I. OVERVIEW

Cholinergic antagonist is a general term for agents that bind to cholinoreceptors (muscarinic or nicotinic) and prevent the effects of acetylcholine (ACh) and other cholinergic agonists. The most clinically useful of these agents are selective blockers of muscarinic receptors. They are commonly known as anticholinergic agents (a misnomer, as they antagonize only muscarinic receptors), antimuscarinic agents (more accurate terminology), or parasympatholytics. The effects of parasympathetic innervation are, thus, interrupted, and the actions of sympathetic stimulation are left unopposed. A second group of drugs, the ganglionic blockers, shows a preference for the nicotinic receptors of the sympathetic and parasympathetic ganglia. Clinically, they are the least important of the cholinergic antagonists. A third family of compounds, the neuromuscular-blocking agents (mostly nicotinic antagonists), interfere with transmission of efferent impulses to skeletal muscles. These agents are used as skeletal muscle relaxant adjuvants in anesthesia during surgery, intubation, and various orthopedic procedures. Figure 5.1 summarizes the cholinergic antagonists discussed in this chapter.

II. ANTIMUSCARINIC AGENTS

Commonly known as anticholinergic drugs, these agents (for example, atropine and scopolamine) block muscarinic receptors (Figure 5.2), causing inhibition of muscarinic functions. In addition, these drugs block the few exceptional sympathetic neurons that are cholinergic, such as those innervating the salivary and sweat glands. Because they do not block nicotinic receptors, the anticholinergic drugs (more precisely, antimuscarinic drugs) have little or no action at skeletal neuromuscular junctions (NMJs) or autonomic ganglia. The anticholinergic drugs are beneficial in a variety of clinical situations. [Note: A number of antihistamines and antidepressants (mainly tricyclic antidepressants) also have antimuscarinic activity.]

A. Atropine

Atropine [A-troe-peen] is a tertiary amine belladonna alkaloid with a high affinity for muscarinic receptors. It binds competitively and
prevents ACh from binding to those sites (Figure 5.3). Atropine acts both centrally and peripherally. Its general actions last about 4 hours, except when placed topically in the eye, where the action may last for days. Neuroeffector organs have varying sensitivity to atropine. The greatest inhibitory effects are on bronchial tissue and the secretion of sweat and saliva (Figure 5.4).

1. Actions:

   a. Eye: Atropine blocks muscarinic activity in the eye, resulting in mydriasis (dilation of the pupil), unresponsiveness to light, and cycloplegia (inability to focus for near vision). In patients with angle-closure glaucoma, intraocular pressure may rise dangerously.

   b. Gastrointestinal (GI): Atropine (as the active isomer, \( \alpha \)-hyoscymamine) can be used as an antispasmodic to reduce activity of the GI tract. Atropine and scopolamine (discussed below) are probably the most potent antispasmodic drugs available. Although gastric motility is reduced, hydrochloric acid

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**Figure 5.2**
Sites of actions of cholinergic antagonists.

**Figure 5.3**
Competition of atropine and scopolamine with acetylcholine for the muscarinic receptor.
production is not significantly affected. Thus, atropine is not effective for the treatment of peptic ulcer. [Note: Pirenzepine, an M₁ muscarinic antagonist, does reduce gastric acid secretion at doses that do not antagonize other systems.] Doses of atropine that reduce spasms also reduce saliva secretion, ocular accommodation, and urination. These effects decrease compliance with atropine.

c. Cardiovascular: Atropine produces divergent effects on the cardiovascular system, depending on the dose (Figure 5.4). At low doses, the predominant effect is a slight decrease in heart rate. This effect results from blockade of the M₁ receptors on the inhibitory prejunctional (or presynaptic) neurons, thus permitting increased ACh release. Higher doses of atropine cause a progressive increase in heart rate by blocking the M₂ receptors on the sinoatrial node.

d. Secretions: Atropine blocks muscarinic receptors in the salivary glands, producing dryness of the mouth (xerostomia). The salivary glands are exquisitely sensitive to atropine. Sweat and lacrimal glands are similarly affected. [Note: Inhibition of secretions by sweat glands can cause elevated body temperature, which can be dangerous in children and the elderly.]

2. Therapeutic uses:

a. Ophthalmic: Topical atropine exerts both mydriatic and cycloplegic effects, and it permits the measurement of refractive errors without interference by the accommodative capacity of the eye. Shorter-acting antimuscarinics (cyclopentolate and tropicamide) have largely replaced atropine due to prolonged mydriasis observed with atropine (7 to 14 days vs. 6 to 24 hours with other agents). [Note: Phenylephrine or similar α-adrenergic drugs are preferred for pupillary dilation if cycloplegia is not required.]

b. Antispasmodic: Atropine is used as an antispasmodic agent to relax the GI tract.

c. Cardiovascular: The drug is used to treat bradycardia of varying etiologies.

d. Antisecretory: Atropine is sometimes used as an antisecretory agent to block secretions in the upper and lower respiratory tracts prior to surgery.

e. Antidote for cholinergic agonists: Atropine is used for the treatment of organophosphate (insecticides, nerve gases) poisoning, of overdose of clinically used anticholinesterases such as physostigmine, and in some types of mushroom poisoning (certain mushrooms contain cholinergic substances that block cholinesterases). Massive doses of atropine may be required over a long period of time to counteract the poisons. The ability of atropine to enter the central nervous system (CNS) is of particular importance in treating central toxic effects of anticholinesterases.
3. **Pharmacokinetics:** *Atropine* is readily absorbed, partially metabolized by the liver, and eliminated primarily in urine. It has a half-life of about 4 hours.

