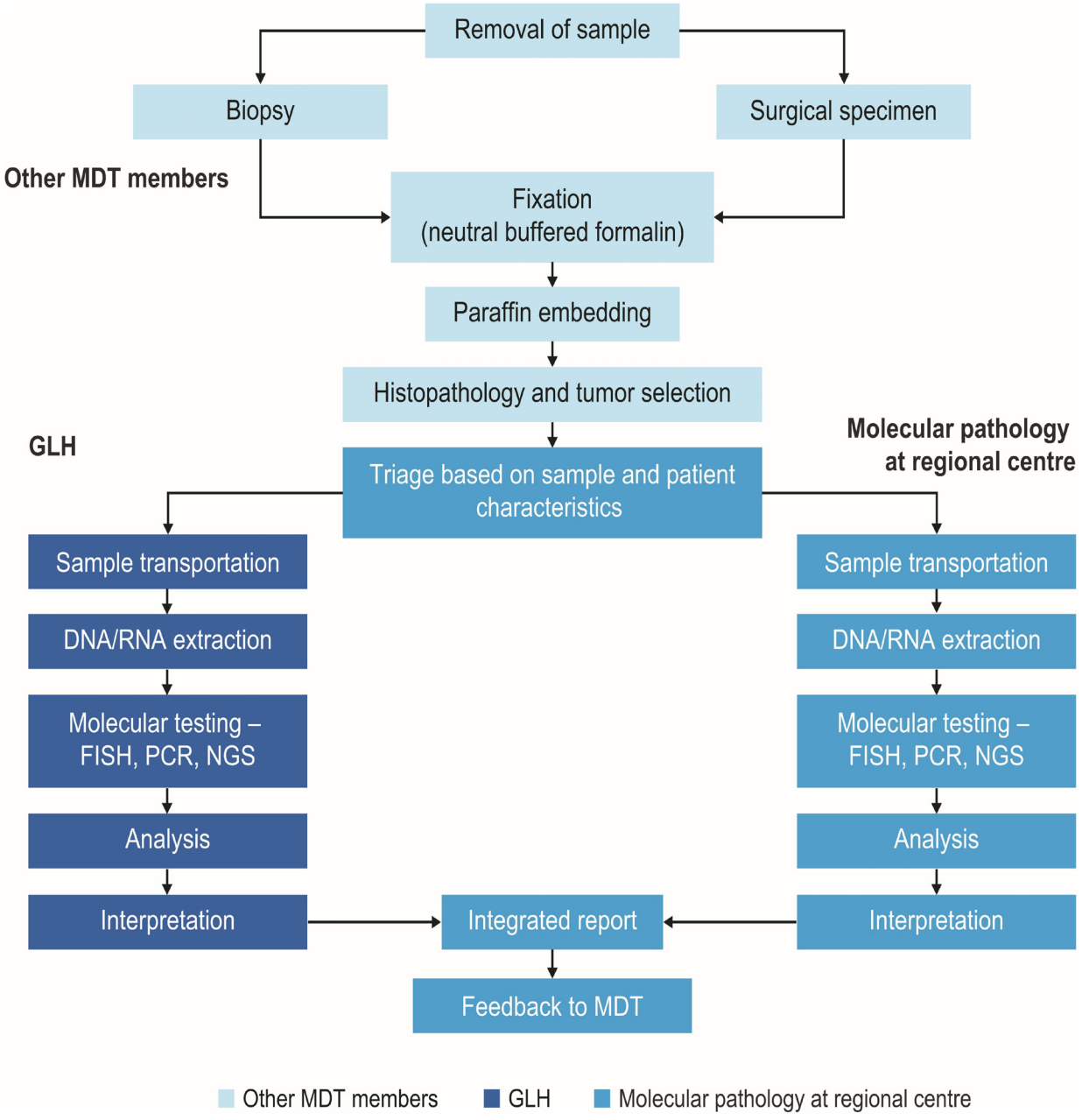


Figure 1 Workflow for genetic testing within the NHS England Genomic Medicine Service Regional pathology plays a central role in supporting the delivery of genomic services. Pathologists have the critical responsibility in driving the evolving diagnostic pathways by integrating and interpreting morphological, immunohistochemical and molecular data from sources alongside other clinical information to offer expert opinions on diagnostic and prognostic information. FISH, fluorescence in situ hybridisation; GLH, Genomic Laboratory Hub; MDT, multidisciplinary team; NGS, next-generation sequencing; NHS, National Health Service.

and logistical challenges that require transformation via collaboration across all members involved in the delivery of clinical diagnostics.[3]

In the view of ongoing centralisation of genomic services in England, the PATHways survey aimed to understand the current and evolving molecular pathology services from the perspective of pathologists, with a focus on testing in breast cancer, lung cancer and melanoma. We aimed to highlight the challenges and support required for pathology laboratories, as a key stakeholder in establishing a diagnostic infrastructure, to ensure all required biomarker results are delivered in clinically relevant timeframes for optimal patient management.

