Antidepressant Tolerability and Potential Clinical Implications of Serotonin-2A Receptor Genotypes

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Abstract
Despite the development of new therapeutic agents for the treatment of mood disorders, drug tolerability remains a major barrier to effective treatment for many patients. Pharmacogenomic studies aim to identify genetic markers that moderate drug response and tolerability, with the intention that this information will aid in drug selection and dosing. The serotonin-2A receptor gene (HTR2A) is one attractive candidate for pharmacogenomic studies of drugs for mood disorders. Numerous studies have examined associations between polymorphisms within this gene and efficacy and tolerability of drugs for mood disorders. Some of these variants are now being included in some commercially-available platforms with the intent of using them for therapeutic decision making. As these technologies become more widely utilized, clinicians will face decision about what this information means for patients and how/if to apply this information clinically. This review summarizes pharmacogenomic studies of HTR2A and tolerability outcomes in a number of adverse drug reaction domains.

Keywords: Antidepressant; SSRI; Tolerability; Adverse drug reaction; Side effects; HTR2A; 5HT2A; Polymorphism

Introduction
Since the introduction of monoamine oxidase inhibitors (MAOIs) in the 1950s, researchers have been searching for antidepressant agents with more favorable tolerability profiles. The introduction of selective serotonin reuptake inhibitors (SSRIs) in the late 1980s provided clinicians with a drug class featuring an improved tolerability profile as compared to MAOIs and tricyclic antidepressants (TCAs), as well as a much wider therapeutic index [1,2].

Despite these considerable advances, side effects from antidepressants greatly affect the treatment course for many patients. A recent study of depressed individuals treated with SSRIs indicated that more than half of the patients reported at least one bothersome side effect from therapy [3]. Approximately one quarter to one third of patients that discontinue antidepressants do so primarily because of side effects [3,4]. Early treatment discontinuation due to side effects is a major barrier to antidepressant therapy as these drugs take a number of weeks to manifest their full positive therapeutic effects [5,6]. And while many patients discontinue antidepressant therapy due to side effects, other patients are able to tolerate them without a need for altering therapy.

Interpatient variability in response to a given drug is a large challenge in psychiatry. Clinically-similar patients often experience vastly different outcomes from the same drug at similar doses. Pharmacogenomic investigations aim to identify how genetic variables may explain a proportion of this variability. It is envisioned that the use of this information in the clinical setting will improve the likelihood of beneficial therapeutic effects while minimizing likelihood of adverse drug reactions (ADRs). Variants of cytochrome P450 genes have often been associated with abnormal drug concentrations and ADRs [7]. Genes directly or indirectly associated with a given drug’s mechanism of action are also attractive candidates for pharmacogenetic studies [8].

The serotonin-2A receptor gene (HTR2A) is located on chromosome 13 and encodes the 5-HT2A receptor [9,10]. Activation of this receptor has been postulated to mediate some side effects from serotonergic antidepressants which may directly or indirectly increase signaling through this receptor [11]. Two common single-nucleotide polymorphisms (SNPs) of HTR2A, 102 T>C (rs6313) [12] and -1438 A>G (rs6311) [13] are attractive candidate polymorphisms for pharmacogenetic studies. These two SNPs are in almost complete linkage disequilibrium (LD): the T allele of 102 T>C is in almost complete LD with the A allele of -1438 A>G and vice versa for the C and G alleles [14]. The minor allele frequency for both SNPs is approximately 0.43 and allele frequencies do not greatly differ between European, African, and Asian ancestry [12,13]. Another frequently studied SNP, 452 His>Tyr (rs6314) has a much lower minor allele frequency of about 0.07 and is more common in Africans than Europeans or Asians [15].

The 102 T>C variation does not result in any change to the encoded polypeptide, however, it may be associated with regulatory changes, perhaps due to its close proximity to the gene promoter or a methylation site [16-18]. The -1438 A>G polymorphism is also near the promoter region, which could influence gene expression. The 452 His>Tyr polymorphism alters amino acid sequence and is located in the C-terminal region of HTR2A. The substitution of tyrosine, which has a hydrophobic side chain, for histidine, with a positively-charged side chain, may affect receptor conformation and/or function of the gene’s product, the 5-HT2A receptor.

