Therapeutic Class Overview
Narcolepsy Agents

INTRODUCTION

- Narcolepsy is a lifelong neurological sleep disorder of hypersomnia characterized by excessive daytime sleepiness (EDS) and intermittent manifestations of rapid eye movement (REM) sleep during wakefulness. Excessive sleepiness is defined by the International Classification of Sleep Disorders, third edition (ICSD-3) as "daily episodes of an irrepressible need to sleep or daytime lapses into sleep" (*Sateia 2014*).
- Patients with narcolepsy often have many nighttime arousals and sleep disturbances that contribute to excessive drowsiness during the day. EDS can vary in severity, and some patients involuntarily fall asleep during normal daily activities. This can put the patient or others at risk if these daytime lapses into sleep occur during activities such as operating a motor vehicle. While all patients with narcolepsy experience EDS, additional symptoms may include cataplexy, which is the sudden and complete loss of muscle tone, dream-like images or hallucinations at sleep onset or awakening, and sleep paralysis (*National Institute of Neurological Disorders and Stroke [NINDS] 2017, Scammell 2019).*
- The ICSD-3 establishes 2 subtypes of narcolepsy: narcolepsy type 1 and narcolepsy type 2. Patients are diagnosed with narcolepsy type 1 if they have 1 or both of the following: (1) a cerebrospinal fluid (CSF) hypocretin-1 deficiency; (2) clear cataplexy and a mean sleep latency of < 8 minutes on the multiple sleep latency test (MSLT) with evidence of 2 sleep-onset rapid-eye movement periods (SOREMPs), one of which may be seen on a preceding overnight polysomnogram. A diagnosis of narcolepsy type 2 also requires a mean sleep latency of < 8 minutes on the MSLT and at least 2 SOREMPs, but cataplexy must be absent and CSF hypocretin-1 levels must not meet the type 1 criterion *(Sateia 2014).*
- Narcolepsy affects males and females equally. While symptoms typically begin to present in the teens or early twenties, they can occur at any time throughout a patients' life (*NINDS 2017, Scammell 2019*). It is estimated that approximately 135,000 to 200,000 people in the United States (US) are diagnosed with narcolepsy; however, this number may actually be higher as many patients often go undiagnosed (*NINDS 2017).* Narcolepsy is a chronic condition, but does not typically get worse over time. There is no cure for narcolepsy, but there are pharmacological and nonpharmacological options that can be implemented to help patients manage their symptoms. The goal of therapy is to mitigate symptoms in order to improve the patient's quality of life (*Morgenthaler et al 2007a, NINDS 2017*).
- This review will focus on 2 wakefulness promoting agents, modafinil (Provigil) and armodafinil (Nuvigil), 1 central nervous system (CNS) depressant agent, sodium oxybate (Xyrem), 1 dopamine norepinephrine reuptake inhibitor (DNRI), solriamfetol (Sunosi), and 1 histamine H_3 antagonist/inverse agonist, pitolisant (Wakix). These 5 medications are approved by the US Food and Drug Administration (FDA) for the symptomatic treatment of narcolepsy. There are several amphetamine-like stimulant medications indicated for the treatment of narcolepsy; however, they will not be covered in this review.
- Modafinil and armodafinil (the longer half-life R-enantiomer of modafinil) are both FDA-approved to improve wakefulness in adult patients with excessive sleepiness associated with narcolepsy, obstructive sleep apnea (OSA), and shift work disorder (SWD). OSA is a sleep disorder that is characterized by obstructive apneas and hypopneas, causing patients to have frequent sleep interruptions due to increased respiratory effort. Often, patients do not feel rested in the morning and continue to have excessive sleepiness throughout the day (*American Academy of Sleep Medicine [AASM] 2009*). SWD is a circadian rhythm sleep disorder that occurs in individuals who work non-traditional hours and is characterized by excessive sleepiness and/or insomnia (*Morgenthaler et al 2007b*). Modafinil and armodafinil have been shown to produce psychoactive and euphoric effects similar to CNS stimulants, as well as alterations in mood, perception, thinking and feelings. As a result, these agents are classified as Schedule IV controlled substances.
- Pitolisant is an H_3 antagonist/inverse agonist. Although it has been studied in patients with narcolepsy with cataplexy, it is currently only approved for the treatment of narcolepsy. Pitolisant has shown no abuse potential and is the only unscheduled agent indicated for the treatment of narcolepsy (*FDA web site*).
- Sodium oxybate is gamma-hydroxybutyric acid (GHB), a known drug of abuse. It is FDA-approved for the treatment of EDS and cataplexy in patients ≥ 7 years of age with narcolepsy and is classified as a Schedule III controlled substance for these indications. However, non-medical uses of sodium oxybate are classified under Schedule I. Sodium oxybate carries a boxed warning regarding CNS depression, abuse, and misuse, and may only be dispensed to patients enrolled

in the Xyrem Risk Evaluation and Mitigation Strategy (REMS) program using a specially certified pharmacy. Prescribers and patients must also be enrolled in this REMS program (*Xyrem REMS Web site).*

- Solriamfetol is FDA-approved to improve wakefulness in adult patients with EDS associated with narcolepsy or OSA. Solriamfetol is a Schedule IV controlled substance (*Sunosi dossier 2019*).
- While placebo-controlled (PC) clinical studies document the efficacy of these agents, the exact mechanisms of action are not completely understood. Head-to-head studies are limited, and current clinical guidelines recommend modafinil and sodium oxybate as first-line treatments for EDS and cataplexy, respectively.
- Medispan class: See Table 1 below

