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# Pharmacogenomic testing: perception of clinical utility, enablers and barriers to adoption in Australian hospitals

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**Key words**
pharmacogenomic testing, tertiary care setting, survey and questionnaire, interdisciplinary study, Australia.

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## Abstract

**Background:** Despite healthcare professionals (HCP) endorsing the clinical utility of pharmacogenomics testing, use in clinical practice is limited.
**Aims:** To assess HCP' perceptions of pharmacogenomic testing and identify barriers to implementation.
**Methods:** HCP involved in prescribing decisions at three hospitals in Sydney, Australia, were invited to participate. The online survey assessed perceptions of pharmacogenomic testing, including: (i) demographic and practice variables; (ii) use, knowledge and confidence; (iii) perceived benefits; (iv) barriers to implementation; and (v) operational and/or system changes and personnel required to implement on site.
**Results:** HCP were predominantly medical practitioners (75/107) and pharmacists (25/107). HCP perceived pharmacogenomic testing was beneficial to identify reasons for drug intolerance (85/95) and risk of side-effects (86/95). Although testing was considered relevant to their practice (79/100), few HCP (23/100) reported past or intended future use (26/100). Few HCP reported confidence in their ability to identify indications for pharmacogenomic testing (14/107), order tests (19/106) and communicate results with patients (16/107). Lack of clinical practice guidelines (62/79) and knowledge (54/77) were identified as major barriers to implementation of pharmacogenomics. Comprehensive reimbursement for testing and clinical practice guidelines, alongside models-of-care involving multidisciplinary teams and local clinical champions were suggested as strategies to facilitate implementation of pharmacogenomic testing into practice.
**Conclusions:** Pharmacogenomic testing was considered important to guide drug selection and dosing decisions. However, limited knowledge, low confidence and an absence of guidelines impede the use of pharmacogenomic testing. Establishment of local resources including multidisciplinary models-of-care was suggested to facilitate implementation of pharmacogenomics.

## Introduction

The introduction of pharmacogenomic information into clinical decision-making was expected to help minimise the incidence of adverse drug reactions and improve clinical outcomes by predicting an individual's response to a drug.[1] Consistent with this, international studies indicate that healthcare professionals (HCP) report that pharmacogenomic information has clinical utility.[2–10] Despite this, the adoption of pharmacogenomic testing in clinical practice has been limited worldwide.[2–8]

It is well understood that the uptake of evidence-based practices depends on behaviour change.[11] The capability, opportunity and motivation model of behaviour (COM-B) is one theory that has been used to identify barriers and facilitators of behaviour change in multiple contexts,

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including public health (Table 1).[11–13] The dynamic interaction between capability, opportunity and motivation suggests a multidimensional approach addressing individual and institutional factors is required to facilitate behaviour change to promote adoption of pharmacogenomic testing into clinical practice.

A key barrier to the adoption of pharmacogenomic testing is a lack of knowledge; most HCP report no formal education in pharmacogenomics.[2,8,9] Poor understanding of available pharmacogenomic tests and interpretation of results has been found across disciplines including medical practitioners, pharmacy and nursing.[2–8,13–20] Consequently, HCP report a lack of confidence in their ability to incorporate pharmacogenomic information into patient care.[2,4,8–10,20] Training in the clinical application of pharmacogenomic testing has been found to positively impact uptake by HCP.[4,5,10]

Additional barriers to the adoption of pharmacogenomic testing include uncertainty about the value of testing,[3,5,8] a lack of clinical practice guidelines,[2,10,19,21] concerns about confidentiality and privacy[3,4,10,20] and cost of insurance cover.[2,4–6,8,10,16,19,20] At an operational level, barriers include absence of supporting infrastructure and readiness of information systems to implement and integrate pharmacogenomic testing into clinical workflows.[19] HCP report that addressing some of these barriers through the development of clinical practice guidelines,[4,5,22] publication of systematic reviews[5,22] and regulatory approval[5,22] would facilitate adoption and use.

These findings primarily reflect the perceptions and opinions of HCP practising outside Australia. Limited research into pharmacogenomics practice or HCP' perceptions has been conducted in Australia. Although prescribing decisions are commonly made by medical practitioners, previous Australian studies,[17,18] from 2011 to 2014, were conducted exclusively with pharmacists.

