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# Bridging the Gap in Genomic Implementation: Identifying User Needs for Precision Nephrology

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**Introduction:** Genomic medicine holds transformative potential for personalized nephrology care; however, its clinical integration poses challenges. Automated clinical decision support (CDS) systems in the electronic health record (EHR) offer a promising solution but have shown limited impact. This study aims to glean practical insights into nephrologists' challenges using genomic resources, informing precision nephrology decision support tools.

**Methods:** We conducted an anonymous electronic survey among US nephrologists from January 19, 2021 to May 19, 2021, guided by the Consolidated Framework for Implementation Research. It assessed practice characteristics, genomic resource utilization, attitudes, perceived knowledge, self-efficacy, and factors influencing genetic testing decisions. Survey links were primarily shared with National Kidney Foundation members.

**Results:** We analyzed 319 surveys, with most respondents specializing in adult nephrology. Although respondents generally acknowledged the clinical use of genomic resources, varying levels of perceived knowledge and self-efficacy were evident regarding precision nephrology workflows. Barriers to genetic testing included cost/insurance coverage and limited genomics experience.

**Conclusion:** The study illuminates specific hurdles nephrologists face using genomic resources. The findings are a valuable contribution to genomic implementation research, highlighting the significance of developing tailored interventions to support clinicians in using genomic resources effectively. These findings can guide the future development of CDS systems in the EHR. Addressing unmet informational and workflow support needs can enhance the integration of genomics into clinical practice, advancing personalized nephrology care and improving kidney disease outcomes. Further research should focus on interventions promoting seamless precision nephrology care integration.

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Genomic medicine holds immense promise in delivering personalized care across various medical domains, offering potential benefits to the millions of Americans living with chronic kidney disease.[1] In particular, genomic sequencing approaches are valuable tools for identifying the genetic underpinnings of kidney diseases in up to 37% of cases, facilitating the development of precision medicine strategies.[2-9] The successful integration of genomic sequencing into clinical practice poses several challenges. One study showed that despite the integration of genomic information into the EHR, it did not guarantee clinicians' engagement or the advancement or delivery of precision care. A prominent issue is the varying degrees of experience that clinicians possess in the realm of genomics.[10-22] Using this information necessitates an understanding of specialized terminology; familiarity with diverse diagnostic sequencing approaches; an awareness of genomic result categories; and a grasp of ethical, legal, and technical considerations.[10,21]

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The adoption of automated CDS tools within the EHR has gained significant traction, presenting a promising avenue for advancing the broader implementation of genomics in medicine.[13,19,23–25] CDS provides clinicians with information at the point of care, with the intention of improving outcomes or delivering higher quality care.[26] These tools hold the potential to streamline the incorporation of genomics into clinical workflows. However, to fully harness the capabilities of CDS tools and ensure their usability and effectiveness in assisting clinical decision-making, it is paramount to first comprehend the needs, requirements, preferences, and expectations of the target end-users, particularly physicians.[27–30]

To address these knowledge gaps and understand the potential needs of target users better, we initiated a comprehensive needs assessment study involving key stakeholders. Our primary focus is on US nephrologists, including those working in academic institutions and other healthcare settings. This study used an anonymous electronic survey to gather nephrologists' experiences and viewpoints on using genomic resources in patient care. Our goal was to collect practical insights that will guide the development of precision nephrology decision support tools, ensuring that they align with the needs and expectations of healthcare professionals who will use them. This needs assessment study set out to uncover the specific requirements and preferences of potential users in the realm of precision nephrology.

## METHODS

We conducted an anonymous survey to explore nephrologists' experiences and perspectives on the use of genomic resources and technologies in nephrology patient care. The survey assessed their practice characteristics, use of genomic resources, factors influencing the decision to order or refer patients for genetic testing and their views on various aspects related to genomics in nephrology care. An anonymous, self-administered electronic survey was developed and distributed nationwide to practicing nephrologists in the United States. The study received approval from Columbia University's Institutional Review Board (IRB-AAAT4755).

### Development of the Survey Instrument

The survey instrument was developed based on prior studies and used the Consolidated Framework for Implementation Research as a theoretical framework.[10,11,15,16,19,31–38] The Consolidated Framework for Implementation Research framework considers various domains to identify and address factors that influence successful implementation and adoption. The survey was iteratively developed between September 1 and December 31, 2020, with input from a core study team composed of clinical nephrologists, kidney genomics experts, and biomedical informatics specialists. The survey underwent robust functionality testing after being entered into Research Electronic Data Capture for electronic distribution.[39] A pilot study was conducted among 5 local nephrologists to assess face and content validity, as well as survey duration. Adjustments were made to ensure clarity and a short completion time (<15 minutes).

In addition to demographic and practice-related questions, the survey consisted of 6 sections (Supplementary Table S1). These sections focused on different aspects, such as respondents' experiences with genomic resources, attitudes toward using genomic resources in clinical care, willingness to adopt new diagnostic technologies, and knowledge and self-efficacy in using genomics. Attitudes toward using genomic resources, willingness to adopt new diagnostic tools, and barriers to using genomic resources were adapted from published genomic implementation studies.[12,16,17,34,40–42] These aspects were measured using Likert scales. To assess willingness, we used a genomics-adapted version of the Evidence-Based Practice Attitude Scale called EBPAS-GII.[12,40–42] This scale measured willingness across 3 parameters: (i) openness to new practices (2 items), (ii) perceived divergence from usual practice (2 items), and (iii) intuitive appeal of using new resources for informed care. Total scores were calculated based on respondents' willingness and their responses to 11 perceived barriers. Furthermore, to assess perceived knowledge and self-efficacy, the survey included a clinical vignette, a conceptual precision nephrology workflow (depicted in Figure 1), and nephrology-specific survey items. These nephrology-related survey items were derived from 2 primary sources: (i) qualitative interviews conducted with nephrologists as part of a pilot study on genomics return of results workflow,[10] and (ii) insights gathered from discussions with nephrologists from various regions who refer their patients to our genetics clinic.[31] To evaluate objective knowledge, we used the Genetic Variation Knowledge Assessment Index.[20]