Table 1. Medications Included Within Class Review

Drug	Generic Availability
Stimulants - Misc	
Nuvigil (armodafinil)	✔
Provigil (modafinil)	✔
Dopamine and Norepinephrine Reuptake Inhibitors (DNRIs)	
Sunosi (solriamfetol)	-
Histamine H_3-Receptor Antagonist/Inverse Agonists	
Wakix (pitolisant)	-
Anti-Cataplectic Agents	
Xyrem (sodium oxybate)	-

(*Drugs@FDA 2020, Orange Book: approved drug products with therapeutic equivalence evaluations 2020*)

INDICATIONS

Table 2. Food and Drug Administration Approved Indications

Indication	Nuvigil (armodafinil)	Provigil (modafinil)	Sunosi (solriamfetol)	Wakix (pitolisant)	Xyrem (sodium oxybate)
Improve wakefulness in adult patients with excessive sleepiness associated with narcolepsy, OSA, or SWD	✔	✔			
Treatment of EDS in adult patients with narcolepsy				✔	
Improve wakefulness in adult patients with EDS associated with narcolepsy or OSA			✔		
Treatment of cataplexy and EDS in narcolepsy in patients ≥ 7 years of age					✔

(*Prescribing information: Nuvigil 2019, Provigil 2019, Sunosi 2019, Wakix 2019, Xyrem 2018*)

- Information on indications, mechanism of action, pharmacokinetics, dosing, and safety has been obtained from the prescribing information for the individual products, except where noted otherwise.

CLINICAL EFFICACY SUMMARY

Narcolepsy

- The efficacy of modafinil for EDS associated with narcolepsy was established in 2 multicenter (MC), double-blind (DB), PC, randomized controlled trials (RCTs). In both studies, patients treated with modafinil showed statistically significant improvement in objective measures of excessive sleepiness as measured by the MSLT and Maintenance of Wakefulness Test (MWT); and the subjective Epworth Sleepiness Scale (ESS) compared to placebo ($p < 0.001$ for all endpoints in both studies). Overall clinical condition as rated by the Clinical Global Impression of Change (CGI-C) at the final visit was also significantly improved over baseline for patients treated with modafinil compared to placebo in both

studies (p < 0.005 and p < 0.03) (*US Modafinil in Narcolepsy Multicenter Study Group 1998, US Modafinil in Narcolepsy Multicenter Study Group 2000).*

- The efficacy of armodafinil for EDS associated with narcolepsy was established in a MC, DB, PC, RCT. Patients treated with armodafinil showed a statistically significant enhanced ability to remain awake as measured by the MWT compared to placebo (p < 0.01), as well as improvement in overall clinical condition as rated by the CGI-C compared to placebo (p < 0.0001). Armodafinil was also associated with statistically significant improvements in memory, attention, and fatigue (p < 0.05) (*Harsh et al 2006).*
- The efficacy and safety of pitolisant were evaluated in two 8-week, Phase 3, active-controlled, DB, PC, MC, RCTs evaluating the treatment of EDS in adults with narcolepsy with or without cataplexy (HARMONY 1 and HARMONY 1bis) (*Dauvilliers et al 2013*, *Wakix dossier 2019, Wakix FDA clinical review 2019*).
  - HARMONY 1 (N = 95) compared pitolisant 10, 20, or 40 mg per day to modafinil 100, 200, or 400 mg per day. Of the 94 patients in the intent-to-treat (ITT) analysis, 81% had cataplexy, 45% had received psychostimulants (mostly modafinil or methylphenidate) and 35% were receiving anticataplectic drugs and continued them at stable doses during the trial (sodium oxybate, n = 8; antidepressants, n = 25). The primary analysis of between-group differences in mean ESS score at endpoint (adjusted for baseline) showed pitolisant to be superior to placebo (p = 0.024), but not non-inferior to modafinil (p = 0.250).
    - A post-hoc analysis of ESS responder rate (final ESS score ≤ 10) showed a significantly greater response with pitolisant vs placebo (p < 0.0006) and a similar response between pitolisant and modafinil (p = 0.908).
    - MWT values decreased from baseline in the placebo group but improved in the pitolisant group demonstrating superiority of pitolisant (p = 0.044). MWT also improved from baseline in the modafinil group. There was no statistically significant difference between pitolisant and modafinil (p = 0.173).
  - HARMONY 1bis (*Wakix dossier 2019, Wakix FDA clinical review 2019*) compared pitolisant titrated to 20 mg per day to modafinil 200 to 400 mg/day in 166 patients. Of the 164 patients included in the extended ITT population, a history of cataplexy was present in 75% of patients in the pitolisant group, 77% in the modafinil group, and 81% in the placebo group.
    - The pitolisant group had a significantly greater ESS score improvement from baseline compared with placebo, demonstrating superiority (p = 0.036). The non-inferiority of pitolisant compared to modafinil could not be concluded (p = 0.002), most likely due to an imbalance between dosages of both drugs and the short treatment period.
    - The ESS responder rate (final ESS score ≤ 10 or ESS score reduction ≥ 3) was significantly greater in the pitolisant group (64.2%) compared to the placebo group (34.4%) (p = 0.002). There was no significant difference between pitolisant and modafinil (p = 0.052).
    - MWT values decreased from baseline in the placebo group but improved in the pitolisant group (p = 0.022). MWT also improved from baseline in the modafinil group; however, no statistically significant difference between pitolisant and modafinil was seen (p = 0.198).
- A 12-month, open-label (OL), MC, uncontrolled longitudinal study (HARMONY III) was conducted to evaluate the long-term safety of pitolisant (*Dauvilliers et al 2019*). Patients (N = 102, 75 with cataplexy) received pitolisant of whom 73 were treatment-naïve. Sixty-eight patients (51 with cataplexy) completed the 12-month treatment. Common treatment-emergent adverse events (AEs) were headache (11.8%), insomnia (8.8%), weight gain (7.8%), anxiety (6.9%), depressive symptoms (4.9%), and nausea (4.9%). Seven patients had a serious AE, unrelated to pitolisant except for a possibly related miscarriage. One-third of patients stopped pitolisant, mostly (19.6%) for insufficient efficacy. ESS score decreased by 4.6 ± 0.6. Two-thirds of patients completing the treatment were responders (ESS ≤ 10 or ESS decrease ≥ 3), and one-third had normalized ESS (≤ 10). Complete and partial cataplexy, hallucinations, sleep paralysis, and sleep attacks were reduced by 76%, 65%, 54%, 63%, and 27%, respectively.
- The effectiveness of sodium oxybate in the treatment of EDS in patients with narcolepsy was established in 2 MC, DB, PC, RCTs.
  - In the first study, patients treated with sodium oxybate 6 and 9 grams per night achieved statistically significant improvements on the ESS, MWT, and CGI-C compared to the placebo group (p < 0.001 for all) (*Xyrem International Study Group 2005a*).
  - The second study required patients to be taking a stable dose of modafinil before study randomization. Patients were randomized to placebo, sodium oxybate, modafinil, or sodium oxybate plus modafinil. Patients who were switched from modafinil to sodium oxybate did not experience any decrease in sleep latency, suggesting that both medications are equally effective for EDS. Patients taking sodium oxybate alone and sodium oxybate plus modafinil had statistically significant improvements in sleep latency from baseline as measured by MWT compared to the placebo