The present study aimed to understand current potential barriers and enablers to the adoption of pharmacogenomic testing among HCP in Australian hospitals. In addition, perceptions on clinical utility, current and future use, knowledge and benefits of pharmacogenomic testing were explored. This study will inform the design of strategies to enhance the appropriate use of pharmacogenomic testing.

**Table 1** Summary of capability, opportunity and motivation model of behaviour (COM-B)[11–13]

| Factor | Subcategory | Description |
|---|---|---|
| Capability | Psychological | Knowledge, attention, decision processes |
| | Physical | Skills, proficiencies, abilities acquired through practice |
| Opportunity | Social context | Ethical, legal and social concerns, norms and pressures |
| | Environmental context and resources | Organisational resources and materials, access and process factors, collegial support and work culture, professional regulatory guidelines |
| Motivation | Reflective | Beliefs about capabilities (confidence) and consequences (utility), roles, identity, intention |
| | Automatic | Reinforcement, incentives |

## Methods

The survey (Supporting Information Appendix S1) was adapted from previously published surveys[2,3,5,7,15] and was piloted with six HCP (pharmacists, scientist, registrar, psychology post-doctoral student) for validity. Specific questions were modified to improve clarity and relevance to the Australian healthcare setting (e.g. deletion of reference to the Foods and Drug Administration, and the addition of one item relating to Medicare). Survey items assessed: (i) demographic and practice variables; (ii) knowledge, confidence, current and intended use, including which of the 23 gene–drug pairs as outlined in the Clinical Pharmacogenetics Implementation Consortium (CPIC) guidelines (as at 2019)[23] they had used, or intended to use; (iii) benefits of pharmacogenomics; and (iv) barriers to implementation. Two additional open-ended questions were included for Westmead and Royal Prince Alfred Hospital participants to describe the operational and/or system changes that would be required and HCP who should be involved in implementation. The survey was hosted by SurveyMonkey and took approximately 10 min to complete.

The survey was conducted across three tertiary care hospitals located in Sydney, New South Wales. St Vincent's Hospital Sydney is a 360-bed academic hospital with an average of 32 000 admissions per year. The Royal Prince Alfred Hospital is a 950-bed academic hospital with approximately 80 000 admissions per year. Westmead Hospital is a 1278-bed academic hospital with approximately 107 000 admissions per year. All three institutions have a pathology service located on site that provides pharmacogenomic testing and an electronic medication management system.

HCP including prescribers, hospital scientists and pharmacists at each hospital were invited to participate in the survey through email, newsletters and/or clinical meetings. Invitations and reminders were sent over a 3-month period (June–August 2020) at St Vincent's Hospital and over a 2-month period (April–May 2021) at Westmead and Royal Prince Alfred Hospitals.

The study was approved by the St Vincent's Human Research Ethics Committee (2019/ETH13566).

Participants provided informed consent prior to completing the survey.

Descriptive statistics were used to summarise survey responses. The most endorsed barriers to implementation and short-answer responses to the survey item 'what operational and/or systems changes are needed to implement pharmacogenomic testing' were grouped by topic as outlined in the COM-B framework (Table 1).[11–13] The open-ended responses were independently analysed by two authors (AP, BT) and consensus reached through discussion. Independent samples *t*-tests were used to assess mean differences between groups for the following variables: (i) HCP, categorised as medical practitioners and pharmacists (psychiatrists were excluded from group difference analyses as the sample size was small; 6/107); and (ii) Education, those who had prior education in pharmacogenomics and those who did not. Chi-squared analyses were used to assess the categorical variables of education and use. The Statistical Package for the Social Sciences (SPSS) version 26 was used to conduct the analyses. Data were analysed using pair-wise deletion (available-case analysis); therefore, $N$ varies by item and category. Only significant ($P < 0.05$) differences between groups are reported. Post-hoc analyses were conducted to compute effect size (Cohen $d$) and power was calculated using GPower*[24] with $\beta$ set at >0.80. Analysed effect sizes were moderate to large (0.57–0.80) and based on our sample sizes, we had 81–99% power ($\beta$ = 0.81–0.99) to detect moderate to large effect sizes at the 5% level.