### Recruitment and Data Management

The survey was available online from January 19 to May 19, 2021, and United States based nephrologists were targeted for recruitment. The survey links were sent to National Kidney Foundation members via 2 email invitations in March 2021. Additionally, the survey link was shared with members of the Network of Minority Health Research Investigators, and on social media platforms. Prospective participants were

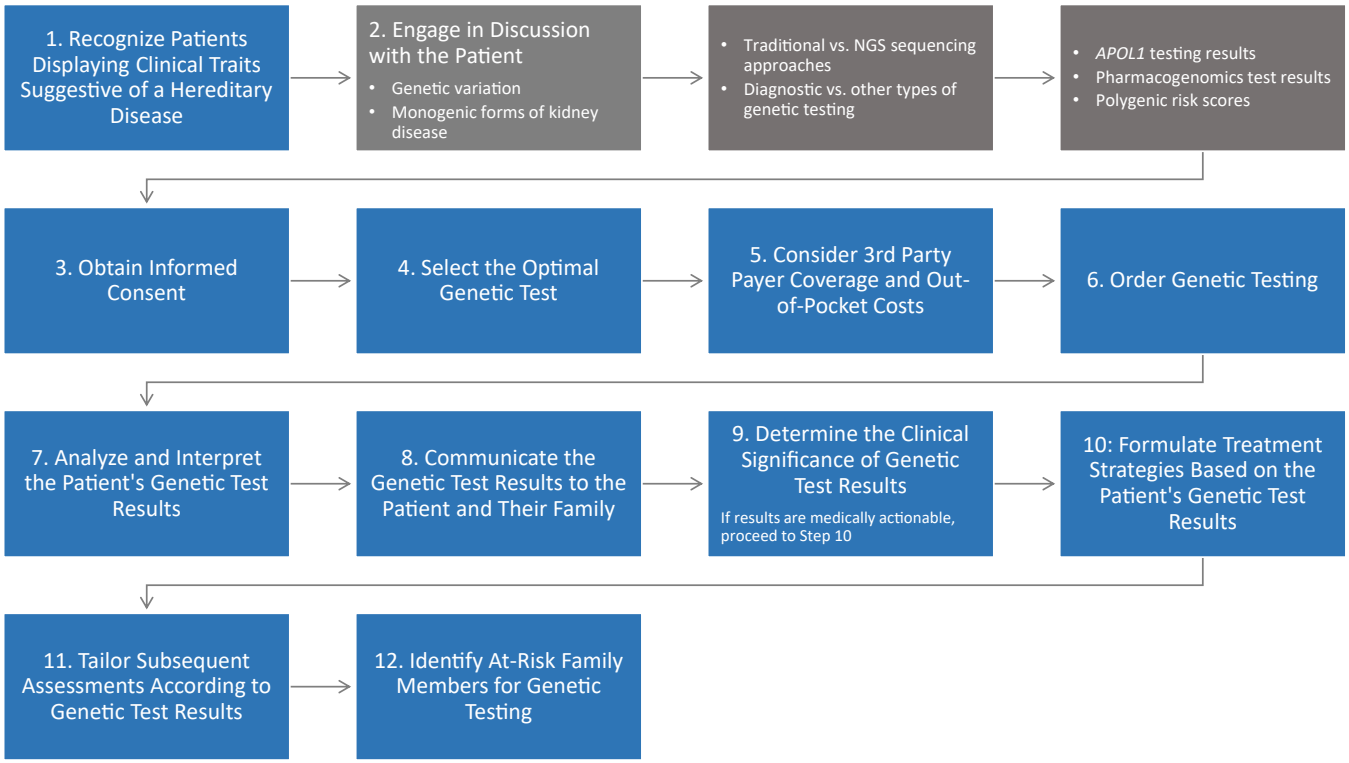


**Figure 1.** Conceptual precision nephrology workflow for nephrologists. This figure shows a conceptual precision nephrology workflow. Respondents' perceived knowledge and self-efficacy were evaluated using survey items specifically designed to assess their proficiency in various tasks related to a conceptual genomics workflow. These survey items were presented alongside a clinical vignette, enhancing the context and relevance of the assessment.

incentivized with a chance to win electronic gift cards. Respondents provided written consent to participate. Completed surveys from board-certified/eligible US nephrologists in active clinical practice were included in the analysis. Uniqueness was assessed using multiple methods, including the evaluation of date and time stamps to identify potential duplicate submissions.

## Data Analyses

Descriptive statistics were used to summarize the data. To evaluate the relationship between prior experience in ordering genetic testing and various factors related to respondents' characteristics, their willingness to adopt new diagnostic technologies, their perceived knowledge and self-efficacy in executing tasks within a conceptual genomics workflow, and their perceived obstacles to ordering or referring patients for genetic testing, we conducted between-group comparisons. For ordinal variables represented by Likert-type scales, we applied the Mann-Whitney U test, whereas for nominal variables, we used the Pearson $\chi^2$ test. All statistical analyses were executed using R, a freely available software environment for statistical computing and graphics (R Core Team, 2021).[43] We considered statistical significance at a level of $P < 0.05$ and adjusted for multiple comparisons using the Holm-Bonferroni correction method.

Comprehensive information on survey development, participant enlistment, data analysis, and the definitive survey version can be found in Supplementary Methods of the Supplementary Appendix.