group ($p < 0.001$). The sodium oxybate plus modafinil group showed a significantly greater increase in sleep latency from baseline compared to the sodium oxybate alone group ($p < 0.001$), suggesting that the combination of drugs had an additive effect (*Black & Houghton 2006*).

- The efficacy of sodium oxybate in the treatment of cataplexy in patients with narcolepsy was established in 2 DB, PC, RCTs.
  - In the first study, patients treated with 6 and 9 grams per night saw a significant decrease in cataplexy attacks compared to placebo ($p < 0.05$ for both doses) (*U.S. Xyrem Multicenter Study Group 2002*).
  - The second study was a randomized withdrawal trial including narcoleptic patients already established on sodium oxybate therapy prior to study entry. Patients were randomized to continue treatment with sodium oxybate or to placebo, which included discontinuation of sodium oxybate therapy. Patients who discontinued sodium oxybate experienced a significant increase in cataplexy attacks compared to patients who remained on sodium oxybate ($p < 0.001$) (*U.S. Xyrem Multicenter Study Group 2004*).
- The efficacy of solriamfetol for the treatment of narcolepsy or narcolepsy with cataplexy was evaluated in a DB, PC, MC, RCT (*Thorpy et al 2019*). Patients were stratified on the basis of presence or absence of cataplexy. Cataplexy was present in 50.8% of patients overall, with similar percentages of patients with cataplexy in each of the treatment groups. At week 12, treatment with solriamfetol significantly improved mean sleep latency measured by the MWT vs placebo ($p < 0.0001$) and ESS scores ($p \leq 0.02$). Significantly higher percentages of patients treated with solriamfetol also reported improvements in Patient Global Impression of Change (PGI-C) vs placebo ($p < 0.0001$). There was no clear effect of solriamfetol on the number of cataplexy attacks per week among patients with cataplexy, although this study was not powered or designed to rigorously evaluate the effects of solriamfetol on cataplexy (data not shown).
- Although not FDA-approved for treatment of narcolepsy with cataplexy, pitolisant has demonstrated efficacy in 1 DB, PC, MC, RCT in 106 patients *(*HARMONY CTP; *Szakacs et al 2017*). From a baseline weekly cataplexy rate (WCR) of 9.15 in the pitolisant group and 7.31 in the placebo group, the WCR was significantly reduced by a relative 75% in the pitolisant group compared with 38% in the placebo group ($p < 0.0001$). For almost all secondary endpoints, a significant superiority of pitolisant was shown (ie, proportion of patients with WCR > 15 at the end of treatment, mean ESS decrease, patient proportion with final ESS ≤ 10, MWT mean change, CGI-C, Patient's global opinion (PGO), and frequency of hallucinations).

