Contents lists available at ScienceDirect

Academic Pathology 10/3 (2023) 100090

Academic Pathology

journal homepage: www.journals.elsevier.com/academic-pathology

Special Article

The Genomics Organization for Academic Laboratories (GOAL): A vision for a genomics future for academic pathology

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A B S T R A C T

Innovative and self-sustaining clinical genomics laboratories specializing in cutting-edge oncology testing are critical to the success of academic pathology departments and resident and fellow education in molecular pathology. However, the pressures and challenges facing these laboratories are numerous, including the complexities of validating comprehensive cancer next-generation sequencing (NGS) panels, competition from commercial laboratories, and the reimbursement and regulatory hurdles inherent in high-complexity testing. Cross-institutional collaborations, including shared assay content and interpretative frameworks, are a valuable element to academic laboratory success. To address these and other needs, the Genomics Organization for Academic Laboratories (GOAL) was conceived in 2018, incorporated in 2020 and has grown to include 29 participating institutions in 2022. Here, we describe the mission of GOAL, its structure, and the outcomes and projects undertaken in its first years.

Keywords: Laboratory medicine, Molecular, Next-generation sequencing, Precision medicine

Cancer genomics comes of age

Traditionally, academic molecular laboratories have crafted their own test menus based on the needs of their institutions and patient populations and the available local resources in expertise, personnel and equipment.[1] This has been particularly true for next-generation sequencing (NGS) assays for oncology applications. Like all NGS assays, oncology-based NGS assays require not only expensive reagents and equipment, complex wet-lab protocols, and multi-step analytical pipelines, but also careful coordination with oncologists and hematologists to ensure assay gene content is appropriate for institutional priorities.[2] As the complexity and scope of cancer NGS assays has increased, this focus on locally driven priorities regarding genomic content has been challenged by commercial and regulatory trends in NGS testing (Table 1).

Comprehensive genomic oncology panels and the beginnings of GOAL

Faced with the high costs of designing and validating complex, comprehensive NGS assays in their own labs, Laboratory Directors Jeremy Segal at the University of Chicago and Dara Aisner at the University of Colorado conceived of a project in 2017 to share the design and purchase of a core reagent set across multiple laboratories, namely, individually synthesized and quality-controlled probes for capture-based NGS. Well-designed probes generated through high-fidelity synthesis approaches are perhaps the most critical reagent for effective capture-based NGS. This project was initially borne out of a desire to cost share among participating academic laboratories, given that the reagent purchase was beyond the budget of any individual laboratory, but within scope if shared, with a scale large enough to ensure a nearly unlimited supply for a large number of academic-scale laboratories. In order to distribute the cost, Drs. Segal and Aisner sought out collaboration with the intent of identifying three additional academic laboratories to participate in a joint capture probe purchase. Through web-based meetings to introduce the idea, an additional fifteen laboratories indicated interest and willingness to participate in the joint reagent purchase (Table 2).

These seventeen laboratories convened multiple meetings to discuss strategies for a joint probe purchase, which ultimately identified genomic content as a major potential obstacle for laboratories to consider joining.

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https://doi.org/10.1016/j.acpath.2023.100090
Received 10 February 2023; Received in revised form 26 May 2023; Accepted 18 June 2023; Available online xxxx
eISSN2374-2895/

Table 1
Developments in oncology NGS testing over the last three decades highlighting advancements, challenges, and opportunities.

Progress	Early NGS: Short read technology 1990s–2000s	Commercialization: Instruments 2000s–2010s	Commercialization: Medical Testing 2013 - present
Advancements	• Human Genome Project (HGP)	• Illulimina, Solexa, Ion Torrent, Roche 454, etc.	• Clinical, physician, patient, and insurers acceptance of the clinical value of NGS
Challenges	• Cost of sequencing was barrier to entry ($3 M for the Human Genome Project) • Technology not readily available.	• Cost of instruments was barrier to entry • Data analysis required rare bioinformaticians. • Not yet approved for reimbursement	• Upfront cost of reagents/instruments remains a barrier. • Validation and proof of interlaboratory concordance is complex. • Variant interpretation • No established industry-wide data analysis pipeline
Opportunities	• Collaboration was instrumental to the success of the HGP and its public availability	• Collaboration required to access instruments. • Academic development of public databases • Basic research developed a foundation of knowledge.	• Collaboration between labs can improve patient care and test quality. • Access to shared data can improve concordance. • Pooling resources • Access to data for research and clinical trials

