



## Stimulants and Related Agents Therapeutic Class Review (TCR)

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July 7, 2017

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## FDA-APPROVED INDICATIONS

Drug	Manufacturer	ADHD			Narcolepsy (Age ≥ 6 years)	Other Indications
		Age 3–5 years	Age ≥ 6 years	Adults		
<b>Stimulants: Immediate-Release</b>						
amphetamine sulfate (Evekeo™) <sup>1</sup>	Arbor	X	X	--	X	Exogenous obesity age ≥ 12 years
armodafinil (Nuvigil®) <sup>2</sup>	generic, Cephalon	--	--	--	--	Excessive sleepiness associated with narcolepsy, OSA, and SWD for age ≥ 17 years
dexamethylphenidate IR (Focalin™) <sup>3</sup>	generic, Novartis	--	X	--	--	--
dextroamphetamine IR (Zenzedi™) <sup>4</sup>	generic, Arbor	X	X (≤ 16 years)	--	X	--
dextroamphetamine solution (Procentra™) <sup>5</sup>	generic, Independence	X	X (≤ 16 years)	--	X	--
methamphetamine (Desoxyn®) <sup>6</sup>	generic, Recordati	--	X	--	--	Exogenous obesity in adults and adolescents ≥ 12 years
methylphenidate IR (Methylin®, Ritalin®) <sup>7,8</sup>	generic, Shionogi	--	X	--	X	--
mixed amphetamine salts IR (Adderall®) <sup>9</sup>	generic, Teva	X	X	--	X	--
modafinil (Provigil®) <sup>10</sup>	generic, Cephalon	--	--	--	--	Excessive sleepiness associated with narcolepsy, OSA, and SWD for age ≥ 17 years
<b>Stimulants: Extended-Release</b>						
amphetamine ER (Adzenys XR-ODT™) <sup>11</sup>	Neos	--	X	X	--	--
amphetamine ER (Dyanavel™ XR) <sup>12</sup>	Tris	--	X	X	--	--
dexamethylphenidate ER (Focalin XR™) <sup>13</sup>	generic, Novartis	--	X	X	--	--
dextroamphetamine ER (Dexedrine®) <sup>14</sup>	generic, Amedra	--	X (≤ 16 years)	--	X	--
lisdexamfetamine dimesylate (Vyvanse™) <sup>15</sup>	Shire	--	X	X	--	Moderate to severe binge eating disorder in adults
methylphenidate ER OROS (Concerta®) <sup>16</sup>	generic, Janssen	--	X	X	--	--

**FDA-Approved Indications (continued)**

Drug	Manufacturer	ADHD			Narcolepsy (age ≥ 6 years)	Other Indications
		Age 3–5 years	Age ≥ 6 years	Adults		
<b>Stimulants: Extended-Release (continued)</b>						
methylphenidate ER <sup>†</sup> (Metadate CD <sup>®</sup> ) <sup>17</sup>	generic, UCB	--	X	--	--	--
methylphenidate ER (Metadate ER <sup>®</sup> ) <sup>18,19</sup>	generic, Upstate	--	X	X	X	--
methylphenidate ER (Aptensio XR <sup>®</sup> ) <sup>20</sup>	Rhodes	--	X	X	--	--
methylphenidate ER (Cotempla XR-ODT <sup>®</sup> ) <sup>21</sup>	Neos	--	X	--	--	--
methylphenidate ER (Quillichew <sup>™</sup> ER) <sup>22</sup>	Tris/Pfizer	--	X	X	--	--
methylphenidate ER (Quillivant XR <sup>®</sup> ) <sup>23</sup>	NextWave/Pfizer	--	X	X	--	--
methylphenidate ER (Ritalin LA <sup>®</sup> ) <sup>24</sup>	generic, Novartis	--	X	--	--	--
methylphenidate transdermal (Daytrana <sup>™</sup> ) <sup>25</sup>	Noven	--	X	--	--	--
mixed amphetamine salts ER (Adderall XR <sup>®</sup> ) <sup>26</sup>	generic, Shire	--	X	X	--	--
mixed amphetamine salts ER (Mydayis <sup>™</sup> ) <sup>27</sup>	Shire	--	--	-- (≥ 13 years)	--	--
<b>Non-Stimulants</b>						
atomoxetine (Strattera <sup>®</sup> ) <sup>28</sup>	generic, Eli Lilly	--	X	X	--	--
clonidine ER (Kapvay <sup>™</sup> ) <sup>29</sup>	generic, Concordia	--	X	--	--	Treatment of ADHD as adjunct to stimulants
guanfacine ER (Intuniv <sup>™</sup> ) <sup>30</sup>	generic, Shire	--	X	--	--	Treatment of ADHD as adjunct to stimulants

OSA – obstructive sleep apnea; SWD – shift work disorder.

\*In OSA, modafinil and armodafinil are indicated as an adjunct to standard treatment(s) (e.g., continuous positive airway pressure [CPAP]) for the underlying obstruction.

†UCB has discontinued Metadate CD with the final shipment sent in April 2017. Product may remain available until stock is depleted.

## OVERVIEW

### Attention Deficit Hyperactivity Disorder (ADHD)

The most common use of stimulants is for the treatment of ADHD, for which they are considered first-line therapy.<sup>31,32,33,34,35,36</sup> ADHD, which affects 4% to 12% of school-aged children and about 4% of adults, is a chronic condition with core symptoms of inattention, hyperactivity, and impulsivity.<sup>37,38,39</sup> It may also be accompanied by internalized disorders, such as sadness and anxiety, as well as aggressive and oppositional disorders.<sup>40,41,42</sup> The 3 main types of ADHD are primary hyperactive, primary inattentive, and mixed.

Children with ADHD may experience academic underachievement, difficulties in personal relationships, and low self-esteem.<sup>43,44</sup> Early recognition of the signs and symptoms of ADHD, assessment, and treatment can help redirect the educational and social development of most children with ADHD. According to the 2011 ADHD guidelines developed by a subcommittee of the American Academy of Pediatrics (AAP), the primary care clinician should initiate an evaluation for ADHD for any child 4 through 18 years of age who presents with academic or behavioral problems and symptoms of inattention, hyperactivity, or impulsivity.<sup>45</sup> The treatment of patients with ADHD should maximize function to improve relationships and performance at school, decrease disruptive behaviors, promote safety, increase independence, and improve self-esteem.

According to the 2011 ADHD guidelines in children and adolescents, the AAP recommends parent- and/or teacher-administered behavior therapy as first-line treatment for children 4 to 5 years of age.<sup>46</sup> Methylphenidate (MPH) may be prescribed if the behavior interventions do not provide significant improvement and there continues to be moderate to severe disturbance in the child's function. For children 6 to 11 years of age, the evidence is particularly strong for stimulant medication use and sufficient, but less strong evidence, for atomoxetine, extended-release guanfacine, and extended-release clonidine; however, medication therapy in addition to behavioral therapy is recommended. For patients 12 to 18 years of age, the AAP recommends FDA-approved medications, with the adolescent's assent, and behavior therapy as treatment for ADHD, preferably both.

The Medical Letter suggests that school-age children begin with an oral stimulant, noting that none of the agents have shown to be more effective than another.<sup>47,48</sup> They indicate that short-acting stimulants may be useful in small children to demonstrate effectiveness or in instances where there is not an appropriately low dose of a long-acting agent. The methylphenidate patch (Daytrana) is recommended for use when oral administration is problematic. Atomoxetine (Strattera), a non-stimulant agent, is recommended if there are objections to using a controlled substance, if stimulant-induced weight loss is problematic, or for patients with anxiety, mood, tic, or substance abuse disorders. Extended-release formulations of guanfacine or clonidine may be helpful when used concurrently with a stimulant in patients who cannot tolerate usual doses of the stimulant, particularly those with tics. Mixing short- and long-acting stimulants can be helpful to achieve an early stimulant effect for early-morning school classes or for reducing rebound irritability or overactivity toward the end of the day, especially when studying in the evening.

Numerous studies indicate that stimulants are effective in the treatment of ADHD in preschool children.<sup>49,50</sup> Some have expressed concern that the use of neuropsychiatric drugs in children in this age group could have long-term effects on neurotransmitters in the brain.<sup>51</sup> The 2007 American Academy of Child and Adolescent Psychiatry (AACAP) practice parameters for ADHD recommend individualized and comprehensive treatment plans for patients with ADHD.<sup>52</sup> Initial psychopharmacological treatment should be a trial with an FDA-approved agent. If satisfactory results are not achieved, the diagnosis of

ADHD should be assessed and referral to a child and adolescent psychiatrist considered. The addition of behavior therapy may be beneficial. Off-label use of bupropion, tricyclic antidepressants, and  $\alpha$ -agonists have been used in select pediatric patients. Periodic assessment should be performed to determine continued need for treatment or if symptoms have remitted and for effect of treatment on patient height and weight; treatment should continue as while symptoms remain present and have patient impact. Revised ADHD guidelines are in development by AACAP.

Symptoms of ADHD tend to improve with age; however, this may be due in part to improved coping skills. The continuation of synaptogenesis and myelination into adolescence and young adulthood (especially in the frontal lobes) may also play a role in the improvement of symptoms. Still a majority of children, 60% to 80%, with ADHD will continue to require treatment throughout adolescence and into adulthood.<sup>53,54,55,56</sup>

Studies have shown that 70% to 75% of patients respond to the first stimulant medication on which they are started.<sup>57</sup> Response increases to 90% to 95% when a second stimulant is tried. Treatment failures with stimulants are often due to improper doses rather than ineffectiveness of the medication. It may take 1 to 3 months to adequately establish the best medication dose and dosage form for an individual patient. The AAP recommends that, if a trial with 1 drug compound group is ineffective or poorly tolerated, a trial of a medication from a different drug group should be used.<sup>58</sup>

## Hypersomnolence

Excessive sleepiness, or hypersomnolence, is the primary and often debilitating symptom experienced by patients with narcolepsy, obstructive sleep apnea-hypopnea syndrome (OSAHS), and shift work sleep disorder (SWSD). The defining characteristic of hypersomnolence is a consistent inability to stay awake and alert enough to safely and successfully accomplish tasks of daily living. Persons experiencing excessive sleepiness who seek medical attention typically complain of fatigue, tiredness, lapses of attention, lack of energy, low motivation, difficulty concentrating, disrupted sleep, snoring, or difficulties at work.

While continuous positive airway pressure (CPAP) therapy has been shown to improve daytime sleepiness in patients with obstructive sleep apnea (OSA), the level of sleepiness does not always normalize.<sup>59,60,61,62,63,64</sup> To address this residual daytime sleepiness, pharmacologic treatments may be beneficial in users of CPAP. Modafinil (Provigil) and armodafinil (Nuvigil) are FDA-approved for excessive daytime sleepiness associated with OSAHS, as well as sleep problems resulting from circadian rhythm disruption (e.g., SWSD).<sup>65,66,67</sup>

Modafinil and armodafinil, along with central nervous system (CNS) stimulants, such as dextroamphetamine (Dexedrine, Procentra, Zenzedi), methylphenidate (Methylin, Ritalin, Metadate ER), mixed amphetamine salts (Adderall), and amphetamine sulfate (Evekeo), are used for narcolepsy. The potential for adverse cardiovascular events with CNS stimulant use may be of concern, especially in this overall high-risk patient population. Due to their lack of sympathomimetic activity, modafinil and armodafinil are relatively free of adverse cardiovascular effects.<sup>68</sup>

## Exogenous Obesity

Stimulants may have other CNS actions or metabolic effects, in addition to the appetite suppression, that result in weight-loss.<sup>69</sup> In relatively short-term clinical trials, adult subjects instructed in dietary management and treated with stimulants lost more weight on average than those treated with placebo

and diet. However, the magnitude of increased weight loss of drug-treated patients over placebo-treated patients is only a fraction of a pound per week. The rate of weight loss is greatest in the first weeks of therapy for both drug and placebo subjects and tends to decrease in subsequent weeks. Studies have not permitted conclusions regarding the relative importance of drug and non-drug factors on weight loss. Furthermore, natural history of obesity is measured in years, whereas studies cited are limited to a few weeks; therefore, the impact of weight loss due to medication versus diet alone must be considered clinically limited. Methamphetamine (Desoxyn) and amphetamine sulfate (Evekeo) are FDA-approved in adults for short-term adjunctive therapy in a weight reduction regimen based on caloric restriction for patients in whom obesity is refractory to alternative therapy.

## Binge-Eating Disorder

Binge-eating disorder (BED) is characterized by uncontrolled eating occurring at least once every week for 3 months and  $\geq 3$  of the following behaviors: eating rapidly, eating until uncomfortably full, eating when not hungry, eating alone due to embarrassment, and/or feeling of guilt after eating. BED occurs in approximately 1 out of 35 adults in the U.S.<sup>70</sup> The 2006 Practice Guidelines for the Treatment of Patients with Eating Disorders suggest that serotonin reuptake inhibitor (SSRI) treatment is associated with at least a short-term reduction in BED symptoms, but not with considerable weight loss.<sup>71</sup> The 2012 Guideline Watch states the 2006 guidelines remain current despite recent studies. Additional studies support the use of imipramine, sertraline and citalopram/escitalopram, and topiramate for BED.<sup>72</sup> SSRIs, imipramine, and topiramate are not FDA-approved for BED. Lisdexamfetamine dimesylate (Vyvanse) is the first and only FDA-approved product for moderate to severe BED in adults. Lisdexamfetamine dimesylate is not indicated for weight loss and it is not known if it is safe and effective for obesity treatment.