METHODS

Survey design and dissemination

Consultant pathologists (CPs) from regional pathology laboratories across England were invited to participate in a nationwide survey (January–March 2022). Each participating pathology laboratory was engaged in one-to-one remote interviews with members of the Novartis Medical Science Liaison (MSL) team. The interviews were facilitated with a structured questionnaire developed in collaboration with an expert steering committee (SC) comprising of three leading UK pathologists. The involvement of the SC ensured the survey was clinically accurate and relevant to the healthcare community. A virtual

interview method was selected to allow capture of the nuances of CPs experiences, and as it allowed for rapid data collection considering the temporal relevance of the data. The survey was conducted in accordance with the British Healthcare Business Intelligence Association (BHBIA) guidance for the conduct of market research. The survey included 34 multiple-choice questions, some with free-text fields. The questions were grouped into the following five sections: referring centre profile, testing for specific cancers of interest, diagnostic pathway and logistics, impact of the COVID-19 pandemic as well as the GMS and GLH on current and future services, and lastly, barriers and support for optimal delivery of the GMS. Each pathology laboratory was administered with one questionnaire. However, multiple CPs from each site may have contributed to the responses based on their subspecialist expertise.

Centre recruitment

The expert SC connected with a network of pathology laboratories in England, configured in 29 pathology networks, to enquire about their interest to participate. The survey aimed to include a sample size of 29 centres across England for geographical representation. Recruitment was completed after 2.5 months of data collection, with agreed participation of 15 labs across the 29 networks.

Data analysis

Descriptive analysis of survey responses was undertaken by a third party, OPEN Health. A data quality check was performed for identifying missing/incorrect responses. Queries were resolved with the respondents and/or with the MSL. Data capture was impacted by some respondents providing free-text response, more than one answer or no answers. Quantitative data were analysed using appropriate descriptive statistics; categorical variables were described by frequency and percentages (denominator is 15, unless otherwise stated). For free-text responses, important concepts were identified and categorised into themes with assistance from the SC.

Patient and public involvement

No patient or the public was involved in the development of research questions and design, conduct or reporting of the study. The results of this research will be disseminated to stakeholders across the molecular diagnostic pathway after being published in a scientific journal to facilitate wider access.

RESULTS

The analysis of the survey responses was divided into five sections in alignment with the questionnaire. The total number of centres involved was 15 unless specified otherwise.

Section 1: referring centre profile

In total, 15 centres from England completed the survey. Of these, 93% reported as regional centres, and all the centres managed samples from referral networks. Twelve of these centres covered an estimated median (IQR) population size of 2.5 (1.9–3.6) million each. Respondents were aligned to six of seven GLHs in England (online supplemental figure S1). In their current practice, pathologists reported using the following technologies in-house: immunohistochemistry (IHC; 100%), real-time PCR (RT-PCR; 60%), fluorescence in-situ hybridisation (27%), as well as Sanger sequencing and NGS (13% each, online supplemental figure S2). Biomarker testing was also performed in coordination with external laboratories and GLHs.

Section 2: specific cancer testing in focus

The estimated median samples received per month for breast cancer, lung cancer and melanoma were 130, 65 and 52.5, respectively (online supplemental table S1). The median estimated turnaround time (TAT, calendar days), which was the time from receipt of sample to test results, for standard markers in breast cancer, lung cancer and melanoma ranged from 2 to 3 days by IHC (excluding NTRKfus in breast and lung cancers and BRAF in melanoma), 6–15 days by RT-PCR (excluding KIT for melanoma) to 17.5–24.5 days by NGS (excluding *PIK3CA* for breast cancer; table 1). In-house technologies such as IHC and RT-PCR were the preferred methods by 60% of laboratories for samples requiring results outside of the NGS time frame. Sixty-seven per cent of laboratories also sent these samples to GLH for NGS, if possible, following local testing. The testing of these samples was most often funded by the NHS trust (60%) or a combination of NHS Trust and NHS England (20%).