**Table 2** Characteristics of survey responders

| Characteristic | *n* (%†) |
|---|---|
| Sex (*n* = 107) | |
| Female | 52 (49) |
| Male | 55 (51) |
| Age (*n* = 107) (years) | |
| 20–39 | 46 (43) |
| 40–59 | 44 (25) |
| ≥60 | 17 (16) |
| Years in practice (*n* = 107) | |
| 0–9 | 44 (41) |
| ≥10 | 63 (59) |
| Healthcare profession (*n* = 107) | |
| Medical practitioner | 75 (70) |
| Pharmacist | 25 (3) |
| Psychiatrist | 5 (5) |
| Other | 2 (2) |
| Relevancy of pharmacogenomics to current practice (*n* = 100) | |
| Not relevant at all | 7 (7) |
| Unsure | 14 (14) |
| Somewhat relevant | 54 (54) |
| Relevant | 25 (25) |
| Prior instruction/education in pharmacogenomics (*n* = 107) | |
| Yes | 50 (47) |
| No | 57 (53) |
| Training/education (*n* = 50)‡ | |
| Undergraduate medical curriculum | 24 (48) |
| Postgraduate coursework | 9 (18) |
| Residency training | 8 (16) |
| Self-instruction | 25 (50) |
| Continuing medical education seminars | 18 (36) |
| Seminar/workshop | 16 (32) |
| Grand rounds | 4 (8) |

†Percentages have been rounded to the nearest whole number. Table columns therefore approximate 100%.
‡Could choose more than one answer.

## Results

### Characteristics of survey responders

Data were available for 107 HCP. Although it is not possible to determine response rate, the sample represents 3.8% of the pharmacists and medical practitioners registered across the three locations. This is comparable with rates reported in the United States.[7] The majority of HCP were medical practitioners (75/107) from a range of specialties (Appendix S2) and aged between 20 and 59 years (90/107). Most (63/107) had practiced for more than 10 years. Approximately half (57/107) of the HCP had no prior formal education in pharmacogenomics. Of the HCP who had received prior education (50/107), this was primarily through undergraduate coursework (24/57) and self-instruction (25/50). Most (79/107) HCP considered pharmacogenomic testing somewhat relevant to their practice (Table 2). However, only four HCP indicated using pharmacogenomic testing to inform drug-dosing decisions.

### Current and intended future use of pharmacogenomic testing

Only 23 HCP had ordered a pharmacogenomic test in the past 12 months (1/25 pharmacists and 22/75 medical practitioners) and only 26 intended to order one in the next 12 months (5/25 pharmacists and 18/75 medical practitioners spread across multiple specialities). HCP had requested, or intended to request, all 23 recommended gene–drug pairings for pharmacogenomic testing as outlined in the CPIC guidelines (2019).[23]

### Perceived benefits of pharmacogenomic testing

The majority of HCP reported that pharmacogenomic testing informed drug selection decisions by identifying individuals at risk of hypersensitivity reactions (85/95) and other serious side-effects (86/95) (Table 3). Testing

**Table 3** Descriptive statistics for the perceived benefits of pharmacogenomic testing and confidence of healthcare professionals to implement pharmacogenomics into clinical practice