## PHARMACOLOGY

Stimulants act by blocking the reuptake of norepinephrine and dopamine into the presynaptic neuron and increasing their release into the extraneuronal space. Amphetamines appear to release newly synthesized dopamine while MPH causes the release of stored dopamine.<sup>73</sup> Unlike MPH, the amphetamine-induced elevation of synaptic dopamine does not appear to be highly dependent upon impulse-released dopamine. Stimulants tend to have selectivity for cortical, rather than striatal, dopamine presynaptic terminals. As a result, lower doses have more of an effect on attention than on motor activity.

Symptoms of inattention in ADHD may be due to dopamine and/or norepinephrine dysfunction in critical areas of the cerebral cortex controlling cognition. It seems as though patients with inattention symptoms need a boost in their dopamine/norepinephrine and, when they are given agents such as stimulants that boost these systems, their symptoms of inattentiveness can improve.

Symptoms of hyperactivity and impulsivity associated with ADHD are more likely mediated by the nigrostriatal dopamine pathway, which controls motor activity. Due to a presumed greater sensitivity of the mesocortical dopamine terminals in patients with ADHD, lower doses of stimulants prefer the cerebral cortex. Thus, the effects of stimulants on inattentiveness usually appear before their effects on motor behaviors.

Amphetamine and MPH are available as racemic or single isomer products. The d-enantiomer of amphetamine, dextroamphetamine (Dexedrine, Zenzedi, ProCentra), has much less of an effect on norepinephrine release than the l-enantiomer. Thus, the combination of the 2 isomers of amphetamine

may provide additional benefit over dextroamphetamine in some patients. This combination is available as mixed amphetamine salts (Adderall, Adderall XR, Mydayis), which contains d- and l-amphetamine in a 3:1 ratio, amphetamine sulfate (Evekeo), which contains d- and l- amphetamine in a 1:1 ratio, amphetamine extended-release (Dyanavel XR), which contains d- and l- amphetamine in a 3.2:1 ratio, or amphetamine extended-release (Adzenys XR-ODT), which contains d- and l- amphetamine in a 3:1 ratio.<sup>74,75,76</sup> Mixed amphetamine salts tend to have fewer adrenergic side effects than MPH. MPH is a racemic mixture of d- and l-enantiomers, the former of which is more pharmacologically active.<sup>77,78</sup> A product containing only the d-enantiomer, dexamethylphenidate (Focalin, Focalin XR), is also available. Lisdexamfetamine dimesylate (Vyvanse) is a prodrug in which d-amphetamine is covalently bonded to L-lysine and converted to these components by enzymatic hydrolysis.<sup>79</sup> Lisdexamfetamine is rapidly absorbed from the gastrointestinal (GI) tract after oral administration and converted to dextroamphetamine, which is responsible for its activity. Conversion is believed to occur by first-pass intestinal and/or hepatic metabolism. Metabolism does not occur by cytochrome P450 enzymes.<sup>80</sup>

Compared to immediate-release dosage forms, extended-release preparations offer the advantages of less fluctuation in activity and removal of the need for dose administration in school. Their prolonged action, however, may be less intense, and their use forfeits the advantages of flexibility and control of titrating than the more frequent dosing schedule of immediate-release dosage forms.<sup>81</sup> It is also important that extended-release dosage forms do not produce a flat stimulant plasma concentration, which could lead to acute tolerance.<sup>82</sup> There is increased experience with combining immediate- and extended-release preparations to produce optimal symptom control throughout the day.

Atomoxetine (Strattera) is a selective inhibitor of the presynaptic norepinephrine transporter. It increases norepinephrine and dopamine levels, especially in the prefrontal cortex.<sup>83</sup> It has minimal affinity for other monoamine transporters. Its mechanism of action suggests that atomoxetine is unlikely to have abuse potential or to cause motor tics.<sup>84,85</sup> Atomoxetine has a slower onset of action than stimulants; therapeutic effects may not be seen until a week after the start of treatment. It also has a longer duration of action compared to stimulants with the possibility of symptom relief during the evening and early-morning hours.<sup>86</sup>

Guanfacine ER (Intuniv) is a selective alpha-2A-adrenergic receptor agonist.<sup>87</sup> Clonidine (Kapvay) is a centrally acting alpha-2-adrenergic receptor agonist.<sup>88</sup> These drugs reduce sympathetic nerve impulses to the heart and blood vessels leading to a decrease in blood pressure. This mechanism of action in the treatment of ADHD is not known.

Modafinil (Provigil) appears to act by selective activation of the cortex without generalized stimulation of the CNS. It has wake-promoting actions like the sympathomimetic agents. It also causes psychoactive and euphoric effects, as well as the alterations in mood, perception, thinking, and feelings typical of other CNS stimulants. *In vitro*, modafinil binds to the dopamine reuptake site and causes an increase in extracellular dopamine. *In vivo* models, however, have not detected enhanced dopaminergic activity. Modafinil, then, may also work through other neurotransmitter systems. Armodafinil (Nuvigil) is the R-enantiomer of modafinil. Both armodafinil and modafinil have shown similar pharmacological properties.

**PHARMACOKINETICS**<sup>89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117</sup>

Drug	Time(s) to Peak Concentration(s) (hours)	Onset of Action (minutes)	Half-Life (mean, in hours)	Duration of Action (hours)	Extended-Release Delivery System (where applicable)
<b>Stimulants: Immediate-Release</b>					
amphetamine sulfate (Evekeo)	--	--	--	--	--
armodafinil (Nuvigil)	2	--	15	--	--
dexmethylphenidate (Focalin)	1–1.5	30	2.2	4–6	--
dextroamphetamine IR (Zenzedi)	3	20–60	12	4–6	--
dextroamphetamine solution (ProCentra)	--	--	11.75	--	--
methamphetamine (Desoxyn)	--	--	4–5	--	--
methylphenidate IR (Methylin, Ritalin) <sup>118</sup>	1.5–3	15–20	2–4	2–4	--
mixed amphetamine salts IR (Adderall)	3	30–60	children: 9–11 adults: 10–13	4–8	--
modafinil (Provigil)	2–4	--	15	--	--
<b>Stimulants: Extended-Release</b>					
amphetamine ER (Adzenys XR-ODT)	5 (d-amphetamine [d])/5.25 (l-amphetamine [l])	--	children: 9–10 (d)/ 10–11 (l) adults: 11 (d)/ 14 (l)	--	50% IR and 50% ER components
amphetamine ER (Dyanavel XR)	children: 3.9 – 4.5 adults: 4	--	children: 10.43 (d)/12.14(l) adults: 12.36 (d)/15.12(l)	--	IR and ER components; ER component coated with pH-independent polymer
dexmethylphenidate (Focalin XR)	1.5, then 6.5	--	children: 2–3 adults: 2–4.5	children: 8–12 adults: 8	50% each IR and enteric-coated, delayed-release beads
dextroamphetamine ER (Dexedrine)	8	60	12	≤ 24	initial dose delivered immediately with remaining medication released over 6–8 hours
lisdexamfetamine dimesylate (Vyvanse) <sup>119,120</sup>	dexamfetamine = 3.5 (capsule) and 4.4 (chewable tablet)* (prodrug = 1)	--	12 (prodrug <1)	~10	Active drug slowly released by rate-limited hydrolysis



**Pharmacokinetics (continued)**

Drug	Time(s) to Peak Concentration(s) (hours)	Onset of Action (minutes)	Half-Life (mean, in hours)	Duration of Action (hours)	Extended-Release Delivery System (where applicable)
<b>Stimulants: Extended-Release (continued)</b>					
methylphenidate ER OROS (Concerta) <sup>121</sup>	1–2, then 6–8	30–60	3.5	8–12	22% IR overcoat; 78% controlled release core; osmotic-release oral system
methylphenidate ER ODT (Cotempla XR-ODT)	4.6-5.3	1	3.9-4.3	12	25% IR and 75% ER components
methylphenidate ER (Metadate CD)	1.5, then 4.5	30–90	6.8	7–12	30% IR, 70% ER beads
methylphenidate ER (Metadate ER) <sup>122,123</sup>	4.7	30–180	2–4	8	Various
methylphenidate ER (QuilliChew ER)	5	--	5.2	--	30% IR, 70% ER
methylphenidate ER (Quillivant XR)	5	45	4.2-6.2	12	extended-release oral suspension
methylphenidate ER (Ritalin LA)	1–3, then 4–8	30–110	2.5–3.5	7–12	50% dose IR beads, 50% dose enteric-coated, delayed release beads
methylphenidate ER (Aptensio XR)	2, then 8	60	5	12	multi-layer beads 40% IR, 60% ER
methylphenidate transdermal (Daytrana)	7.5–10.5	120	3-4	~3 following patch removal	concentrated drug cells in patch
mixed amphetamine salts ER (Adderall XR)	7**	30-60	children: 9–11 adults: 10–13	8–10	50% each of immediate- and delayed-release beads
mixed amphetamine salts ER (Mydayis)	children: 7-10† adults: 8†	2-16	10-13	≤16	Triple-beaded providing immediate-, pulsatile delayed, and sustained-release activity
<b>Non-Stimulants</b>					
atomoxetine (Strattera)	1–2	3–4 weeks	5.2	~24	--
clonidine ER (Kapvay)	6.5–6.8	--	12–16	--	extended-release tablet
guanfacine ER (Intuniv)	5–6	--	18 (adults)	--	matrix consisting of ionic polymers, enteric polymers, and organic acids

\* Food prolongs the Tmax of converted prodrug (d-amphetamine) by 1 hour

\*\* Food prolongs the Tmax of mixed amphetamine salts ER (Adderall XR) by 2.5 hours

† Food (high fat meal) prolongs the Tmax of mixed amphetamine salts ER (Mydayis) by 4.5-5 hours

The half-life and blood concentration of amphetamine is directly related to urinary pH, increasing with alkaline pH and decreasing with acidic pH. For every unit increase in pH, the half-life of mixed amphetamine salts (Adderall XR, ProCentra) increases by an average of 7 hours. As a result, urine acidifying and urine alkalinizing agents should be avoided with the use of amphetamine sulfate (Evekeo), amphetamine extended-release (Dyanavel XR), amphetamine extended-release (Adzenys XR-ODT), and mixed amphetamine salts, if possible, to maintain consistent amounts of the active drug in the system.

Except for mixed amphetamine salts, stimulants are de-esterified in the liver to pharmacologically inactive metabolites. In contrast, mixed amphetamine salts are metabolized in the liver by hydroxylation, dealkylation, and deamination. Urinary excretion accounts for nearly all of the elimination of the stimulants and atomoxetine (Strattera), as well as their metabolites.

Mydayis consists of 3 types of drug-releasing beads that deliver immediate, pulsatile delayed, and sustained release of mixed amphetamine salts.<sup>124</sup> Patients  $\leq 12$  years experienced higher plasma exposure of mixed amphetamine salts (Mydayis) with than patients  $\geq 13$  years at the same dose and experienced higher rates of adverse reactions (e.g., insomnia, decreased appetite).

Methylphenidate extended-release OROS (Concerta) and dexmethylphenidate ER (Focalin XR) have similar pharmacodynamic profiles, with the main difference being that the latter contains only dexmethylphenidate. The release profiles of Metadate CD and Ritalin LA, also extended-release formulations of MPH, are very similar to each other.

Atomoxetine has a slower onset of action than the stimulants; onset of effect may take 1 week and full effect may not be seen for up to 4 weeks.<sup>125,126</sup> The effects of atomoxetine appear to last longer than would be expected from its pharmacokinetic profile.<sup>127</sup> The reasons for these pharmacokinetic – pharmacodynamic differences are not clear, but may be due to a variance between brain and plasma pharmacokinetics, or by continued effects on the norepinephrine transporter. Atomoxetine is metabolized in most patients primarily by the CYP2D6 enzymatic pathway. Medications that inhibit CYP2D6 (e.g., paroxetine, fluoxetine, quinidine) increase the bioavailability of atomoxetine. Atomoxetine does not appear to induce or inhibit the CYP2D6 enzyme system.<sup>128</sup> Approximately 5% to 10% of patients are “slow metabolizers” in which the mean half-life of atomoxetine is 21.6 hours, over 4 times longer than in “rapid metabolizers.”<sup>129</sup>

Exposure to guanfacine ER (Intuniv) was higher in children (6 to 12 years of age) compared to adolescents (13 to 17 years of age) and adults, probably attributable to the lower body weight of children compared to adolescents and adults.<sup>130</sup> The pharmacokinetics of a single dose of guanfacine ER 4 mg was affected when administered with a high-fat breakfast. The mean exposure increased (C<sub>max</sub> 75% and area under the curve [AUC] 40%) compared to dosing in a fasted state.

When opened and sprinkled on cold applesauce, the bioavailability of methylphenidate ER (Aptensio XR, Metadate CD, and Ritalin LA), dexmethylphenidate ER (Focalin XR), and mixed amphetamine salts ER (Adderall XR, Mydayis) are the same as the intact capsules.