# RESULTS

Out of the total 603 survey entries gathered, 47% ($n = 284$) were excluded from the analysis (Figure 2). This exclusion involved 87 responses from nephrologists who were not actively practicing in the United States ($n = 71$) and those without board certification or board eligibility ($n = 16$). Furthermore, 195 incomplete survey entries were also omitted. Among the incomplete responses, it was found that in 95% of cases, <10% of the survey questions were answered. In the remaining instances, <15% of the survey was completed. Additionally, 2 survey entries, suspected to be duplicates (methods detailed in the Supplementary Appendix), were omitted. Consequently, the final analysis included a total of 319 completed anonymous electronic survey entries from eligible participants.

## Within-Group Comparisons

### *Demographics and practice setting characteristics*

The majority of respondents self-identified as White (53%) and non-Hispanic/non-Latino (84%)

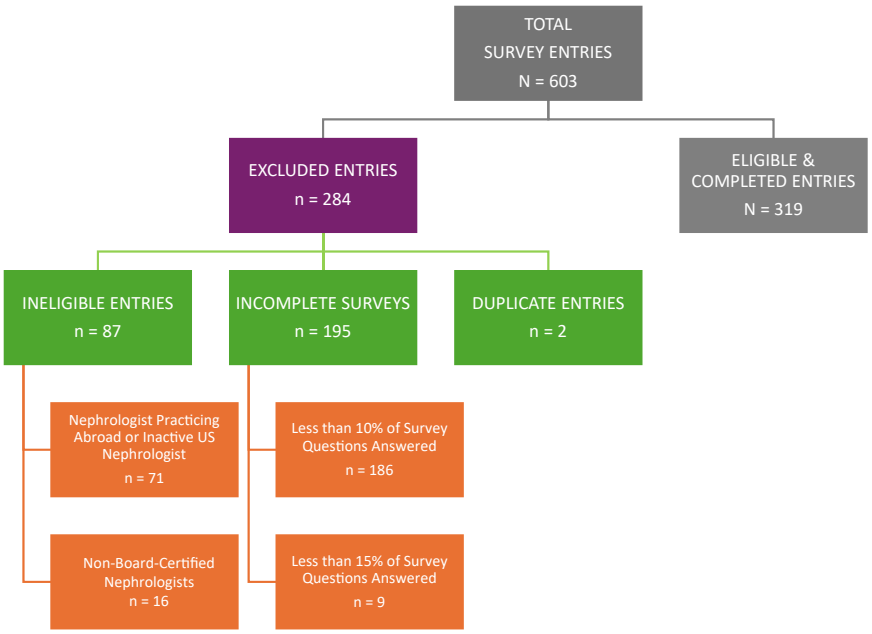


**Figure 2.** Study flow chart. This figure illustrates the study flow chart. The final analysis included only completed anonymous electronic survey entries from eligible participants. Two survey entries were deemed to be duplicates by examining date and time stamps to identify possible duplicate submissions (as detailed in the Supplementary Appendix).

(Table 1; Supplementary Figure S1 in Supplementary Results of the Supplementary Appendix). Approximately one-third were female (34%). Most respondents had at least 5 years of attending-level experience in nephrology (74%), specialized in adult-level care (87% vs. 13% in pediatric nephrology), and spent at least 50% of their efforts in patient-facing care (75%). The majority of respondents worked with advanced practitioners, such as NPs and/or PAs (74%). Almost half of the number of those worked in an academic institution (46% vs. 54%). Respondents were geographically distributed across the United States, with the highest percentages in the South (35%) and North-East (32%). Epic Systems (Madison, WI) was the most commonly used EHR system (61%).

### *Experiences using genomics*

A majority of respondents had prior experience in ordering genetic testing (76%) (Table 2; Supplementary Table S2). Fifty-six percent of respondents reported participation in returning genetic test results to patients. Approximately half of the number of respondents (49%) believed that genetic test results have meaningful clinical implications in ≤30% of cases. Approximately a third of the number of respondents (32%) favored a clinical workflow in which nephrologists both ordered genetic testing for their patients and communicated the results.

### *Attitudes toward the utilization of genomic resources*

Respondents' evaluations of the clinical utility of genomic resources yielded a median rating of 4, with quartiles spanning from 4 to 4 on a 5-point scale (Table 3). In terms of their training and preparedness, respondents had a median response level of 3, with quartiles ranging from 3 to 3.5. When it came to their willingness to embrace new diagnostic technologies, the range of scores varied widely. For the total willingness score, which ranged from 5 to 25, the minimum score recorded was 12, the first quartile reached 18, the median score was 20, the third quartile was 21, and the maximum score was 25.

Assessing respondents' self-efficacy across tasks within the conceptual precision nephrology workflow (as shown in Figure 1), the median response level was 3, with quartiles ranging from 3 to 3.25. Respondents expressed high comfort levels in using the EHR, computers, and CDS tools, such as online risk calculators, all of which received a median response rating of 5, with quartiles at 5.

In terms of their perceived knowledge of using genomic resources, the median response level was 3, with quartiles spanning from 2.5 to 4. Assessing their objective knowledge using the Genetic Variation Knowledge Assessment Index, the total scores exhibited a wide range: the minimum score was 2, the first quartile was 5, the median score was 6, the third quartile was 6, and the maximum score reached 8.