OSA

- The efficacy of modafinil for EDS associated with OSA was established in 2 DB, PC, RCTs. In both studies, patients treated with modafinil saw a statistically significant improvement in wakefulness compared to placebo ($p < 0.001$ for both) (*Black et al 2005, Pack et al 2001*).
- The efficacy of armodafinil for EDS associated with OSA was established in 2 PC, DB, RCTs. In both studies, patients treated with armodafinil showed a statistically significant improvement in the ability to remain awake as measured by the MWT ($p < 0.001$ and $p = 0.0003$) and overall clinical condition per the CGI-C compared to placebo ($p < 0.001$ and $p = 0.0069$) (*Roth et al 2006, Hirshkowitz et al 2007*).
- The efficacy of solriamfetol for the treatment of EDS in patients with OSA with current or prior sleep apnea treatment was demonstrated in a DB, PC, MC, RCT (*Schweitzer et al 2018*). At week 12, solriamfetol-treated patients had significantly greater improvements in mean sleep latency assessed by the MWT ($p < 0.001$) and ESS score ($p \leq 0.02$). At week 12, higher percentages of patients on solriamfetol reported overall improvement on the PGI-C vs placebo ($p < 0.0001$).
- A randomized withdrawal study evaluated the maintenance of efficacy and safety of solriamfetol vs placebo for the treatment of EDS in adults with OSA (*Strollo et al 2019*). After 2 weeks of clinical titration and 2 weeks of stable dose administration, patients who reported "much improved" or "very much improved" on the PGI-C and had numerical improvements on the MWT and ESS were randomly assigned to placebo or solriamfetol for 2 additional weeks. From baseline to week 4, mean sleep latency on the MWT and ESS scores improved. From weeks 4 to 6 (randomized withdrawal phase), solriamfetol-treated patients maintained improvements in MWT and ESS. During the randomized withdrawal phase, more patients who were switched to placebo reported worsening on the PGI-C and CGI-C vs those who continued solriamfetol.
- An OL extension study evaluated the long-term safety and maintenance of efficacy of solriamfetol for up to 52 weeks in the treatment of patients with narcolepsy or OSA who completed previous trials of solriamfetol (*Sunosi dossier 2019*). In a 2-week OL titration phase, patients received solriamfetol, titrated to a maximum tolerated dose, followed by a maintenance phase. During a 2-week PC randomized withdrawal phase ~6 months later, patients were randomized

either to placebo or to continue their maintenance solriamfetol dose for 2 weeks. From the beginning to the end of the randomized withdrawal phase, the ESS score was significantly improved with solriamfetol vs placebo ($p < 0.0001$). The percentage of patients who were reported as worse on the PGI-C at the end of the randomized withdrawal phase was greater for patients randomized to placebo compared to patients on solriamfetol ($p < 0.0001$). Long-term maintenance of efficacy of solriamfetol was demonstrated by sustained reductions in ESS scores. During the randomized withdrawal period, patients did not demonstrate rebound sleepiness or withdrawal after abrupt discontinuation of solriamfetol.

SWD

- The efficacy of modafinil in treating EDS associated with SWD was evaluated in a DB, PC, RCT. Patients treated with modafinil showed a statistically significant improvement in nighttime sleep latency as measured by the MSLT ($p = 0.002$) (*Czeisler et al 2005*).
- The efficacy of armodafinil in treating EDS associated with SWD was evaluated in a DB, PC, RCT. Patients treated with armodafinil showed a statistically significant improvement in sleep latency as measured by nighttime MSLT compared to placebo ($p < 0.001$) (*Czeisler et al 2009*).
- A head-to-head study conducted by Tembe et al compared armodafinil to modafinil in patients with SWD. The study compared the response rate, defined as the proportion of patients showing ≥ 2 grades of improvement based on the Stanford Sleepiness Score (SSS). After 12 weeks of therapy, there was no statistically significant different in response rates between patients treated with armodafinil vs modafinil ($p = 0.76$). Compliance to therapy and adverse events (AEs) were also similar between groups ($p = 0.63$ and $p = 0.78$, respectively) (*Tembe et al 2011*).

- Some studies have demonstrated that concurrent therapy with sodium oxybate and modafinil had a greater effect on EDS and wakefulness than either agent on its own, suggesting an additive effect (*Alshaikh et al 2012, Billiard et al 1994, Black & Houghton 2006, Black et al 2010a, Black et al 2010b, Black et al 2016, Broughton et al 1997, Kuan et al 2016, Schwartz et al 2010, Weaver et al 2006, Xyrem International Study Group 2005b).*

CLINICAL GUIDELINES

Narcolepsy:

- The 2007 AASM practice parameters for the treatment of narcolepsy and other hypersomnias of central origin (*Morgenthaler et al 2007a*) recommend pharmacologic therapy based on the diagnosis and targeted symptoms. Most of the agents used to treat EDS have little effect on cataplexy or other REM sleep associated symptoms, while most antidepressants and anticataplectics have little effect on alertness; however, some medications act on both symptoms. Co-administration of 2 or more drug classes may be required in some patients to adequately address their symptoms. Scheduled naps may be beneficial, but seldom suffice as primary therapy for narcolepsy. The guidelines state that modafinil is effective for treatment of EDS due to narcolepsy, and sodium oxybate is effective for treatment of cataplexy, EDS, and disrupted sleep due to narcolepsy. Sodium oxybate may be effective for treatment of hypnagogic hallucinations and sleep paralysis. Amphetamine, methamphetamine, dextroamphetamine, and methylphenidate are effective for treatment of EDS due to narcolepsy. Antidepressants (tricyclics, selective serotonin reuptake inhibitors [SSRIs], venlafaxine) may be effective for treatment of cataplexy. Tricyclics, SSRIs, and venlafaxine may be effective treatment for sleep paralysis and hypnagogic hallucinations.
- The European Academy of Neurology (EAN) 2011 guidelines on management of narcolepsy in adults (*Billiard et al 2011*) recommend modafinil as the first-line treatment for EDS associated with narcolepsy when EDS is the most disturbing symptom. Sodium oxybate is recommended when EDS, cataplexy, and poor sleep coexist. The guideline notes that the combination of modafinil and sodium oxybate may be more effective than sodium oxybate alone. Methylphenidate may be an option if the response to modafinil is inadequate and when sodium oxybate is not recommended. Naps are best scheduled on a patient-by-patient basis.
- While armodafinil has been shown in clinical studies to be effective for EDS in narcolepsy, its specific place in therapy is not discussed in the current guidelines.