## **CONTRAINDICATIONS/WARNINGS**<sup>131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154</sup>

### **Contraindications**

All products in this review are contraindicated in patients with a history of hypersensitivity to those individual products' active or inactive ingredients. **Hypersensitivity reactions, including angioedema and**

anaphylaxis, have been reported with many medications used to treat ADHD, including amphetamine and methylphenidate products.

All products in this review, except clonidine ER (Kapvay) and guanfacine ER (Intuniv), are contraindicated during or within 14 days following administration of a monoamine oxidase inhibitor (MAOI); concurrent use can prolong and intensify the cardiac stimulation and vasopressor effects of stimulants. These drugs are also contraindicated in patients with glaucoma.

Stimulants are contraindicated in patients with marked anxiety or agitation as these symptoms may be aggravated. If paradoxical aggravation occurs a decrease in dose or cessation of therapy may be needed.

Amphetamines are contraindicated in patients with advanced arteriosclerosis, symptomatic cardiovascular disease, moderate to severe hypertension, hyperthyroidism, or a history of drug abuse.

Methylphenidate (Concerta, Daytrana, Methylin, Metadate CD, Metadate ER, Ritalin, Ritalin LA) and dexamethylphenidate (Focalin, Focalin XR) are contraindicated in patients with tics or a diagnosis or family history of Tourette's syndrome. While this may be a class effect, labeling for Aptensio XR, Cotempla XR, Quillichew ER, and Quillivant XR do not include this contraindication.

Atomoxetine (Strattera) is contraindicated in patients with severe cardiac or vascular disorders whose condition would be expected to deteriorate with clinically significant increases in blood pressure or heart rate. Increases in blood pressure and heart rate, orthostasis, and syncope have been reported. Atomoxetine should be used with caution in patients with hypertension, tachycardia, or cardiovascular or cerebrovascular disease.

## Warnings

### *Behavioral/Mental Health*

Stimulants have boxed warnings regarding the high potential for abuse. Prolonged use of these agents can lead to drug dependence, tolerance, and social disability. Prescribers should assess the risk of abuse prior to prescribing, monitor patients for signs of abuse and dependence, and re-evaluate the need for stimulants.

Stimulants should be used with caution in patients with pre-existing psychosis, bipolar disorder, or aggression as these conditions may be exacerbated. Treatment-emergent psychotic or manic symptoms have been reported in 0.1% of patients receiving stimulants and 0.2% of patients receiving atomoxetine (Strattera).

Atomoxetine has a boxed warning regarding the increased risk of suicidal ideation in children and adolescents. In a combined analysis of 12 short-term placebo-controlled trials of over 2,200 patients, suicidal ideation occurred in approximately 0.4% of patients compared with no patients receiving placebo. All occurrences were reported during the first month of treatment in children  $\leq$  12 years. Monitoring, including face-to-face contact with patients or caregivers, should occur weekly during the first 4 weeks of treatment, then every other week for 4 weeks, then again at 12 weeks.

Patients on atomoxetine should be monitored for the appearance or worsening of aggressive behavior or hostility.

Patients should be carefully supervised during withdrawal from MPH and dexamethylphenidate as it may result in depression and/or unmasking of symptoms.

Modafinil (Provigil) and armodafinil (Nuvigil) have also been reported to induce mania, delusions, hallucinations, suicidal ideations, and aggression in patients with and without a prior history of psychiatric illness. Two cases of suicide ideation were observed in armodafinil clinical trials.

### **Cardiovascular**

Sudden death, stroke, and myocardial infarction have been reported in adults using stimulants at recommended dosages. Sudden death has also been reported in association with stimulants and with atomoxetine at usual doses in children and adolescents with structural cardiac abnormalities or other serious heart problems. Stimulants and atomoxetine generally should not be used in patients with known serious structural cardiac abnormalities, cardiomyopathy, serious heart rhythm abnormalities, or other serious cardiac problems that may place them at increased vulnerability to the noradrenergic effects of atomoxetine. In addition, stimulants and atomoxetine can cause increased blood pressure and heart rate. All patients being considered for pharmacologic treatment of ADHD should be evaluated for the presence of cardiac disease (e.g., personal history, family history, physical exam). Caution is indicated in treating patients with pre-existing hypertension, heart failure, recent myocardial infarction, or ventricular arrhythmia. Pulse and blood pressure should be monitored at baseline and during therapy.

Dose-dependent decreases in blood pressure and heart rate have been seen in patients using clonidine ER or guanfacine ER. Heart rate and blood pressure should be measured prior to initiation of therapy, following dose increases, and periodically while on therapy. Use with caution in patients with a history of hypotension, heart block, bradycardia, cardiovascular disease, or syncope. The sympatholytic action of clonidine ER and guanfacine ER may worsen sinus node dysfunction and atrioventricular (AV) block, especially in patients taking other sympatholytic drugs. Advise patients to avoid becoming dehydrated or overheated. Guanfacine ER should be titrated slowly in patients with history of hypotension or underlying conditions that may be worsened by hypotension and bradycardia, as well as patients with cardiac conduction abnormalities.<sup>155</sup> To avoid adverse effects on blood pressure when discontinuing therapy, the clonidine ER or guanfacine ER dose should generally be tapered off.

In 2011 the FDA published two safety communications. The first publication was based on studies that evaluated heart attacks, strokes, and sudden cardiac death in children, adolescents, and young adults ( $\leq 24$  years) treated with certain ADHD. The study did not find an association between the use of ADHD medications and cardiovascular events.<sup>156</sup> The second publication addressed heart attacks, sudden cardiac death, and strokes in adults age 25-64 year old. The publication stated studies did not show an increased risk of serious adverse cardiovascular events in adult patients treated with ADHD medications. The medications included in both of these publications were medications amphetamines, methylphenidate, atomoxetine, and pemoline (no longer marketed).<sup>157</sup>

All stimulants used to treat ADHD are associated with peripheral vasculopathy, including Raynaud's phenomenon. Signs and symptoms generally improve after reduction in dose or discontinuation of the drug. Monitor for digital changes during treatment with ADHD stimulants.

### **Dermatological**

Use of MPH transdermal system (Daytrana) may lead to contact sensitization as evidenced by allergic contact dermatitis. MPH transdermal system should be discontinued if this occurs. Patients may develop systemic sensitization or other systemic reactions to MPH-containing products given via other routes. It is possible that some patients sensitized to MPH may not be able to take MPH in any form.

In June 2015, the FDA issued a warning that MPH transdermal system (Daytrana) use may result in permanent loss of skin color, or chemical leukoderma, in areas ranging  $\leq 8$  inches in diameter.<sup>158</sup> A review of chemical leukoderma cases associated with the drug suggest that the skin condition's time to onset ranged from 2 months to 4 years after starting the MPH transdermal system. Patients and caregivers should watch for new areas of lightened skin, particularly in areas where the skin patch was rotated; however, skin color changes have been reported in other areas where the patch was never applied.

Rare cases of serious rash, such as Stevens-Johnson syndrome, toxic epidermal necrolysis, and drug rash with eosinophilia and systemic symptoms, have occurred in patients taking modafinil and armodafinil. The cases reported have occurred within 1 to 5 weeks after initiating drug treatment, and predictors to occurrence of rash are not known.

### **Other**

Stimulants may cause long-term suppression of growth and has been associated with weight loss. Growth and weight should be monitored during therapy and those who are not growing and/or gaining weight as expected may need their therapy interrupted. However, other studies have concluded final growth at maturity is not impacted by ADHD or medications used to treat ADHD (see Effects on Growth section).

Stimulants may lower the seizure threshold and may cause visual disturbances.

Accommodation and vision blurring have been reported with stimulant treatment.

Rare cases of GI obstruction have been reported with nondeformable controlled-release formulations similar to MPH OROS (Concerta).

Methylphenidate ER (Quillichew ER) contains phenylalanine, which may be harmful to patients with phenylketonuria (PKU).

Painful and prolonged penile erections and priapism have been reported with atomoxetine, mixed amphetamine salts, dextroamphetamine, methamphetamine, lisdexamfetamine, methylphenidate, and dexamethylphenidate products. Priapism has not been reported with drug initiation but developed after some time on the drug, often subsequent to a dosage increase. Priapism has also appeared during a period of drug withdrawal (e.g., drug holidays, during discontinuation). Immediate medical attention should be sought if signs or symptoms of painful or prolonged penile erections or priapism are observed.

Limited reports of multi-organ hypersensitivity reactions have been reported after initiation of treatment between 4 to 33 days in patients taking modafinil. Some of the presenting signs and symptoms were fever, rash, pruritus, asthenia, myocarditis, hepatitis, liver function test abnormalities, and dermatological abnormalities. A similar risk of multi-organ hypersensitivity reactions with armodafinil has also been reported.

Atomoxetine has a warning regarding severe liver injury; rare, but marked, elevations of hepatic enzymes and bilirubin have been reported. In 2 case reports, liver injury resolved after discontinuation of atomoxetine (with concomitant immunosuppressive therapy in 1 case).<sup>159</sup> The manufacturer warns to discontinue atomoxetine permanently in patients with any sign of jaundice or hepatic lab abnormality; other treatment options should be considered.

## DRUG INTERACTIONS<sup>160,161,162,163,164,165,166,167,168,169,170,171</sup>

Gastrointestinal (e.g., antacids) and urinary (e.g., acetazolamide, some thiazides) alkalinizing agents increase blood levels and activity of amphetamines and possibly methylphenidate. Gastrointestinal (e.g., ascorbic acid) and urinary (e.g., ammonium chloride) acidifying agents decrease absorption and activity of the amphetamines and possibly methylphenidate. Proton pump inhibitors reduce gastric acidity; patients who co-administer them with amphetamines should be monitored for changes in clinical effect due to the potential for decreases in the time to maximum concentration of amphetamine products. Amphetamines may delay the intestinal absorption of ethosuximide and the anticonvulsants, phenytoin and phenobarbital, which may produce a synergistic anticonvulsant action.

Extended-release amphetamine (Adzenys XR-ODT, Dyanavel XR) may enhance the effect of tricyclic antidepressants, including cardiac effects. Patients taking these agents concomitantly should have increased monitoring and dose adjustments as clinically indicated.

Lithium may antagonize the central stimulating effects of amphetamines and should be avoided.<sup>172</sup> Likewise, MPH should not be used concurrently with lithium since this may alter the effects of the agents on the underlying mood disorder. Haloperidol and chlorpromazine also inhibit the central stimulant effects of the amphetamines.

Serotonin syndrome may occur when amphetamines are used with other medications that impact the serotonergic neurotransmitter systems (e.g., MAOIs, SSRIs, SNRIs, triptans, TCAs, fentanyl, lithium, tramadol, tryptophan, buspirone, St. John's wort) and cytochrome P450 2D6 inhibitors. Monitor for signs and symptoms of serotonin syndrome including mental status changes, autonomic instability, neuromuscular symptoms, seizures, and GI symptoms.<sup>173</sup>

Amphetamines inhibit adrenergic blocking agents and may decrease the effects of antihistamines and antihypertensives; however, amphetamines potentiate the effects of meperidine and norepinephrine.

Effects can be additive when stimulants are used concurrently with other psychostimulants or sympathomimetics.<sup>174</sup> Due to the potential for excessive CNS or cardiovascular stimulation, combination therapy should be avoided unless necessary, and, if unavoidable, then used with caution.<sup>175</sup> In general, the concurrent use of MPH (Aptensio XR, Concerta, **Cotempla XR-ODT**, Daytrana, Methylin, Metadate ER, Metadate CD, Quillivant XR, Ritalin, Ritalin LA) with amphetamines is not recommended. Since there are no clinical data regarding the concurrent use of MPH and atomoxetine (Strattera), concurrent use should be avoided.

MPH and dexamethylphenidate may inhibit the metabolism of coumarin anticoagulants, anticonvulsants (e.g., phenobarbital, phenytoin, primidone), and some antidepressants (tricyclics and selective serotonin reuptake inhibitors). Downward dose adjustment of these drugs may be required when given concomitantly with MPH.

Armodafinil (Nuvigil) and modafinil (Provigil) have not been evaluated for interactions with drugs with MAOI activity. Until more is known regarding the pharmacology of modafinil, it may be prudent to caution against the use of these agents in the presence of a MAOI.

Armodafinil and modafinil moderately induce CYP3A activity. Drugs that are substrates for CYP3A4/5, such as cyclosporine, may require dosage adjustment. Armodafinil and modafinil moderately inhibit CYP2C19 activity. Drugs that are substrates for CYP2C19, such as omeprazole, may require dosage reduction.

Use of modafinil (Provigil) with other psychostimulants has not been extensively studied, and concurrent use is not recommended. Co-administration of amphetamine and modafinil may increase stimulant-associated side effects.<sup>176</sup> Single-dose studies of MPH combined with modafinil showed that the rate of absorption of modafinil was delayed up to 1 hour in the presence of MPH. No changes occurred in the metabolism and extent of absorption of either medication.

The effectiveness of steroidal contraceptive may be reduced with concurrent use of either armodafinil or modafinil and for 1 month after discontinuation of therapy. Alternative or concomitant methods of contraception are recommended during therapy and for 1 month after discontinuation of armodafinil or modafinil.

Where data specific to armodafinil drug interactions are not available, any available information on modafinil should be applicable to armodafinil, according to the prescribing information.