| Perceived benefit | Number (%†) who disagreed/agreed with each statement | | | *M* (SD) | *n* |
|---|---|---|---|---|---|
| | Strongly/Disagree[1/2] | Unsure/Neutral[3] | Strongly/Agree[4/5] | | |
| Be useful to identify medication intolerance and reduce drug toxicity | – | 10 (11) | 85 (89) | 4.13 (0.57) | 95 |
| Help determine whether a patient is at high or low risk of serious side-effects | – | 9 (10) | 86 (90) | 4.12 (0.54) | 95 |
| Be useful to determine a patient's optimal dose of medication | 1 (1) | 14 (15) | 80 (84) | 3.92 (0.52) | 95 |
| Improve drug effectiveness | – | 14 (15) | 81 (85) | 3.97 (0.52) | 95 |
| Help to decrease the time it takes to find the optimal dose of medication | 3 (3) | 15 (16) | 77 (81) | 3.89 (0.68) | 95 |
| Facilitate exchanges of inter-professional information about patient care | 7 (7) | 42 (44) | 46 (48) | 3.44 (0.73) | 95 |
| Reduce the number of consultations with patients | 14 (15) | 34 (36) | 47 (50) | 3.37 (0.88) | 95 |
| Provide additional information to decide the best treatment | 27 (28) | 22 (23) | 46 (48) | 3 (1.33) | 95 |
| Reduce overall costs for patients | 15 (16) | 45 (47) | 35 (37) | 3.2 (0.81) | 95 |
| Improve patient's adherence to therapy | 20 (21) | 46 (48) | 29 (31) | 3.15 (0.81) | 95 |
| Confidence in ability to: | | | | | |
| Identify clinical situations in which pharmacogenomic testing is indicated | 71 (66) | 22 (21) | 14 (13) | 2.19 (0.99) | 107 |
| Order pharmacogenomic tests | 61 (58) | 26 (25) | 19 (18) | 2.33 (1.07) | 106 |
| Inform patients of the risks and benefits of testing | 60 (56) | 31 (29) | 16 (15) | 2.36 (1.00) | 107 |
| Apply pharmacogenomic information to manage patients' drug therapy | 50 (48) | 29 (28) | 26 (25) | 2.60 (1.04) | 105 |
| Make appropriate adjustments to drug therapy based on test results | 45 (43) | 30 (28) | 31 (29) | 2.68 (1.12) | 106 |

†Percentages have been rounded to the nearest whole number. Table columns and rows therefore approximate 100%.

was also perceived to inform dose selection decisions by identifying optimal doses (80/95), effectiveness of drug therapy (81/95) and decreasing the time to optimal dosing (77/95). Fewer HCP indicated that testing would help to reduce the number of consultations with patients (47/95), medical costs for patients (35/95), improve adherence to treatment (20/95) or provide additional information to determine the best treatment option(s) (46/95). Pharmacists' perceived pharmacogenomics had significantly higher utility to determine optimal dose than medical practitioners (Appendix S2). There were no differences based on prior education in pharmacogenomics.

## Self-reported knowledge of pharmacogenomic testing

Overall, few HCP rated their knowledge of the principles of pharmacogenomics as very good or excellent (Table 4). Very few HCP were aware of specific drugs that require pharmacogenomic testing (6/107) and the type of tests available (6/106). For all knowledge items, more than half rated their knowledge as poor to fair. For all items, HCP with prior education in pharmacogenomics rated their knowledge higher than those without prior education (Appendix S2). Medical practitioners rated their knowledge of basic genetic principles significantly higher than pharmacists (Appendix S2).

## Confidence to implement pharmacogenomic testing into clinical practice

Few HCP reported confidence in their ability to identify clinical situations in which pharmacogenomic testing may be indicated (14/107), order tests (19/106) and communicate pharmacogenomic results with patients (16/107). Confidence in the application of pharmacogenomic information to manage (26/105) and adjust therapy (31/106) was slightly higher, although approximately half of the HCP lacked confidence in these areas (Table 3). For all items, except for confidence to order tests, HCP with prior education in pharmacogenomics had more confidence in their ability to apply pharmacogenomic testing to their practice compared to those without prior education (Appendix S2). There were no differences between the pharmacist and medical specialist groups.

**Table 4** Self-reported knowledge of healthcare professionals on specific pharmacogenomic concepts

| Knowledge item | Number (%†) rating their knowledge poor to excellent | | | | *M* (SD) | *n* |
|---|---|---|---|---|---|---|
| | Poor[(1)] | Fair[(2)] | Good[(3)] | Very good/Excellent[(4/5)] | | |
| The role of drug metabolism phenotypes (e.g. poor metaboliser) | 15 (14) | 35 (33) | 35 (33) | 22 (21) | 2.64 (1.06) | 107 |
| Basic genetics principles (e.g. inheritance patterns, somatic versus germline mutation) | 22 (21) | 36 (34) | 31 (29) | 18 | 2.47 (1.09) | 107 |
| Drug transporters and genes associated with toxicity | 40 (37) | 36 (34) | 18 (17) | 12 (11) | 2.03 (1.03) | 107 |
| Pharmacogenomic testing and availability | 48 (45) | 37 (35) | 16 (15) | 6 (6) | 1.82 (0.92) | 107 |
| Drugs that should be accompanied by pharmacogenomic testing | 46 (43) | 41 (39) | 13 (12) | 6 (6) | 1.80 (0.87) | 106 |

†Percentages have been rounded to the nearest whole number. Table columns and rows therefore approximate 100%.