Four of 15 laboratories performed molecular testing using liquid biopsy samples, of which 2 laboratories used this only for EGFR analysis in lung cancer. The potential applications of liquid biopsy suggested from this survey were: testing to complement tissue sample results (87%) and as an alternative where suitable tissue was not available (60%). In addition, panel testing (53%) was preferred to single gene testing with liquid biopsies. The reported challenges associated with liquid biopsies included technical issues (86%) such as poor clinical sensitivity due to variable levels of circulating tumour DNA (ctDNA) in sample, and limited testing options, and logistical issues (50%) such as additional administrative work, pathway integration, funding and results interpretation. The challenges associated with the use of archival tissue are explained in online supplemental figure S3. Six of 15 laboratories were implementing in-house NGS capabilities for lung cancer, breast cancer or melanoma for future developments.

Section 3: diagnostic pathway and logistics

Funding/resource allocation (87%), test validation (80%), administration (60%) and timelines for implementation (53%) were reported to be the main challenges with implementing a new test. The CPs from all regional laboratories involved in this survey discussed results at standard multidisciplinary team meetings (MDTs). Only 20% of respondents attended and participated in genomic tumour advisory board (GTABs). It was reported by 100% and 67% of laboratories that tests were initiated by pathologists and oncologists, and to a lesser extent by MDT members such as respiratory physicians, surgeons, clinical scientists and others (details on contact and communication with the MDT are in online supplemental figures S4A,B). Most respondents (60%) stated that clinical interpretation of the molecular results was reported with reference to both published disease area management recommendations and available targeted therapies.

Section 4: impact of the GMS

The roll-out of the GMS was perceived to have a high impact on current services by 53% of respondents. The attributes leading to perceived negative impact were primarily logistical issues (80%) including funding, higher resource requirement, poor information technology (IT) system compatibility, absence of streamlined pathways and suboptimal information sharing and communication, all these potentially leading to increased TAT. Technical issues (20%) included higher tissue requirements leading to high failure rates and incomplete results. Factors associated with perceived positive impact included logistical aspects

Table 1 Biomarker testing for breast cancer, lung cancer, melanoma

		Current estimated turnaround time (calendar days)			Test location			
Test	Biomarkers	n*	Median	IQR	n*	Pathology	External lab	GLH
Biomarker testing for breast cancer								
IHC	HR	8	2.0	2.0–2.2	9	9	0	0
	HER2	8	2.8	2.0–3.2	9	7	2	0
	PgR	8	2.0	2.0–2.6	9	9	0	0
	PD-L1	7	3.0	2.2–11.2	8	6	2	0
	NTRKfus	4	19.2	12.4–25.9	4	1	1	2
FISH	HER2	7	7.0	3.5–10.2	8	4	1	3
	NTRKfus	4	24.5	21.9–25.9	4	0	1	3
RT-PCR	PIK3CA	3	14.0	10.8–22	4	1	0	3
	BRCA1/2	1	15.0	15.0–15.0	2	0	0	2
	NTRKfus	3	15.0	11.2–22.5	4	1	0	3
NGS	PIK3CA	1	40.0	40.0–40.0	2	0	0	2
	NTRKfus	4	24.5	22.2–28.4	5	1	0	4
	BRCA1/2	3	24.5	24.5–32.2	4	0	0	4
Other	Ki67 (IHC)	–	NA	NA	1	1	0	0
	Oncotype Dx	1	24.5	24.5–24.5	3	0	3	0
Biomarker testing for lung cancer								
IHC	PD-L1	14	2.5	2.0–3.0	15	14	1	0
	ROS1fus	12	2.8	2.0–7.0	13	11	2	0
	ALKfus	13	2.5	2.0–3.0	15	14	1	0
	BRAF	1	3.0	3.0–3.0	1	1	0	0
	NTRKfus	3	7.5	5.2–18.8	3	2	1	0
FISH	ALKfus	8	7.2	5.5–10.0	8	5	0	3
	ROS1fus	8	7.2	5.5–10.0	8	5	0	3
	METamp	5	10.0	7.5–21.0	5	2	1	2
	HER2amp	4	8.8	6.1–12.8	4	2	0	2
	RETfus	6	8.8	4.9–18.2	6	3	1	2
	NTRKfus	4	7.0	3.5–12.8	4	2	0	2
RT-PCR	EGFR	11	6.0	2.0–7.2	11	9	1	1
	ROS1fus	2	4.8	3.4–6.1	2	2	0	0
	ALKfus	2	4.8	3.4–6.1	2	2	0	0
	ALK	2	4.8	3.4–6.1	2	2	0	0
	BRAF	9	7.0	2.0–14.0	9	6	2	1
	KRAS	7	7.5	3.0–21.0	7	4	2	1
	METex14	6	10.8	4.9–24.5	6	3	2	1
	HER2	3	7.5	5.8–18.8	3	2	1	0
	RETfus	5	7.5	4.0–14.0	5	3	1	1
	NTRKfus	5	7.5	4.0–14.0	6	3	2	1
NGS	EGFR	11	17.5	13.0–21.8	12	2	0	10
	ROS1fus	9	19.0	14.0–24.5	10	0	0	10
	ALKfus	10	18.5	14.0–24.5	11	0	0	11
	BRAF	11	17.5	13.0–21.8	12	1	0	11
	KRAS	11	17.5	13.0–21.8	12	1	0	11
	METex14	10	17.8	14.0–23.1	11	1	0	10
	HER2	7	17.5	14.0–21.2	8	0	0	8
	RETfus	10	18.5	14.0–24.5	11	0	0	11
	NTRKfus	9	19.0	14.0–24.5	10	0	0	10
Other	PIK3CA, TP53	–	NA	NA	1	0	0	1
Biomarker testing for melanoma								
IHC	BRAF	3	7.0	4.5 to 18.5	3	1	2	0
	PD-L1	2	17.0	10.5 to 23.5	2	1	1	0
Sanger sequencing	BRAF	1	7.0	7.0 to 7.0	1	0	1	0
	NRAS	–	NA	NA	–	–	–	–
Pyrosequencing	BRAF	–	NA	NA	–	–	–	–