OSA:

- The 2006 AASM practice parameters for the medical therapy of OSA (*Morgenthaler et al 2006*) provide recommendations for patients with OSA who do not adapt well to or respond to initial therapy with continuous positive airway pressure (CPAP), oral appliances, or surgical modification. Dietary weight loss in obese individuals may be beneficial and should be combined with a primary treatment for OSA. Modafinil is recommended for the treatment of

residual EDS in OSA patients who have sleepiness despite effective PAP treatment and who are lacking any other identifiable cause for their sleepiness.

SWD:

- The AASM practice parameters for the clinical evaluation and treatment of circadian rhythm sleep disorders (*Morgenthaler et al 2007b*) recommend planned napping before or during the night shift to improve alertness and performance in patients with SWD. Timed light exposure in the work environment and light restriction in the morning, when feasible, is indicated to decrease sleepiness and improve alertness during night shift work. Administration of melatonin prior to daytime sleep is indicated to promote daytime sleep among night shift workers. Hypnotic medications may be used to promote daytime sleep among night shift workers. Carryover of sedation to the nighttime shift with potential adverse consequences for nighttime performance and safety must be considered. Modafinil is indicated to enhance alertness during the night shift for SWD. Caffeine is indicated to enhance alertness during the night shift for SWD.

SAFETY SUMMARY

- Modafinil/armodafinil:
  - Warnings and precautions of modafinil/armodafinil include rare serious skin reactions including Stevens-Johnson syndrome (SJS) and toxic epidermal necrolysis (TEN); drug rash with eosinophilia and systemic symptoms (DRESS); multiorgan hypersensitivity; angioedema and anaphylaxis reactions; persistent sleepiness; psychiatric AEs; and cardiovascular AEs including chest pain, palpitations, dyspnea, and transient ischemic T-wave changes on electrocardiogram (ECG) in association with mitral valve prolapse or left ventricular hypertrophy. Increased monitoring of heart rate and blood pressure (BP) may be appropriate in patients receiving modafinil/armodafinil. Caution should be exercised when these drugs are prescribed to patients with known cardiovascular disease.
  - The most common AEs (≥ 5%) with armodafinil vs placebo were headache (17 vs 9%), nausea (7 vs 3%), dizziness (5 vs 2%), and insomnia (5 vs 1%).
  - The most common AEs (≥ 5%) with modafinil vs placebo were headache (34 vs 23%), nausea (11 vs 3%), nervousness (7 vs 3%), rhinitis (7 vs 6%), diarrhea (6 vs 5%), back pain (6 vs 5%), anxiety (5 vs 1%), insomnia (5 vs 1%), dizziness (5 vs 4%), and dyspepsia (5 vs 4%).
- Pitolisant:
  - Pitolisant is contraindicated in patients with severe hepatic impairment. Pitolisant is extensively metabolized by the liver, and there is a significant increase in pitolisant exposure in patients with moderate hepatic impairment.
  - Pitolisant has a warning for QT prolongation. Use should be avoided with drugs that also increase the QT interval and in patients with risk factors for prolonged QT interval. Patients with hepatic or renal impairment should be monitored for increased QTc.
  - In the PC trials, the most common AEs (occurring in ≥ 5% of patients and at twice the rate of placebo) with the use of pitolisant were insomnia (6%), nausea (6%), and anxiety (5%).
- Sodium oxybate:
  - Sodium oxybate is contraindicated in combination with sedative hypnotics or alcohol and in patients with succinic semialdehyde dehydrogenase deficiency, a rare inborn error of metabolism.
  - Sodium oxybate carries a boxed warning concerning CNS depression and the potential for misuse/abuse. Abuse or misuse of illicit GHB is associated with CNS AEs, including seizure, respiratory depression, decreased consciousness, coma, and death.
  - Because of the risks of CNS depression and abuse and misuse, sodium oxybate is available only through a restricted distribution program called the Xyrem REMS Program. Prescribers must be specially certified, and the drug may be dispensed only by a central pharmacy that is specially certified.
  - Other warnings and precautions include respiratory depression and sleep disordered breathing; depression and suicidality; parasomnias; and use in patients sensitive to high sodium intake due to the high salt content of sodium oxybate.
  - The most common AEs in adults (≥ 5% and at least twice the incidence with placebo) were nausea, dizziness, vomiting, somnolence, enuresis, and tremor.
  - The most common AEs in pediatric patients (≥ 5%) were enuresis, nausea, headache, vomiting, weight decreased, decreased appetite, and dizziness.
- Solriamfetol:

- Solriamfetol is contraindicated with concomitant use of monoamine oxidase inhibitors (MAOIs), or within 14 days following discontinuation of an MAOI because of the risk of hypertensive reaction.
- Warnings and precautions of solriamfetol include BP and heart rate increases and psychiatric symptoms such as anxiety, insomnia, and irritability.
- The most common AEs (≥ 5% and greater than placebo) in either the narcolepsy or OSA populations vs placebo were headache (16 vs 7%), nausea (7 vs 4%), decreased appetite (9 vs 1%), insomnia (5 vs 4%), and anxiety (6 vs 1%).