Desired gene lists submitted by participating laboratories ranged from approximately 100 to greater than 1400 individual genes for inclusion. With the intention that each laboratory should maintain autonomy in determining genomic content for local assays, a consensus was reached to facilitate a group purchase of all desired genomic content in a one-gene-per-tube format, allowing each laboratory to utilize the probe set in a locally determined fashion (Fig. 1). The final specifications for the hybrid-capture probe purchase included the coding regions of 2640 genes, plus selected intronic territory for 18 genes in which intron-tiling for fusions may be relevant, as well as pools for additional genomic features such as microsatellite instability (MSI), human tumor-associated viruses, and a polymorphic set of single nucleotide polymorphisms (SNPs) (Table 3). Laboratories participating in the group purchase received individual shares split into two sets of 96-well plates, designed to be stored in separate freezers on separate circuits, to avoid single-point-of-failure events. An overabundant quantity of the probes were provided in suspension at concentrations designed to facilitate custom generation of pools for numerous assays through the use of equal volume combinations across individual tubes. The group purchase of the initial gene panel serves as the driving example of cost savings among academic laboratories. For example, if the bulk synthesis of an abundant number of reactions has an initial cost of $300,000 and 12 labs joined the group purchase for the $300,000, then each lab would be directly invoiced for $25,000 by the vendor for an equal share, which is a cost savings of more than 90%.

As with any validation process, each laboratory was and will continue to be responsible for validating the probes independently as part of their CLIA certification. Each site is responsible for the validation of any internal assay using their own parameters, and as such data analysis is entirely flexible, and guided by the principles of assay validation. Laboratories that began assay validation with these probes reported substantial improvements compared to previously purchased bulk-synthesized probes, including improved capture of G-C-rich genomic regions, improved capture uniformity, and improved on-target rates. All of these metrics contribute to reducing costs and increasing the throughput of sequencing instruments utilized by laboratories. At the time of this writing, fourteen academic laboratories have implemented GOAL probes within their own workflows with a wide variety of approaches and targeted coverage, ranging from smaller panels at one end of the spectrum to spike-ins of more than 1000 genes into an exome backbone at the other end of the spectrum.

While a notable benefit of the distribution plan was the ability of each laboratory to determine what genomic content was included in a locally deployed assay (as opposed to pre-defined pools of genomic content), a limitation to this approach was the recognized potential for genomic content to diverge substantially among sites. Thus, in order to facilitate potential harmonization and standardization, members from several sites convened to identify a set of genomic content that could serve as a uniform 'core gene set'. Laboratory adoption of a core gene set would provide specific benefits to an individual laboratory, including: 1) the ability to participate in multi-site concordance evaluation; 2) the ability to promote a set of content deployed at a network of sites allowing for greater consideration for partnerships with other organizations around this shared content; and 3) the ability to develop computational resources

Table 2
Academic laboratories joining together for a group bulk purchase of common NGS reagents.

Initial concept to share in a group purchase (2017)	First group purchase (2018–2019)	Subsequent group purchases (2020 to present)
• University of Chicago • University of Colorado	• Brigham and Women's Hospital • Columbia University • Dartmouth-Hitchcock Medical Center • Johns Hopkins University • Medical College of Wisconsin • The Ohio State University • University of California, Los Angeles • University of California, San Francisco • University of California, San Diego • University of North Carolina, Chapel Hill • University of Pennsylvania • University of Texas Southwestern • University of Vermont • University of Washington • Yale New Haven Hospital	• Cedars Sinai Medical Center • Cincinnati Children's Hospital • National Cancer Institute • Stanford University • University of Alabama at Birmingham • University of Florida • University of Iowa • University of Minnesota • University of Rochester • University of Texas Health Science Center at Houston • University of Texas Health, San Antonio • Washington University in Saint Louis