Studies with positive findings have associated the 102C and -1438G variants with decreased 5-HT2A expression, and the 452Tyr variant with decreased intracellular signaling. A number of expression studies have failed to replicate these findings, a discrepancy that may be explained by sample size, patient/cell line used, expression assay, or influence from other polymorphisms [19,20]. A recent meta-analysis

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showed a statistically significant association between the -1438 G/G (or 102 C/C) genotype and drug response during SSRI treatment (p=0.04, n=429) [21]. This finding did not hold when studies of non-SSRI antidepressants were included (p=0.69, n=1012).

The present review summarizes available literature on antidepressant tolerability as it relates to HTR2A genotype. As a consequence of a number of positive associations between tolerability/efficacy and HTR2A genotype, some commercially-available genotyping platforms now include HTR2A polymorphisms with the intention that clinical judgments regarding treatment selection, side effect risk, or likelihood of response may be made with this information. The authors intend for this concise review to assist clinicians in therapeutic decision-making as pharmacogenomic concepts become more prevalent in clinical practice.

Materials and Methods

To identify relevant studies for this review, the authors searched Medline/PubMed for original research publications available as of April 2013 regarding antidepressant tolerability and HTR2A genotype. This search was performed in a systematic fashion, using the terms HTR2A, HTR2A, serotonin 2A, polymorphism, adverse, side effects, tolerability, discontinuation, tricyclic, TCA, amitriptyline, clomipramine, desipramine, doxepin, imipramine, nortriptyline, SSRI, citalopram, escitalopram, fluoxetine, fluvoxamine, paroxetine, sertraline, vilazodone, SNRI, venlafaxine, duloxetine, mirtazapine, trazodone, MAOI, lithium, valproate, carbamazepine, oxcarbazepine, and lamotrigine in all logical iterations. Additional articles were identified by examining the reference lists from articles identified in the initial search. Studies were considered relevant for the present review if they described positive or negative findings in terms of differences in ADRs between genotype groups. If studies had overlapping patient populations, only the study with the larger number of participants was used.

Results

General tolerability

SSRI antidepressants increase synaptic serotonin, which interacts with pre- and post-synaptic serotonin receptors and may contribute to untoward serotonergic effects unrelated to mood [11,22]. A number of studies have reported on the incidence of side effects and/or study drug discontinuation as related the HTR2A genotype. Table 1 summarizes the studies included in this review. Potential mechanisms for HTR2A influence on specific ADR domains will be discussed.

Murphy et al. studied 246 depressed elderly subjects (age ≥ 65) randomized to treatment with paroxetine (n=124) or mirtazapine (n=122) [23]. The authors examined pharmacogenetic relationships with these two antidepressant treatments due to the differing mechanisms underlying antidepressant action. Paroxetine is a potent selective serotonin reuptake inhibitor, whereas mirtazapine increases noradrenergic and serotonergic transmission and antagonizes 5-HT2 and 5-HT3 receptors [24]. In this 8-week trial, survival analysis showed a strong association between paroxetine treatment discontinuation and the 102 C/C genotype group (n=41). Forty-six percent of paroxetine-treated patients with the C/C genotype dropped out of the study due to adverse events, compared to 16% of those with C/T or T/T genotypes (p=0.001). There were no significant differences between participants with C/C and those with other genotypes in terms of age, gender distribution, ethnicity, plasma drug concentrations, baseline cognition, or baseline depression severity.

Furthermore, for paroxetine-treated patients, there was a positive linear relationship between number of C alleles and probability of discontinuation at all assessment points (all p<0.03). In contrast, survival analysis for mirtazapine-treated patients did not show any association between HTR2A genotype and discontinuation at any point in the study.

