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2020

Sun, S. (2020). Between personalized and racialized precision medicine: A relative resources perspective. *International Sociology*, 35(1), 90–110.
doi:10.1177/0268580919885292

<https://hdl.handle.net/10356/143462>

<https://doi.org/10.1177/0268580919885292>

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Between personalized and racialized precision medicine: A relative resources perspective

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Abstract

Since the completion of the first human genome sequencing project in 2003, the potential for incorporating genomics into clinical practice in the pursuit of precision medicine has garnered a great amount of attention and interest. Existing literature presents a dichotomous view of the future of medicine: either precision medicine will replace race-based medicine or race-based medicine will persist despite developments in genetic research and genomic medicine. Drawing on interview data with 46 physicians and scientists in the USA, Canada and Singapore who are conducting research or practicing precision medicine in the context of cancer treatment and prevention, this paper attempts to contribute to the existing debate by proposing a “relative resources” perspective to explain which approach will dominate in a particular healthcare setting. We elaborate on “heterogeneity of resources” and suggest that the extent to which precision medicine will be personalized or racialized/ethnicized in the clinic will most likely be a function of the relative availability of resources - including but not limited to financial, human and computer informatics, legal and infrastructural resources – at individual and collective levels in healthcare contexts.

Keywords: Precision medicine, genetics/genomics, race, ethnicity, clinic

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Abstract

Since the completion of the first human genome sequencing project in 2003, the potential for incorporating genomics into clinical practice in the pursuit of precision medicine has garnered a great amount of attention and interest. Existing literature presents a dichotomous view of the future of medicine: either precision medicine will replace race-based medicine or that race-based medicine will persist despite developments in genetic research and genomic medicine. Drawing on interview data with 46 physicians and clinician-scientists in the USA, Canada and Singapore, who are conducting research or practicing precision medicine in the context of cancer treatment and prevention, this paper attempts to contribute to the existing debate by proposing a “relative resources” perspective to explain whether personalized precision medicine or racialized precision medicine will dominate in a particular healthcare setting. We elaborate on “heterogeneity of resources” and suggest that the extent to which precision medicine will be personalized or racialized/ethnicized will most likely be a function of the relative availability of resources - including but not limited to, financial, human and computer informatics, and legal infrastructural resources – at individual and collective levels in healthcare contexts.

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Introduction

Since the completion of the first human genome sequencing project in 2003, the potential for incorporating genomics into clinical practice in the pursuit of precision medicine has garnered a great amount of attention and interest. Amidst large-scale investments in precision medicine (Cyranoski, 2016; Office of the Press Secretary, 2015), there is an on-going debate regarding whether medicine will really be “personalized” according to an individual’s unique genetic makeup or, instead, continue to be administered in relation to patients’ racial and ethnic identities.

Existing literature seems to present a dichotomous view of the future of medicine. Opinions fall into two main camps: either optimism that precision medicine will replace race-based medicine (Chaussabel and Pulendran, 2015; Dancey, 2012; Fullwiley, 2007; Hunt and Kreiner, 2012; Tutton et al., 2008), or that race-based medicine will persist despite developments in genetic research and genomic medicine (Hunt and Kreiner, 2012; Kahn, 2004; 2012; Lee et al., 2001; Prainsack, 2015; Roberts, 2011a; Root, 2003; Tate and Goldstein, 2004; Weigmann, 2006; Wolinsky, 2011).

Numerous studies have looked at the challenges hindering full realization of personalized precision medicine. Some studies pointed out barriers to achieving precision medicine (see literature review), while others highlighted the heterogeneity of resources in the genomic medicine context (Hall and Olopade, 2005; Markens 2017;

Senier et al. 2015; Sleeboom-Faulkner, 2009; for a Canadian example see Cooke-Hubley and Maddalena, 2011). However, these existing studies have yet to examine specifically what this heterogeneity of resources mean in relation to the debate about race/ethnicity's relationship to precision medicine, or go beyond individual barriers to distil the key resources that shape precision medicine at the clinical level.

We conducted a phenomenological study to describe and understand the meaning of the phenomenon of precision medicine for scientists and physicians in the context of cancer treatment and prevention on the West Coast of the United States (primarily California), in the Province of British Columbia (Canada), and in Singapore. The objectives of this paper is to contribute to the existing debate on two levels: Firstly, we propose a "relative resources" perspective to explain whether personalized precision medicine or racialized/ethnicized medicine will dominate in a particular setting. We hypothesize that whether personalized precision medicine is pursued in the clinic is dependent on the circumstance for each patient, which can vary due to the heterogeneous mix of resources available to each patient. If a patient is unwilling or unable to afford genetic testing and/or targeted drugs, clinicians have no choice but to fall back the next highest level of guidance in their clinical decision-making process, which tends to be racialized precision medicine. Secondly, we aim to provide empirical evidence to support this "relative resources" perspective and elaborate on the different kinds of resources that matter."

Literature review: The debate

Personalized or racialized precision medicine?

With efforts like the Human Genome project and Haplotype Map Project, precision medicine, which ‘fundamentally aims to utilize genomic, epigenomic and environmental factors to determine the biological characteristics of a disease and subsequently provide specific individualized treatment to the patient’ (U.S. Food and Drug Administration, 2013), has emerged as an alternative to race-based medicine. Chakravarti (2015:12), for example, has noted that the introduction of ‘the concept of individualized medicine...is a fundamental change in medicine that has long relied on the idea of a typological patient.’ In their study of warfarin pharmacogenomics in Asia, Chan et al. (2012:317) concluded that ‘information from genetic testing is superior to clinical biomarkers and self-reported population/ethnic membership for predicting warfarin dose requirements’, suggesting that individual genotyping is better able to capture variations within racial and ethnic groups, providing improved prediction accuracy compared to non-genetic clinical criteria such as age, weight, or self-identified race/ethnicity (Chan et al., 2012; Fullwiley, 2007).