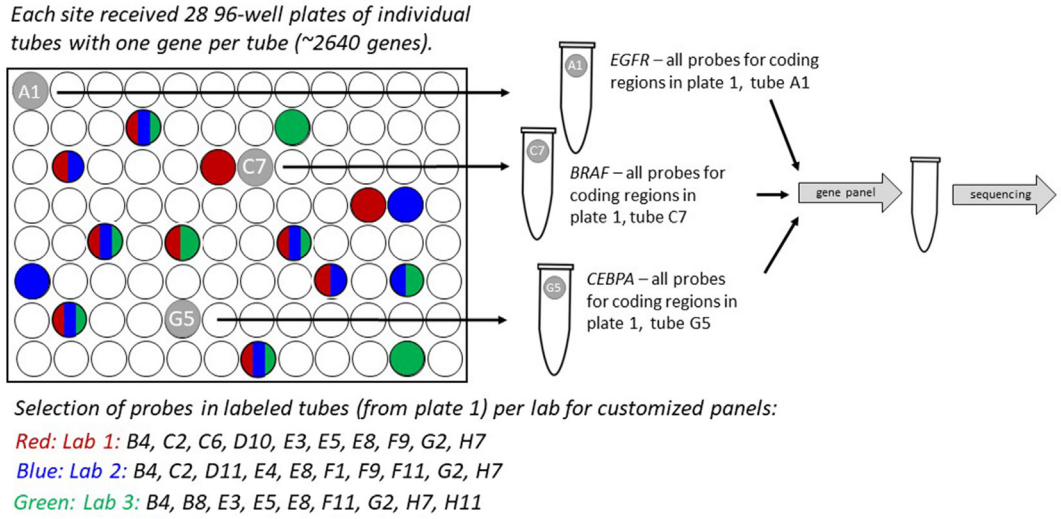

Fig. 1. Schematic example of one-gene-per-tube allowing custom panel design by individual member laboratories.

centered on this shared content. The consensus list for the core gene set was 497 cancer-associated genes that include targets relevant for solid tumors and hematologic neoplasms.

Due to the successes of these initial stages, the possibility of a formal organization with a mission of facilitating collaboration among academic laboratories came into clearer focus. Having achieved consensus among seventeen laboratories, the co-founders looked for an external organization to formally mediate such collaborations. In order to facilitate a transition from an informal assemblage to a formal organization, the co-founders approached the Association of Pathology Chairs (APC) in 2019 to determine if the APC would be willing to foster the growth and development of this nascent group. The APC is a non-profit society, which serves as the voice of academic departments of pathology. APC exists to provide leadership and advocacy for the dynamic discipline of pathology and to enable academic departments to meet the demands of their three missions: medical education, research, and clinical practice. The collaborative group established its own mission to drive the advancement of cutting-edge genomic testing at academic and non-profit laboratories by facilitating inter-institutional projects and data sharing, and leveraging group resources and expertise to lower developmental and other barriers. Both parties determined that the missions of the two organizations were well-aligned. Specifically, the nascent organization needed the support of academic chairs, and academic chairs needed ways to ensure continued feasibility of genomic laboratory medicine within pathology departments. In 2020, with the aid of the APC, the collaborative organization was legally incorporated in Washington, D.C. as the Genomics Organization for Academic Laboratories (GOAL).

The transition of GOAL to a formal organization with a mission to assist academic clinical genomics laboratories to sequence and report clinical cancer studies in a robust and fiscally sustainable manner required a well-designed organizational infrastructure to ensure ongoing support for the laboratories involved. The needs of the laboratories included continuation of the use of group purchasing power to improve the financial sustainability (reagents and equipment, GOAL's initial rallying point), and inter-laboratory collaborations to assist in best practices for bioinformatics and variant interpretation. There are many successful and well-functioning organizations in genomics and molecular pathology that address some of the challenges to clinical oncology laboratories, such as the American College of Medical Genetics (ACMG), College of American Pathologists (CAP), the Association for Molecular Pathology (AMP), and the American Association for Cancer Research (AACR)-sponsored Genomics, Evidence, Neoplasia, Information, Exchange (GENIE) project. GOAL does not intend to duplicate these efforts. Rather, GOAL was designed to focus and meet the specific "crowd-sourced" needs of its members to develop best practices and establish consensus among GOAL member laboratories on issues such as biospecimen and protocol sharing to facilitate validation and quality assurance, shared bioinformatic platforms, group purchasing for cost savings, profiling laboratory practice landscapes, and reporting genomic sequencing results to ordering clinicians.

Table 3
Specifications for group purchase of final probe set of 95,109 probes.