A second study examined fluvoxamine tolerability as related to HTR2A-1438 A>G in a Japanese Major Depressive Disorder (MDD) population (n=100) [25]. Survival analysis did not show a difference in onset rate for all side effects, nor was there a difference in the total number of side effects between genotype groups. There was no difference in incidence of study discontinuation between genotype groups. Of note, these authors assessed outcomes separately across HTR2A-1438 genotype groups (A/A, A/G, G/G). A trend was observed where patients with the G/G genotype had faster onset of side effects and at a lower dose, but these findings were not statistically significant.

The association of HTR2A genotype and SSRI tolerability may be more pronounced in elderly patients than the general population. The study by Suzuki et al. [25] with less compelling findings was not only in a younger study population, but also used fluvoxamine, which is a less potent SSRI than paroxetine. A study by Kato et al. [26] examined both paroxetine and fluvoxamine efficacy and ADRs as related to the HTR2A-1438 A>G polymorphism in a non-elderly study population of 100 Japanese patients with MDD randomized to either study drug. Paroxetine-treated subjects with the G/G genotype (n=10) had greater severity of ADRs (p=0.04). HTR2A genotype did not affect fluvoxamine tolerability. In the combined group of patients treated with paroxetine or fluoxetine, the G/G genotype had a numerically higher percentage of patients discontinuing due to side effects (16% vs. 8%), reporting severe nausea (20 vs. 6.7%), and reporting any side effect (52 vs. 34.7%), though these findings were not statistically significant.

Further evidence of an association between HTR2A and paroxetine ADRs comes from Wilkie et al. [27]. This study examined 166 patients with unipolar depression, many of whom were taking an antidepressant at baseline. First, investigators optimized the dose of their pre-enrollment antidepressant. Over half the participants were treated with SSRIs during this phase. HTR2A 102 T>C and 452 His>Tyr were not associated with ADR incidence (both p>0.5) during this initial dose optimization phase. Non-responders that were not initially treated with an SSRI were switched to paroxetine for the second phase of the trial. In these paroxetine-treated patients, the HTR2A 102 C/C genotype was associated with increased overall ADR incidence (17% vs. 0%, p=0.01). It should be noted that only four participants experienced ADRs with paroxetine; all of these participants had the C/C genotype. HTR2A 452 His>Tyr genotype was not associated with ADR incidence during paroxetine therapy.

Lanctot et al. [28] examined this association with citalopram response and tolerability in 90 subjects with depression secondary to traumatic brain injury. Subjects were genotyped for six candidate genes, including HTR2A -102 T>C and the serotonin transporter promoter polymorphism (5HTTLPR). The authors performed a backward stepwise linear regression for adverse event index; only 5HTTLPR significantly explained variability in the adverse event index.

A recent meta-analysis of pharmacogenomic markers for treatment response and side effects examined HTR2A among other serotonergic and neurotrophic candidate genes [21]. Pooling seven studies (n=801) resulted in a very significant association between the -1438 A>G G/G genotype and side effects (OR 1.91, 95% CI 1.32-2.78, p=0.0006).
When only SSR1-treated subjects were included, the association was even stronger (OR 2.33, 95% CI 1.53-3.56 p<0.0001).

Taken together, there appears to be an association between the 
HTR2A 102 C (or linked -1438 G) allele and general tolerability as 
examined by dropout rates, overall ADR incidence, and/or ADR 
severity in SSR1-treated patients with depression. This finding is 
only seen in SSR1s based on current literature, and is most evident 
when only SSR1-treated subjects were included, the association was 
not seen in SSR1s based on current literature, and is most evident 
in patients treated with paroxetine. Chronic administration of SSRIs 
only seen in SSR1-based on current literature, and is most evident 
severity in SSRI-treated patients with depression. This finding is 
examined by dropout rates, overall ADR incidence, and/or ADR 
HTR2A 

-1438 A>G; also 5HTTLPR, 
HTR3A, and HTR3B 

Wilkie et al. [25] 166 Caucasian patients with 
unipolar depression 
Stepwise treatment 
algorithm with the largest 
proportion receiving 
paroxetine 
HTR2A 102 T>C and 452 Hs>Tyr; 
also 5HTTLPR, SLC6A4 intron 2, 
HTR6, HTR1B, and HTR5A 
102 C/C genotype associated with paroxetine-induced ADRs. No association with 452 Hs>Tyr or for any other drugs.