### *Perceived barriers to ordering or referring patients for genetic testing*

Regarding factors that have a negative influence on their decision to order or refer a patient for genetic testing, "Cost/lack of insurance coverage for testing," "Limited expertise," "Concern for unintended

**Table 1.** Respondents' demographic and practice characteristics

| Respondents' demographic and practice characteristics | Overall (*N* = 319) *n* (col %) |
|---|---|
| Sex | |
| Female | 107 (34%) |
| Age groups | |
| < 25 yr old | 38 (12%) |
| 25–34 yr old | 111 (35%) |
| 35–44 yr old | 93 (29%) |
| 45–54 yr old | 40 (13%) |
| 55–64 yr old | 28 (9%) |
| ≥ 65 yr old | 9 (3%) |
| Race | |
| White | 168 (53%) |
| Asian | 108 (34%) |
| Black or African American | 8 (3%) |
| Other/more than one race | 8 (3%) |
| American Indian or Alaska Native | 3 (1%) |
| Prefer not to answer | 24 (8%) |
| Ethnicity | |
| Hispanic/Latino | 29 (9%) |
| Non-Hispanic/Non-Latino | 267 (84%) |
| Prefer not to answer | 23 (7%) |
| Graduated from a US medical school | 132 (41%) |
| Yr of nephrology experience (excluding fellowship) | |
| Less than 5 yr | 83 (26%) |
| 5–10 yr | 62 (19%) |
| 11–15 yr | 54 (17%) |
| 16–20 yr | 39 (12%) |
| 21–30 yr | 42 (13%) |
| Over 30 yr | 39 (12%) |
| Clinical role | |
| Adult nephrologist | 249 (78%) |
| Adult transplant nephrologist | 27 (9%) |
| Pediatric nephrologist | 42 (13%) |
| Pediatric transplant nephrologist | 1 (0.3%) |
| Participate in kidney transplant evaluations | 115 (36%) |
| Work with advanced practitioners (i.e., NPs, PAs) | 235 (74%) |
| Percent of total effort dedicated to patient care | |
| 75%–100% | 168 (53%) |
| 50%–74% | 70 (22%) |
| 25%–49% | 40 (13%) |
| Less than 25% | 41 (13%) |
| Major professional activities | |
| Outpatient and inpatient | 213 (67%) |
| Mostly outpatient | 51 (16%) |
| Mostly inpatient | 26 (8%) |
| Research | 26 (8%) |
| Other | 3 (1%) |
| Current employer | |
| Academic institution | 147 (46%) |
| Academic affiliated practice | 45 (14%) |
| Veterans Affairs | 18 (6%) |
| Private group practice | 78 (24%) |
| Private solo/2-physician practice | 21 (7%) |
| Other (nonacademic) | 10 (3%) |
| Academic appointment | 237 (74%) |
| Academic title (*n* = 237) | |
| Instructor | 18 (8%) |
| Assistant professor | 104 (44%) |
| Associate professor | 54 (23%) |
| Professor | 56 (24%) |
| Other | 5 (2%) |
| US region | |
| South | 110 (35%) |
| North-East | 102 (32%) |
| Mid-West | 56 (18%) |
| West | 44 (14%) |
| Not reported | 7 (2%) |
| Practice location | |
| Large city | 201 (63%) |
| Small city | 70 (22%) |
| Suburb of large or small city | 29 (9%) |
| Town | 13 (4%) |
| Rural area | 6 (2%) |
| How are most patients insured at your practice? | |
| Government-sponsored insurance | 219 (69%) |
| Private insurance | 49 (15%) |
| HMO or managed care plans | 16 (5%) |
| Uninsured/self-pay/sliding scale or other | 5 (2%) |
| Unsure | 30 (9%) |
| What EHR system do you mostly use at your practice? | |
| Epic | 194 (61%) |
| Cerner | 35 (11%) |
| Athenahealth | 8 (3%) |
| Allscripts | 19 (6%) |
| eClinicalworks | 14 (4%) |
| Other EHR systems (NextGen, Meditech, Vista (CPRS), etc.) | 46 (14%) |
| None | 3 (1%) |

EHR, electronic health record; HMO, Health Medical Orga; NPs, Nurse Practitioners; PAs, Physician Assistants.

psychoemotional harm to patient/family," and "Lack of ancillary support/staff" were considered either a "Minor reason" or a "Major reason" by a substantial proportion of respondents, ranging from 58% to 90% (Table 4; Supplementary Figure S2). Conversely, factors with the least impact on their decisions, in which respondents indicated "Not a reason," included "Personal and/or religious views," "Privacy concerns," "No time," and "Concern for medical liability." The proportion of respondents in this category varied from 60% to 88%. The total barrier score, which ranged from 0 to 22, showed variation among participants: the minimum score was 0, the first quartile was 4, the median score was 7, the third quartile was 11, and the maximum score reached 19.

## Between-Group Comparisons

### *Prior experiences ordering genetic testing*

Using the Mann-Whitney U test for ordinal variables, we identified statistically significant differences in the

**Table 2.** Respondents' experiences and attitudes towards genomics utilization

| Respondents' experiences and attitudes towards genomics utilization | Overall ($N = 319$) *n* (col %) |
|---|---|
| Have you ever ordered genetic testing for a patient? | |
| Yes | 241 (76%) |
| How many patients have you ordered genetic testing for in the past 2 yr? ($n = 241$) | |
| 0 patients | 10 (4%) |
| 1 to 4 patients | 121(50%) |
| 5 to 9 patients | 40 (17%) |
| More than 10 patients | 70 (29%) |
| How often are you involved in returning genetic results to patients? | |
| Never | 50 (16%) |
| Almost never | 90 (28%) |
| Occasionally or sometimes | 71 (22%) |
| Almost every time | 63 (20%) |
| Every time | 45 (14%) |
| How often do genetic test results have meaningful implications in patient care? | |
| Never | 0 |
| Rarely (in less than 10% of cases) | 58 (18%) |
| Occasionally (in about 30% of cases) | 99 (31%) |
| Sometimes (in about 50% of cases) | 90 (28%) |
| Frequently (in about 70% of cases) | 54 (17%) |
| Usually (in about 90% of cases) | 13 (4%) |
| Every time | 5 (2%) |
| Which workflow do you prefer? | |
| Nephrologist refers patient to genomic professional[a] who orders genetic test, then nephrologist returns the results | 146 (46%) |
| Nephrologist refers patient to genomic professional who orders test and returns the results | 57 (18%) |
| Nephrologist orders the genetic test and returns the results | 102 (32%) |
| Other | 12 (4%) |