Some authors have expressed optimism that precision medicine can and will eventually supersede race-based medicine (Dancey, 2012; Fullwiley, 2007; Hunt and Kreiner, 2012; Tutton et al., 2008). However, other studies have revealed that actual rates of implementation are low – clinicians continue to perceive and rely on race and

ethnicity as important clinical factors, while viewing widespread clinical uptake of genomics as a distant reality (Bonham et al., 2009; Collier, 2012; Hunt and Kreiner, 2012; Petersen et al., 2014).

This slow pace has been attributed to a wide range of barriers. Cost is frequently raised as a concern because of the additional expenses required for genomic/genetic sequencing and interpretation, increased prices of drugs as a result of smaller target groups, as well as a possible lack of sufficient insurance coverage (Bonham et al., 2016; Jensen and Murray, 2005; Kahn, 2012; Kohane, 2015; Petersen et al., 2014; Root, 2003; Rothstein, 2016; Sun, 2017). Others have highlighted a precision medicine skills and knowledge gap amongst healthcare professionals (Bonham et al., 2016; Cyranoski, 2016; Mirnezami et al., 2012; Rothstein, 2016). In addition, there is a lack of infrastructure to implement genomics in medical practice, and limited evidence that precision medicine improves health (Dzau and Ginsberg, 2016; Kahn, 2012). The turnaround time for genetic tests is long (Satel, 2002b), while knowledge about the phenotypic consequences of alleles appears to be deficient (Tutton et al., 2008).

Computational capabilities, effective diagnostic and clinical decision support tools that are able to provide real-time support in identifying, measuring and interpreting how genomics, environment and lifestyle factors impact health outcomes at the point of care, have also been found to be lacking (Bonham et al., 2009; Bonham et al., 2016; Kohane,

2015; Mirnezami et al., 2012). Moreover, privacy and discrimination concerns have been cited as barriers, in part due to inadequate regulatory frameworks to protect the interests of patients (Mirnezami et al., 2012; Rothstein, 2016).

The persistence of race-based medicine

The completion of the Human Genome Project, which showed humans to be 99.5% similar and generated optimism that use of race in the medical field could be laid to rest, has actually led to a re-inscription of race at the molecular level (Duster, 2006). In a similar vein, some authors have cautioned that, despite efforts to move away from race, race-based medicine will continue to persist in precision medicine (Hunt and Kreiner, 2012; Kahn, 2004, 2012; Lee et al., 2001; Prainsack, 2015; Roberts, 2011b; Root, 2003; Satel 2002a; Tate and Goldstein, 2004; Weigmann, 2006; Wolinsky, 2011). Indeed, even though ‘race is a complex but empirically demonstrable stratifying practice that creates identity and hierarchy through social interaction’ (Ossorio and Duster, 2005: 119; see also Omi and Winant 1984), the usage of race as a “temporary proxy” of genetics is perpetuated by different stakeholders involved in precision medicine (Fullwiley, 2007; Rajagoplan and Fujimura, 2012), giving it opportunities to re-enter as biological categories ‘through the backdoor’ (Prainsack, 2015).

Fullwiley (2007) and Montoya (2007) showed that even when genetic scientists and researchers are aware of the limitations of racial/ethnic classifications, they tend not

to stop using them in their work. Even if genome-based studies are conducted in a race-neutral manner, race/ethnicity continues to be used as a classification tool in analyzing and presenting results (Prainsack, 2015; Weigmann, 2006). In fact, one reason that race/ethnicity has been predicted to persist is precisely its usefulness as a ‘residual category’ (Kahn, 2004, 2012, 2013:158) to account for differences in drug efficacy between populations that are not captured by genetics (Kahn, 2004, 2012; Roberts, 2011a).

This persistent usage of racial categories is fueled, in part, by various forms of activism involved in lobbying for the mandatory inclusion of women and minorities in genetic research in the United States (Epstein, 2007). Such activism has led to policies concerning the use of racial/ethnic categories in genetic research (Duster, 2006; Fullwiley, 2007; Knerr et al., 2011; Roberts, 2008), such as the NIH Policy and Guidelines on The Inclusion of Women and Minorities as Subjects in Clinical Research (National Institutes of Health, 2017). While intended to ensure greater participation by minorities in clinical research and reduce health disparities between racial groups, such policies have, ironically, further encouraged the framing of studies and findings along racial/ethnic lines by making racially-and-ethnically-based comparisons a condition for receiving funding. This, in turn, reinforces the idea that health disparities can be attributed to inherent genetic differences between racial groups (Duster, 2006; Fullwiley, 2007; Roberts, 2008). Over time, race and ethnicity remain an ostensibly

accurate basis of bioscientific findings, and such data are eventually passed down to other actors within the medical industry and become naturalized through future study designs (Montoya, 2007).

Clinicians are influenced by the pervasive use of racial/ethnic categories in scientific research. So long as existing literature only contains statistics based on race/ethnicity, doctors fall back on race/ethnicity as a proxy to make clinical decisions (Root, 2003). Studies have revealed that race and ethnicity continue to play an important role in the clinic, even with advancements in pharmacogenetics (Hunt and Kreiner, 2012; Petersen et al., 2014). With warfarin, for example, despite the identification of specific genetic alleles influencing drug response and the availability of resources to test for these alleles, the framing of results from scientific studies and subsequently, translation into clinical practice has continued to take on a racial tone, with the focus placed on different allele frequencies amongst different ethnic groups. This mindset of using race as a diagnostic shortcut seems to have been cultivated during medical school training, where study materials often utilize racial categories for stratification purposes (Brooks, 2015; Swetlitz, 2016). However, ‘it is possible to make arbitrary groupings of populations defined by geography, language, self-identified faiths, other identified physiognomy and so on and still find statistically significant allelic variations between these groupings’ (Duster, 2006:434). Indeed, for example, Takezawa et al. (2014:3) note that ‘even among mainland Japanese, statistically

meaningful genetic differentiation was found among individuals in different regions, such as Tohoku, Kanto, Kinki, and Kyushu.’ As such, to assume that the allelic frequency variations reflect the innate biological differences between racial or ethnic groups is unwarranted.