Continued

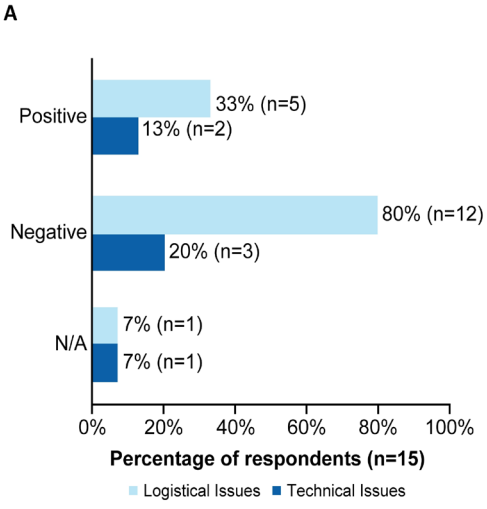
Table 1 Continued

Test	Biomarkers	Current estimated turnaround time (calendar days)			Test location			
		n*	Median	IQR	n*	Pathology	External lab	GLH
RT-PCR	BRAF	9	6.0	2.5 to 7.5	9	6	2	1
	NRAS	3	7.5	5.8 to 24.8	2	1	1	0
	KIT	2	23.0	13.5 to 32.5	2	0	2	0
NGS	BRAF	7	21.5	15.8 to 26.2	7	1	0	6
	NRAS	7	21.5	15.8 to 26.2	8	1	1	6
	KIT	7	21.5	15.8 to 26.2	8	1	1	6
Others	Pyrosequencing (KIT)	–	NA	NA	1	1	0	0
	NTRK1-3	–	NA	NA	1	0	0	1
	FISH (BRAF)	1	0	0	1	0	1	0

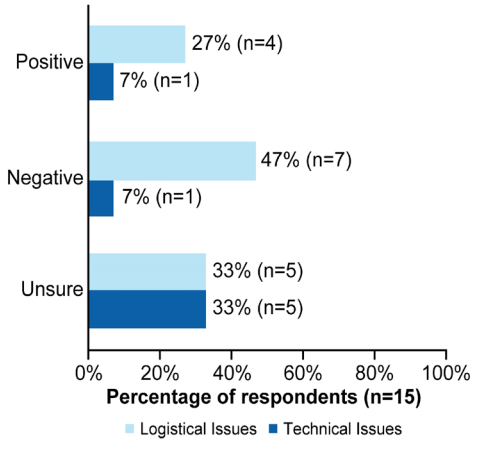
*The n values represent the total number of responses received for the corresponding questionnaire field on test location and estimated TAT. The median estimated TAT was the time from receipt of sample to test results.
ALKfus, ALK fusion; FISH, fluorescence in situ hybridisation; GLH, Genomic Laboratory Hub; HER2amp, HER2 amplification; HR, hormone receptor, which may include ER or PgR; IHC, immunohistochemistry; METamp, MET amplification; METex14, MET exon 14; NA, not applicable; NGS, next-generation sequencing; NTRKfus, NTRK fusion; PD-L1, programmed death ligand-1; PgR, progesterone receptor; RETfus, RET fusion; ROS1fus, ROS1 fusion; RT-PCR, real-time PCR; TAT, turnaround times.