Lancot et al. [26] 90 Post-traumatic brain injury 
patients with a major 
depressive episode 
Citalopram 20 mg/day fixed-
dose 
HTR2A 102 T>C; also HTR1A, BDNF, 
TPH2, and MTHFR 
HTR2A not associated with ADRs

Yoshida et al. [31] 66 Japanese patients with MDD 
Fluvoxamine with dose 
escalation protocol 
HTR2A -1438 G>A; also MAOA 
HTR2A not associated with nausea

Tanaka et al. [32] 72 Japanese patients with 
patients with depression disorder (n=57) 
or anxiety disorder (n=15) 
Paroxetine with dose 
escalation protocol 
HTR2A 102 T>C; also HTR3A, 
HTR3B, CYP2D6, and 5HTTLPR 
HTR2A not associated with nausea

Bishop et al. [39] 89 Outpatients with depression 
Citalopram, escitalopram, 
fluvoxamine, paroxetine, or 
sertraline 
HTR2A -1438 A>G; also GNB3 
-1438 G/G genotype associated with 
sexual dysfunction

Perlis et al. [41] 1473 Caucasians with depression 
from the STAR*D study 
Citalopram with dose-
escalation protocol 
HTR2A -452 His>Tyr, and three 
other HTR2A SNPs: n2770296, 
n594242, and n1928040; also 64 
other polymorphisms associated with serotonin, glutamate, dopamine, 
adrenergic receptors, neurotrophic systems, and antidepressant 
response 
HTR2A not associated with sexual 
dysfunction

Liang et al. [42] 56 Drug-naïve patients with first 
episode MDD 
SSRI (n=43) or venlafaxine 
(n=2) 
HTR2A -1438 A>G 
-1438 A/A genotype associated with 
sexual dysfunction

Perroud et al. [44] 796 Patients with MDD 
Escitalopram or nortriptyline 
with flexible dosing 
129 polymorphisms related to 
neurotrophic, serotonergic, 
and noradrenergic pathways 
HTR2A polymorphisms not 
associated with worsening suicidal 
ideation

Serretti et al. [47] 169 Patients with bipolar disorder 
(type I (n=103) or type II 
(n=66) with manic switch and 
247 matched bipolar controls 
A variety of antidepressants 
(SSRIs, TCAs, MAOIs) 
HTR2A 102 T>C and -1420 C>T; 
also 5HTTLPR, TPH, GNB3, MAOA, 
COMT, DRD2, DRD4 
HTR2A polymorphisms not 
associated with switching

Murata et al. [51] 56 Japanese patients with MDD 
(n=37) or anxiety disorder 
(n=18). One with pain 
disorder 
Paroxetine with an abrupt 
discontinuation or dose 
reduction for any reason 
HTR2A102 T>C and 452 Hs>Tyr; 
also HTR1A, HTR2C, HTR3A, 
HTR3B, 5HTTLPR, and CYP2D6 
HTR2A polymorphisms not 
associated with paroxetine discontinuation syndrome

### Table 1: Summary of studies reporting drug tolerability as related to HTR2A genotype.

A number of gastrointestinal (GI) ADRs are commonly reported with antidepressant use, including nausea, diarrhea, and constipation. These ADRs occur at incidence rates of about 20, 15, and 5%, respectively [1] and are thought to be related to serotonin signaling. Serotonin signaling plays a role in gut motility through 5-HT2A receptors expressed on peripheral smooth muscle [30]. Administration of the 5-HT3 receptor antagonist ondansetron attenuates SSR1-associated nausea [31], providing further evidence of a serotonergic mechanism for at least some SSR1-induced GI ADRs. To reconcile this finding with the current studies of variation in HTR2A, serotonin binding to the post-synaptic 5-HT3 receptor results in depolarization of the postsynaptic membrane, presumably affecting 5-HT2A activation [32].