From a commercial standpoint, race-based medicine is marketable because it is imbued with a form of social traction. BiDil, for example, was highly supported by African-American medical practitioners (Caulfield, 2011; Kahn, 2004). Pharmaceutical companies are keen on utilizing biology ‘to get at race in drug marketing’ (Kahn, 2004). Such commercial forces will, in turn, revitalize the assumption that race is more biological than social and political (Duster, 2006).

The persistence of racial/ethnic categories in precision medicine also has roots in politics. For example, attributing differences in health status to biology instead of class or societal factors shifts the blame away from the government, thereby serving certain political ideologies (Prainsack, 2015). Moreover, a growing number of countries around the world (such as Mexico and India) are claiming sovereignty over the DNA of their populations. While this has been explained as a way for countries to protect themselves from being exploited through ‘possible bio-piracy from the pharmaceutical industry’, branding of a country’s genomes as being biologically distinct from those of other

populations further institutionalizes biological meanings of racial/ethnic constructs (Benjamin, 2009; Duster, 2015).

Data collection, analysis and interpretation

The type of problem best examined using a phenomenological approach is one in which it is important to understand several individuals' *common or shared experiences of a phenomenon*. In this work, we believe that it is important to understand these common experiences in places where precision medicine is more advanced (the USA and Canada), and those to which such knowledge and practices have disseminated (i.e. Singapore). This will enable the development of practices or policies with clinicians' lived experiences in mind, and garner a fuller understanding about the features of precision medicine in different places.

Study implementation

Semi-structured face-to-face interviews were conducted with a total of 46 interviewees, who were identified using the snowball sampling technique, regarding their clinical decision-making in the context of precision medicine (Table 1). Snowball sampling is a multistage technique that begins with one or a few people or cases and spreads out on the basis of links to the initial cases. This technique is appropriate for selecting members of a difficult-to-reach, specialized population. In '*Women of the Upper Class*', Ostrander (1984) used a snowball sampling technique to approach 36

interviewees due to the rather closed nature of their upper-class circles. Similarly, clinicians/clinician-scientists are professionals with social prestige, status, and full schedules, and hence, may understandably be less amenable to interviews; as such, snowball sampling is appropriate to approach potential interviewees.

With respect to sample size, Duke (1984) recommends three to ten subjects for phenomenological studies and Riemen (1986) studied ten individuals in his phenomenological study of a caring interaction in the nursing profession. There are medical centers in Vancouver (Canada), California (USA) and Singapore where precision medicine is practiced, and we approached one of the scientists and/or clinician-scientists at each center to begin data collection, and, at the conclusion of each interview, asked the clinician/clinician-scientist to recommend another clinician/clinician-scientist with experience in genome-based personalized medicine who might be willing to talk to the author and/or two research assistants (Y. L. and Z. O). This practical way of gaining access to respondents has theoretical as well as methodological advantages. We were referred to clinician/clinician-scientists with experience in genome-based personalized medicine. Thus, we did not speak with clinician/clinician-scientists who had only heard of precision medicine but did not have experience with it. In the end, ten scientists and/or clinician-scientists were interviewed on the West Coast of the United States, eleven in British Columbia Canada, and 25 in Singapore. Interviews were conducted at a public space chosen by the interviewee

according to their convenience. Interviewees were assured of privacy and confidentiality. Each interview lasted between 45 and 60 minutes. All 46 interviews were audio-recorded and transcribed verbatim.

Data analysis followed systematic procedures that move from narrow units of analysis (e.g. significant statements) to detailed descriptions focused on two elements, “what” individuals have experienced and “how” they have experienced it. This thematic analysis was achieved through manual analysis of transcripts by two researchers (Y.L. and Z.O.) and myself in a six-step process adapted from Braun and Clarke (2006): (1) independent reading and coding of the first three de-identified transcripts to identify major themes, (2) discussion and construction of the preliminary coding schema, (3) independent application of the preliminary coding schema to subsequent transcripts, (4) discussion and derivation of the final coding schema, including any new themes previously not identified, (5) reanalysis of all transcripts with the final coding schema, and (6) resolution of discrepancies with the help of a third, adjudicating researcher who has also independently coded the transcripts (S.S.). Interviews are quoted from the original spoken English.

Findings

While interviewees were generally aware of precision medicine’s purported benefits, a few mentioned that the usage of race/ethnicity as a proxy for genetic variants

has continued. For example, when asked about whether and why physicians use race/ethnicity to decide on medical treatment, Dr. Campbell (Canada) remarked:

They just don't have the *resources* to go and look for the genomic signature. So they've been using race instead [be]cause it's easy, race is cheap, you just tick it off on a box, versus trying to sequence everybody, for an extra thirty to fifty thousand dollars per patient...that's going to add hundreds of million dollars to your cost. So if you just do it this way, this is just the cheap version of figuring out your genomics, to be quite honest, right? ... [T]hat's why I say *race is really the poor man's genomic test*.

When asked why the government might use a racial or ethnic group to decide who to screen for a particular polymorphism, Dr. Wu in Singapore explained:

...that's a pragmatic decision, it's not actually based upon racial things, rather that it's a hint, and you're doing that because of...a cost model, because it's more prevalent in that population...if I were to tell you that you were to screen 10,000 Chinese to benefit one, and you screen 100 [Indians] to benefit seven, *and you only have that amount of resource[s]*, then you would choose to screen only the Indians, and that would be sensible and pragmatic.

While stakeholders were aware that the precision medicine approach to health should be based upon (each individual's) genetics, it was limitations in resources that propelled them to fall back on using race/ethnicity as a proxy for genetic variants instead. Indeed, none of the interviewees believes that racialized decision-making is better than precision genetics decision-making. As shown above, some of them do admit that race/ethnicity can be useful in certain circumstances, but insofar as the context is about managing an actionable genetic disease, they all agree that precision genetics decision-making is better because the drug is molecularly-based.