Caution should be used when guanfacine ER (Intuniv) is administered to patients taking strong CYP3A4/5 inhibitors (e.g., ketoconazole), which can cause a substantial increase in the rate and extent of guanfacine exposure (AUC) leading to an increased risk of adverse events such as hypotension, bradycardia, and sedation.

Concomitant use of guanfacine ER with a CYP3A4 inducer (e.g., rifampin) can cause a significant decrease in the rate and extent of guanfacine exposure (AUC). An increase in the dose of guanfacine ER within the recommended dose range may be considered.

Co-administration of guanfacine and valproic acid can result in increased concentrations of valproic acid. Adjustments in the dose of valproic acid may be required.

Somnolence and sedation with guanfacine ER and clonidine ER were commonly reported adverse reactions in clinical studies, especially during initial use. Caution should be used when operating heavy equipment or driving and when using with other CNS depressants, including alcohol. Furthermore, alcohol should be avoided while taking MPH.

Antihypertensive drugs and drugs affecting sinus node function or AV nodal conduction have the potential for additive effects when used with clonidine. Serious adverse events have been reported during concomitant use of MPH and clonidine; however, no causality has been established.

## **ADVERSE EFFECTS**<sup>177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204</sup>

For the most part, adverse effects of stimulants are dose-dependent, mild to moderate in severity, and diminish with alteration of medication dose or timing.<sup>205</sup> They commonly subside spontaneously during the first 1 to 2 weeks of treatment.<sup>206</sup> Nonetheless, the majority of children treated with stimulants do experience some adverse effects, and these adverse effects are often the reason stimulant treatment is discontinued.<sup>207,208</sup>

Most side effects associated with stimulants, such as decreased appetite, headaches, stomachaches, insomnia, nervousness, and social withdrawal, can usually be managed by adjusting the dosage and/or timing of administration. For instance, administering stimulants with or after meals can reduce appetite suppression. Moving the last daily dose to an earlier time can reduce insomnia. If children are on too high of a dosage or are overly sensitive to the stimulants, the agents may cause them to be over focused,

appear dull, or overly restricted. Lowering the dosage of medication or changing to a different medication can usually reduce the effects.

In a double-blind study, investigators found that, based on parent assessment, only 2 adverse effects were more prevalent after initiation of stimulants than prior to initiation. These were insomnia (dextroamphetamine) and poor appetite (dextroamphetamine and MPH).<sup>209</sup> Investigators also found that the severity of several adverse effects (insomnia, irritability, crying, anxiousness, sadness/unhappiness, and nightmares) was higher in dextroamphetamine than in MPH; there were no adverse effects with higher severity in MPH than in dextroamphetamine.

In general, a review of the evidence shows no statistically significant differences in the incidence of adverse effects between immediate-release and extended-release formulations. There is no evidence to support statistically significant differences with respect to adverse effects of dextroamphetamine (Dexedrine, Zenzedi, ProCentra) and MPH (Aptensio XR, Concerta, **Cotempla XR-ODT**, Daytrana, Methylin, Metadate ER, Metadate CD, Quillichew ER, Quillivant XR, Ritalin, Ritalin LA).

Long-term use of stimulant therapy has not demonstrated any obvious ill effects through observational data; however, there are no formal long-term studies.

### Adverse Effects in Children (\*Adults Only)

Drug	Headache	Abdominal pain	Anorexia	Insomnia
<b>Stimulants: Immediate-Release</b>				
amphetamine sulfate (Evekeo)	reported	nr	reported	nr
armodafinil (Nuvigil)*	17 (9)	2 (1)	1 (0)	5 (1)
dexmethylphenidate (Focalin)	nr	15 (6)	6 (1)	nr
dextroamphetamine IR (Zenzedi)	reported	reported <sup>†</sup>	reported	reported
dextroamphetamine solution (ProCentra)	reported	nr	reported	reported
methamphetamine (Desoxyn)	reported	nr	reported	reported
methylphenidate IR (Methylin, Ritalin)	reported	reported	reported	reported
mixed salt amphetamines IR (Adderall)	reported	nr	reported	reported
modafinil (Provigil)*	34 (23)	1 (≥1)	4 (1)	5 (1)
<b>Stimulants: Extended-Release</b>				
amphetamine ER (Adzenys XR-ODT)	26 (13)	11–14 (2–10)	22–36 (2)	12–27 (2–13)
amphetamine ER (Dyanavel XR)	nr	3.8 (2.1)	reported	reported
dexmethylphenidate (Focalin XR)	25 (11)	nr	30 (9)	reported
dextroamphetamine ER (Dexedrine)	reported	nr	reported	reported
lisdexamfetamine (Vyvanse)	reported	12 (6)	2-5 (0)	13–27 (3–4)
methylphenidate ER (Metadate ER)	reported	reported	reported	reported



**Adverse Effects in Children (\*Adults Only; continued)**

Drug	Headache	Abdominal pain	Anorexia	Insomnia
<b>Stimulants: Extended-Release <i>continued</i></b>				
methylphenidate ER (Aptensio XR)	10.9 (8.5)	8.2 (0)	4.9 (0)	9.8 (2.1)
<b>methylphenidate ER (Cotempla XR-ODT)</b>	<b>nr</b>	<b>reported</b>	<b>reported</b>	<b>reported</b>
methylphenidate ER (Quillichew ER)	2.4 (0)	reported	2.4 (0)	reported
methylphenidate ER (Quillivant XR)	nr	≥ 5	2 (0)	2 (0)
methylphenidate ER OROS (Concerta)	<1	6.2 (3.8)	<1	2.8 (0.3)
methylphenidate ER (Metadate CD)	12 (8)	7 (4)	9 (2)	5 (2)
methylphenidate ER (Ritalin LA)	>5 (nr)	>5 (nr)	>5 (nr)	>5 (nr)
methylphenidate transdermal (Daytrana)	12.4–15.3 (11.8–12.5)	4.8–7.1 (0–5.9)	4.8–5.1 (1.2–1.4)	6.2–13.3 (2.8–4.7)
mixed salt amphetamines (Adderall XR)	reported	11–14 (2–10)	22 (2)	12–17 (2–4)
<b>mixed salt amphetamines (Mydayis)</b>	<b>reported</b>	<b>reported</b>	<b>22</b> <b>(6)</b>	<b>8</b> <b>(3)</b>
<b>Non-Stimulants</b>				
atomoxetine (Strattera)	19 (15)	18 (10)	3 (1)	≥2 (nr)
clonidine ER (Kapvay)	19–29 (18)	13–20 (17)	nr	4–6 (1)
guanfacine ER (Intuniv)	21–24 (13–19)	10–11 (3–9)	5–7 (3–4)	12 (6)

Adverse effects are reported as a percentage. Adverse effects data are obtained from prescribing information and are not meant to be comparative or all inclusive. Incidences for the placebo group are indicated in parentheses. nr = not reported

\* Adults only

† Zenedi adverse event reported as GI disturbance

Other side effects common to the stimulants include irritability, flattened affect, social withdrawal, weepiness, mood lability, tremor, weight loss, and reduced growth velocity.

Paresthesia (including formication) has been associated with treatment on mixed amphetamine salts (Adderall, Adderall XR, **Mydayis**).

Stimulants can cause unpredictable motor tics, which transiently occur in 15% to 30% of children. Tics may appear in some patients when they are on stimulant medication and disappear with discontinuation of the medication. Fifty percent of patients with Tourette’s disorder also have ADHD which may present 2 or 3 years before the tics appear. It is believed that stimulants do not cause Tourette’s disorder, but simply unmask the disorder. Motor and verbal tics have not been associated with atomoxetine (Strattera).<sup>210</sup>

Rhabdomyolysis has been identified as an adverse reaction during post-approval use of stimulants and atomoxetine (Strattera).

In clinical trials for mixed amphetamine salt ER (Mydayis), pediatric patients 6 to 12 years of age experienced higher rates of adverse reactions compared to patients 13 years and older, including insomnia (30% versus 8%) and decreased appetite (43% versus 22%).

The majority of patients in the pivotal phase 3 clinical trial of MPH transdermal (Daytrana) had minimal to definite erythema. Erythema generally caused little discomfort and did not usually result in discontinuation from treatment. However, use of MPH transdermal may lead to contact sensitization and should be discontinued if contact sensitization is suspected. Patients sensitized from use of MPH transdermal may develop systemic sensitization or other systemic reactions if methylphenidate-containing products are taken via other routes (e.g., orally). The most common adverse reactions with the extended-release suspension (Quillivant XR) reported in the phase 3 controlled study conducted in 45 ADHD patients (6 to 12 years) were affect lability, excoriation, initial insomnia, tic, decreased appetite, vomiting, motion sickness, eye pain, and rash. Other common adverse reactions with the extended-release methylphenidate (Quillichew ER) not reported above but reported in a controlled study conducted in 90 ADHD patients (6 to 12 years) were aggression, emotional poverty, nausea, and decreased weight.

Post-marketing adverse effects cited for armodafinil (Nuvigil) include mania, delusions, hallucinations, and suicidal ideation. Many of the patients who developed psychiatric adverse reactions had previous history of psychiatric conditions.

## Effects on Growth

The 2011 AAP Clinical Practice Guideline for the School Aged Child with ADHD acknowledges that appetite suppression and weight loss are common adverse effects of stimulants, but studies of stimulant use have found little or no decrease in expected height; any decrease in growth early in treatment is later compensated.<sup>211</sup> A temporary slowing in growth rate (2 cm less growth in height and 2.7 kg less increase in weight over 3 years) has been noted in children starting treatment with MPH at ages 7 through 10 years. In 2014, the AAP released a statement indicating ADHD medications did not impact a child's final adult height.<sup>212</sup> In one longitudinal study, boys who received ADHD medications for  $\geq 3$  months had a growth spurt later in life, compared to boys not receiving the medication, but there was no difference in the magnitude of the growth spurt. The study concluded that neither ADHD nor stimulant medication treatment was linked with growth problems or short stature at maturity.

Over 18 months, patients on atomoxetine were reported to gain weight (average 6.5 kg) and height (average 9.3 cm), although there was a net loss in mean weight and height percentile points. Mean weight decreased from the 68<sup>th</sup> to 60<sup>th</sup> percentile, and mean height decreased from the 54<sup>th</sup> to 50<sup>th</sup> percentile. Attenuation of the effects on growth occurs by 24 months.<sup>213</sup>

## SPECIAL POPULATIONS<sup>214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232</sup>

### Pediatrics

Many immediate-release stimulants, dextroamphetamine IR tablets (Zenedi), dextroamphetamine solution (ProCentra), amphetamine sulfate (Evekeo), and mixed amphetamine salts (Adderall), are indicated for children as young as 3 years. Dextroamphetamine IR tablets (Zenedi) and solution (ProCentra) are approved through the age of 16 for ADHD. Methamphetamine (Desoxyn), MPH (Aptensio XR, Concerta, **Cotempla XR-ODT**, Daytrana Methylin, Metadate CD, Metadate ER, Quillichew ER, Quillivant XR, Ritalin, Ritalin LA), dexamethylphenidate (Focalin, Focalin XR), amphetamine extended-

release (Adzenys XR-ODT, Dyanavel XR), mixed amphetamine salts ER (Adderall XR), lisdexamfetamine (Vyvanse), and atomoxetine (Strattera) are indicated for children  $\geq 6$  years of age for the treatment of ADHD. Dextroamphetamine ER (Dexedrine) is indicated for children 6 to 16 years of age. **Mixed amphetamine salts ER (Mydayis) is indicated for children  $\geq 13$  years for the treatment of ADHD.** The prescribing information for the drugs in this class used for the treatment of ADHD include a warning about using the drugs in children younger than the indicated age, but there are some data on the use of these drugs in younger children.

The safety and efficacy of guanfacine ER (Intuniv) in pediatric patients  $< 6$  years of age have not been established. For children and adolescents  $\geq 6$  years, efficacy beyond 9 weeks and safety beyond 2 years of treatment have not been established.

The safety and efficacy of clonidine ER (Kapvay) in ADHD patients  $< 6$  years of age have not been established. Maintenance therapy beyond 5 weeks has not been evaluated; patients should be periodically re-evaluated to determine the long-term usefulness of clonidine ER.

Safety and effectiveness in patients  $< 17$  years for modafinil (Provigil) and armodafinil (Nuvigil) have not been established. Serious rash has been reported in pediatric patients receiving these agents.

Agents approved for narcolepsy (amphetamine sulfate [Evekeo], dextroamphetamine IR [Zenzedi, ProCentra], methylphenidate IR [Methylin, Ritalin], mixed amphetamine salts IR [Adderall], dextroamphetamine ER [Dexedrine], and methylphenidate ER [Metadate ER]) are approved in pediatric patients ages  $\geq 6$  years. Amphetamine sulfate (Evekeo) also is approved for exogenous obesity in patients  $> 12$  years. For exogenous obesity, methamphetamine (Desoxyn) is indicated in patients  $\geq 12$  years. Safety and efficacy of lisdexamfetamine (Vyvanse) for the treatment of binge-eating disorder have not been established in patients  $< 18$  years old.

## Pregnancy

Guanfacine ER is Pregnancy Category B. Amphetamine extended-release (Dyanavel XR), **mixed amphetamine salts extended-release (Mydayis)**, lisdexamfetamine (Vyvanse), and extended-release methylphenidate (Aptensio XR, **Cotempla XR-ODT**, Quillichew ER, Quillivant XR) have not been assigned a Pregnancy Category based on the FDA's revised pregnancy risk formatting; data on use of amphetamines and methylphenidate in this population are limited to inform of drug associated risks. All other agents in this class are Pregnancy Category C.