- 2640 genes (exon coverage)
- Introns for fusions for 18 genes:
  - *ALK*, *BRAF*, *CD74*, *EGFR*, *ETV6*, *FGFR1*, *FGFR2*, *FGFR3*, *MET*, *NTRK1*, *NTRK2*, *PAX8*, *RAF1*, *RET*, *ROS1*, *RSPO3*, *TFE3*, *TFEB*
- Tumor associated viruses:
  - EBV type 1, EBV type 2, HHV8, HTLV1, HTLV2, HPV (multiple strains), HPyV7, JC, BK, MCPyV
- Single nucleotide polymorphisms (SNPs) for identity
- Microsatellite pool for microsatellite instability (MSI)

Structure of the organization: Institution-centric membership

To provide members with an infrastructure that could identify and meet the needs of member institutions, GOAL established a Board of Directors (BOD) to provide governance, developed bylaws to define the legal guidelines for GOAL, and received non-profit 501(c)3 federal tax exemption status from the U.S. Internal Revenue Service in 2022. This allows GOAL to receive tax-deductible contributions while providing grant funding as a public charity to its member institutions. Partnership with the APC has provided expert structural organization of GOAL along with access to legal advice. The inaugural BOD were individuals from large academic sites performing NGS oncology-based testing (University of Chicago, University of Colorado, Johns Hopkins University, The Ohio State University, and the University of Pennsylvania) and representatives from APC. Membership in GOAL is institution-based, similar to the structure used by oncology cooperative groups. This also mirrors the departmental membership structure of the APC.

GOAL's bylaws provided guidelines for membership, governance, committee and working group creation, meetings, and the financial aspects of GOAL. As described in the bylaws, GOAL's mission is to (a) facilitate the advancement and standardization of personalized molecular diagnostics at academic and nonprofit organizations through leveraging inter-laboratory interactions and (b) to advance patient care and access to genomic testing through sustainable, cost-effective and

streamlined collaboration among academic laboratory departments. The leadership recognized that the key to interaction between each of the institutional members and GOAL itself was a legally binding contract. The master participation agreement was developed to facilitate and coordinate projects, distribute biospecimens, allow data collection and analysis, handle intellectual property issues and risks, and fund GOAL-initiated or sponsor-initiated projects, publications, meetings, and other activities.

In general, academic and not-for-profit laboratories are eligible to participate as GOAL expands its membership with the principles of group purchasing, networking, and resourcing. In the adopted bylaws of the organization, the requirement is codified for a lab to 1) formally join GOAL through institutional ratification of the master participation agreement and 2) participate in a general group purchase which may apply to more than just the initial capture probe package that was purchased by the inaugural member labs in two rounds from 2018 to 2020. GOAL is currently exploring another round of group purchase as a mechanism for a new round of sites to join. As of this writing, that opportunity remains open, and we anticipate additional opportunities in subsequent years. Sites interested in joining the GOAL network should contact the GOAL office via the email address (info@goalabs.org) listed on the organization's website: www.goalabs.org.

The focus during the early, formative, grass-roots efforts of becoming an organization has been on laboratories utilizing Illumina sequencing platform(s). Naturally, the resulting network of expertise on using the initial probes and capture reagents has been similarly isolated to users of Illumina sequencing technology. The intent was not to exclude any interested academic laboratory; rather, the strategy was on focusing on the needs, expertise, and sequencing platforms of similar academic labs. In a similar vein, there has been interest among participant labs in establishing work groups beyond the current focus and bandwidth of the volunteers of the organization, such as the technical issues related to constitutional disease testing. While laboratories utilizing Illumina sequencing technology are best poised to immediately benefit from the group expertise of the GOAL network, we remain agnostic as to sequencing platform and should sites with a specific interest in developing this approach on different sequencing technology emerge, there is no prohibition from joining on this basis. Under the subsequent directorship of the Board, bylaws have been adopted that establish clear, objective criteria for inclusion of additional sites moving forward.

In addition to academic laboratories, pharmaceutical and industry partnerships are an important component of the GOAL infrastructure. Founding pharmaceutical sponsors have provided unrestricted funds that assisted in the establishment of GOAL. In return for these funds, sponsors have access to the BOD industry liaison to discuss projects, attend GOAL annual scientific meetings (currently conducted virtually), and initiate and/or participate in projects with GOAL laboratories through mechanisms outlined in the bylaws, with project requests subject to Board review. Supporters from the manufacturing or supplier sectors have been focused on market distribution in GOAL through discounts on reagents, equipment, or supplies.