In the sections below, we examine different types of resources critical for the realization of precision medicine to elucidate a relative resources hypothesis for the trajectories between personalized and racialized precision medicine; that is, the resource-rich are more likely to get precise medicine, while the resource-poor get racialized/ethnicized medicine.

Availability of financial resources

In line with existing literature, several interviewees cited high treatment cost as an impediment to adoption of precision medicine in patient care:

even though the benefits of target drugs are really impressive...the cost of the target drugs is prohibitive. These drugs are coming to the marketplace now at...astronomical prices, prices that the vast majority of patients would not be able to afford even with a co-pay. ...these drug prices are...not sustainable. (Dr. Young, USA)

The adoption of personalized versus racialized precision medicine is influenced by the availability of financial resources at both systemic and individual levels. At the systemic level, single-payer public health systems, such as Canada's, offer greater financial support than multi-payer public health systems, as healthcare costs for every individual, in the former case, are borne by the government. Consequently, the cost pressure on physicians and patients is reduced and personalized precision medicine is received more optimistically by clinicians:

I think it is good, it keeps the hospital functioning, patients can go back to work and they feel good.... So, for example, Gefitinib, there's a small population of patients [who have] a very high chance of getting a response to...very easy non-toxic drugs that do not actually cost the medical system anything in terms of

nurses, chemo time or any of that stuff. They feel great and they live longer and contribute back to society with \$2600 a month. (Dr. Scott, Canada)

However, the price of molecular-based drugs remains a concern, even in a publicly-funded system like Canada's, where an oncologist shared how the impact of such exorbitantly priced target drugs on patients can in fact be substantial:

In the US, the cost [of targeted therapy] may be higher than in Canada. Even if you cut down the price by half...gefitinib costs about \$20,000 Canadian dollars here; Tarceva is about \$3000, and crizotinib is about \$50,000....everything is out of our control. Look at all the drugs, who is going to pay for it? ... I have some patients who sell their house and buy this drug to live for two months. (Dr. Grant, Canada)

In contrast, multi-payer public health systems like those in the USA and Singapore offer less financial support, so healthcare costs are either borne by the patient or covered by insurance. In such systems, personalized precision medicine is deemed more likely when insurance coverage is available:

...provided you have insurance, [genetic testing is pretty much] covered without much question. ...I don't think [EGFR mutation testing is] a major barrier now, especially because it's approved.... [T]here are more expensive type tests, like...[the] Oncotype Dx test... and I think in [the] US, it is about \$4,000 for the test...and patients will have to pay out of pocket for that, so that's more challenging. (Dr. Johnson, USA)

When the required genetic testing and/or targeted drug is not covered by insurance, physicians and patients are instead forced to consider the individual's ability to afford treatment. Should the cost of a drug be deemed too high, a cheaper but feasible alternative is offered:

...even if the patient has got a[n] EGFR mutation, and you say that "Look, you've got to spend \$3,000...a month to pay for this drug, and you got 18 months of [expected survival]"...the guy might say, "so for the extra year, ...I'm gonna spend a heck of a lot of money for something that is ultimately going to kill me. So why don't I save the money and give it to my kids for their education?" (Dr. Xie, Singapore)

If I say this in front of [the] patient's children, “Here are three drugs for your mother, you can have \$10,000, \$5000, \$1000, which one do you want?” How do you...expect [them] to answer this question? ... So here, we roughly assess and look at the patient's and family's financial background...and we make our own decision, “Look, I think that six months extra life is not worth putting in all this money”.... If I think using this drug is good enough, I will treat this patient with this drug and I will not escalate. (Dr. Zhang, Singapore)

In addition, if patients are unwilling or cannot afford genetic testing, physicians can only fall back on using race/ethnicity as a way of fine-tuning their treatment decisions, as they do when genetic testing is not feasible or available:

[T]hey [race/ethnicity-based data] are helpful in the sense that if we have no information, and we have these characteristics...it gives us an *a priori* probability that the treatment will work...if we...cannot get a result from [a] biopsy, or [if] a patient is not able to undergo [a] biopsy, somebody who's really sick...we might treat empirically. ... These [data] are very helpful to make decisions. (Dr. Perry, USA)

In sum, when financial resources are readily available, patients and physicians have the luxury of accessing personalized precision medicine, even if it involves additional costs relating to genetic testing or more expensive molecular-based drugs. The availability of financial resources can be assessed on two levels: systemic financial support (be it in terms of a single-payer [government] public health system or insurance coverage in a multi-payer public health system) and the individual's ability to pay healthcare costs. Without sufficient systemic financial support, the issue of an individual's financial capacity to manage the out-of-pocket costs comes to the forefront. In the absence of both adequate systemic financial support and individual financial capability, personalized precision medicine is often forsaken, and racialized precision medicine, which is seen as a pragmatic way of balancing optimized health management against the high costs of more precise medicine, becomes the next best option.

Availability of human and informatics resources

Precision medicine is a field that transverses numerous traditionally distinct fields, including medicine, genetics, epidemiology and informatics. Even for professionals such as clinicians, it 'becomes more and more difficult for the doctor to have that amount of knowledge with them' (Dr. Liang, Singapore), let alone the untrained general public. Access to experts armed with knowledge in these areas at both individual and systemic levels is therefore important for the implementation of precision medicine.

The support of healthcare professionals with different expertise and perspectives concerning precision medicine is also necessary for seamless incorporation of genetic information into clinical decisions as a system. Discussing genotype-phenotype evidence and appropriate medical treatments within a multidisciplinary team can build a better knowledge base of participating members, and ultimately improve patient care. Reinforcing this view, Dr. Baker from Canada noted:

...I don't think one person can be making the decision, I think there need[s] to be ideally experts in the field to come together.... We're talking about medical geneticists, ethicists, sometimes lawyers...you need to put together all the minds, in order to figure out how to safely and most effectively use this tool.... So for example, my unit [of] thinking [is] patients, but then there are some people whose units of thinking are genes, proteins, cells....