## Hepatic Impairment

Dose reductions of atomoxetine (Strattera) are required for patients with moderate (Child-Pugh Class B) and severe (Child-Pugh Class C) hepatic impairment.

The bioavailability of the inactive metabolite, modafinil acid, is increased 9-fold in patients with severe renal impairment (creatinine clearance [CrCl]  $\leq 20$  mL/min); safety and efficacy of modafinil (Provigil) in this patient group have not been determined. For patients with severe hepatic impairment, the dosage of modafinil (Provigil) should be reduced by 50%.

The dose of armodafinil (Nuvigil) should be reduced in patients with severe hepatic impairment.

## Renal Impairment

**Clearance of amphetamine is reduced in patients with severe renal insufficiency (GFR 15 to  $< 30$  mL/min/1.73 m<sup>2</sup>); therefore the maximum dose of mixed amphetamine salts extended release (Mydayis)**

in adults should be reduced. Patients 13 to 17 years of age with severe renal impairment may receive the recommended starting dose if tolerated; however the dose should not be increased. Mixed amphetamine salts extended release (Mydayis) is not recommended for use in patients with end-stage renal disease (GFR < 15 mL/min/1.73 m<sup>2</sup>).

Patients with severe renal impairment taking lisdexamfetamine (Vyvanse) should not exceed a maximum dose of 50 mg/day. The recommended maximum dose of lisdexamfetamine in patients with end stage renal disease is 30 mg/day.

**DOSAGES** <sup>233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260</sup>

Drug	Ages	Usual Initial Dosage	Maximum Dosage	Dosage Forms
<b>Stimulants: Immediate-Release</b>				
amphetamine sulfate (Evekeo)	3–5 years	2.5 mg once daily	40 mg/day in 2 or 3 divided doses	Tablets: 5 mg, 10 mg
	6–17 years	5 mg once or twice daily		
armodafinil (Nuvigil)	≥17 years	150 mg to 250 mg once daily in the morning	250 mg/day	Tablets: 50 mg, 150 mg, 200 mg, 250 mg
dexmethylphenidate (Focalin)	6–17 years	2.5 mg twice daily	10 mg twice daily	Tablets: 2.5 mg, 5 mg, 10 mg
dextroamphetamine IR (Zenzedi)	3–5 years	2.5 mg once daily	40 mg/day	Tablets: 5 mg, 10 mg Tablets (Zenzedi): 2.5 mg, 5 mg, 7.5 mg, 10 mg, 15 mg, 20 mg, 30 mg
	6–16 years	5 mg once or twice daily	40 mg/day in 2 or 3 divided doses	
dextroamphetamine solution (ProCentra)	3–5 years	2.5 mg once daily	40 mg/day; initial dose upon waking, additional 1-2 doses every 4 to 6 hours	Oral solution: 5 mg/5 mL
	6–16 years	5 mg once or twice daily	40 mg/day; initial dose upon waking, additional 1-2 doses every 4 to 6 hours	
methamphetamine (Desoxyn)	6–17 years	5 mg once or twice daily	20 to 25 mg/day in 2 divided doses	Tablets: 5 mg
methylphenidate IR (Methylin, Ritalin)	6–17 years	5 mg twice daily	60 mg/day in 2 or 3 divided doses	Tablets: 5 mg, 10 mg, 20 mg Chewable tablets: 2.5 mg, 5 mg, 10 mg Oral solution: 5 mg/5 mL, 10 mg/5 mL
mixed amphetamine salts IR (Adderall)	3–5 years	2.5 mg once daily	40 mg/day	Tablets: 5 mg, 7.5 mg, 10 mg, 12.5 mg, 15 mg, 20 mg, 30 mg
	6–17 years	5 mg 1 or 2 times daily		
modafinil (Provigil)	≥17 years	200 mg once daily in the morning	400 mg/day	Tablets: 100 mg, 200 mg

Drug	Ages	Usual Initial Dosage	Maximum Dosage	Dosage Forms
<b>Stimulants: Extended-Release</b>				
amphetamine ER (Adzenys XR-ODT)	6–17 years	6.3 mg once daily in the morning	6 to 12 years: 18.8 mg/day 13 to 17 years: 12.5 mg/day	Orally disintegrating tablets (ODT): 3.1 mg, 6.3 mg, 9.4 mg, 12.5 mg, 15.7 mg, and 18.8 mg
	≥ 18 years (adults)	12.5 mg once daily in the morning	12.5 mg/day	
amphetamine ER (Dyanavel XR)	≥ 6 years	2.5 to 5 mg once daily in the morning	20 mg/day	Suspension: 1,160 mg/464 mL (2.5 mg/mL)
dexamethylphenidate ER (Focalin XR)	6–17 years	5 mg once daily	30 mg/day	Capsules: 5 mg, 10 mg, 15 mg, 20 mg, 25 mg, 30 mg, 35 mg, 40 mg
	≥ 18 years (adults)	10 mg once daily	40 mg/day	
dextroamphetamine ER (Dexedrine)	6–16 years	5 mg once daily	40 mg once daily	Capsules: 5 mg, 10 mg, 15 mg
lisdexamfetamine (Vyvanse)	≥ 6 years	30 mg daily in the morning	70 mg daily in the morning	Capsules: 10 mg, 20 mg, 30 mg, 40 mg, 50 mg, 60 mg, 70 mg Chewable tablets: 10 mg, 20 mg, 30 mg, 40 mg, 50 mg, 60 mg
methylphenidate ER (Aptensio XR)	≥ 6 years	10 mg once daily	60 mg once daily	Capsules: 10 mg, 15 mg, 20 mg, 30 mg, 40 mg, 50 mg, 60 mg
methylphenidate ER (Cotempla XR-ODT)	≥ 6 years	17.5 mg once daily in the morning	51.8 mg once daily	Extended-release ODT: 8.6 mg, 17.3 mg, 25.9 mg
methylphenidate ER OROS (Concerta)	6–12 years	18 mg once daily	54 mg once daily	Tablets: 18 mg, 27 mg, 36 mg, 54 mg
	13–17 years	18 mg once daily	72 mg once daily (< 2 mg/kg/day)	
	18–65 years (adults)	18 or 36 mg once daily	72 mg once daily	
methylphenidate ER (Metadate CD)	6–17 years	20 mg once daily, in the morning before breakfast	60 mg once daily, in the morning before breakfast	Capsules: 10 mg, 20 mg, 30 mg, 40 mg, 50 mg, 60 mg
methylphenidate ER (Metadate ER)	6–17 years	5 mg twice daily or equivalent (e.g., 10 mg once daily)	60 mg/day in 1 or 2 divided doses	Tablets: 10 mg (generic only), 20 mg
	≥ 18 years	20 to 30 mg daily		
methylphenidate ER (Quillichew ER)	≥ 6 years	20 mg once daily in the morning	60 mg/day	Chewable tablets: 20 mg, 30 mg, 40 mg (20 and 30 mg strengths are scored; 40 mg is not scored)
methylphenidate ER (Quillivant XR)	≥ 6 years	20 mg once daily	60 mg once daily	Suspension for reconstitution: 300 mg/60 mL, 600 mg/120 mL, 750 mg/150 mL, 900 mg/180 mL (5 mg/mL)

## Dosages (continued)

Drug	Ages	Usual Initial Dosage	Maximum Dosage	Dosage Forms
<b>Stimulants: Extended-Release (continued)</b>				
methylphenidate ER (Ritalin LA)	6–17 years	20 mg once daily	60 mg once daily	Capsules: 10 mg (brand only), 20 mg, 30 mg, 40 mg, 60 mg (generic only)
methylphenidate transdermal (Daytrana)	6–17 years	10 mg patch worn 9 hours daily	30 mg patch worn 9 hours daily	Patches: 10 mg, 15 mg, 20 mg, 30 mg per 9 hours
mixed amphetamine salts ER (Adderall XR)	6–17 years	10 mg once daily	30 mg once daily	Capsules: 5 mg, 10 mg, 15 mg, 20 mg, 25 mg, 30 mg
	≥ 18 years (adults)	20 mg once daily	20 mg once daily	
mixed amphetamine salts ER (Mydayis)	13-17 years	12.5 mg once daily in the morning upon awakening	25 mg once daily	Capsules: 12.5 mg, 25 mg, 37.5 mg, 50 mg
	≥ 18 years (adults)		50 mg once daily	
<b>Non-Stimulants</b>				
atomoxetine (Strattera)	≥ 6 years and <70 kg	0.5 mg/kg/day in 1 or 2 divided doses	1.4 mg/kg/day in 1 or 2 divided doses	Capsules: 10 mg, 18 mg, 25 mg, 40 mg, 60 mg, 80 mg, 100 mg
	≥ 6 years and >70 kg and adults	40 mg/day in 1 or 2 divided doses	100 mg/day given in 1 or 2 divided doses	
clonidine ER (Kapvay)	6–17 years	0.1 mg at bedtime	0.2 mg twice daily	Tablets: 0.1 mg
guanfacine ER (Intuniv)	6–17 years	1 mg once daily in the morning or evening	4 mg once daily in the morning or evening	Tablets: 1 mg, 2 mg, 3 mg, 4 mg

The above table represents doses used for the treatment of ADHD, except in the cases of Nuvigil (armodafinil) and Provigil (modafinil), which are only approved to treat shift work disorder, narcolepsy, and sleep apnea.

Amphetamine extended-release (Dyanavel XR) dosage may be increased by 2.5 to 10 mg per day every 4 to 7 days. Do not substitute for other amphetamine agents on an equal milligram basis; they are not interchangeable.

Mixed amphetamine salts ER (Mydayis) should be taken consistently with or without food and upon wakening since its effects can last for 16 hours. Doses of mixed amphetamine salts ER (Mydayis) may be titrated in increments of 12.5 mg on a weekly basis in pediatric patients. In patients with severe renal impairment, the daily dose of mixed amphetamine salts ER (Mydayis) should not exceed 25 mg in adults and 12.5 mg in pediatrics. Do not substitute mixed amphetamine salts ER (Mydayis) for other amphetamine products.

Methylphenidate extended release orally disintegrating tablets (Cotempla XR-ODT) should be taken consistently with or without food. Dexmethylphenidate (Focalin, Focalin XR) and MPH extended-release can be administered without regard to meals. MPH immediate-release (Methylin, Ritalin) should be administered 30 to 45 minutes before meals. The timing of the mid-day dose of MPH immediate-release and dexmethylphenidate immediate-release should be individualized based on patient response. The last daily dose of MPH extended-release should be given several hours before bedtime. Do not substitute other methylphenidate products on a milligram per milligram basis due to different methylphenidate base compositions and pharmacokinetic profiles.

Lisdexamfetamine capsules can be substituted with lisdexamfetamine chewable tablets on a mg per mg basis. Lisdexamfetamine (Vyvanse) should not exceed a maximum dose of 50 mg/day in patients with

severe renal impairment. The recommended maximum dose of lisdexamfetamine in patients with end stage renal disease is 30 mg/day.

The recommended target dose range for guanfacine ER (Intuniv), depending on tolerability and the clinical response of the patient, is 0.05–0.12 mg/kg/day. Doses > 4 mg/day have not been evaluated in children between 6 and 12 years of age and doses > 7 mg/day have not been evaluated in patients between 13 and 17 years of age. If switching from guanfacine IR to guanfacine ER (Intuniv), discontinue guanfacine IR and titrate with guanfacine ER according to the recommended dosing schedule. Prescribers should re-evaluate patients often and adjust weight-based dosage, as needed. Patients may experience increases in blood pressure and heart rate after discontinuing guanfacine ER (Intuniv) treatment. Daily dose should be reduced in decrements no > 1 mg every 3 to 7 days to prevent rebound hypertension and patients should be closely monitored.

Clonidine ER (Kapvay) doses should be increased at a frequency of 0.1 mg per week. Do not substitute clonidine ER for immediate-release clonidine on a milligram-for-milligram basis. When discontinuing therapy, clonidine ER decrements should not exceed 0.1 mg every 3 to 7 days.

For patients with swallowing difficulties, several ADHD therapy options exist. Many solid oral dosage forms (e.g., mixed amphetamine salts extended release [Mydayis], methylphenidate extended release [Aptensio XR]) may be opened up and their contents sprinkled over food; contents should not be chewed or divided. Lisdexamfetamine (Vyvanse) capsules may be opened and the entire contents dispersed in water, yogurt, or orange juice and consumed immediately. A spoon may be used to break apart any compacted powder in the water. The contents should be stirred until completely dispersed. The active ingredient dissolves completely once dispersed; however, a film containing the inactive ingredients may remain in the glass once the water is consumed.

Other products specifically designed for patients who may have difficulty swallowing include orally disintegrating tablets (amphetamine ER [Adzenys XR; dissolve in mouth's saliva prior to swallowing], methylphenidate extended release [Cotempla XR-ODT; remove from blister pack with dry hands just prior to dosing and allow to disintegrate; no liquid is needed to be consumed]), chewable tablets (lisdexamfetamine [Vyvanse], methylphenidate [Quillichew ER]) which should be chewed thoroughly prior to swallowing, oral suspensions (methylphenidate extended release [Quillivant XR; reconstitute and shake for ≥ 10 seconds], amphetamine extended release [Dyanavel XR; no reconstitution required]), and transdermal patches (methylphenidate [Daytrana; applied 2 hours prior to onset of activity and worn for 9 hours or individualized based on patient response]).