4. **Adverse effects:** Depending on the dose, *atropine* may cause dry mouth, blurred vision, "sandy eyes," tachycardia, urinary retention, and constipation. Effects on the CNS include restlessness, confusion, hallucinations, and delirium, which may progress to depression, collapse of the circulatory and respiratory systems, and death. Low doses of cholinesterase inhibitors, such as *physostigmine*, may be used to overcome *atropine* toxicity. *Atropine* may also induce troublesome urinary retention. The drug may be dangerous in children, because they are sensitive to its effects, particularly to rapid increases in body temperature that it may elicit.

**B. Scopolamine**

*Scopolamine* [skoe-POL-a-meen], another tertiary amine plant alkaloid, produces peripheral effects similar to those of *atropine*. However, *scopolamine* has greater action on the CNS (unlike *atropine*, CNS effects are observed at therapeutic doses) and a longer duration of action as compared to *atropine*. It has some special actions as indicated below.

1. **Actions:** *Scopolamine* is one of the most effective anti-motion sickness drugs available (Figure 5.5). It also has the unusual effect of blocking short-term memory. In contrast to *atropine*, *scopolamine* produces sedation, but at higher doses, it can produce excitement. *Scopolamine* may produce euphoria and is susceptible to abuse.

2. **Therapeutic uses:** The therapeutic use of *scopolamine* is limited to prevention of motion sickness and postoperative nausea and vomiting. For motion sickness, it is available as a topical patch that provides effects for up to 3 days. [Note: As with all drugs used for motion sickness, it is much more effective prophylactically than for treating motion sickness once it occurs.]

3. **Pharmacokinetics and adverse effects:** These aspects are similar to those of *atropine*.

**C. Ipratropium and tiotropium**

*Ipratropium* [i-pra-TROE-pee-um] and *tiotropium* [ty-oh-TROPE-e-em] are quaternary derivatives of *atropine*. These agents are approved as bronchodilators for maintenance treatment of bronchospasm associated with chronic obstructive pulmonary disease (COPD). *Ipratropium* is also used in the acute management of bronchospasm in asthma. Both agents are delivered via inhalation. Because of their positive charges, these drugs do not enter the systemic circulation or the CNS, isolating their effects to the pulmonary system. *Tiotropium* is administered once daily, a major advantage over *ipratropium*, which requires dosing up to four times daily. Important characteristics of the muscarinic antagonists are summarized in Figures 5.6 and 5.7.
D. Tropicamide and cyclopentolate
These agents are used as ophthalmic solutions for mydriasis and cycloplegia. Their duration of action is shorter than that of atropine. Tropicamide produces mydriasis for 6 hours and cyclopentolate for 24 hours.

E. Benztropine and trihexyphenidyl
Benztropine and trihexyphenidyl are useful as adjuncts with other antiparkinsonian agents to treat Parkinson’s disease (see Chapter 8) and other types of parkinsonian syndromes, including antipsychotic-induced extrapyramidal symptoms.

F. Darifenacin, fesoterodine, oxybutynin, solifenacin, tolterodine, and trospium chloride
These synthetic atropine-like drugs are used to treat overactive bladder. By blocking muscarinic receptors in the bladder, intravesical pressure is lowered, bladder capacity is increased, and the frequency of bladder contractions is reduced. Side effects include dry mouth, constipation, and blurred vision, which limit tolerability of these agents if used continually. Oxybutynin [ox-i-BYOO-tin] is available as a transdermal system (topical patch), which is better tolerated because it causes less dry mouth than oral formulations. The overall efficacies of these antimuscarinic drugs are similar.

III. GANGLIONIC BLOCKERS
Ganglionic blockers specifically act on the nicotinic receptors of both parasympathetic and sympathetic autonomic ganglia. Some also block the ion channels of the autonomic ganglia. These drugs show no selectivity toward the parasympathetic or sympathetic ganglia and are not effective as neuromuscular antagonists. Thus, these drugs block the entire output of the autonomic nervous system at the nicotinic receptor. Except for nicotine, the other drugs mentioned in this category are nondepolarizing, competitive antagonists. The responses of the nondepolarizing blockers are complex and mostly unpredictable. Therefore, ganglionic blockade is rarely used therapeutically, but often serves as a tool in experimental pharmacology.