Dr. Cook from Canada further suggested that beyond simply assembling interdisciplinary teams, there is also a need for infrastructural support, for example, in the form of clinical decision support software that can quickly provide evidence-based recommendations with respect to incorporating personalized medicine into care:

You have attended some of the meetings and you can see there are many people physically in the room and a lot of them are involved in the analysis of tumor[s] and also there's two to three month gap between the time you do the biopsy and the time you get the read out. The time of it...and the manpower required at the moment is impractical. When it becomes more automated, there's this kind of electronic library of searchable treatments.... Where a computer does most of that work then the time will [be] cut down and it may become more practical.

Clearly, forming interdisciplinary teams that can pool together different expertise is an essential resource for physicians to make sense of genetic information and make well-informed medical decisions in a timely manner. At the same time, recognizing practical limitations in manpower, development and adoption of properly-designed computational tools could be useful to support such interdisciplinary efforts.

Based on the interview data, such manpower and informatics resources seem to be more easily attainable in systems with better financial support (such as in Vancouver, Canada). Health systems that are unable to support the development and deployment of such human and informatics resources, we surmise, will likely fall back on race-based medicine, as it requires less of such resources.

Related to the availability of informatics and multi-disciplinary expertise, the type of medical care institution at which a patient is treated was seen as affecting access to personalized medical care. Academic medical centers (as opposed to publicly-funded hospitals, for instance) have historically led adoption of new technologies in patient care. This appears to be true in the case of Singapore and the USA, where respondents described precision medicine as the province of academic medical centers – institutions that have access to the resources, nexus of academic and pharmaceutical company collaborators, and expertise to deliver targeted, personalized patient care:

...if the provider doesn't offer testing, the patient would never have probably known of it. ...[W]ith any technology, there is a diffusion and...rates of testing are just a lot higher around academic medical centres...where you...have...a lot more updates and...advanced choices.... (Dr. Johnson, USA)

Availability of legal infrastructural resources

Genetic profiling is a key component of personalized precision medicine. Uncovering the genetic profile of an individual allows for prediction of disease susceptibility and drug response to improve health outcomes. Yet, the ability to predict

for particular phenotypes from genetic testing – germline testing in particular – also has repercussions on other areas of life beyond clinical decision-making. Employment and health insurance are two main areas:

... it's very clear to me that, you know if you have a genetic risk or something, it can affect your job, it can affect your health insurance, it can affect what kind of medical care you get.... (Dr. Morgan, USA)

From a systemic perspective, employers and health insurers run the risk of suffering monetary losses by getting involved with individuals with high genetic risks of diseases (Billings et al., 1992; Gostin, 1991; Hall and Rich, 2000; Levin, 2013; Miller, 1998; Roberts et al., 2011; Taylor, 2001). As such, employers and health insurers might seek to minimize their organizational risk by not hiring or charging higher premiums for individuals with high genetic risk of disease:

...genetic germline testing...or...even acquired mutations...which could predispose people to certain diseases...could be used as a basis for denying employment, denying...medical healthcare coverage, all those things. So, of course

that's...more tricky, because that data, used in the wrong way...could be harmful to the individual. (Dr. Koh, Singapore)

In an environment in which there is no legal protection at the systemic/societal level against potential genetic discrimination, individual patients may be warier about exposing themselves to such potential harm and less willing to undergo genetic testing. In studying the three systems, we found that the U.S. and Canadian governments have taken steps to protect the interests of individuals undergoing genetic testing through specific federal laws, respectively known as the Genetic Information Nondiscrimination Act (GINA)¹ and the Genetic Non-Discrimination Act (GNDA). However, in the case of Singapore, we note that genetic data privacy is insufficiently safeguarded by existing legislation governing medical data in general, namely the Private Hospitals and Medical Clinics Act and the Human Biomedical Research Act (Chong et al., 2018; MOH, 2017). In July 2018, Singapore also introduced a 'Code of Practice Standards for the Provision of Clinical Genetic/Genomic Testing Services' (MOH, 2018) to provide guidance on appropriate ordering of genetic tests, competency and training of personnel, the delivery of such services, and use of genetic data (MOH, 2018).

This lack of legal protection, according to our respondents, could lend itself to discrimination and severe socio-economic consequences for patients and their families:

¹ US Department of Labor. Available : <https://www.dol.gov/agencies/ebsa/laws-and-regulations/laws/gina>

...in Singapore, we have no law to prevent...discrimination for patients with germline mutations. Say, you are found with [a] BRCA mutation...and you go for a job interview, if somehow you have blogged about it on your Facebook, and your...employers see it; and he...chooses not to employ you because he is worried about you taking sick leave if you do get breast cancer, there is nothing to protect [you]. (Dr. Neo, Singapore)

While it may be understandable for organizations to seek to protect their own interests, the interests of the individual – the focus of precision medicine – must also be taken into account, and this requires the establishment of a legal infrastructure as a resource in itself. Laws against abuse of genetic information would help to curb systemic discrimination, while endowing patients with the confidence and assurance to take up genetic testing for a more accurate molecular-based approach to treatment. The availability of such legal infrastructure can be translated to individual legal resources against genetic discrimination and contribute to a conducive environment for precision medicine to flourish. In the absence of such legal infrastructure, even if the above mentioned financial, human and informatics resources were all in place, patients might be unwilling to put other important aspects of their lives (e.g. employment, insurance) at risk, and instead, choose not to take up personalized medicine, no matter how feasible.

Discussion

The intention of this paper is not to argue for genetic determinism, but to examine that slice of clinical practice in which genetic data is thought to be highly useful. Various studies have highlighted barriers hindering the realization of precision medicine (Bonham et al., 2016; Kohane, 2015; Mirnezami et al., 2012; Rothstein, 2016). Unsurprisingly, in examining the impact of limited resources on medicine, most of these barriers have also been alluded to in this current study. These include the high costs of molecular-based drugs and genetic testing, lack of precision medicine knowledge amongst stakeholders, lack of computational support tools, and lack of well-developed privacy laws. This study provides additional empirical evidence from the perspectives of clinicians and clinician-scientists to support the argument that these are critical barriers for the realization of precision medicine.