Atomoxetine capsules are not to be opened as they are an ocular irritant. Clonidine ER (Kapvay) tablets should not be chewed, crushed, or split.

For patients with moderate (Child-Pugh Class B) hepatic impairment, the initial and target doses of atomoxetine (Strattera) should be reduced by 50%. For patients with severe (Child-Pugh Class C) hepatic impairment, the initial and target doses should be reduced by 75%. For patients taking strong CYP2D6 inhibitors (e.g., paroxetine, fluoxetine, quinidine) or in patients who are known to be CYP2D6 poor metabolizers, atomoxetine should be started at 0.5 mg/kg/day and only increased to the usual target dose of 1.2 mg/kg/day if symptoms fail to improve after 4 weeks and the initial dose is well tolerated.

For patients with severe hepatic impairment, the dosage of modafinil (Provigil) should be reduced by 50%.

## Hypersomnolence

Armodafinil (Nuvigil) – for adults ( $\geq 17$  years) with narcolepsy or obstructive sleep apnea/hypopnea syndrome, 150 or 250 mg is given once daily in the morning. For patients with shift work sleep disorder, 150 mg should be administered 1 hour prior to the start of the work shift.

Modafinil (Provigil) – for adults ( $\geq 16$  years) with narcolepsy or obstructive sleep apnea/hypopnea syndrome, 200 mg is given once daily in the morning. For patients with shift work sleep disorder, the dose should be administered 1 hour prior to work.

Amphetamine sulfate (Evekeo) and mixed amphetamine salts (Adderall) – for the treatment of narcolepsy, 5 mg to 60 mg daily in divided doses. The suggested initial dose for patients 6 to 12 years of age is 5 mg daily; dose may be titrated in increments of 5 mg per day at weekly intervals until optimal response is obtained. In patients  $\geq 12$  years, start with 10 mg daily which may be titrated by 10 mg per day at weekly intervals until optimal response is obtained.

Dextroamphetamine IR (Zenzedi, ProCentra) – for children 6 to 12 years, 5 mg once daily; for patients  $\geq 12$  years old, begin with 10 mg daily. The usual dose is 5 mg to 60 mg daily divided into doses every 4 to 6 hours. Once the dosage has been stabilized, patients can be converted to an equivalent dosage of dextroamphetamine extended-release (Dexedrine) given once daily.

Dextroamphetamine ER (Dexedrine) - the initial dose in pediatrics patients age 6-12 years is 5 mg daily; in patients  $\geq 12$  years the initial dose is 10 mg daily. The usual dosage range is 5 mg to 60 mg daily in divided doses.

Methylphenidate (Ritalin, Methylin, Metadate ER) – dosages for the treatment of narcolepsy are the same as those for ADHD.

## Exogenous Obesity

For adjunctive treatment of exogenous obesity, in patients  $\geq 12$  years, methamphetamine (Desoxyn) 5 mg is administered 30 minutes before each meal. Treatment should last only a few weeks.

For exogenous obesity, the recommended dose of amphetamine sulfate (Evekeo) is up to 30 mg daily divided in doses of 5 to 10 mg given 30 to 60 minutes before meals. Use in children  $< 12$  years is not recommended.

## Binge Eating Disorder

The recommended dose of lisdexamfetamine dimesylate (Vyvanse) is 50 mg to 70 mg per day, following a starting dose of 30 mg every morning with a 20 mg weekly titration schedule.

## CLINICAL TRIALS

Articles were identified through searches performed on PubMed and review of information sent by manufacturers. Search strategy included the use of all drugs in this class. Randomized, controlled, comparative trials are considered the most relevant in this category. Studies included for analysis in the review were published in English, performed with human participants, and randomly allocated participants to comparison groups. In addition, studies must contain clearly stated, predetermined outcome measure(s) of known or probable clinical importance, use data analysis techniques consistent with the study question, and include follow-up (endpoint assessment) of at least 80% of participants entering the investigation. Despite some inherent bias found in all studies including those sponsored



and/or funded by pharmaceutical manufacturers, the studies in this therapeutic class review were determined to have results or conclusions that do not suggest systematic error in their experimental study design. While the potential influence of manufacturer sponsorship and/or funding must be considered, the studies in this review have also been evaluated for validity and importance.

Studies of ADHD of less than 4 weeks' duration were excluded as it is generally accepted that it takes at least this long to adequately titrate to the optimal dosage of a given agent. Studies conducted more than 25 years ago were excluded, primarily due to a lack of well-controlled clinical trials from that time period. Many of these older studies verified the effectiveness of the stimulants available at that time in treating the symptoms of ADHD.

## **Attention Deficit Hyperactivity Disorder (ADHD)**

### ***Rating Scales***

#### **Specific**

- Conners' Parent Rating Scale (CPRS) – The scale provides the parents' or caregivers' perspective on a child's behavior. The scale is 92% sensitive and 94% specific.
- Swanson, Nolan, and Pelham scale (SNAP) – The scale has been shown to have greater than 94% sensitivity and specificity in distinguishing hyperactive, inattentive, and impulsive children with ADHD from those without ADHD based on DSM-III-R criteria.
- Swanson, Kotlin, Agler, M-Flynn, and Pelham scale (SKAMP) – A validated rating scale that assesses ADHD manifestations in a classroom setting; specifically assesses context-bound behaviors critical to school settings.
- ADHD Rating Scale-IV (ADHD RS) – The scale, which can be completed by a parent, teacher, or clinician, is less effective than the SNAP in differentiating children with ADHD from those without ADHD. It has been shown to have good internal consistency and test-retest reliability. The parent form is 84% sensitive and 49% specific; the teacher form is 72% sensitive and 86% specific.
- Permanent Product Measure of Performance (PERMP) – A skill adjusted math test; sum of the number of math problems attempted plus the number of math problems answered correctly in a 10-minute session.

#### **Global**

Broad-band scales are not useful as tools to detect clinical-level problems in children presenting; they have low sensitivities and specificities of 70% to 80%.

- CGI-I – Clinical Global Impression improvement subscale
- CGI-S – Clinical Global Impression severity subscale
- C-GAS – Children's Global Assessment Scale

### ***atomoxetine (Strattera) versus MPH immediate-release***

Two identical 12-week double-blind trials were conducted in 291 children (ages 7 to 13 years) with ADHD.<sup>261</sup> Stimulant-naïve patients were randomized to atomoxetine (up to 2 mg/kg/day or 90 mg), MPH (up to 1.5 mg/kg/day, or 60 mg), or placebo. Patients with prior stimulant exposure were randomized only to atomoxetine or placebo. Atomoxetine significantly reduced ADHD RS total scores, the primary endpoint, compared with placebo in each study ( $p < 0.001$ ). Changes in the CGI-S and CPRS also showed atomoxetine to be significantly superior to placebo in reducing ADHD symptoms. There was no

significant difference between atomoxetine and MPH. A subsequent subanalysis of 51 female subjects showed that atomoxetine was similarly superior to placebo in this patient subset.<sup>262</sup>

### ***atomoxetine (Strattera) versus MPH OROS (Concerta)***

A randomized, double-blind, placebo-controlled study compared the response, as measured by the ADHD Rating Scale of atomoxetine, MPH OROS, and placebo.<sup>263</sup> A total of 516 children ages 6 to 16 years with ADHD were randomized to receive 0.8-1.8 mg/kg per day of atomoxetine (n=222), 18-54 mg/day of MPH OROS (n=220), or placebo (n=74) for 6 weeks. Patients who had previously had an inadequate response to stimulant treatment were excluded from the study. After 6 weeks, using double-blind conditions, the patients receiving MPH OROS were switched to atomoxetine. Response was determined by a 40% reduction from baseline as measured by the ADHD Rating Scale. Response results indicated that atomoxetine and MPH OROS were better than placebo, with atomoxetine resulting in a 45% response, MPH OROS resulting in a 56% response, and placebo resulting in a 24% response. The response rate for MPH OROS was significantly higher than atomoxetine ( $p=0.016$ ). Seventy patients who received MPH OROS did not respond, but 30 of these patients (43%) responded after being switched to atomoxetine. Also, note that 69 patients did not respond to atomoxetine treatment, but 29 (42%) of these patients previously responded to MPH OROS treatment. Completion and discontinuations rates due to adverse events were low and similar for all treatment groups. Results indicated that response to MPH OROS was greater than atomoxetine, but patients not responding to MPH OROS initially may respond to atomoxetine treatment instead. Both agents had a superior response rate over placebo.

### ***atomoxetine (Strattera) versus MPH immediate-release***

A randomized, double-blind, crossover trial compared the efficacy of atomoxetine and MPH for treating ADHD, as well as their effects on the sleep of children with ADHD.<sup>264</sup> Eighty-five children with ADHD, either in a private practice setting or a hospital setting, were given twice daily atomoxetine (mean dose 42.29 mg/day) and 3 times daily MPH (mean dose 58.27 mg/day), each for approximately 7 weeks. Relative to baseline, actigraphy data indicated that MPH increased sleep latency significantly more than did atomoxetine (39.2 versus 12.1 minutes;  $p<0.001$ ); these results were consistent with polysomnography data. Compared with MPH, child diaries indicated that taking atomoxetine had less sleep disturbance adverse effects. For example, it was easier to wake up in the morning, took less time to fall asleep, and the patients recorded better sleep with atomoxetine treatment. Parents reported similar findings, such as the children were less irritable, had fewer difficulties with waking in the morning, and were less resistant at night to prepare for bed when administered atomoxetine as opposed to MPH. Using the main measures of efficacy, the medications had similar efficacy for treatment of ADHD. Greater incidence of decreased appetite and insomnia with MPH were the only significant differences in treatment-emergent adverse events. Both medications decreased night time awakenings, but the decrease was greater for MPH.

### ***clonidine ER (Kapvay) versus placebo***

The efficacy of clonidine ER in the treatment of ADHD was established in 2 manufacturer approval trials in pediatric patients with ADHD ages 6 to 17 years.<sup>265</sup> Signs and symptoms of ADHD were evaluated using the ADHD RS-IV total score including hyperactive/impulsivity and inattentive subscales. Study 1 was a randomized, double-blind, placebo-controlled, study of 236 patients who were randomly assigned to clonidine ER 0.2 mg or 0.4 mg daily or placebo daily. At both doses, improvements in ADHD symptoms were statistically significantly superior in clonidine ER patients compared with placebo patients at the

end of 5 weeks as measured by the ADHD RS-IV total score. Study 2 was a randomized, double-blind, placebo-controlled, study in 198 pediatric patients. Patients had previously been treated with methylphenidate or amphetamine for 4 weeks with inadequate response. Patients were randomly assigned to clonidine ER as adjunct to the stimulant or the previous stimulant alone. The clonidine ER dose was initiated at 0.1 mg daily and titrated upward, as clinically appropriate. ADHD symptoms were statistically significantly improved in clonidine ER plus stimulant group compared with the stimulant-alone group at the end of 5 weeks as measured by the ADHD RS-IV total score.

### ***guanfacine ER (Intuniv) versus placebo***

The efficacy of guanfacine ER in the treatment of ADHD was evaluated in 2 placebo-controlled trials in children and adolescents ages 6 to 17 years.<sup>266</sup> Study 1 evaluated guanfacine ER 2, 3, or 4 mg dosed once daily in an 8-week, double-blind, placebo-controlled, parallel-group (n=345) trial. Study 2 evaluated guanfacine ER 1, 2, 3, or 4 mg dosed once daily in a 9-week, double-blind, placebo-controlled, parallel-group (n=324) trial. Doses were titrated in increments of up to 1 mg/week. The mean reductions in ADHD RS scores at endpoint were statistically significantly greater for guanfacine ER compared to placebo for both studies. Due to the relatively small proportion of adolescent patients (13–17 years of age) enrolled into these studies (approximately 25%), these data may not be sufficient to demonstrate efficacy in the adolescent subgroup. When evaluated regarding dose per body weight, clinically relevant improvements were observed beginning at doses in the range 0.05–0.08 mg/kg/day. In these studies, dosages were not optimized by body weight, and over half (55%) of the adolescent patients received doses of 0.01–0.04 mg/kg. The most commonly reported treatment-emergent adverse events were headache, somnolence, fatigue, upper abdominal pain, and sedation. Small to modest changes in blood pressure, pulse rate, and electrocardiogram parameters were observed but were not clinically meaningful.

### ***mixed amphetamine salts ER (Adderall XR) versus MPH OROS (Concerta)***

A randomized, double-blind, placebo-controlled study compared mixed amphetamine salts ER, MPH OROS, and placebo on ADHD neuropsychological functioning.<sup>267</sup> Adolescents (n=35, 19 males) with a diagnosis of ADHD completed 3 separate assessments (5:00 p.m., 8:00 p.m., 11:00 p.m.) on 3 different days and medications (mixed amphetamine salts ER, MPH OROS, placebo). Delayed Matching-to-Sample and Go/No-go (GNG) neuropsychological tests, which measure visual memory, attention span, and response inhibition, were used to evaluate outcomes. Neuropsychological functioning, as measured by commission errors, reaction time, and recall accuracy, showed significant improvement when patients were taking MPH OROS as opposed to placebo. Results suggest that MPH OROS impacts both symptomatic behavior, as well as cognitive functioning, which have implications for both academic performance and daily functioning.