Four studies specifically reported on GI ADRs as related to HTR2A genotype. Yoshida et al. examined incidence of fluvoxamine-induced nausea in respect to HTR2A-1438 G>A genotype [33]. Sixty-six Japanese patients with MDD were treated with fluvoxamine for six weeks. Sixteen patients experienced nausea during the study. There was no difference in genotype distribution or allele frequency in participants that experienced nausea versus those who did not.
Tanaka et al. [34] used a similar methodology to evaluate the incidence of paroxetine-induced nausea as related to a number of serotonergic and metabolism related polymorphisms in 72 Japanese patients with depression or anxiety. Twenty-one (29%) subjects experienced nausea, leading to treatment discontinuation in two. The HTR2A -1438 G/A genotype distribution was not different between those experiencing nausea and those who did not.

Previously described studies by Suzuki et al. and Kato et al. also commented specifically on GI ADRs [25,26]. In the Suzuki et al study of fluvoxamine-induced ADRs, 53 subjects reported GI ADRs. The number of HTR2A-1438G alleles was associated with risk for GI ADRs in a Cox regression analysis. In the Kato et al study of paroxetine or fluvoxamine-treated patients with depression, the HTR2A-1438 G/G genotype was associated with greater severity of nausea in paroxetine-treated patients (p=0.01). There was no difference between genotypes in fluvoxamine-treated patients. The recent meta-analysis by Kato and Serretti [21] examined GI ADRs in four studies of SSRI-treated patients and found a strong association in the same direction (OR 2.3, 95% CI 1.26-4.21, p=0.007).

Though less robustly studied than general tolerability, a similar trend was observed when focusing on GI ADRs. The two largest studies reporting antidepressant-induced GI ADRs did report some positive findings, though two smaller studies failed to replicate this finding. In positive studies, the lower-expressing -1438G and 102C alleles were associated with ADRs.

Sexual ADRs

Animal studies have associated serotonin agonism at 5-HT2A and decreased sexual arousal and ejaculation [35]. Additional evidence for the involvement of 5-HT2A receptors in sexual side effects comes from human drug studies that have identified lower rate of sexual ADRs with 5-HT2A antagonist antidepressants such as nefazodone [36] and mirtazapine [37]. Furthermore, pharmacologic 5-HT2A antagonism attenuates SSRI-induced sexual dysfunction [38-40].

Bishop et al. studied HTR2A and sexual side effects as measured by the Changes in Sexual Function Questionnaire (CSFQ) during antidepressant therapy as a primary outcome [41,42]. The initial study sample examined SSRI-associated sexual dysfunction in 81 outpatients treated with citalopram, escitalopram, fluoxetine, paroxetine, or sertraline. Sexual dysfunction was reported in 35% of females and 18% of males. In this study, the HTR2A-1438 G/G genotype (n=21) was associated with sexual dysfunction, both in unadjusted analyses and when controlling for age, gender, and anxiety/depression scores. However, the G allele alone was not associated with sexual dysfunction. Women with the G/G genotype had significantly lower scores in arousal and desire/frequency subscores of the rating tool; this association was not significant in males. A follow-up paper by the same research group indicated that use of oral contraceptives may be a strong effect mediator of the HTR2A-sexual ADR association [41].

Perlis et al. [43] examined genetic and clinical predictors of sexual dysfunction in the Sequenced Treatment Alternatives to Relieve Depression (STAR*D) study. The phenotype used in this study was comprised of three items from the Patient-Rated Inventory of Side Effects (PRISE) concerning erectile function, libido, and orgasm. HTR2A 452His>Tyr genotypewas examined, as well as additional HTRA SNPs: rs2770296, rs594242 and rs1928040. HTR2A-1438 G/A was not examined, but is in strong LD with rs1928040. None of the SNPs was associated with sexual dysfunction in this study, either in the cohort as a whole or stratified by gender.