[a]Genomics professionals encompass clinical geneticists, genetic counselors, and nephrologists who possess expertise in genomics.

distribution of responses for numerous survey items related to the clinical usefulness of genomic resources, as well as respondents' perceptions of their training and preparedness, perceived self-efficacy, and knowledge regarding the use of genomic resources between those with and without prior experience ordering genetic testing for their patients (Supplementary Table S3). Additionally, we observed significant differences in the distribution of responses between both groups across several perceived barriers: limited experience ($P < 0.001$), lack of ancillary support/staff ($P < 0.05$), concern for medical liability ($P < 0.001$), and concern for unintended psychoemotional harm to patient/family ($P < 0.05$).

Furthermore, using $\chi^2$ analysis for nominal variables, we detected significant differences in the likelihood of reporting prior experience ordering genetic testing based on specific factors (Table 5); pediatric nephrologists were notably more likely to have experience in ordering genetic testing compared with their adult counterparts (93% vs. 73%; $P < 0.05$); respondents who did not collaborate with advanced practitioners were significantly more likely to report experience in ordering genetic testing compared with those who did (63% vs. 50%; $P < 0.05$); and individuals employed at academic institutions showed a significantly higher likelihood than those practicing outside of academic institutions to report experience in ordering genetic testing (84% vs. 69%; $P < 0.05$).

These findings maintained their statistical significance even after accounting for multiple comparisons, underscoring the robustness of the results.

## DISCUSSION

The objective of this study was to evaluate nephrologists' knowledge, attitudes, and willingness to use genomic resources in clinical practice, and identify factors influencing their decision to order or refer patients for genetic testing. We found that most respondents recognized the clinical usefulness of genomic resources and expressed a willingness to adopt new diagnostic technologies across diverse practice environments. However, variations emerged when examining their self-perceived knowledge and self-efficacy levels in tasks related to a conceptual precision nephrology workflow. These findings indicate potential areas for focused training and support to enhance nephrologists' comfort and ease in using genomic resources. Furthermore, the study identified perceived barriers to the ordering or referral of patients for genetic testing. Concerns about the financial aspects of genetic testing and the respondents' perceived lack of experience in genomics were among the prominent obstacles reported. These barriers bear significant implications for the successful integration of genomics into nephrology practice, because they have the potential to impede the delivery of personalized patient care. Importantly, this is where CDS tools, embedded within the EHR, can play a pivotal role in supporting nephrologists in providing precision care.

Similar to previous genomic implementation studies, our survey instrument was constructed using the Consolidated Framework for Implementation Research conceptual framework and included genomics implementation-specific questions sourced from previously published surveys.[15,16,32,33,37,38] Our findings also align with a prior study that identified perceived barriers to genetic testing among nephrologists, particularly noting concerns about cost and ease of use of such testing.[44] However, our study differentiates itself by focusing on identifying unmet needs among practicing US nephrologists, with the specific aim of informing the development of nephrology-tailored decision support tools. To achieve this goal, our survey incorporated unique elements, including a clinical