Projects planned and some early outcomes

Validating GOAL-based NGS cancer panels

As described above, the organization was founded on a mission to share gene content, reagents, and assay protocols for a DNA-based comprehensive genomic testing panel; that has remained the paramount priority in its initial years (Table 4). As of this writing, fourteen laboratories have successfully completed clinical validation of locally deployed assays for oncology utilizing the group-purchased probes.

The balance between the desire for inclusion of all cancer-associated gene content and a cost-effective and efficient panel size resulted in the 497-gene core GOAL probe set discussed above and arrived at through a highly collaborative process among member institutions. This up-front harmonization has facilitated the next step in GOAL's focus and priorities, which is a cross-institutional concordance study (Table 4). This type of highly coordinated cross-institutional concordance study of a comprehensive NGS panel has only been published sporadically.[3]

In our study, participating laboratories each analyze a set of shared, crowd-sourced samples using their local protocols and their analytic pipeline(s) and submit data for assessment of variant detection accuracy. A powerful secondary aim is evaluation of the primary data using a centrally designed bioinformatic pipeline. This study design allows for cross-laboratory assessment of the contribution of variations in wet-bench and bioinformatics processes to concordance, or lack thereof. The creation of a centrally designed bioinformatic pipeline could gather best practices across multiple institutional members and result in a shared platform that could be distributed back to the member laboratories (Table 4).

Following the assessment of variant detection accuracy, the GOAL concordance study will compare secondary outputs in laboratories' pipelines such as tumor mutation burden (TMB). The shared content and capture reagents are hypothesized to reduce analytic variation that has affected some prior TMB harmonization initiatives.[4,5,6] Comparison of additional pipeline outputs, such as copy number determination, will be aided by referencing shared SNP backbones across the genome included in the GOAL design. Testing and analyses are currently being performed locally and in aggregate among the participating sites. We intend to elaborate on these details in a forthcoming publication examining many elements of the concordance study.

Promoting use of therapeutically linked NGS panels at our institutions and the surrounding community oncology practices

Although the sophistication of tumor genomic assays has continued to progress, the efficient enrollment of patients in individualized therapy trials has lagged both at the most sophisticated cancer centers[7] and in community practices.[8] Improving the comprehensive and efficient use of NGS data in therapy decision-making initially and at relapse/progression has long been a priority of clinical oncologists, federal regulators, and the pharmaceutical industry.[9] Leveraging the cumulative cancer volume and diverse patient populations of GOAL's member institutions can contribute to the ongoing effort to improve access to large genomics panels, especially in finding therapeutically relevant genomic changes in less common tumors (Table 4).[10]

Supporting laboratory-centric genomics study design

As discussed above, an important consideration in the founding of GOAL was the pressures academic laboratories have faced in competing with commercial genomics companies. Send-out genomics testing has an under-recognized potential to produce fragmented and suboptimal clinical care, as involvement and integration by pathology are often critical for the recognition of results with basic diagnostic implications. Furthermore, outsourcing genomics testing away from medical centers may lead to challenges to timely and cost-effective cancer care. For example, turn-around time delays can result from confusion on testing algorithms and approval processes, or when tissue samples are limited, or when duplicative testing leads to potentially conflicting genomic findings. For clinical trial sponsors, these problems are especially acute leading to delays in or abrogated trial recruitment, failure to achieve needed enrollment, and incomplete regulatory data submissions. Neither the pharmaceutical sponsors nor the testing laboratories have been satisfied with this system.[11] Some clinical trials, notably the National Cancer Institute's Molecular Analysis for Therapy Choice (NCI-MATCH) trial[12] and the American Society of Clinical Oncology's Targeted Agent and Profiling Utilization Registry (TAPUR) study,[13] have addressed this with a distributed model of clinical genomics laboratory testing, laying the groundwork for successful approaches which do not require central laboratory trial screening.

Table 4
Ongoing GOAL initiatives by areas of focus, engagement, and outcomes.