DOSING AND ADMINISTRATION

Table 3. Dosing and Administration

Drug	Available Formulations	Route	Usual Recommended Frequency	Comments
Nuvigil (armodafinil)	Tablets	Oral	*Narcolepsy or OSA*: once daily in the morning. *SWD*: once daily, approximately 1 hour prior to the start of the work shift.	The dose should be reduced in patients with severe hepatic impairment and geriatric patients.
Provigil (modafinil)	Tablets	Oral	*Narcolepsy or OSA*: once daily in the morning. *SWD*: once daily, approximately 1 hour prior to the start of the work shift.	Patients with severe hepatic impairment should reduce the dose to one-half the recommended dose. Consider a lower dose in geriatric patients.
Sunosi (solriamfetol)	Tablets	Oral	*Narcolepsy or OSA:* once daily	Renal impairment: dose adjustments required; not recommended for use in patients with end-stage renal disease.
Wakix (pitolisant)	Tablets	Oral	*Narcolepsy:* once daily in the morning	Hepatic impairment: dose adjustments required in moderate impairment Renal impairment: dose adjustments required in moderate and severe renal impairment; not recommended in end stage renal disease Dose adjustments are required with concomitant use of strong CYP2D6 inhibitors, strong CYP3A4 inducers and in patients who are known CYP2D6 poor metabolizers
Xyrem (sodium oxybate)	Solution	Oral	Adults: administer nightly in 2 equal divided doses: at bedtime and 2.5 to 4 hours later; titrate to effect as directed	Both doses should be prepared prior to bedtime; dilute each dose with approximately ¼ cup of water in pharmacy-provided vials.

Drug	Available Formulations	Route	Usual Recommended Frequency	Comments
			Pediatrics: weight-based dose administered at bedtime and 2.5 to 4 hours later; titrate to effect as directed.	Take each dose while in bed and lie down after dosing. Patients with hepatic impairment should reduce the starting dose by 50%. When using concomitantly with divalproex sodium, an initial dose reduction of at least 20% is recommended.

See the current prescribing information for full details

CONCLUSION

- Narcolepsy is a chronic neurological condition that causes excessive sleepiness throughout the day. EDS can vary in severity and in the most severe cases patients suddenly fall asleep during normal activities. Patients with narcolepsy present with or without clear evidence of cataplexy (type 1 vs type 2, respectively). There is no cure for narcolepsy, and current treatments focus on alleviating symptoms and improving quality of life.
- Current clinical evidence supports the use of modafinil as a first-line agent in treating EDS associated with narcolepsy. Sodium oxybate can be used as a second-line agent for EDS in narcolepsy, but is considered first-line therapy for patients diagnosed with cataplexy. While armodafinil has been shown in clinical studies to be effective in treating narcolepsy-associated EDS, the current clinical guidelines do not discuss a specific place in therapy. Amphetamine, methamphetamine, dextroamphetamine, and methylphenidate are additional treatment alternatives for EDS due to narcolepsy, while TCAs, SSRIs, and venlafaxine are second-line alternatives for patients with cataplexy. Solriamfetol and pitolisant are potential first-line agents for narcolepsy, but they have not yet been incorporated into the guidelines. Sodium oxybate is the only agent FDA-approved for the treatment of narcolepsy in pediatric patients.
- Patients with OSA should be treated with primary CPAP therapy, and then may use modafinil, armodafinil, or solriamfetol as an adjunctive treatment for residual sleepiness.
- SWD should be treated by utilizing a planned sleep schedule, including regular naps before and during the work shift; modafinil or armodafinil may be used to enhance wakefulness in these patients.
- While current clinical data indicate that modafinil, armodafinil, pitolisant, sodium oxybate, and solriamfetol are all effective for their respective FDA-approved indications, there are a lack of head-to-head data among these agents. These agents have some differences in their AE profiles; thus, a treatment plan should be individualized for all patients and the risks and benefits should be evaluated before beginning any pharmacological therapy.
- Modafinil, armodafinil, pitolisant, and solriamfetol are oral tablets that are dosed once daily. Sodium oxybate is an oral solution that must be taken at bedtime and repeated 2.5 to 4 hours later. Currently, modafinil and armodafinil are available generically.
- Sodium oxybate carries a boxed warning for the risk of CNS depression, misuse, and abuse. Sodium oxybate is only available through the Xyrem REMS program; patients and prescribers must enroll in the program, and sodium oxybate is only dispensed through a specially certified pharmacy.
- Pitolisant does not appear to have significant abuse potential and is the only unscheduled narcolepsy agent.

REFERENCES

- Alshaikh MK, Tricco AC, Tashkandi M, Mamdani M, Straus SE, BaHammam AS. Sodium oxybate for narcolepsy with cataplexy: systematic review and meta-analysis. *J Clin Sleep Med.* 2012;8(4):451-458.
- American Academy of Sleep Medicine. Clinical Guideline for the evaluation, management, and long-term care of obstructive sleep apnea in adults. *J Clin Sleep Med.* 2009;5(3):263-276.
- Billiard M, Dauvilliers Y, Dolenc-Grošelj L, Lammers GJ, Mayer G, Sonka K. Chapter 38. Section 6. Sleep Disorders. Management of narcolepsy in adults. European Academy of Neurology. 2011.
- Billiard M, Besset A, Montplaisir J, et al. Modafinil: A double-blind multicenter study. *Sleep*. 1994;17(8):S107-12.
- Black J, Houghton WC. Sodium oxybate improves excessive daytime sleepiness in narcolepsy. *Sleep*. 2006;29:939-946.