The fact that interviewees in this study were recruited from three different countries (Singapore, the USA, Canada) suggests that these barriers are not unique to a particular country. By adopting a relative resources perspective, we now understand why it is more likely that the future of medicine will be a heterogeneous experience involving varying degrees of race/ethnicity-based precision medicine. When the focus is on individual barriers, one may assume that elimination of such barriers would result in the complete eradication of race-based medicine in favor of precision medicine.

However, when challenges are organized in terms of various types of resources, it becomes apparent that the outcome is unlikely to be so clear-cut.

Instead, the experience of medicine is likely to be a cumulative function of the degree of availability of each required resource, resulting in a range of experiences from a high level of precision medicine (when all resources are accessible) to increasing reliance on race-based medicine (when one or more resources are increasingly scarce).

The knowledge gap hypothesis (Tichenor et al., 1970) suggests that knowledge, like wealth, is differentially distributed such that as mass media information is infused into a population, those with higher socioeconomic status tend to acquire information at a faster rate than those with lower socioeconomic status. The vast range of resources discussed in this paper serves as a reminder that the realization of precision medicine is an endeavor that requires investments in many different areas, beyond just financial resources. Importantly, this also draws attention to the possibility that without sufficient investment in different kinds of resources to keep pace with the development of precision medicine, inequality with respect to medical treatment is likely to become even more pronounced. Those who are resource-poor will not only be subjected to less accurate medical treatment through a continued reliance on the race-based approach, but also be more vulnerable to genetic discrimination at both individual and population levels.

Conclusion

In *Fatal Invention: How Science, Politics, and Big Business Re-create Race in the Twenty-First Century*, Roberts (2011a) concludes that ‘social change [in perspectives and reliance on race/ethnic categories in medicine] cannot be accomplished with a technological fix.’ This paper further suggests that progression beyond race-based medicine requires various resources. We add to the existing literature of heterogeneity of resources in genomic medicine by providing an empirically demonstrated conclusion that resource-relativity exacerbates a trade-off between personalized and racialized precision medicine. In this paper, race presumptively includes ethnic categories, subject to empirical verification in countries and societies where ethnicity is more salient than race. The 46 interviewees in this study did not differentiate between the terms race and ethnicity and used these terms interchangeably. The specific way in which race/ethnicity is defined is different in Singapore, US, and Canada, but the racial/ethnic categories are used the same way as key categories of social stratification. In other words, race and ethnicity are not biological in origin, but social interactions based on individuals’ perceived racial and ethnic identities have biological consequences for individuals so designated in these societies.

We also show that the extent of personalization or racialization in precision medicine is shaped by the availability of various types of resources, including financial,

human and informatics, and legal infrastructural resources. These resources are critical as they affect the entire journey of realizing precision medicine, from research to drug development to clinical implementation and even implications beyond the clinic. However, given that resources are finite and usually unevenly distributed (Cazap, 2014; Chong et al., 2018; Gray et al., 2017), this paper also argues that the future of medicine is unlikely to move entirely away from race-based medicine to individualised precision medicine. The degree to which precision medicine is implemented or experienced will be a function of the availability of the abovementioned resources, with racial/ethnic groupings as ‘the poor man’s genomic test’, a traditional means of making clinical decisions when stakeholders are “poor” in any of the resources noted in the paper.

As a matter of hard science, a patient’s genetic mutation status affects drug response. Yet, as demonstrated in this paper, genetic testing may not always be possible due to the heterogeneity of resources. One may then wonder, if ‘race’ correlates with ancestry, and ancestry correlates with at least a few health-related traits on certain biological levels as well as social ones, then is using ‘race’ as the poor man’s substitute for genomic data not an appropriate fallback for clinicians facing limited resources? Having proxies for genetics would arguably be a better alternative than having to make decisions without any guidance at all. However, conceptually and methodologically, we do not support the use of race and ethnicity as proxies for genetics to make precision medicine more accessible to the public. Future research needs to explore better ways of

conceptualizing “population” in population-based human genetic/genomic variation studies and delivering precision medicine to all patients whose illnesses have an actionable genetic basis. One possibility is to examine the usage of family history as a substitute for genetics in resource-poor settings. In addition, are there other types of resources that may affect whether precision medicine is going to be personalized or racialized? Finally, another possible future research project addresses an empirical issue; this paper assumes that patients would like to know their genetic testing results and has identified resources necessary at the individual and collective levels to make the patients’ wishes a reality. Future research should empirically explore why patients may or may not want such genetic testing results.

References

Benjamin R (2009) A Lab of Their Own: Genomic Sovereignty as Postcolonial Science Policy. *Policy and Society* 28(4): 341-355.

Billings PR, Kohn MA, de Cuevas M et al. (1992) Discrimination as a consequence of genetic testing. *American Journal of Human Genetics* 50(3): 476-482.

Bonham VL, Callier SL and Royal, C.D (2016) Will Precision Medicine Move Us Beyond Race? *New England Journal of Medicine* 374(21): 2003-2005.

Bonham VL, Sellers SL, Gallagher TH et al. (2009) Physicians' Attitudes Toward Race, Genetics, and Clinical Medicine. *Genetics in Medicine* 11(4): 279-286.

Brooks K (2015) A Silent Curriculum. *JAMA* 313(19): 1909-1910.

Caulfield T (2011) Public Representation of Genetics: Refining Race. In Maheu L and Macdonald RA (eds) *Challenging Genetic Determinism: New Perspectives on the Gene in its Multiple Environments*. McGill-Queen's University Press, pp. 158-181.

Braun V and Clarke V (2006) Using Thematic Analysis in Psychology. *Qualitative Research in Psychology* 3(2): 77-101.

Cazap E (2014) Personalised Cancer Care - A Global Perspective. *European Oncology & Haematology* 10(2): 104–106.