(33%) such as formally funded pathways, streamlined pathways and improved communication. Technical aspects (13%) included improved TAT, reduced failure rates and higher scope of genetic analysis (figure 2A). The recent COVID-19 pandemic was also perceived to have a high impact on the current services (online supplemental figure S5).

Similarly, it was perceived that the GMS roll-out would have a high impact on future services, indicated by 67% of respondents,



	Type of impact caused by GMS rollout	Issues reported under each category
Positive	Logistical issues	Funding, efficiency/ streamlined pathway, communication
	Technical issues	Improved TAT, improved failure rates, higher sequence coverage
Negative	Logistical issues	Funding, long TAT, increase resource requirements, additional administrative burden, poor compatibility with IT, fragmented pathway and further from patient, suboptimal information sharing and communication
	Technical issues	Higher tissue quality requirements, high failure rates, incomplete testing



	Type of impact caused by GMS rollout	Issues reported under each category
Positive	Logistical issues	More capacity locally for urgent samples, reduced workload
	Technical issues	Improved diagnostics
Negative	Logistical issues	Additional administrative burden, inefficient reporting, division of pathway, longer turnaround times, lack of guidance, funding concerns
	Technical issues	Higher tissue requirements

Figure 2 (A) Perceived impact of the GMS roll-out on current services. (B) Perceived impact of the GMS roll-out on future services Responses are not mutually exclusive. GMS, Genomic Medicine Service; IT, information technology; n, number of respondents; TAT, turnaround time.