- Black J, Pardi D, Hornfeldt CS, Inhaber N. The nightly use of sodium oxybate is associated with a reduction in nocturnal sleep disruption: a double-blind, placebo-controlled study in patients with narcolepsy. *J Clin Sleep Med*. 2010[a];6:596-602.
- Black J, Swick T, Bogan R, Lai C, Carter LP. Impact of sodium oxybate, modafinil, and combination treatment on excessive daytime sleepiness in patients who have narcolepsy with or without cataplexy. *Sleep Med*. 2016;24:57-62.
- Black JE, Hirshkowitz M. Modafinil for treatment of residual excessive sleepiness in nasal continuous positive airway pressure-treated obstructive sleep apnea/hypopnea syndrome. *Sleep*. 2005;28(4):464-471.
- Black JE, Hull SG, Tiller J, Yang R, Harsh JR. The long-term tolerability and efficacy of armodafinil in patients with excessive sleepiness associated with treated obstructive sleep apnea, shift work disorder, or narcolepsy: an open-label extension study. *J Clin Sleep Med*. 2010[b];6:458-466.
- Broughton RJ, Felming JAE, George CF, et al. Randomized, double blind, placebo controlled crossover trial of modafinil in the treatment of excessive daytime sleepiness in narcolepsy. *Neurology*. 1997;49(2):444-451.
- Czeisler CA, Walsh JK, Roth T, et al. Modafinil for excessive sleepiness associated with Shift-Work Sleep disorder. *N Engl J Med*. 2005;353:476-86.
- Czeisler CA, Walsh JK, Wesnes KA, Arora S, Roth T. Armodafinil for treatment of excessive sleepiness associated with shift work disorder: a randomized controlled study. *Mayo Clin Proc*. 2009;84:958-972.
- Dauvilliers Y, Bassetti C, Lammers GJ, et al; HARMONY I study group. Pitolisant versus placebo or modafinil in patients with narcolepsy: a double-blind, randomized trial. *Lancet Neurol*. 2013;12(11):1068-1075.
- Dauvilliers Y, Arnulf I, Szakacs Z, et al; HARMONY III study group. Long-term use of pitolisant to treat patients with narcolepsy: Harmony III Study. *Sleep*. 2019;42(11)1-11.
- Drugs@FDA: FDA approved drug products. Food and Drug Administration Web site. https://www.accessdata.fda.gov/scripts/cder/daf/. Accessed January 7, 2020.
- Erman MK, Yang R, Seiden DJ. The effect of armodafinil on patient-reported functioning and quality of life in patients with excessive sleepiness associated with shift work disorder: a randomized, double-blind, placebo-controlled trial. *Prim Care Companion CNS Disord*. 2012;14(4).
- Harsh JR, Hayduk R, Rosenberg R, et al. The efficacy and safety of armodafinil as treatment for adults with excessive sleepiness associated with narcolepsy. *Curr Med Res Opin*. 2006;22(4):761-774.
- Hirshkowitz M, Black JE, Wesnes K, Niebler G, Arora S, Roth T. Adjunct armodafinil improves wakefulness and memory in obstructive sleep apnea/hypopnea syndrome. *Respir Med.* 2007;101:616-627.
- Kuan YC, Wu D, Huang KW, et al. Effects of modafinil and armodafinil in patients with obstructive sleep apnea: a meta-analysis of randomized controlled trials. *Clin Ther*. 2016;38(4):874-88.
- Morgenthaler TI, Kapur VK, Brown TM, et al. Standards of practice committee of the AASM: practice parameters for the treatment of narcolepsy and other hypersomnias of central origin. *Sleep*. 2007[a];30:1705-1711.
- Morgenthaler TI, Lee-Chiong T, Alessi C, et al. Practice parameters for the clinical evaluation and treatment of circadian rhythm sleep disorders. *Sleep*. 2007[b];30(11):1445-1459.
- National Institute of Neurological Disorders and Stroke. Narcolepsy Fact Sheet. NIH Web Site. https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Narcolepsy-Fact-Sheet. Updated May 14, 2019. Accessed January 7, 2020.
- Nuvigil [package insert], North Wales, PA: Cephalon, Inc., a wholly owned subsidiary of Teva Pharmaceutical Industries Ltd.; July 2019.
- Orange Book: approved drug products with therapeutic equivalence evaluations. Food and Drug Administration Web site. https://www.accessdata.fda.gov/scripts/cder/ob/default.cfm. Accessed January 7, 2020.
- Pack AI, Black JE, Schwartz JR, Matheson JK. Modafinil as adjunct therapy for daytime sleepiness in obstructive sleep apnea. *Am J Respir Crit Care Med*. 2001;164(9):1675-81.
- Provigil [package insert], North Wales, PA: Cephalon, Inc., a wholly owned subsidiary of Teva Pharmaceutical Industries Ltd.; July 2019.
- Qaseem A, Holty JE, Owens DK, et al. Management of obstructive sleep apnea in adults: a clinical practice guideline from the American College of Physicians. *Ann Intern Med*. 2013;159(7):471-83.
- REMS@FDA: Xyrem REMS document. Food and Drug Administration Web site. https://www.accessdata.fda.gov/scripts/cder/rems/index.cfm?event=IndvRemsDetails.page&REMS=345. Updated October 26, 2018. Accessed January 7, 2020.
- Roth T, White D, Schmidt-Nowara W, et al. Effects of armodafinil in the treatment of residual excessive sleepiness associated with obstructive sleep apnea/hypopnea syndrome: a 12-week, multicenter, double-blind, randomized, placebo-controlled study in nCPAP-adherent adults. *Clin Ther*. 2006;28:689-706.
- Sateia MJ. International classification of sleep disorders-third edition: highlights and modifications. *Chest*. 2014;146(5):1387-1394.
- Scammell TE. Clinical features and diagnosis of narcolepsy in adults. UpToDate Web Site. http://www.uptodate.com. Updated January 16, 2019. Accessed January 8, 2020.
- Schwartz JR, Khan A, McCall WV, Weintraub J, Tiller J. Tolerability and efficacy of armodafinil in naïve patients with excessive sleepiness associated with obstructive sleep apnea, shift work disorder, or narcolepsy: a 12-month, open-label, flexible-dose study with an extension period. *J Clin Sleep Med*. 2010;6(5):450-7.
- Schweitzer PK, Rosenberg R, Zammit GK, et al. Solriamfetol for excessive sleepiness in obstructive sleep apnea (TONES 3): A randomized controlled trial. *Am J Respir Crit Care Med*. 2018. doi: 10.1164/rccm.201806-1100OC. [Epub ahead of print].
- Strollo PJ, Hedner J, Collop N, et al. Solriamfetol for the treatment of excessive sleepiness in OSA. A placebo-controlled randomized withdrawal study. *Chest*. 2019;155(2): 364-374.
- Sunosi [package insert], Palo Alto, CA: Jazz Pharmaceuticals, Inc.; October 2019.
- Sunosi [dossier], Palo Alto, CA: Jazz Pharmaceuticals, Inc.; April 2019.
- Szakacs Z, Dauvilliers Y, Mikhaylov V, et al; HARMONY-CTP study group. Safety and efficacy of pitolisant on cataplexy in patients with narcolepsy: a randomised, double-blind, placebo-controlled trial. *Lancet Neurol*. 2017;16(3):200-207.
- Tembe DV, Dhavale A, Desai H, et al. Armodafinil vs modafinil in patients of excessive sleepiness associated with shift work sleep disorder: A randomized double blind multicentric clinical trial. *Neurol Res Int*. 2011;2011:514351.
- Thorpy MJ, Shapiro C, Mayer G, et al. A randomized study of solriamfetol for excessive sleepiness in narcolepsy. *Ann Neurol*. 2019; 85:359-370.