Liang et al. [44] investigated sexual dysfunction via the Arizona Sexual Experience Scale (ASEX) - Chinese version, in previously drug-naive male patients with depression who were beginning therapy with an SSRI (fluoxetine, paroxetine, sertraline, escitalopram n=43) or SNRI (venlafaxine n=2). Sixteen of the 45 subjects experienced sexual dysfunction after drug initiation. The HTR2A-1438 A/A genotype was significantly associated with sexual dysfunction. Additionally, G-allele carriers were less likely to experience sexual dysfunction. The authors also note that the sexual dysfunction group had higher mean baseline Hamilton Depression Rating Scale (HAM-D) scores.

Sexual ADRs is the only ADR domain with conflicting positive studies. Explanations for these discordant findings are not easily discernible. For one, there may be a gender effect, as Liang et al. [44] exclusively studied male sexual dysfunction and Bishop et al. [41] mostly observed sexual ADRs in women. Bishop and Liang excluded patients over 40 and 30 years of age, respectively, while the mean age was 41 in Perlis's study. In addition, Bishop et al. used the CSFQ. Liang et al. used the ASEX, and Perlis et al. used a less-robust phenotype of 3 items on a broad side effect questionnaire. Another consideration is that the ethnicity of participants differed between studies, with Bishop et al. and Perlis et al. studying primarily Caucasians and Liang et al. recruiting from a hospital in Taiwan. Conflicting results in subjects with different ethnicities has been observed in HTR2A/treatment response studies and may thus be a variable for further investigation in tolerability studies as well [21].

Neuropsychiatric ADRs

A number of studies have examined the potential for an association between HTR2A polymorphisms and suicidality with conflicting results. A review by Serretti summarizes the various lines of conflicting evidence for association with HTR2A [20]. A recent meta-analysis of 73 studies showed largely negative measures of association between HTR2A genotype and suicidality [45], though this analysis was not specific to suicidality during antidepressant therapy. One study examined increased suicidal ideation during antidepressant treatment [46]. Subjects in the Genome-based Therapeutic Drugs for Depression (GENDEP) study were treated with flexible-dose escitalopram or nortriptyline for 12 weeks. 727 subjects were included in genetic analyses. Of these, 236 had increases in suicidal ideation (a composite score of items on the HAM-D, Beck Depression Inventory, and Montgomery-Asberg Depression Rating Scale), while 491 did not. The authors examined 123 polymorphisms in 9 neurotrophic, serotonergic, and noradrenergic pathways for association with increased suicidal ideation. HTR2A polymorphisms were only examined in escitalopram-treated subjects as part of the a priori analysis plan due to the drug's mechanism of action. None of the investigated serotonergic gene polymorphisms, including those in HTR2A, was associated with increased suicidality.

Serotonin system genes may predispose individuals to antidepressant-induced mania. The serotonin transporter 5HTTLPR is the most frequently studied polymorphism for this ADR. Two recent meta-analyses examined this association [47,48] while the role of HTR2A remains less defined. Serretti et al. [49] examined eight candidate genes in relation to antidepressant-induced mania or hypomania in bipolar disorder in a case-control fashion. Cases (n=169) were defined as bipolar I or bipolar II individuals who presented with at least one acute manic or hypomanic episode within 3 weeks of starting antidepressant therapy, with no interposed euthymic period (“switching”). Controls (n=247) were matched on sex, age, and ethnicity and had a diagnosis of bipolar disorder without a history of
switches. HTR2A 102 T>C and HTR2A-1420 C>T were not associated with switching in unadjusted analyses or after correcting for potential clinical confounders like mood polarity of onset episode, presence of psychotic features, age, and number of previous manic episodes.