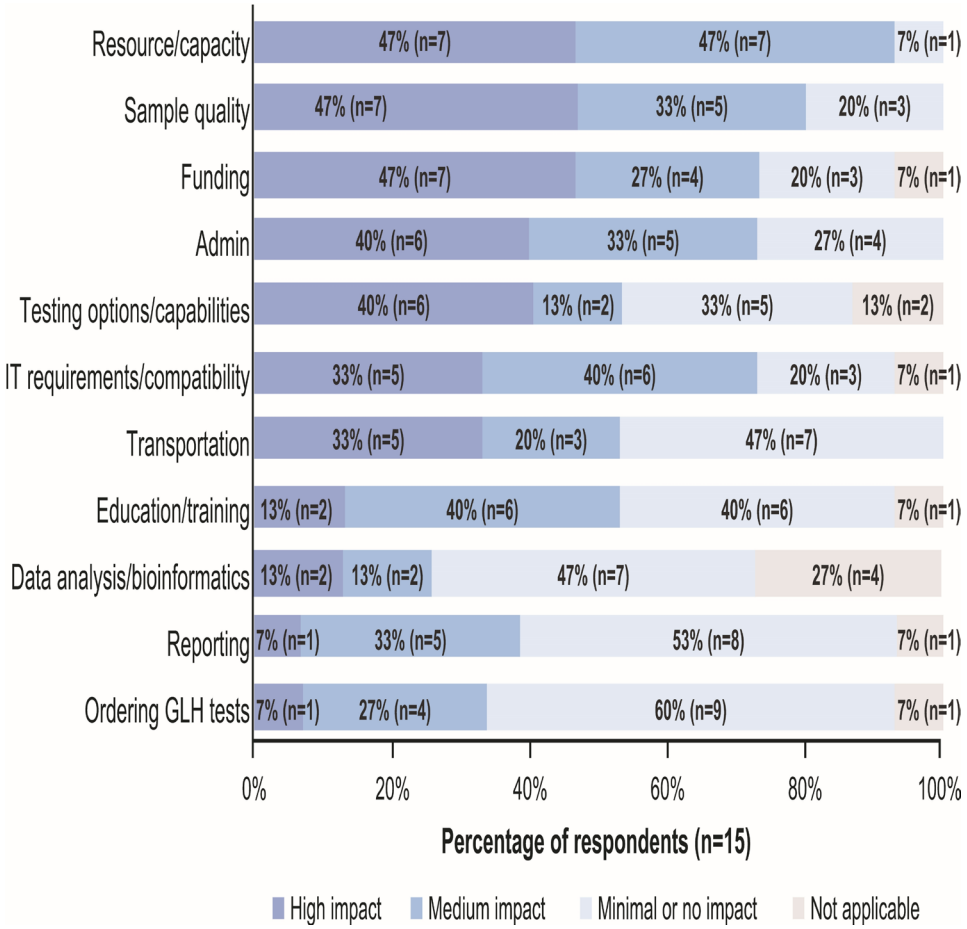


Figure 3 Barriers for optimal delivery of the GMS responses are not mutually exclusive. GLH, genomic laboratory hub; GMS, Genomic Medicine Service; IT, information technology; n, number of respondents.

highlighting logistical issues (47%) as well as potential benefits (27%) (figure 2B). Thirty-three per cent of respondents reported being unsure of the future impact of the GMS on the service.

Respondents highlighted that their responsibilities included sample preparation (87%), education/training (87%) and reflex test requests (80%) (online supplemental figure S6). All respondents indicated that conducting at least some form of testing including urgent or first-line testing as critical responsibilities of pathology laboratories.

Section 5: optimal delivery of the GMS—barriers and support

The high-impact barriers to the optimal delivery of the GMS are detailed in figure 3. The most frequently identified educational needs for pathologists included understanding the new molecular testing pathways and best practice sharing (figure 4A). Educational support suggested for clinical colleagues primarily comprised patient information of testing and results and tissue requirements (figure 4B; additional resource requirements are detailed in online supplemental figure S7). The preferred mode of information dissemination suggested by the respondents were digital education (80%), virtual educational meeting (73%) and in-person educational meeting (60%) (online supplemental figure S8).

DISCUSSION

The centralisation of genomic testing to seven GLHs in England aims to ensure equitable access of tests specified in the national test directory.[2] The consolidation of genomic testing to GLHs is also aimed at standardisation of these tests to improve cost efficiency of laboratories as well as facilitating a broader scope of analysis to inform clinical trial eligibility.[4] The role of CPs has become increasingly complex with recent advances in the genomic testing landscape. Our survey results provide an overview of the current services and challenges for cancer diagnostics in pathology laboratories in England and highlight the areas requiring further support to facilitate a diagnostic infrastructure for optimal and equitable patient management.

Fifteen geographically spread regional pathology laboratories in England participated, 12 of which reported to cover a median estimated population of 2.5 million each. This would roughly indicate that the survey covered services for 37.5 of 56 million residents of England.[5]

Our survey highlighted the pivotal activities of the pathologist within this complex molecular testing pathway. In addition to conducting diagnostic tests, pathologists are also involved in interpretation of test results within the clinicopathological context of the case, attending standard disease-specific MDTs as well as increasingly participating in GTABs. This practice is in alignment with evolving international practice and recommendations.[6] With rapid consolidation of genomic testing to GLHs, the pathologists have a central role in facilitating closer collaboration between the regional centres and the GLHs as they hold both the patient's clinical information and the tissue, and can guide appropriate diagnostic and downstream testing, particularly where small sample size may limit testing. The survey results exemplify the vital role of pathology laboratory teams in tissue