Chakravarti A (2015) Perspectives on Human Variation through the Lens of Diversity and Race. *Cold Spring Harbor Perspectives in Biology* 7(9), a023358.

Chan S, Suo C, Lee S et al. (2012) Translational aspects of genetic factors in the prediction of drug response variability: a case study of warfarin pharmacogenomics in a multi-ethnic cohort from Asia. *The Pharmacogenomics Journal* 12(4): 312-318.

Chaussabel D and Pulendran B (2015) A Vision and a Prescription for Big Data-Enabled Medicine. *Nature Immunology* 16(5): 435-439.

Chong HY, Allotey PA and Chaiyakunapruk N (2018) Current landscape of personalized medicine adoption and implementation in Southeast Asia. *BMC Medical Genomics* 11:94. DOI:10.1186/s12920-018-0420-4

Collier R (2012) A Race-based Detour to Personalized Medicine. *Canadian Medical Association Journal* 184: E351-E353.

Cooke-Hubley S and Maddalena V (2011) Access to Genetic Testing and Genetic Counseling in Vulnerable Populations: the d/Deaf and hard of hearing population. *Journal of Community Genetics* 2(3): 117-125.

Cyranoski D (2016) China Embraces Precision Medicine on a Massive Scale. *Nature* 529(7584): 9-10.

Dancey J (2012) Genomics, Personalized Medicine and Cancer Practice. *Clinical Biochemistry* 45(6): 379-81.

Duke S (1984) Phenomenological Methodology in the Human Sciences. *Journal of Religion and Health* 23(3): 197-203.

Duster T (2006) The molecular reinscription of race: unanticipated issues in biotechnology and forensic science. *Patterns of Prejudice*, 40(4-5): 427-441.

Duster T (2015) A post-genomic surprise. The molecular reinscription of race in science, law and medicine. *The British Journal of Sociology* 66(1):1-27.

Dzau VJ and Ginsberg GS (2016) Realizing the Full Potential of Precision Medicine in Health and Healthcare. *Journal of the American Medical Association* 316(16): 1659-1660.

Epstein S (2007) *Inclusion: The Politics of Difference in Medical Research*. Chicago and London: University of Chicago Press.

Fullwiley D (2007) The Molecularization of Race: Institutionalizing Human Difference in Pharmacogenetics Practice. *Science as Culture* 16(1):1-30.

Gray M, Lagerberg T and Dombrádi V (2017) Equity and Value in 'Precision Medicine'. *The New Bioethics* 23: 87-94. DOI: 10.1080/20502877.2017.1314891.

Gostin L (1991) Genetic Discrimination: The Use of Genetically Based Diagnostic and Prognostic Tests by Employers and Insurers. *American Journal of Law and Medicine* 17(1-2): 109-144.

Hall M and Olopade OI (2005) Confronting genetic testing disparities: knowledge is power. *Journal of the American Medical Association* 293(14):1783-1785.

Hall MA and Rich SS (2000) Patients' fear of genetic discrimination by health insurers: the impact of legal protections. *Genetics in Medicine* 2(4):214-221.

Hunt LM and Kreiner MJ (2012) Pharmacogenetics in Primary Care: The Promise of Personalized Medicine and the Reality of Racial Profiling. *Culture, Medicine, and Psychiatry* 37(1): 226-235.

Hunt LM, Truesdell ND and Kreiner MJ (2013) Genes, Race, and Culture in Clinical Care. *Medical Anthropology Quarterly* 27(2): 253-271.

Jensen K and Murray F (2005) INTELLECTUAL PROPERTY: Enhanced: Intellectual Property Landscape of the Human Genome. *Science* 310(5746): 239-240.

Kahn J (2004) How a Drug Becomes "Ethnic": Law, Commerce, and the Production of Racial Categories in Medicine. *Yale Journal of Health Policy, Law, and Ethics* 4(1): 1-46.

Kahn J (2012) The Troubling Persistence of Race in Pharmacogenomics. *Journal of Law, Medicine and Ethics* 40(4): 873-885.

Kahn J (2013) *Race in a Bottle: The Story of BiDil and Racialized Medicine in a Post-Genomic Age*. New York and West Sussex: Columbia University Press.

Knerr S, Wayman D and Bonham VL (2011) Inclusion of Racial and Ethnic Minorities in Genetic Research: Advance the Spirit by Changing the Rules? *Journal of Law, Medicine and Ethics* 39(3): 502-512.

Kohane IS (2015) Ten Things We Have to Do to Achieve Precision Medicine. *Science* 349(6243): 37-38.

Lee SS-J, Mountain J and Koenig BA (2001) Meanings of Race in the New Genomics: Implications for Health Disparities Research. *Yale Journal of Health Policy, Law and Ethics* 1(1): 33-76.

Levin N (2013) A Defense of Genetic Discrimination. *Hastings Center Report* 43: 33-42. DOI: 10.1002/hast.193.

Markens S (2017) 'I'm not sure if they speak to everyone about this option': analysing disparate access to and use of genetic health services in the US from the perspective of genetic counselors. *Critical Public Health* 27(1): 111-124.

Miller PS (1998) Genetic discrimination in the workplace. *Journal of Law Medicine, and Ethics* 26(3): 189-97.

Ministry of Health, Singapore. (2017). Speech by Minister Gan Kim Yong at the National Health IT Summit 2017. Available: <https://www.moh.gov.sg/news-highlights/details/speech-by-mr-gan-kim-yong-minister-for-health-at-the-national-health-it-summit-2017-30-may-2017>.

Ministry of Health, Singapore. (2018). Code of Practice on the Standards for the Provision of Clinical Genetic/Genomic Testing Services. Available: <https://www.moh.gov.sg/docs/librariesprovider5/licensing-terms-and-conditions/genetic-testingstandards.pdf>.

Mirnezami R, Nicholson J and Darzi A (2012) Preparing for Precision Medicine. *New England Journal of Medicine* 366(6): 489-491.