## Perceived barriers to implementation of pharmacogenomic testing

Barriers to implementation of pharmacogenomic testing were identified and grouped according to the COM-B framework: (i) Capability: lack of knowledge about pharmacogenomic testing (54/77); (ii) Opportunity: lack of clinical practice guidelines (62/79) and evidence-based information about pharmacogenomics (54/79), delays between prescribing and receiving results (54/78), lack of available testing services (51/77), expense to patients (46/77) and lack of reimbursement through government subsidy (47/77); and (iii) Motivation: perceptions of uncertain value (48/79) and testing accuracy (47/79). Explaining results to patients (12/78) and any potential liability issues (12/78) were infrequently reported as barriers (Table 5). The barriers reported were similar irrespective of medical profession or prior education in pharmacogenomics.

## Facilitators to implementation of pharmacogenomic testing into clinical practice

Respondents were asked to rate the importance of the following items in maximising the likelihood that they would order or recommend a pharmacogenomic test. Nearly all (91/97) HCP indicated the availability of clinical practice guidelines, followed by guidance from their local institution (84/97), evidence of clinical utility from systematic reviews (85/97), regulatory guidance from the Therapeutic Goods Administration (74/97), recommendations from colleagues (77/96), CPIC guidelines (71/97) or an original peer-reviewed research article (71/97). Guides supplied by third-party pathology services (32/97) or information on drug labels (54/97) were less frequently reported as facilitators. Perceived facilitators to pharmacogenomic testing were similar irrespective of medical profession and prior pharmacogenomic education.

HCP from Westmead and Royal Prince Alfred Hospitals were asked to indicate system and/or operational changes that would facilitate the implementation of pharmacogenomic testing. Of the 72 respondents from these institutions; 25 identified components that could increase their capability or opportunity to implement pharmacogenomics testing. These were grouped according to the COM-B framework and included: (i) opportunity factors – (a) social context, such as reimbursement of testing costs, particularly through Medicare; (b) environmental context and resource organisational factors, such as: access to standardised testing services, including clear logistical instructions; electronic systems to manage and maintain data, ensuring patient privacy and confidentiality; integration of testing processes into current electronic medical systems; guidance and templates for consenting patients and faster turn-around times; and (c) professional regulatory factors such as the development of clinical practice guidelines, including when and where to integrate testing into practice; and (ii) capability factors, such as the inclusion of pharmacogenomics in the undergraduate and postgraduate medical curriculum, further education *in situ* and more experiential opportunities.

## Models of care for implementation of pharmacogenomic testing into clinical practice

Eighteen respondents from Westmead and Royal Prince Alfred Hospitals suggested that within the hospital setting, physicians (including clinical pharmacologists) and pharmacists would be integral to the implementation of pharmacogenomics into practice. The development of models-of-care hat include multidisciplinary teams (including physicians, hospital pharmacists, genetic counsellors, medical geneticists, general practitioners and laboratory staff) were reported to support appropriate incorporation of pharmacogenomic data into clinical decision-making.