**Table 3.** Respondents' attitudes, knowledge, and self-efficacy utilizing genomic resources

| Respondents' attitudes, knowledge, and self-efficacy utilizing genomic resources | | | Overall ($N$ = 319) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $n$ (ROW %) or Median (IQR) on a 5-point Likert scale | | | | | | |
| Please indicate how much you agree or disagree with the following statements: | | | Strongly disagree (1) | Disagree (2) | Neither agree nor disagree (3) | Agree (4) | Strongly agree (5) | Median (IQR) | |
| Clinical usefulness | Genetic testing for hereditary forms of kidney disease offers information that is clinically useful | | 4 (1%) | 4 (1%) | 25 (8%) | 166 (52%) | 120 (38%) | 4 (4–5) | 4 (4–4) |
| | Genetic testing for risk alleles associated with common diseases offers information that is clinically useful | | 3 (1%) | 25 (8%) | 77 (24%) | 169 (53%) | 45 (14%) | 4 (3–4) | |
| | Genetic test results will improve my ability to care for patients | | 3 (1%) | 8 (3%) | 57 (18%) | 169 (53%) | 82 (26%) | 4 (4–5) | |
| | I believe genetic testing for hereditary forms of kidney disease is relevant to my current clinical practice | | 4 (1%) | 12 (4%) | 44 (14%) | 157 (49%) | 102 (32%) | 4 (4–5) | |
| | Broader access to genetic testing will improve how I currently evaluate and manage patients with suspected hereditary conditions | | 3 (1%) | 12 (4%) | 29 (9%) | 163 (51%) | 112 (35%) | 4 (4–5) | |
| | Having point-of-care access to patients genetic risk information will significantly improve my ability to care for them | | 3 (1%) | 15 (5%) | 59 (19%) | 163 (51%) | 79 (25%) | 4 (4–4) | |
| | Diagnostic molecular findings for hereditary forms of kidney disease will improve my ability to care for patients | | 2 (1%) | 17 (5%) | 48 (15%) | 168 (53%) | 84 (26%) | 4 (4–5) | |
| Training & preparedness | My training has prepared me to work with patients at high risk for genetic conditions | | 25 (8%) | 81 (25%) | 102 (32%) | 78 (25%) | 33 (10%) | 3 (2–4) | 3 (3–3.5) |
| | I am confident in my ability to use genetic test results | | 15 (5%) | 79 (25%) | 105 (33%) | 94 (30%) | 26 (8%) | 3 (2–4) | |
| | Genetic testing fits within the processes I currently use to care for nephrology patients | | 13 (4%) | 52 (16%) | 86 (27%) | 27 (40%) | 41 (13%) | 4 (3–4) | |
| | In my place of practice, clear goals have been established to integrate genetic testing into clinical care | | 44 (14%) | 100 (31%) | 86 (27%) | 55 (17%) | 34 (11%) | 3 (2–4) | |
| | In my place of practice, staff have the resources needed to integrate genetic testing into clinical care | | 38 (12%) | 96 (30%) | 76 (24%) | 77 (24%) | 32 (10%) | 3 (2–4) | |
| | In my place of practice there is a clearly designated person/team that leads the effort to implement genetic testing into clinical care | | 58 (18%) | 84 (26%) | 69 (22%) | 70 (22%) | 38 (12%) | 3 (2–4) | |
| | I can find/use reliable sources of the information I need to apply genetic test results while caring for patients | | 17 (5%) | 67 (21%) | 70 (22%) | 125 (39%) | 40 (13%) | 4 (2–4) | |
| Willingness to use new technologies | I like to use new types of therapies/interventions to help my patients | Openness | 3 (1%) | 9 (3%) | 35 (11%) | 167 (52%) | 105 (33%) | 4 (4–5) | 4 (4–5) |
| | I am willing to use new diagnostic approaches like genetic testing to help patients | | 3 (1%) | 2 (1%) | 22 (7%) | 160 (50%) | 132 (41%) | 4 (4–5) | |
| | I know better than the scientists about how to care for my patients | Divergence[a] | 39 (12%) | 97 (30%) | 125 (39%) | 46 (14%) | 12 (4%) | 3 (2–3) | 2 (2–3) |
| | I would not be willing to prescribe different treatments based on genetic test results | | 80 (25%) | 151 (47%) | 55 (17%) | 26 (8%) | 7 (2%) | 2 (1.5–3) | |
| | I am willing to use genetic test results to inform my patient's care if they "made sense" to me | Appeal | 5 (2%) | 7 (2%) | 51 (16%) | 178 (56%) | 78 (25%) | 4 (4–4) | |
| | Total Willingness Score (modified EBPAS-GII) (Range 5–25) | | Minimum 12 | 25% 18 | Median 20 | 75% 21 | Maximum 25 | | |
| Please indicate your level of comfort with each of the following: | | | Not at all comfortable (1) | Not very comfortable (2) | Neither comfortable or uncomfortable (3) | Comfortable (4) | Very comfortable (5) | Median | Median |
| Perceived self-efficacy | Choosing the most appropriate genetic test for this patient | | 23 (7%) | 90 (28%) | 72 (23%) | 110 (35%) | 24 (8%) | 3 (2–4) | 3 (3–3.25) |
| | Ordering the test | | 29 (9%) | 82 (26%) | 66 (21%) | | 32 (10%) | 3 (2–4) | |
| | Ensuring the patient can provide informed consent for the genetic test | | 19 (6%) | 59 (19%) | 58 (18%) | 145 (46%) | 38 (12%) | 4 (3–4) | |

*(Continued on following page)*

**Table 3.** (Continued) Respondents' attitudes, knowledge, and self-efficacy utilizing genomic resources

| Respondents' attitudes, knowledge, and self-efficacy utilizing genomic resources | Overall ($N = 319$) | | | | | |
|---|---|---|---|---|---|---|
| | *n* (ROW %) or Median (IQR) on a 5-point Likert scale | | | | | |
| Please indicate how much you agree or disagree with the following statements: | Strongly disagree (1) | Disagree (2) | Neither agree nor disagree (3) | Agree (4) | Strongly agree (5) | Median (IQR) |
| Interpreting this patient's genetic test results | 26 (8%) | 84 (26%) | 75 (24%) | 113 (35%) | 21 (7%) | 3 (2–4) |
| Explaining the genetic test results to the patient and their family | 19 (6%) | 76 (24%) | 80 (25%) | 120 (38%) | 24 (8%) | 3 (2–4) |
| Making management decisions based on this patient's genetic test results | 18 (6%) | 71 (22%) | 79 (25%) | 130 (41%) | 21 (7%) | 3 (2–4) |
| Identifying which of this patient's family members need genetic testing | 25 (8%) | 100 (31%) | 82 (26%) | 94 (30%) | 18 (6%) | 3 (2–4) |
| Referring this patient for further evaluation based on genetic test results | 15 (5%) | 59 (19%) | 57 (18%) | 136 (43%) | 52 (16%) | 4 (3–4) |
| Using the electronic health record | 0 | 2 (1%) | 10 (3%) | 78 (25%) | 226 (72%) | 5 (4–5) |
| Using computers | 0 | 2 (1%) | 5 (2%) | 67 (21%) | 242 (77%) | 5 (5–5) |
| Using clinical decision support tools (e.g., online risk calculators, etc.) | 0 | 3 (1%) | 17 (5%) | 91 (29%) | 205 (65%) | 5 (4–5) |
| Perceived knowledge | 20 (6%) | 56 (18%) | 73 (23%) | 147 (46%) | 23 (7%) | 4 (3–4) |
| Genetic variation | 52 (16%) | 130 (41%) | 65 (20%) | 57 (18%) | 15 (5%) | 2 (2–3) |
| Traditional vs. next-generation sequencing approaches | 13 (4%) | 38 (12%) | 52 (16%) | 161 (51%) | 55 (17%) | 4 (3–4) |
| APOL1 test results | 40 (13%) | 99 (31%) | 86 (27%) | 80 (25%) | 14 (4%) | 3 (2–4) |
| Pharmacogenomic results | 62 (19%) | 120 (38%) | 88 (28%) | 43 (14%) | 6 (2%) | 2 (2–3) |
| Polygenic risk scores | 28 (9%) | 48 (15%) | 55 (17%) | 135 (42%) | 53 (17%) | 4 (3–4) |
| Monogenic forms of kidney diseases | 34 (11%) | 93 (29%) | 104 (33%) | 77 (24%) | 11 (3%) | 3 (2–4) |
| Medically actionable secondary (incidental) findings | Minimum 2 | 25% 5 | Median 6 | 75% 6 | Maximum 8 | |
| Objective knowledge | | | | | | |
| Total Objective Knowledge Score (GKAI) (Range 0–8) | | | | | | |