Focus	Goal(s)	Design and Results	Participation
Group Purchasing	GOAL Cancer Panel with shared gene content and probe design	• Gene content designed by shared interest survey • Shared purchases of large set of NGS probes (>1000 genes) • Core gene set established for cross-laboratory studies	• Initially 2 academic laboratories • Buy-in from 15 other academic laboratories on original group purchase • 12 additional academic laboratories to date • Group financial savings
Concordance in Testing	GOAL Cancer Panel Concordance Study	• Benchmark phase to establish initial concordance rates	• 9 member laboratories participating
Bioinformatics	GOAL Bioinformatics Group/Pipeline Development	• Monthly Bioinformatics working group formed • Common elements of analytic pipeline outlined • Alignment of platform development with the joint GOAL pipeline, while respecting individual laboratory pipelines	• 43 representatives from 23 member labs • Monthly meetings since July 2021
Research	Support clinical trial-associated genomics work and studies on genomics data and practice	• Mechanisms created for project submission, review and management • Refinement of processes with initial submissions	• 2 research projects currently active • 1 research project at the initial conceptualization phase • Anticipating 2–3 more projects in 2023 • Staffing for projects managed by GOAL (project managers)
Clinical Practice Improvement	**Network Practice Support and Sharing:** Sharing technical expertise and updates among different laboratories	• Provide several easy-to-use platforms for members to share expertise and laboratory needs • Provide career advancement opportunities for junior faculty and trainees at annual meeting and monthly discussions	• 163 subscribers to all-member listservs, along with 9 subgroups or committees for different interests and responsibilities varying from 8 to 45 subscribers. • "GOAL Café" open forum monthly meeting with approximately 20 members in attendance and sharing expertise • Hosted 10 monthly meetings in 2021, and 9 in 2022. • Hosted 1 in-person event in the fall of 2022 with 44 members from a majority of the 29 member laboratories • Hosted annual Virtual Meetings in 2021 and 2022 with attendance of approximately 150 registrants each • Hosted inaugural Member Business Meeting in January 2022
	Developing Laboratory Best Practices: Practice Surveys and Best Practice Recommendations	• Ongoing member landscape analysis of NGS/non-NGS offerings in solid tumors & hematology • Survey on reporting elements to define specifications for shared database and reporting elements	• 18 respondents to NGS practices among 28 laboratories for NGS testing of hematological malignancies in the fall of 2021 • Manuscript on heme survey to be submitted in early 2023 • Currently, task force developing a reporting practices survey to be distributed in early 2023

The networking aspects of GOAL are perceived as providing added value. Aggregating laboratory data across many institutions in different parts of the country serving different populations has the potential to add robustness to assertions about outcomes (Table 4). GOAL is also exploring the possibility of applying for grants from other organizations directed at provision of high-value care, such as the Agency for Healthcare Research and Quality at the National Institute of Health (NIH). As a direct outcome of improved communication between laboratories and sponsors, GOAL drives scholarly efforts and academic credit for molecular pathologists thus serving an underlying mission of the member institutions.

To date, GOAL is facilitating and coordinating two retrospective studies that are in various stages of design and review, with support from Founding Sponsors (Table 4). The review process begins with a feasibility assessment of the core project by GOAL laboratories, refinement by GOAL, assignment of the GOAL overall PI(s), and finalization of the scope of work and budget in collaboration with the sponsor. Upon finalization, the study will be opened for participation by all interested GOAL laboratories that meet the minimum eligibility criteria. Final participating laboratories will be selected based on the needs of each project, available case mix at each site, and internal review board (IRB) approval. GOAL will provide a grant to each participating laboratory to perform the research project as described in a statement of work, ideally appended to the executed Master Participation Agreement. Notably, the ability of GOAL to facilitate projects is not designed to merely function in a manner analogous to a contract research organization (CRO), but rather to identify projects that bring academic value to participating sites and projects must align with GOAL's mission in order to be considered for organizational effort.

Tools to Foster Collaboration and Exchange Expertise: Expanding beyond the core GOAL panel

Recently, GOAL has established communication tools including specialized working groups, monthly open discussions ("GOAL Cafe"), and an active email/listserv community to share expertise and support member laboratories beyond the core NGS panel (Table 4). Experience with and protocols for additional elements of oncology NGS testing including RNA sequencing, methods for calculating TMB, homologous recombination deficiency (HRD), and other mutation signatures have been shared and discussed.