- U.S. Modafinil in Narcolepsy Multicenter Study Group. Randomized trial of modafinil for the treatment of pathological somnolence in narcolepsy. *Ann Neurol*. 1998;43(1):88-97.
- U.S. Modafinil in Narcolepsy Multicenter Study Group. Randomized trial of modafinil as a treatment for the excessive daytime somnolence of narcolepsy. *Neurology*. 2000;54(5):1166-1175.
- U.S. Xyrem Multicenter Study Group. A randomized, double blind, placebo-controlled multicenter trial comparing the effects of three doses of orally administered sodium oxybate with placebo for the treatment of narcolepsy. *Sleep*. 2002;25(1):42-9.
- U.S. Xyrem Multicenter Study Group. Sodium oxybate demonstrates long-term efficacy for the treatment of cataplexy in patients with narcolepsy. *Sleep Med*. 2004;5:119-123.
- Wakix [package insert], Plymouth Meeting, PA: Harmony Biosciences LLC; August 2019.
- Wakix FDA clinical review. FDA Web site. August 14, 2019. https://www.accessdata.fda.gov/drugsatfda_docs/nda/2019/211150Orig1s000MedR.pdf. Accessed October 14, 2019.
- Wakix [dossier], Plymouth Meeting, PA: Harmony Biosciences LLC; November 2019.
- Weaver TE, Cuellar N. A randomized trial evaluating the effectiveness of sodium oxybate therapy on quality of life in narcolepsy. *Sleep*. 2006;29(9):1189-1194.
- Wise MS, Arand DL, Auger RR, Brooks SN, Watson NF. Treatment of narcolepsy and other hypersomnias of central origin [an American Academy of Sleep medicine review]. *Sleep*. 2007;30(12):1712-1727.
- Xyrem [package insert], Palo Alto, CA: Jazz Pharmaceuticals, Inc.; October 2018.
- Xyrem International Study Group. A double-blind, placebo-controlled study demonstrates sodium oxybate is effective for the treatment of excessive daytime sleepiness in narcolepsy. *J Clin Sleep Med*. 2005[a];1:391-397.
- Xyrem International Study Group. Further evidence supporting the use of sodium oxybate for the treatment of cataplexy: a double-blind, placebo-controlled study in 228 patients. *Sleep Med.* 2005[b];6(5):415-21.
- Xyrem Risk Evaluation and Mitigation Strategy (REMS) Program Web site. https://www.xyremrems.com/. Accessed January 7, 2020.

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