The abrupt cessation of SSRI therapy is known to induce discontinuation symptoms in some patients [50]. The severity and occurrence of these discontinuation symptoms appears to differ based on characteristics of the withdrawn medication [51] whereby potent agents with short half-lives such as paroxetine tend to be associated with more significant discontinuation symptoms [52]. Murata et al. [53] examined whether serotonin- or drug metabolism-related polymorphisms influence the incidence and severity of paroxetine discontinuation syndrome. The study population consisted of 56 Japanese patients with diagnoses of MDD or anxiety disorder that were treated with paroxetine for 8 weeks or longer. Participants then had a dose reduction under the direction of a psychiatrist, or abruptly discontinued the drug themselves for psychosocial reasons. Participants were interviewed directly about a number of symptoms that could be associated with paroxetine discontinuation; those expressing at least one new symptom within 7 days of medication reduction/discontinuation were identified as having discontinuation syndrome. Patients were genotyped for the HTR2A 102 T>C and 452 His>Tyr polymorphisms. Of the 56 patients, 20 (36%) experienced at least one symptom of paroxetine discontinuation syndrome. The most common symptoms were dizziness, vivid dreams, fatigue, nausea/vomiting, headache, and anxiety. There was no difference between cases in controls in genotype distribution of either HTR2A polymorphism. Of note, all cases and controls were 452 His/His.

Limitations of Current Literature

There are a number of limitations to the available literature on HTR2A and ADRs. Most studies have focused on two SSRIs, fluvoxamine and paroxetine. It is possible that specific antidepressant agents may modify the HTR2A/ADR relationship. For example, Kato et al. [26] identified an association between HTR2A and tolerability in patients treated with paroxetine but not fluvoxamine. This nuance of the data makes it difficult to apply findings to other SSRIs or antidepressants of other classes. Furthermore, there were very few studies of non-SRRI antidepressants, and no HTR2A studies concerning tolerability for mood stabilizers found in our search.

Additionally, studies were performed primarily in Caucasian and Asian populations. As discordant results between ethnicities have been seen in other genetic studies, this may limit the applicability of current findings to a broader patient population [21]. Other polymorphisms associated with antidepressant tolerability, such as 5HTTLPR [21], were not controlled for in many of the studies summarized in our review, which may also confound the results.

Summary

In summary, there is mounting evidence that HTR2A genotype may play a role in the tolerability of SSRI antidepressants. The direction of the finding is mostly consistent, in which patients with the -1438 G or 102 C variant alleles experience greater side effect burden or incidence of events. The magnitude of effect appears clinically relevant, with a recent meta-analysis indicating about twice the odds of side effects for the -1438 G/G genotype [21]. There are insufficient studies addressing 452 His>Tyr. The minor allele frequency for this polymorphism complicates research efforts, though it is plausible that it could influence side effect burden, given studies linking this variant to lower activity, like -1438 A/G and 102 T/C [20].

The strongest and largest body of data supporting the association of HTR2A and tolerability comes from studies that examined broad outcomes such as study discontinuation or general occurrence of side effects. Studies of specific side effects are mixed. In studies of GI ADRs, many positive findings were identified with the -1438G or 102C carriers at increased risk for adverse outcomes. While studies of sexual ADRs identified positive associations with genotypes, the direction of association is conflicting. Studies of neuropsychiatric ADRs were negative.

As genetic information becomes commonplace in clinical practice, opportunities will arise to combine clinical and genetic factors to optimize drug selection and dose titration. Based on the findings of this review, practitioners with the benefit of HTR2A genetic data available for their patients may consider HTR2A genotype, with the most data to support relationships with lower tolerability to paroxetine-associated ADRs in those who are -1438G or 102C allele carriers. Whether prospectively testing patients for these variants decreases the time needed to identify a tolerable treatment and improve quality of life and broad clinical outcomes has not been explicitly tested. Thus while the findings summarized herein are scientifically interesting and appear to represent clinically relevant effect sizes, we must interpret these findings with caution and more explicitly identify how and when to provide genetic analyses in clinical environments. Additionally requiring formal testing is the hypothesis that patients that are historically sensitive to side effects with low-expression HTR2A variants may benefit from non-SSRI therapies.

In the coming decade, we hope to see prospective data validating a genotype-informed approach to drug selection and titration in mood disorders.

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