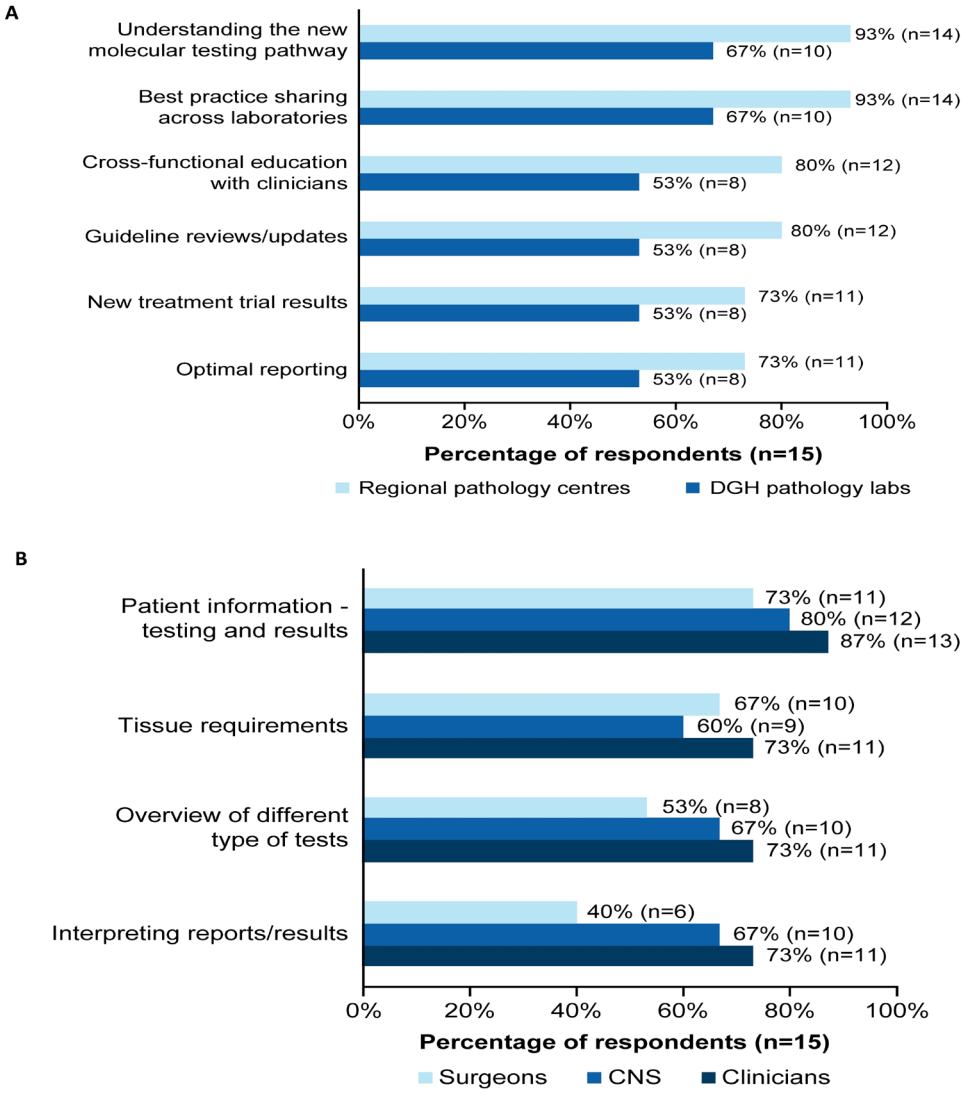


Figure 4 (A) Educational support for pathologists from different sites. (B) Educational support for surgeons, clinical nurse specialist and clinicians. Responses are not mutually exclusive. CNS, clinical nurse specialist; n, number of respondents.

provision for genomic tests. In their current practice, regional pathology centres reported working with their GLHs through activities such as initiation of test requests, sample preparation, interpretation of results and integration of GLH reports into local systems.

Our survey indicated a perceived high impact of the GMS implementation on current and future pathology services. Potential positive impacts of the GMS were highlighted, such as improved and standardised diagnoses, handling of complex cases by GLHs ensuring more capacity for routine testing and reduced workloads. However, most respondents expressed concerns around logistical issues including funding, increased pathologist/laboratory/administrative workload, poor IT compatibility and the need to streamline pathways, all potentially leading to increased TAT. The authors welcome the intention stated in the recently published NHS 5-year Genomic Medicine Strategy to optimise cancer tissue pathways by working with stakeholders such as NHS England and NHS Improvement pathology networks and the Royal College of Pathologists to address concerns including those mentioned in the survey. Further, the plan acknowledges the need for pathway redesign via collaboration across clinical specialties, and between the GMS and Cancer Alliances.[7]

The tests covered in the national genomic test directories are funded centrally by NHS England leading to potential savings for local pathology laboratories, delivering or funding these tests from their own budgets. However, increased costs may be incurred for tissue preparation with repeat biopsies, as and when the test directory offering and uptake expand and when there are changes in practice.[7] To ensure equitable access to required testing for patients across all regions, consideration should be made for national commissioning of all required biomarkers (via all techniques, including predictive IHC) in addition to ongoing resources supporting sample preparation for downstream molecular testing.