**Table 5** Perceived barriers to implementation of pharmacogenomic testing into practice by healthcare professionals grouped by capability, opportunity and motivation model of behaviour factors

| Barriers to implementation | Number (%†) indicating it would/would not affect implementation | | | *M* (SD) | *n* |
|---|---|---|---|---|---|
| | Would not affect(1) | Unsure(2) | Would affect decision(3) | | |
| Capability | | | | | |
| Do not have enough personal knowledge about pharmacogenomic testing | 8 (10) | 15 (20) | 54 (70) | 2.60 (0.67) | 77 |
| Opportunity | | | | | |
| No clear clinical practice guidelines for the use of these tests | 6 (8) | 11 (14) | 62 (78) | 2.71 (0.60) | 79 |
| Lack of evidence-based information | 7 (9) | 18 (23) | 54 (68) | 2.59 (0.65) | 79 |
| Long delays between prescribing a test and receiving results impacts on their usefulness | 8 (10) | 16 (21) | 54 (69) | 2.59 (0.67) | 78 |
| Testing services are not readily available | 6 (8) | 20 (26) | 51 (66) | 2.58 (0.64) | 77 |
| Few pharmacogenomic tests are covered by Medicare | 3 (4) | 27 (35) | 47 (61) | 2.57 (0.57) | 77 |
| Testing is too expensive for most patients | 5 (7) | 26 (34) | 46 (60) | 2.53 (0.62) | 77 |
| Not familiar with the legal issues and regulations of testing | 8 (10) | 32 (41) | 38 (49) | 2.38 (0.67) | 78 |
| Patients are resistant to testing | 13 (17) | 37 (47) | 28 (36) | 2.19 (0.70) | 78 |
| Testing could affect a patients' insurance | 12 (16) | 40 (57) | 25 (33) | 2.17 (0.68) | 77 |
| Patients should seek counselling about the risks, benefits and consequences before testing | 20 (26) | 31 (40) | 27 (35) | 2.09 (0.78) | 78 |
| Pharmacogenomic testing could cause a patient psychological distress | 19 (25) | 33 (43) | 24 (32) | 2.07 (0.75) | 76 |
| Time consuming to keep up to date on advances in the field | 26 (34) | 31 (40) | 20 (26) | 1.92 (0.77) | 77 |
| Pharmacogenomic testing might add liability | 24 (31) | 42 (54) | 12 (15) | 1.85 (0.67) | 78 |
| Difficult to ensure patients' test results will remain confidential | 36 (47) | 27 (35) | 14 (18) | 1.71 (0.76) | 77 |
| Time consuming to order and explain results to patients | 45 (58) | 21 (27) | 12 (15) | 1.58 (0.75) | 78 |
| Motivation | | | | | |
| Pharmacogenomic test results may not be accurate | 8 (10) | 24 (30) | 47 (60) | 2.49 (0.68) | 79 |
| Uncertain value in pharmacogenomic testing | 9 (11) | 22 (28) | 48 (61) | 2.49 (0.70) | 79 |

†Percentages have been rounded to the nearest whole number. Table columns and rows therefore approximate 100%.

## Discussion

The major barriers in implementing pharmacogenomic testing in Australian hospitals, as identified in this study, centred on a lack of knowledge, inadequate guidance and HCP' low confidence in their ability to use and implement pharmacogenomic data in practice. These barriers have been identified previously in other countries[4–6,8,10,15,16,18] in both tertiary[2,9,14,17,20] and primary care[3,7,19,25,26] and align and expand on previous research conducted in Australia more than 7 years ago.[17,18]

Barriers and facilitators to the implementation of pharmacogenomic testing in Australian hospitals aligned with all three domains of the COM-B framework. Consistent with previous research[3,4,7,20] the majority of HCP perceived benefit in pharmacogenomic testing to improve patient care (COM-B Motivation facilitator), particularly to understand a patient's risk of serious adverse drug reactions and individualise dosing regimens. Despite this, very few HCP reported incorporating pharmacogenomic testing into practice. This finding too aligns with previous research from other countries.[4,5,7,8,21] Although HCP believe pharmacogenomic testing is beneficial there are additional barriers to changing behaviour to order and use these results to inform clinical decisions. Consequently, the potential to improve patient safety and clinical outcomes is lost.

Echoing findings from other countries[4,5,7,9,10,20] and supporting Australian research conducted solely with pharmacists in both hospital and community settings,[17,18] a limited understanding of pharmacogenomic testing (COM-B Capability barrier) was reflected in the lack of confidence of HCP (COM-B Motivation barrier) to identify clinical situations where pharmacogenomics is indicated, be able to order tests and discuss pharmacogenomic test results with patients. Although prior education significantly improved both applied knowledge and confidence, HCP with prior education in pharmacogenomics still rated their knowledge and confidence low in absolute terms.