Montoya MJ (2007) Bioethnic Conscription: Genes, Race, and Mexicana/o Ethnicity in Diabetes Research. *American Anthropological Association* 22(1): 94-128.

National Institutes of Health (2017) NIH Policy and Guidelines on The Inclusion of Women and Minorities as Subjects in Clinical Research. Available at: https://grants.nih.gov/grants/funding/women_min/guidelines.htm (accessed December 2018).

Office of the Press Secretary (2015) Factsheet: President Obama's Precision Medicine Initiative. Available at: <https://obamawhitehouse.archives.gov/the-press-office/2015/01/30/fact-sheet-president-obama-s-precision-medicine-initiative> (accessed February 2019).

Omi, M and Winant H (1986, 1994, 2014) *Racial Formation in the United States: From the 1960s to the 1990s*. London and New York: Routledge.

Ostrander SA (1984) *Women of the Upper Class*. Philadelphia: Temple University Press.

Ossorio, P and Duster T (2005) Race and Genetics: Controversies in Biomedical, Behavioral, and Forensic Sciences, *American Psychologist* 60 (1): 115-128.

Petersen K, Prows C, Martin L and Maglo K (2014) Personalized Medicine, Availability, and Group Disparity: An Inquiry into How Physicians Perceive and Rate the Elements and Barriers of Personalized Medicine. *Public Health Genomics* 17(4): 209-220.

Public Broadcasting Service (2008) *Unnatural Causes: Is Inequality Making Us Sick?*

Prainsack B (2015) Is personalized medicine different? (Reinscription: the sequel) A response to Troy Duster. *The British Journal of Sociology* 66(1):28-35.

Rajagopalan R and Fujimura JH (2012) Will Personalized Medicine Challenge or Reify Categories of Race and Ethnicity? *American Medical Association Journal of Ethics Virtual Mentor* 14(8): 657-663.

Riemen, D. J. (1986). The essential structure of a caring interaction: Doing phenomenology. In P. M. Munhall & C. J. Oiler (Eds.), *Nursing research: A qualitative perspective* (pp. 85-105). Norwalk, CT: Appleton-Century-Crofts.

Roberts DE (2008) Is Race-Based Medicine Good for Us?: African American Approaches to Race, Biomedicine, and Equality. *Journal of Law, Medicine & Ethics* 36(3): 537-45.

Roberts DE (2011a) *Fatal Invention: How Science, Politics, and Big Business Re-create Race in the Twenty-First Century*. New York: New Press.

Roberts DE (2011b). What's Wrong with Race-Based Medicine?: Genes, Drugs, and Health Disparities. *Minnesota Journal of Law, Science & Technology* 12(1):1-21.

Roberts LW, Barry LK and Warner TD (2011) Potential Workplace Discrimination Based on Genetic Predisposition: Views of Workers. *AJOB Primary Research* 2(3): 1-12, DOI: 10.1080/21507716.2011.617717.

Root M (2003) The Use of Race in Medicine as a Proxy for Genetic Differences. *Philosophy of Science* 70(5):1173-83.

Rothstein MA (2016) Some Lingering Concerns about the Precision Medicine Initiative. *Journal of Law, Medicine & Ethics* 44(3):520-525.

Satel S (2002a) Medicine's Race Problem. *Policy Review* 110: 49-58.

Satel S (2002b). I Am a Racially Profiling Doctor. Available at: <http://www.nytimes.com/2002/05/05/magazine/i-am-a-racially-profiling-doctor.html> (accessed November 2016).

Senier L, Kearney M and J Orne (2015) Using Public-Private Partnerships to Mitigate Disparities in Access to Genetic Services: Lessons from Wisconsin. *Genetics, Health and Society* 16: 269-305.

Sleeboom-Faulkner M (2009) *Human Genetic Biobanks in Asia: Politics of Trust and Scientific Advancement*. London and New York: Routledge.

Swetlitz I (2016) Teaching Medical Students to Challenge 'Unscientific' Racial Categories. Available at: <https://www.statnews.com/2016/03/10/medical-schools-teaching-race/> (accessed November 2016).

Sun S (2017) *Socio-economics of Personalized Medicine in Asia*. London and New York: Routledge.

Takezawa Y, Kato K, Oota H et al. (2014) Human Genetic Research, Race, Ethnicity and the Labeling of Populations: Recommendations Based on an Interdisciplinary Workshop in Japan. *BMC Med Ethics* 15:33.

Tate SK and Goldstein DB (2004) Will tomorrow's medicines work for everyone? *Nature Genetics* 36: S34-S42.

Taylor JR (2001) Mixing the Gene Pool and the Labor Pool: Protecting Workers from Genetic Discrimination in Employment. *Temple Environmental Law & Technology Journal* 20(1):51-71.

Tichenor PJ, Donohue GA and Olien CN (1970) Mass Media Flow and Differential Growth in Knowledge. *Public Opinion Quarterly* 34(2): 159-170.

Tutton R, Smart A, Martin PA et al. (2008) Genotyping the Future: Scientists's Expectations about Race/Ethnicity after BiDiL. *Journal of Law, Medicine and Ethics* 36:464-470.

U.S. Food and Drug Administration (2013) Paving the Way for Personalized Medicine: FDA's Role in a New Era of Medical Product Development. Available at: <https://www.fdanews.com/ext/resources/files/10/10-28-13-Personalized-Medicine.pdf> (accessed November 2016)

Weigmann K (2006) Racial medicine: here to stay? *EMBO Reports* 7:246-249.

Wolinsky H (2011) Genomes, race and health. *EMBO Reports* 12(2): 107-109.

Acknowledgments:

I am grateful to my research assistants, Zoe Ong and Yan Ru Lek, for their invaluable practical contributions to the research project. My sincere thanks go out to the respondents who have shared their views with us. Comments and feedback by Zoe Ong, Francis Lim, Hallam Stevens, and Lynette Chan have helped sharpen the analysis. The Singapore Ministry of Education AcRF Tier 1 Grant provided the funding that made this research possible.

Declaration of Interest: The author declares no conflicts of interest.