### ***mixed amphetamine salts ER (Mydayis) versus placebo***

The efficacy of mixed amphetamine salts ER (MAS) in adults was evaluated in 3 randomized, double-blind, placebo-controlled studies.<sup>268</sup> Study 1 assigned 275 patients who met DMS-V criteria for ADHD to daily doses of MAS of 12.5mg for the entire study, 12.5 mg with a forced titration to 37.5 mg, or placebo. At week 4, both doses of MAS demonstrated a statistically significant change from baseline in ADHD-RS total score compared with placebo (-8.1 [-11.7, -4.4] for 12.5 mg/day; -13.4 [-17.1, -9.7] for 37.5 mg/day). Studies 2 and 3 were cross-over studies in patients who met DSM-IV TR criteria for ADHD, which determined efficacy based on the Permanent Product Measure of Performance (PERMP) scale with uses mathematical problems. Efficacy assessments were conducted at 2, 4, 8, 12, 14, and 16 hours post-dose (Study 2 50 mg/day; Study 3 25 mg/day). MAS treatment achieved statistically significant difference

compared to placebo at either 2 hours (Study 2) or 4 hours (Study 3) post-dose to 16 hours post-dose in both studies. In a pre-specified supplementary analysis for Study 2, the maximum approved dose of MYDAYIS (50 mg) demonstrated a statistically significant treatment effect compared with placebo beginning at 2 to 16 hours post-dose.

The efficacy of mixed amphetamine salts ER (MAS) in pediatric patients, ages 13 to 17 years meeting the DSM-IV TR criteria for ADHD, was evaluated in 2 randomized, double-blind, placebo-controlled trials.<sup>269</sup> Study 1 patients (n = 157) were titrated from a dose of 12.5 mg/day until an optimal dose was reached, up to a maximum dose of 25 mg, which was then maintained during a dose-maintenance period. At week 4, MAS demonstrated a statistically significant change in ADHD RS-IV total score from baseline compared to placebo (-8.7 [-12.6, -4.8]). In Study 2, patients were given 25 mg per day or placebo. Efficacy assessments, based on PERMP, were conducted at 2, 4, 8, 12, 14, and 16 hours post-dose. MAS achieved statistical significance at 2 to 16 hours post-dose compared to placebo (difference 41.26 [32.24, 50.29]).

### ***dexmethylphenidate (Focalin), MPH immediate-release, and placebo***

In a randomized, double-blind study, 132 subjects received dexmethylphenidate, MPH, or placebo twice daily for 4 weeks, with titration of the dose based on weekly clinic visits.<sup>270</sup> The primary efficacy variable was change from baseline of Teacher SNAP to last study visit. Secondary efficacy measures included the change on Parent SNAP, CGI-I, and Math Test performance. Treatment with either dexmethylphenidate (p=0.0004) or MPH immediate-release (p=0.0042) significantly improved Teacher SNAP ratings compared with placebo. The dexmethylphenidate group showed significant improvements compared with placebo on the afternoon Parent SNAP (p=0.0003) and on the Math Test scores obtained at 6:00 p.m. (p=0.0236). Improvement based on CGI-I occurred in 67% of patients on dexmethylphenidate and 49% of patients on MPH immediate-release. Both active treatments were well tolerated.

### ***MPH immediate-release, MPH OROS (Concerta), and placebo***

A double-blind, placebo-controlled, randomized, 5-period crossover study in 49 healthy subjects with a history of light (occasional) recreational stimulant use was performed to evaluate the abuse-related subjective effects of MPH OROS with comparable doses of MPH immediate-release.<sup>271</sup> Patients were included in the study if they demonstrated a positive response to a 20 mg dose of dextroamphetamine and a negative placebo response. Patients were then randomized to receive single doses of placebo, 54 and 108 mg MPH OROS, and 50 and 90 mg MPH immediate-release. For each treatment, patients were observed for 24 hours to assess pharmacokinetics, pharmacodynamics, and safety. Both doses of MPH immediate-release produced statistically significant higher positive stimulant effects with respect to placebo for all measures (p<0.001). MPH OROS 108 mg also produced statistically significant differences from placebo (p<0.01), but the more commonly prescribed dose, MPH OROS 54 mg, did not produce significant differences from placebo. Overall, for comparable dose levels, MPH OROS produced lower positive and stimulant subjective effects than MPH immediate-release, and the lowest MPH immediate-release doses produced more of an effect than the highest of MPH OROS doses, showing that formulation may help reduce abuse potential.

In a multicenter, double-blind trial, 282 children (ages 6 to 12 years) with ADHD were randomized to receive MPH immediate-release 5, 10, or 15 mg 3 times daily, MPH OROS 18, 36, or 54 mg once daily, or placebo for 28 days.<sup>272</sup> Response, defined as >30% reduction from baseline IOWA Conners Oppositional/Defiance (O/D) score, occurred in 52%, 59%, and 26% of patients in the MPH immediate-release, MPH OROS, and placebo groups, respectively, as rated by parents (p<0.0001 for comparison of both active treatments to placebo). Teacher-rated response rates were 63%, 68%, and 43%, respectively

( $p < 0.0107$  for comparison of active treatments to placebo). The response rate for the 2 higher doses of MPH OROS (77%) was significantly higher than for MPH immediate-release based on parent ratings ( $p < 0.05$ ). Forty-eight percent of the placebo group discontinued study drug early compared with 14% and 16% in the MPH and OROS MPH groups, respectively.

### ***MPH extended-release orally disintegrating tablet (Cotempla XR-ODT)***

The efficacy of MPH extended-release ODT was evaluated in 87 patients with ADHD (6 to 12 years of age) in a laboratory classroom study.<sup>273</sup> Following washout period, patients entered a 4-week open-label dose-optimization period with an initial dose of 17.3 mg of MPH extended-release ODT once daily in the morning. The dose could be titrated from 17.3 mg to 25.9 mg, 34.6 mg, or 51.8 mg on a weekly basis until an optimal dose or the maximum daily dose of 51.8 mg was reached. Patients were then randomized to a 1-week, double-blind, parallel group treatment period with the individually optimized dose or to placebo. At the end of the week, the primary efficacy endpoint of the average of the SKAMP-Combined (Attention and Department), a validated 13-item teacher-rated scale that assesses manifestations of ADHD in a classroom setting, was measured. SKAMP scores over the test day at 1, 3, 5, 7, 10, 12, and 13 hours post-dosing was statistically significantly lower with MPH ER ODT compared to placebo (14.3 versus 25.3, respectively).

### ***MPH extended-release (Quillichew ER) and placebo***

A 1-week, randomized, double-blind, placebo-controlled, parallel-group laboratory school study evaluated the efficacy of MPH extended-release chewable tablet in 90 subjects (ages 6 to 12 years; ITT population  $n=85$ ) diagnosed with ADHD (based on DSM-IV criteria).<sup>274</sup> Patients entered a 6-week open-label dose optimization period, followed by a 1-week period in which they were randomized to either placebo or the optimized dose (10 to 60 mg) of MPH extended-release chewable tablet. The primary outcome was the average of treatment effects (as measured by the SKAMP-combined score across all time points during the classroom day (0.75, 2, 4, 8, 10, 12, and 13 hours) as rated by teachers and raters. The placebo-subtracted difference in the average of treatment effect across all time points as measured by the SKAMP-combined score was -7 (95% CI, -10.9 to -3.1), demonstrating superiority of MPH extended-release chewable tablet over placebo.

### ***MPH extended-release (Quillivant XR) and placebo***

A total of 45 subjects (ages 6 to 12 years) were enrolled in this dose-optimized, randomized, double-blind, placebo-controlled, crossover laboratory school study. The purpose of this study was to determine the efficacy of extended-release (ER) suspension of MPH compared with placebo in the treatment of ADHD in children.<sup>275</sup> Following a 4 to 6 week open-label dose optimization phase, subjects received 2 weeks of double-blind treatment, 1 week of MPH ER suspension, and 1 week of placebo. Efficacy measures included SKAMP Rating Scale-Combined and Permanent Product Measure of Performance (PERMP) mathematics tests measured at pre-dose and at 0.75, 2, 4, 8, 10, and 12 hours post-dose on each laboratory classroom day. MPH ER suspension resulted in significant ( $p < 0.0001$ ) improvements in the SKAMP-Combined score at 4 hours post-dose (mean=7.12) as compared with placebo (mean=19.58) in the completers ( $n=39$ ). Significant separation from placebo occurred at each time point tested with onset of action at 45 minutes post-dose and duration of efficacy extending to 12 hours post-dose. Adverse events and changes in vital signs following MPH ER suspension were generally mild and consistent with the known safety profile of MPH. MPH ER suspension effectively reduced symptoms of ADHD in children beginning at 45 minutes and continuing for 12 hours post-dose.

### ***MPH OROS (Concerta), MPH transdermal (Daytrana), and placebo***

In a double-blind study, 270 children (ages 6 to 12 years) with ADHD were randomized to 1 of 3 treatment arms: MPH OROS + placebo patch, MPH transdermal + placebo capsule, or placebo capsule + placebo patch.<sup>276</sup> The study consisted of a 5-week dose-optimization phase followed by a 2-week maintenance phase. At the conclusion of the study, the mean daily doses were 43.4 mg and 22.9 mg for the oral and transdermal dosage forms, respectively. The primary endpoint was the change in ADHD RS from baseline. A reduction in ADHD RS of at least 30% was observed in 66%, 78%, and 29% of patients receiving MPH OROS, MPH transdermal and placebo, respectively (p=NS for comparison of active treatments; p<0.05 for comparison of each active treatment to placebo). Reductions from baseline in both the hyperactivity/impulsivity and the inattentiveness subscales were similar in both active treatment groups and were significantly greater than in the placebo group. The manufacturers of MPH transdermal funded the study.

### ***lisdexamfetamine dimesylate (Vyvanse) versus placebo***

A phase 3, multicenter, randomized, double-blind, forced-dose, parallel-group study was conducted at 40 centers across the United States (U.S.).<sup>277</sup> The purpose of the study was to assess the efficacy and tolerability of lisdexamfetamine in school-aged children with ADHD treated in the community, and to characterize the duration of action of lisdexamfetamine compared with placebo. The study included 290 randomized patients; 230 patients completed the study. Sixty patients did not complete the study, mostly due to either lack of efficacy or adverse effects. Significant improvements in ADHD RS-IV scores were seen with all doses (30, 50, or 70 mg) of lisdexamfetamine compared with placebo, and in CPRS scores with all lisdexamfetamine doses versus placebo throughout the day. Efficacy was observed by the first week of treatment, and improvements were observed throughout the day up to about 6:00 p.m. The most frequently reported adverse effects among patients receiving lisdexamfetamine were typical of amphetamine products. Most adverse effects were mild to moderate and occurred in the first week.

A multi-center, randomized, double-blind, placebo-controlled, crossover design, modified analog classroom study of lisdexamfetamine to simulate a workplace environment in 142 adults who met Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV-TR) criteria for ADHD.<sup>278</sup> There was a 4-week open-label, dose optimization phase with lisdexamfetamine (30, 50, or 70 mg/day in the morning). Subjects were then randomized to 1 of 2 treatment regimens: an optimized dose of lisdexamfetamine followed by placebo, each for 1 week, or placebo followed by lisdexamfetamine, each for 1 week. Efficacy assessments occurred at the end of each week, using the Permanent Product Measure of Performance (PERMP), a skill-adjusted math test that measures attention in ADHD. Lisdexamfetamine treatment, compared to placebo, resulted in a statistically significant improvement in attention across all post-dose time points, as measured by average PERMP total scores over the course of one assessment day, as well as at each time point measured. The PERMP assessments were administered at pre-dose (-0.5 hours) and at 2, 4, 8, 10, 12, and 14 hours post-dose.

### ***amphetamine sulfate (Evekeo) versus placebo***

A multicenter, dose-optimized, randomized, double-blind, placebo-controlled crossover laboratory classroom study was conducted to evaluate the safety and efficacy of amphetamine sulfate (Evekeo) in children with ADHD.<sup>279</sup> After an 8-week open-label dose optimization period, 97 children between the ages of 6 and 12 were randomized to 2 weeks of treatment (amphetamine sulfate followed by placebo or placebo followed by amphetamine sulfate). Efficacy measures included the SKAMP rating scale and Permanent Product Measure of Performance (PERMP) which was administered before dose and at 0.75,

2, 4, 6, 8, and 10 hours after dose on 2 laboratory classroom days. Compared to placebo, a single daily dose of amphetamine sulfate significantly improved SKAMP-Combined scores at each time point during classroom days ( $p < 0.0001$ ). Amphetamine sulfate also significantly improved PERMP number of problems attempted and correct ( $p < 0.0001$ ).