[a]A 5-point Likert scale was used, with reverse scoring applied to the two items related to divergence (5 = "strongly disagree" to 1 = "strongly agree").

vignette, a conceptual precision nephrology workflow, and survey items tailored to nephrology practice. These distinctive components were informed by our extensive experience in implementing genomic technologies and assisting colleagues in navigating this emerging field. As a result, we pinpointed potential areas of unmet informational needs that are particularly relevant to nephrology practice, making a distinctive contribution to the field. Our findings underscore the generally positive attitudes of nephrologists toward genomic technologies and their willingness to integrate them into practice. However, the varying levels of perceived knowledge and significant barriers we observed highlight specific areas where focused interventions can be instrumental. These interventions may encompass additional training and support tailored to address knowledge gaps and overcome identified barriers, ultimately facilitating the seamless integration of genomics into nephrology care. In identifying these unmet needs regarding genomic resource use, our study provides comprehensive insights with significant implications for the development of tailored interventions aimed at effectively addressing specific information and workflow support gaps experienced by nephrologists.

Automated CDS tools integrated within the EHR hold substantial promise in meeting clinicians' unmet needs and promoting the broader use of genomic resources in routine patient care.[13,19,23–25] However, challenges of "alert fatigue" and declining response rates to alerts over time have limited their impact on patient care.[45–49] Addressing these challenges effectively requires optimizing the development and implementation of CDS tools within the EHR. This study emphasizes the importance of understanding the needs of target end-users when developing usable CDS tools, providing insights into nephrologists' requirements, preferences, and expectations when using genomic resources for patient care. It identifies specific areas within precision nephrology workflows where nephrology-tailored CDS tools may be instrumental, irrespective of users' experience with genomics. The effectiveness of CDS tools depends on careful selection of clinical conditions to activate CDS rules, ensuring that useful alerts are delivered without causing unnecessary workflow disruptions.[27,28,50] By streamlining critical processes, such as patient identification for genetic testing, guiding test selection, navigating insurance complexities, and aiding in result interpretation and clinical application of medically actionable findings, nephrology-tailored CDS tools have the potential to enhance the delivery of personalized nephrology care.

This study significantly contributes to guiding the development of future effective CDS tools. It uses a

**Table 4.** Respondents' perceived barriers in the utilization of genomic resources

| Respondents' perceived barriers in the utilization of genomic resources | Overall ($N = 319$) | | | | |
|---|---|---|---|---|---|
| | *n* (ROW %) or Mode (Frequency) on a 2-point Likert scale | | | | |
| Please rate degree of influence each has on your decision to not order/refer for genetic testing: | Not a reason (0) | Minor reason (1) | Major reason (2) | Mode | Frequency |
| Perceived barriers | | | | | |
| Personal and/or religious views | 280 (88%) | 26 (8%) | 13 (4%) | Not a reason | 88% |
| Limited experience | 94 (30%) | 122 (38%) | 103 (32%) | Minor/major reason | 71% |
| No time | 199 (62%) | 101 (32%) | 19 (6%) | Not a reason | 62% |
| Lack of ancillary support/staff | 135 (42%) | 129 (40%) | 55 (17%) | Minor/major reason | 58% |
| Cost/lack of insurance coverage for testing | 32 (10%) | 72 (23%) | 215 (67%) | Minor/major reason | 90% |
| Concern for medical liability | 192 (60%) | 96 (30%) | 31 (10%) | Not a reason | 60% |
| Limited access to educational resources | 155 (49%) | 116 (36%) | 48 (15%) | Minor/major reason | 51% |
| Concern for unintended psychoemotional harm to patient/family | 118 (37%) | 147 (46%) | 54 (17%) | Minor/major reason | 63% |
| No local experts | 180 (56%) | 95 (30%) | 44 (14%) | Not a reason | 56% |
| Privacy concerns | 207 (65%) | 84 (26%) | 28 (9%) | Not a reason | 65% |
| Concern it may lead to discrimination to patient/family/community | 150 (47%) | 121 (38%) | 48 (15%) | Minor/major reason | 53% |
| Total Barrier Score (Range 0–22) | Minimum | 25% | Median | 75% | Maximum |
| | 0 | 4 | 7 | 11 | 19 |

comprehensive approach by using the Consolidated Framework for Implementation Research conceptual framework and integrating genomics implementation-specific questions, along with nephrology-specific assessments derived from previous research.[10,11,15,16,19,31–34,36–38] Collaborative efforts with experts and community-based nephrologists during the survey development process have enhanced the survey's content, reliability, and validity. Furthermore, the study leverages insights from previous work on the development of a return of genomics results pipeline for nephrology patients and considers clinicians'