Other significant barriers were associated with the HCP' opportunity to test, which could be restricted by their practice environment, social context and available resources (COM-B Opportunity barrier). Reviews of

pharmacogenomic implementation studies have found that turnaround times of pharmacogenomic test results might be a challenge to implementation.[27,28] Where noted as a barrier, turnaround times were found to vary from 3 to 42 days.[27,28] A combination of institution, laboratory and infrastructure factors contributes to this variability. Delaying prescribing while waiting for pharmacogenomic results is of concern to HCP when compared with standard practice. It has been suggested that widespread pre-emptive testing might, in part, overcome this obstacle.[27–28]

Barriers to be addressed primarily related to clinical guidance in this emerging area. These include a lack of local or national clinical practice guidelines to support HCP in identifying situations in which pharmacogenomic testing is indicated, and guide the ordering of relevant pharmacogenomic tests. These barriers have been identified in other pharmacogenomic studies worldwide,[2,5,6,8,9] driving fragmented development of clinical decision supports, institutional and national guidelines, and pharmacogenomic drug labelling in multiple countries. Finally, the resource implications of testing and the current lack of rebates/Medicare coverage was raised as a key barrier to widespread testing.

The HCP identified strategies to facilitate the implementation of pharmacogenomic testing in Australian hospitals, notably the development of practice guidelines and further education (COM-B Opportunity facilitator). Behaviour change is supported through delivery of education and training as this improves both knowledge and confidence in pharmacogenomics,[10] and education interventions focussing on the clinical application of testing have been shown to positively impact ordering and use,[4,5] helping to realise the promise of pharmacogenomics in clinical care. However, education alone is unlikely to be sufficient in the longer term without addressing key environmental context barriers.[13,29]

Detailed recommendations for system-wide pharmacogenomics enablers identified by the HCP, such as test subsidies or rebates and national pharmacogenomic practice guidelines, are beyond the scope of this paper. However, at the local level, HCP indicated that institution guidance and the expertise of colleagues would increase the likelihood they would adopt pharmacogenomic testing (COM-B Opportunity facilitator). Thus, practical translational programmes that include informal education through networks, including multidisciplinary teams and pharmacogenomic champions, might provide the experiential learning and support required to shift practice.[13] Local implementation programmes also have the benefit of addressing infrastructural barriers including access to tests and the adaptation of existing electronic management systems for pharmacogenomic testing.[13]

There were some limitations in the present study. Although the study was conducted across three major teaching hospitals and included both medical practitioners and pharmacists, the voluntary nature of recruitment might have biased the sample towards HCP who perceive pharmacogenomic testing positively and were therefore more inclined to participate in the study. CPIC gene-drug pairs were used as prompts in the survey to measure usage because they have been specifically proposed as guidelines to adopt for Australia.[30] However, other international guidelines are available including the Dutch Pharmacogenetics Working Group.[31] Although the survey was based on previously published survey items permitting comparisons with previous research, these measures are descriptive and unvalidated. Last, given the small number of HCP per speciality further subgroup analysis was not possible. It remains unclear whether any biases in ordering were influenced by speciality or due to individual and/or institutional factors.

## Conclusions

Australian HCP consider that pharmacogenomic testing has clinical utility particularly to avoid serious adverse drug reactions and personalise dosing regimens. Despite this, the use of pharmacogenomic testing to inform clinical decision-making is very limited and the expectation of improved clinical outcomes has not been fully realised. The main barriers to implementation of pharmacogenomic testing reflect a lack of knowledge of when and how to order a test, how to interpret results and a lack of clinical guidance. However, further education is unlikely to increase use of pharmacogenomic testing unless it is implemented as part of larger efforts that develop opportunity for practice at the local level, developing local capability, infrastructure and champions, and broader system-wide enablers including clinical guidelines and access to evidence-based information to elevate practitioner confidence.

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## Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

**Appendix S1**. Survey items and measurement.
**Appendix S2**. List of specialities and significant differences between groups on perceived benefit, knowledge of and confidence in pharmacogenomics.