### ***methylphenidate extended-release (Aptensio XR) versus placebo***

The efficacy of methylphenidate extended-release was evaluated in 2 studies; first in a randomized double-blind, placebo-controlled, flexible-dose, crossover trial in children ages 6 to 12 ( $n=26$ ), secondly, in a randomized, double-blind multicenter, placebo-controlled, fixed-dose trial in patients ages 6 to 18 years ( $n=230$ ).<sup>280</sup>

In Trial 1, patients received flexible dose methylphenidate extended-release (15 mg, 20 mg, 30 mg, or 40 mg once daily) in a 2 to 4 week optimization phase and were then randomized to continue their dose from the open-label phase or receive placebo. After 1 week, patients were evaluated over a period of 12 hours and then were given the opposite treatment for 1 week, followed by a second evaluation. Patients were assessed at various time points ranging from 1 to 12 hours post-dose using the SKAMP score. SKAMP total scores were significantly lower for methylphenidate extended-release than for placebo at test day average and all time points post-dose.

In Trial 2, patients were randomized to receive methylphenidate extended-release 10 mg, 15 mg, 20 mg, 40 mg, or placebo for 1 week, followed by an 11-week open label phase. The primary efficacy endpoint was the mean decrease from baseline to the end of Week 1 in the ADHD-RS-IV Total Score. Methylphenidate extended-release 20 mg/day and 40 mg/day doses were superior to placebo for the primary endpoint ( $p=0.0145$  and  $p=0.0011$ , respectively).

## **Hypersomnolence**

### ***Rating Scales***

Scales commonly used in the evaluation of hypersomnolence and its treatment include:

- Epworth Sleepiness Scale (ESS) – This is a self-administered questionnaire that has been shown to provide a measurement of the subject’s general level of daytime sleepiness.<sup>281</sup> This scale has a high level of internal consistency.<sup>282</sup>
- Maintenance of Wakefulness Test (MWT) – In the test, the subject sits in bed, resting against pillows in a quiet, dimly lit room, attempting to stay awake for 20 (or 40) minutes while under scrutiny and with electrodes and wires attached.<sup>283</sup>
- Multiple Sleep Latency Test (MSLT) – The test measures how quickly the subject falls asleep, when asked to do so, when lying down in a quiet, darkened bedroom while under scrutiny and with electrodes and wires attached.<sup>284</sup> The test is considered by many to be the gold standard for measuring daytime sleepiness, although analysis has recently shown it to be the least accurate of the 3 tests.<sup>285,286</sup>

### ***modafinil (Provigil) versus placebo – narcolepsy***

A total of 285 subjects between the ages of 18 and 68 years with a diagnosis of narcolepsy were enrolled in a randomized trial to receive modafinil 200 mg, modafinil 400 mg, or placebo once daily for 9 weeks.<sup>287</sup> The mean ESS score was significantly lower for each modafinil treatment group compared to placebo at weeks 3, 6, and 9. Subjective sleepiness ratings at each evaluation were reduced from baseline in all 3

groups. At baseline, 3% of the modafinil 400 mg group, 4% of the modafinil 200 mg group, and 3% of the placebo group were able to remain awake for at least 3 Maintenance of Wakefulness Tests (MWTs). At week 9, the percentage of subjects able to stay awake for at least 3 tests significantly increased to 20% for the modafinil 400 mg group and 14% for the modafinil 200 mg group; no change occurred in the placebo group. Headache was reported to occur statistically significantly more often in the modafinil groups versus the placebo group. This study had an open-label treatment arm with demonstrated efficacy and safety for up to 40 weeks.

### ***modafinil (Provigil) versus placebo – OSA-related daytime sleepiness***

In a double-blind, parallel group, randomized study, investigators studied the efficacy and safety of modafinil versus placebo in 157 patients with OSA-related daytime sleepiness despite CPAP for a total of 4 weeks.<sup>288</sup> Patients were randomized to receive modafinil (n=77) at an initial dose of 200 mg per day during week 1, then increasing over 3 weeks up to 400 mg per day, or placebo (n=80) once daily. Modafinil significantly improved daytime sleepiness, with significantly greater mean changes from baseline in ESS scores at weeks 1 and 4 ( $p<0.001$ ), but not significantly different from placebo in MSLT at week 4 ( $p<0.05$ ). The percentage of patients with normalized daytime sleepiness (ESS  $<10$ ) was significantly higher with modafinil (51%) than with placebo (27%;  $p<0.01$ ). There was no difference between groups in the percentage of patients with normalized MSLT (25% to 29%).

### ***armodafinil (Nuvigil) versus placebo – OSAHS***

The effectiveness of armodafinil in improving wakefulness in patients with excessive sleepiness associated with OSAHS was established in two 12-week studies of outpatients who met the International Classification of Sleep Disorders (ICSD) criteria for OSAHS (which are also consistent with the American Psychiatric Association DSM-IV criteria).<sup>289</sup> In addition, all patients had excessive sleepiness per the ESS, despite treatment with continuous positive airway pressure (CPAP). In the first study, a total of 395 patients with OSAHS were randomized to receive armodafinil 150 mg/day, armodafinil 250 mg/day, or matching placebo every day for 12 weeks. In the second study, 263 patients with OSAHS were randomized to either armodafinil 150 mg/day or placebo. In both studies, patients treated with armodafinil showed improved wakefulness and overall clinical condition.

A 12-week, randomized, double-blind study evaluated armodafinil 150 mg/day compared to placebo as an adjunct treatment for residual excessive sleepiness in 259 patients with OSAHS who were otherwise well controlled with nCPAP.<sup>290</sup> The authors assessed the ability of armodafinil to improve wakefulness and cognition and reduce fatigue in this population. Efficacy assessments were done at baseline and weeks 4, 8, and 12. At the final visit, mean Maintenance of Wakefulness Test (MWT) sleep latency increased from baseline with armodafinil and decreased in the placebo group ( $p=0.0003$ ). Armodafinil improved Clinical Global Impression of Change compared to placebo ( $p=0.0069$ ). Armodafinil significantly improved episodic secondary memory ( $p=0.0102$ ) and patient-estimated wakefulness ( $p<0.01$ ) and reduced fatigue ( $p<0.05$ ) compared with placebo. Armodafinil did not adversely affect nCPAP use. The most common adverse event associated with armodafinil was headache.

### ***armodafinil (Nuvigil) versus placebo – narcolepsy***

Patients with excessive sleepiness, as documented by a mean sleep latency test (MSLT) with a sleep latency of 6 minutes or less and the absence of any other clinically significant active medical or psychiatric disorder, were enrolled in a 12-week study of outpatients who met the ICSD criteria for narcolepsy.<sup>291</sup> A total of 196 patients were randomized to receive armodafinil 150 or 250 mg/day or



matching placebo. Patients treated with armodafinil showed improved wakefulness and overall clinical condition.

### ***armodafinil (Nuvigil) versus placebo – SWSD***

The effectiveness of armodafinil in patients with excessive sleepiness associated with SWSD was demonstrated in a 12-week double-blind, placebo-controlled, parallel-group clinical trial. A total of 254 patients with chronic SWSD of moderate or greater severity were randomized to receive armodafinil 150 mg/day or placebo.<sup>292,293</sup> Patients treated with armodafinil showed a statistically significant prolongation in the time to sleep onset, as measured by the nighttime MSLT at final visit (armodafinil MSLT at baseline=2.3, week 12=5.3; placebo at baseline=2.4, week 12=2.8;  $p<0.001$ ), and improvement in overall clinical condition ratings were seen for armodafinil (79%) compared to placebo-treated patients (59%;  $p=0.001$ ).

## **Binge Eating Disorder**

### ***lisdexamfetamine dimesylate (Vyvanse) versus placebo***

The effectiveness of lisdexamfetamine dimesylate in patients with moderate to severe binge eating disorder (BED) was demonstrated in two 12-week double-blind, placebo-controlled, parallel-group clinical trials.<sup>294</sup> A total of 724 patients aged 18 to 55 years who met DSM-IV criteria for BED were randomized to receive lisdexamfetamine dimesylate or placebo. The severity of BED was determined based on the patient having at least 3 binge days per week for 2 weeks prior to their baseline visit and on the patient having a Clinical Global Impression Severity (CGI-S) score of  $\geq 4$  at the baseline visit. The primary efficacy outcome for each study was the change from baseline at week 12 in the number of binge days per week. Each study consisted of a 4-week dose-optimization phase, followed by an 8-week dose-maintenance phase. In the dose-optimization phase, patients assigned to lisdexamfetamine dimesylate began treatment at 30 mg/day and titrated to either 50 mg/day or 70 mg/day, as tolerated. In both trials, patients treated with lisdexamfetamine dimesylate showed a statistically significant reduction from baseline in mean number of binge days per week compared to placebo (Trial 1: -3.87 versus -2.51, respectively; Trial 2: -3.92 versus -2.26, respectively;  $p<0.001$  for both).

## **META-ANALYSES**

Several meta-analyses and reviews support the short-term efficacy of stimulant medications in reducing the core symptoms of ADHD—inattention, hyperactivity, and impulsivity.<sup>295,296,297,298,299</sup> Research to date has not shown clear advantages of 1 stimulant medication over another or between dosage forms of a given agent. In the policy statement, AAP states that stimulants are equally effective for ADHD. Many children who fail to respond to 1 medication will have a positive response to an alternative stimulant.<sup>300</sup>

Notably, a meta-analysis of 32 studies comparing irritability associated with stimulant use versus placebo found that methylphenidate derivatives were associated with a decreased risk (risk ratio, 0.89; 95% CI, 0.82 to 0.96;  $p=0.004$ ) of irritability while amphetamine derivatives were associated with a higher risk (risk ratio, 2.9; 95% CI, 1.26 to 6.71;  $p=0.01$ ).<sup>301</sup> Comparative studies are needed to confirm this finding.

A meta-analysis of 29 randomized, double-blind, placebo-controlled studies involving over 4,465 children (mean age 10 years) with ADHD showed that MPH and MAS are significantly more effective than non-stimulant medications used to treat ADHD (atomoxetine, bupropion, desipramine, and modafinil).<sup>302</sup> Among stimulants, the meta-analysis found no difference in efficacy among MAS and MPH

or among immediate-release or extended-release agents. The manufacturer of mixed amphetamine salts ER (Adderall XR) and MPH transdermal patch (Daytrana) funded this meta-analysis.

## SUMMARY

The 2011 American Academy of Pediatrics Clinical Practice Guideline for the School Aged Child with ADHD recommends stimulant medication and/or behavioral therapy for the treatment of ADHD in children. The guidelines state that, in many cases, the stimulants improve the child's ability to follow rules and decrease emotional overactivity, leading to improved relationships.

Due to potential difficulties created by multiple daily dosing (e.g., compliance, social stigma, availability, drug diversion, willingness of schools to store and administer medication) once-daily dosage forms may, in some situations, be preferred.

Several medications have been shown to be effective in treating ADHD. Except for atomoxetine (Strattera), clonidine ER (Kapvay), and guanfacine ER (Intuniv), all of the drugs approved for treatment of ADHD by the FDA are stimulants and are classified as controlled substances. The individual agents used for the treatment of ADHD are associated with different contraindications and precautions for use; this may influence the selection of appropriate therapy in patients with comorbidities (e.g., coexistent tic disorders or Tourette's syndrome).

For school-age children, the once-daily dosage forms can enhance compliance and decrease the risk of diversion. The extended-release methylphenidate products, **Cotempla XR-ODT (extended-release orally disintegrating tablet)**, Quillivant XR (extended-release suspension), and Quillichew ER (extended-release chewable tablet), are options for those patients who cannot swallow tablets or capsules and have failed treatment with other long-acting products that can be opened over applesauce. Amphetamine sulfate (Evekeo), mixed amphetamine salts (Adderall, Adderall XR, **Mydayis**), orally disintegrating extended-release amphetamine (Adzenys XR-ODT), and amphetamine extended-release suspension (Dyanavel XR) provide alternatives for patients who cannot tolerate MPH. Clinical trials of dextroamphetamine (Dexedrine, Zenzedi, ProCentra) are generally of poor quality and are somewhat dated. Additionally, dextroamphetamine has a greater potential for diversion and misuse than the other drugs used for ADHD. As a result, the dextroamphetamine formulations would not be the best initial choice over MPH to be used as first-line therapy for the majority of children and adolescents with ADHD.

Lisdexamfetamine dimesylate (Vyvanse), a prodrug of dextroamphetamine, was designed to have an extended duration of effect to allow for once daily dosing and to have less potential for abuse, diversion, or overdose toxicity. However, there is no evidence that it offers an advantage over any other formulation of amphetamine for treatment of children with ADHD.

Modafinil (Provigil) and armodafinil (Nuvigil) may provide a slightly different profile of adverse effects than the stimulant medications traditionally used for the treatment of narcolepsy. Due to their lack of sympathomimetic activity, modafinil and armodafinil are relatively free of adverse cardiovascular effects. The medications also have lower abuse potential.

Methamphetamine (Desoxyn) and amphetamine sulfate (Evekeo) are FDA-approved in adults for short-term adjunctive therapy in a weight reduction regimen based on caloric restriction for patients in whom obesity is refractory to alternative therapy; however, studies showed weight loss due to medication versus diet alone must be considered clinically limited.

The 2006 Practice Guidelines for the Treatment of Patients with Eating Disorders and 2012 Guide Watch support the use select medications that are not FDA-approved for the treatment of binge-eating disorder. However, these guidelines were prior to lisdexamfetamine being FDA approved for the indication in 2015; lisdexamfetamine dimesylate (Vyvanse) is the first and only FDA-approved treatment for moderate to severe binge eating disorder in adults.

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