Practice surveys of the GOAL members have also proved particularly informative in identifying areas where more collaborative discussion is needed with the goal of developing best practice recommendations for member use (Table 4). GOAL will also extend its findings to the larger community. For instance, a manuscript summarizing how member laboratories balance the use of large and small panel NGS and non-NGS assays for hematological malignancies is in preparation (Table 4).

Genomics future for academic pathology

More than a decade ago, Wall and Tonellato's summarizing conference proceedings envisioned a future for pathology in which genomics would revolutionize the field's scope of practice and consequently trainee education.[14] That future state has unquestionably arrived, with an ever-increasing body of genomic-centered knowledge now incorporated into the diagnosis and classification of many disease types, as had already been the case for germline Mendelian disorders. Within the GOAL consortium, we believe there are numerous possible avenues for future academic endeavors. This includes engaging with regulatory authorities for multi-site assay approval, supporting clinical studies in a coordinated effort, establishing the GOAL network as a recognized basis for clinical trial eligibility across different trial networks, engaging with national and international databases, developing custom applications to support GOAL-laboratory workflows, and other possibilities yet to be determined.

Given the ever-increasing number of biomarker-linked therapies, oncology (along with infectious diseases) has been at the forefront of integrating genomic testing into personalized medicine. However, in the near future, genomic medicine is anticipated to more greatly influence the workup of diseases in immunology, cardiology, and neurology among other disciplines. Academic pathology laboratories must remain at the forefront of this wave of practice-changing laboratory medicine. GOAL can serve as a model for how high-quality pathologist-driven initiatives can drive genomic integration in those specialties. Our proactive approach to collectively addressing the threats to academic laboratories from increasing commoditization of sequencing services and other market pressures has already helped ensure laboratory survival, promote robust institutional innovation, and preserve patient access to cutting-edge genomics.

GOAL's collaborative and shared approach, through group reagent purchasing and joint development of critical bioinformatics resources, is one model to promote assay affordability and promote and retain specialized bioinformatics expertise. Given that academic pathology laboratories are generally small entities with a broad clinical mission, development of an appropriately scaled and replicable model for information management, fiscal sustainability, and regulatory frameworks for genomics are needed. Such a model must be flexible, open to incremental improvement, and amenable to distribution. GOAL's model of inter-laboratory agreements may have particular standing with payers, pharmaceutical companies, and regulators. GOAL has the potential to refine best practice recommendations, through thoughtful and collaborative development of well-designed studies and laboratory practices among the GOAL member laboratories. This academic approach becomes an asset in providing reassurances to clinical colleagues and pharmaceutical companies regarding assay quality and clinical utility for diagnostic biomarker testing.

As GOAL continues to develop, the potential for this academic consortium to facilitate professional development and high-impact publications and grant-funded projects has become more apparent. The establishment of a close network around shared technology allows for multi-institutional studies, publication, and mentorship. Maintaining state-of-the-art technology allows for state-of-the-art training with shared teaching across the institutions. However, our efforts are not enough. A rewarding and sustainable future for academic molecular pathology will require many such initiatives including in technology development (free from overly restrictive intellectual property claims) and training, competency, and career development pathways for molecular directors and bioinformatics professionals.

Beyond the benefit to individual genomic laboratories and their respective institutions, though, is the benefit to patients. In many clinical studies, the transition to genomically centered care is already underway. Democratizing genomics is perhaps one of the most important steps that can be taken to establish equitable and consistent healthcare. Such democratization can only come if the barriers to deployment are reduced. When a health system no longer has to look at genomic medicine through the lens of a cost center, but rather can view it as a value proposition, patients will win. Leveraging group strengths can substantially reduce the barriers and thereby increase patient access to cutting-edge testing in a way that keeps up with the state-of-the-art.

The collaborations and shared initiatives undertaken by GOAL represent only a small step towards the essential efforts required to fill the pressing needs and gaps and ensure a bright future for genomics in academic pathology. Nonetheless, we believe this recounting of GOAL's origin and successes to date can be helpful in agenda-setting and gap analysis to guide the efforts of leaders in academic pathology for the future.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank Priscilla Markwood, Executive Director of the APC, for her guidance on the development of this publication and continued advisement on the establishment of GOAL. The authors also thank members of the GOAL administrative team, Tracy Busse and Bryan Gall, for their contributions to this manuscript.

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