The need for a robust bioinformatics infrastructure in handling high-volume data generated at each step of the pathway has been emphasised in previous studies.[8] The development of an integrated IT system across regional centres and GLHs is recommended to aid efficient access to full clinical information and reduce the duplication of effort and risk of transcription errors from one laboratory's system into another. To this end, the NHS 5-year Genomics Medicine Strategy aims to develop an interoperable informatics and data infrastructure.[7]

Our survey respondents suggested that pathologists would benefit from additional education on changes to the molecular testing pathway and from best practice sharing. Opportunities for information sharing and educational support via digital or in-person meetings may enable more effective communication regarding GMS developments. Respondents also highlighted an educational need for other clinicians in the cancer MDT. While current resources such as the Health Education England Genomics Education Programme are available, a more proactive approach to education, especially focused on junior doctors, may facilitate understanding of and enthusiasm for this increasingly important field early in their careers.[9]

Biomarker-based treatment planning is the cornerstone of precision oncology. The biomarkers assessed in our survey, for melanoma, lung cancer and breast cancer based on IHC, RT-PCR and NGS techniques were in line with the guideline recommendations.[10–15] Limited molecular testing was performed routinely for breast cancer at the time of survey, while PIK3CA testing was nationally commissioned since April 2022.[16] Delays in test results potentially lead to greater morbidity, higher costs of care and lower likelihood of survival in patients with solid tumours.[17] As a baseline, NHS England has recommended a timeline of 21 calendar days for standard panel testing of somatic cancers (currently under review by disease type).[18] Moreover, there are differing recommendations between NHS England and other national guidelines such as the National Optimal Lung Cancer Pathway that suggests 10 days for molecular marker testing to inform first-line therapy.[19] In our survey, although several sites reported TATs within these timelines, the upper limit often exceeded the 21 days recommendation. Such variations in guidance and between regions may have an impact on patient care.

Advances in technologies have increasingly indicated the appropriateness of plasma ctDNA analysis (liquid biopsies) for solid tumours in clinical practice, which is considered complementary to tissue biopsies, in guiding therapeutic decisions.[20] Most pathology centres agreed on the positive contribution of the use of liquid biopsies, particularly when tissue samples were not suitable or available, with openness to its future wider adoption. A close collaboration between the clinical team performing liquid biopsies and laboratory scientists and pathologists will be required to facilitate optimal sample handling as well as integration of liquid biopsy results within complete molecular profiling of the cases for accurate and complete assessment.

The PATHways survey was designed to capture the views of pathologists involved in biomarker testing, the current challenges and the opportunities to optimise the transition towards expanded and centralised genomic services. However, there were some limitations to the design:

- The data reflect the conditions at the time of the survey, and there may have been further developments.
- The survey results were based on self-reported practice, subject to recall bias. The questionnaire design, and the conduct of the survey, by Novartis medical department personnel may have resulted in potential response bias.

CONCLUSION

Our survey highlighted the pathologists' views on challenges and opportunities in the centralisation of genomic services. The findings further highlight the concerns that need to be addressed for wider implementation of genomic testing, in alignment with the recent 5-year strategy of the NHS for accelerated uptake of genomic services.[7]

Notable recommendations from our survey included the following:

- Wider proactive engagement and effective communication between oncologists, physicians, surgeons, clinical nurse specialists, scientists and pathologists, to optimise the MDT approach to patient management.
- A pragmatic approach to biomarker detection, ensuring optimal use of technologies for early diagnosis.
- Access to broader profiling for all eligible patients, also supporting clinical trials and research opportunities for patients.
- Multistakeholder pathway review to achieve clinically meaningful TATs for all required biomarkers.
- Upgradation of IT infrastructure to support faster integration of diagnostic, prognostic and predictive information from all relevant sources for analysis and interpretation.
- Further proactive educational training programmes, on areas such as new diagnostic and predictive markers, optimised sample handling and tumour content assessment to facilitate smooth implementation of the GMS.
- Centralised directory and funding of all required cancer biomarker tests beyond genomics and inclusion of protein-based tests such as predictive IHC.

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Competing interests PT consultancy for AstraZeneca, Roche, Boehringer Ingelheim, and Qiagen. AN reportsreceiving personal fees from Merck, Boehringer Ingelheim, Novartis, AstraZeneca, Bristol-MyersSquibb, Roche, AbbVie, Oncologica, UptoDate, European Society of Oncology, Liberum, andTakeda UK and grants and personal fees from Pfizer, outside of the submitted work. JRG received grants from the Medical Research Council (MRC) and Eli Lilly and Company during theconduct of the study, and personal fees from AbbVie, AstraZeneca, Boehringer-Ingelheim, Bristol-Myers Squibb, Diaceutics, Eli Lilly and Company, Merck Sharp & Dohme, Novartis, Pfizer, Roche and Takeda Oncology outside the submitted work. EV

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