**Table 5.** Between-group differences in experience ordering genetic testing across respondent characteristics

| Between-group differences in experience ordering genetic testing across respondent characteristics | Overall ($N = 319$) | Experience ordering genetic testing: Yes ($n = 241$) | Chi square statistic | Adjusted *P*-value |
|---|---|---|---|---|
| Items | *n* (Column %) | *n* (Row %) | | |
| Sex | | | 0.033464177 | NS |
| Female | 107 (34%) | 82 (77%) | | |
| Male | 212 (66%) | 159 (75%) | | |
| Age groups | | | 0 | NS |
| ≥ 35 yr old | 170 (53%) | 128 (75%) | | |
| < 34 yr old | 149 (47%) | 113 (76%) | | |
| Yr of nephrology experience | | | 0.000141416 | NS |
| ≥ 11 yr | 174 (55%) | 132 (77%) | | |
| ≤ 10 yr | 145 (45%) | 109 (75%) | | |
| Clinical role | | | 7.158591627 | $P < 0.05$ |
| Adult nephrology and/or adult transplant nephrology | 276 (87%) | 201 (73%) | | |
| Pediatric nephrology and/or pediatric transplant nephrology | 43 (13%) | 40 (93%) | | |
| Participate in kidney transplant evaluations | | | 5.468377378 | NS |
| Yes | 115 (36%) | 96 (83%) | | |
| No | 204 (64%) | 145 (71%) | | |
| Work with advanced practitioners (i.e., NPs, PAs) | | | 8.679665888 | $P < 0.05$ |
| Yes | 235 (74%) | 188 (50%) | | |
| No | 84 (26%) | 53 (63%) | | |
| Current employer | | | 8.944127091 | $P < 0.05$ |
| Private group or solo/2-physician practice, veterans affairs, academic affiliated practice, and other (nonacademic) | 172 (54%) | 118 (69%) | | |
| Academic institution | 147 (46%) | 123 (84%) | | |
| How are most patients insured at your practice? | | | 0.016188977 | NS |
| Government-sponsored insurance, uninsured/self-pay/sliding-scale or other, and unsure | 254 (80%) | 191 (75%) | | |
| Private insurance, HMO or managed care plans | 65 (20%) | 50 (77%) | | |

HMO, Healthcare Maintenance Organization; NPs, Nurse Practitioners; PAs, Physician Assistants.

interactions with EHR-integrated genomics data as studied in collaboration with the Electronic Medical Records and Genomics Network.[2,10,11] This comprehensive approach provides novel insights into nephrologists' specific needs, informing the development of tailored interventions and educational resources designed to empower nephrologists in harnessing genomic advancements for patient benefit. Additionally, it acknowledges the significance of nephrologists' attitudes and perceived barriers to testing, identified in this study and in prior studies, to facilitate broader genomic integration efforts.

In light of these strengths, it is crucial to acknowledge the study's limitations, which include a convenience sample, a relatively small sample size, and the inclusion of a high proportion of respondents from academic institutions. However, it is crucial to contextualize these constraints within the study's purpose. A needs assessment study, such as this one, seeks comprehensive insights into the needs, preferences, and expectations of a specific target population. In this context, the traditional emphasis on large sample sizes, typical in experimental or population-based surveys, is less critical. The survey was distributed to members of National Kidney Foundation and Network of Minority Health Research Investigators, with extensive efforts to ensure a broad audience. Nonetheless, it may not fully represent the entire nephrology workforce. The invitation reached ∼10% of US nephrologists, as detailed in the Supplementary Appendix. Despite these limitations, this study's number of completed surveys is comparable to or even higher than other genomic implementation studies.[12,15–17,22,32,33] Additionally, the respondents in this study brought diverse experiences in applying genomic technologies in nephrology practice. This diversity aligns with the feedback received from nephrologists within our institution and nationwide, who frequently seek our guidance in managing various clinical cases.[31,36,51] While acknowledging the potential influence of nonrespondents' distinct attitudes toward genomic technologies and its impact on generalizability, it is essential to recognize that needs assessment studies, such as this one, are primarily tailored to pinpoint specific challenges and craft interventions based on identified gaps. In this context, the emphasis is on acquiring profound insights rather than merely maximizing participant quantity. Therefore, despite the acknowledged limitations of a convenience sample, small sample size, and the preponderance of academic respondents, these constraints are not deemed critical given the core aim of this needs assessment study. Future research should prioritize gaining a deeper understanding of nephrologists' unmet needs related to genomic information and workflow support. This can be accomplished through thorough investigations, including qualitative interviews. Furthermore, the development and rigorous testing of customizable educational approaches are essential steps to ensure their usability and effectiveness in improving patient outcomes.

## CONCLUSION

This study unveiled nephrologists' needs and challenges in integrating genomics. Although respondents acknowledge the clinical value and embrace new technologies, targeted support and improved EHR-based CDS systems are vital. These systems can streamline genomics, enhance personalized care, and benefit patients with kidney disease. Further research and focused interventions are key to operationalizing precision nephrology.

## DISCLOSURE

All the authors declared no competing interests.

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## SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

**Supplementary Methods**

Development of needs assessment instrument.

Recruitment and data management.

Data analyses.

Final survey instrument.

**Supplementary Results**

**Figure S1.** Histograms of respondents' demographic and practice characteristics, ($N = 319$).

**Figure S2.** Histograms depicting individual perceived barriers, ($N = 319$).

**Table S1.** Source of adapted and modified tools in the needs assessment study.

**Table S2.** Demographic and practice characteristics of respondents based on experience in ordering genetic testing, (Yes, $n = 241$ vs. No, $n = 78$).

**Table S3.** Comparing group responses on likert-type scales regarding genomic resource utilization based on experience ordering genetic testing, (Yes, $n = 241$ vs. No, $n = 78$).

**Supplementary References**

**STROBE Statement** (PDF)

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