A. Nicotine
A component of cigarette smoke, nicotine [NIK-oh-teen], is a poison with many undesirable actions. It is without therapeutic benefit and is deleterious to health. Depending on the dose, nicotine depolarizes autonomic ganglia, resulting first in stimulation and then in paralysis of all ganglia. The stimulatory effects are complex and result from increased release of neurotransmitters (Figure 5.8), due to effects on both sympathetic and parasympathetic ganglia. For example, enhanced release of dopamine and norepinephrine may be associated with pleasure as well as appetite suppression. The overall response of a physiologic system is a summation of the stimulatory and inhibitory effects of nicotine. These include increased blood pressure and cardiac rate (due to release of transmitter from

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<td>Benztropine</td>
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<td>Darifenacin</td>
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<td>Oxybutynin</td>
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<td>Tropicamide</td>
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<td>Tiotropium</td>
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Figure 5.7
Summary of cholinergic antagonists. *Contraindicated in angle-closure glaucoma. GI = gastrointestinal; COPD = chronic obstructive pulmonary disease.
adrenergic terminals and from the adrenal medulla) and increased peristalsis and secretions. At higher doses, the blood pressure falls because of ganglionic blockade, and activity in both the GI tract and bladder musculature ceases (see Chapter 16 for a full discussion of nicotine).

IV. NEUROMUSCULAR-BLOCKING AGENTS

These drugs block cholinergic transmission between motor nerve endings and the nicotinic receptors on the skeletal muscle (Figure 5.2). They possess some chemical similarities to ACh, and they act either as antagonists (nondepolarizing type) or as agonists (depolarizing type) at the receptors on the endplate of the NMJ. Neuromuscular blockers are clinically useful during surgery to facilitate tracheal intubation and provide complete muscle relaxation at lower anesthetic doses, allowing for more rapid recovery from anesthesia and reducing postoperative respiratory depression.

A. Nondepolarizing (competitive) blockers

The first drug known to block the skeletal NMJ was curare [kyoo-RAH-ree], which native South American hunters of the Amazon region used to paralyze prey. The development of the drug tubocurarine [too-boe-kyoo-AR-een] followed, but it has been replaced by other agents with fewer adverse effects, such as cisatracurium [cis-a-trah-CURE-ih-um], pancuronium [pan-kure-OH-nee-um], rocuronium [roe-kyoor-OH-nee-um], and vecuronium [ve-KYOO-roe-nee-um]. The neuromuscular-blocking agents have significantly increased the safety of anesthesia, because less anesthetic is required to produce muscle relaxation, allowing patients to recover quickly and completely after surgery. Neuromuscular blockers should not be used to substitute for inadequate depth of anesthesia.

1. Mechanism of action:

a. **At low doses:** Nondepolarizing agents competitively block ACh at the nicotinic receptors (Figure 5.9). That is, they compete with ACh at the receptor without stimulating it. Thus, these drugs prevent depolarization of the muscle cell membrane and inhibit muscular contraction. Their competitive action can be overcome by administration of cholinesterase inhibitors, such as neostigmine and edrophonium, which increase the concentration of ACh in the neuromuscular junction. Anesthesiologists employ this strategy to shorten the duration of the neuromuscular blockade. In addition, at low doses the muscle will respond to direct electrical stimulation from a peripheral nerve stimulator to varying degrees, allowing for monitoring of the extent of neuromuscular blockade.

b. **At high doses:** Nondepolarizing agents can block the ion channels of the motor endplate. This leads to further weakening of neuromuscular transmission, thereby reducing the ability of
cholinesterase inhibitors to reverse the actions of the nondepolarizing blockers. With complete blockade, the muscle does not respond to direct electrical stimulation.

2. **Actions:** Not all muscles are equally sensitive to blockade by competitive agents. Small, rapidly contracting muscles of the face and eye are most susceptible and are paralyzed first, followed by the fingers, limbs, neck, and trunk muscles. Next, the intercostal muscles are affected and, lastly, the diaphragm. The muscles recover in the reverse manner.

3. **Pharmacokinetics:** All neuromuscular-blocking agents are injected intravenously or occasionally intramuscularly since they are not effective orally. These agents possess two or more quaternary amines in their bulky ring structure that prevent their absorption from the gut. They penetrate membranes very poorly and do not enter cells or cross the blood–brain barrier. Many of the drugs are not metabolized, and their actions are terminated by redistribution (Figure 5.10). For example, *pancuronium* is excreted unchanged in urine. *Cisatracurium* is degraded spontaneously in plasma and by ester hydrolysis. [Note: *Atracurium* has been replaced by its isomer, *cisatracurium*. *Atracurium* releases histamine and is metabolized to laudanosine, which can provoke seizures. *Cisatracurium*, which has the same pharmacokinetic properties as *atracurium*, is less likely to have these effects.] The amino steroid drugs *vecuronium* and *rocuronium* are deacetylated in the liver, and their clearance may be prolonged in patients with hepatic disease. These drugs are also excreted unchanged in bile. The choice of an agent depends on the desired onset and duration of the muscle relaxation. The onset, duration of action, and other characteristics of the neuromuscular-blocking drugs are shown in Figure 5.11.

4. **Adverse effects:** In general, these agents are safe with minimal side effects. The adverse effects of the specific neuromuscular blockers are shown in Figure 5.11.

5. **Drug interactions:**

   a. **Cholinesterase inhibitors:** Drugs such as *neostigmine*, *physostigmine*, *pyridostigmine*, and *edrophonium* can overcome the action of nondepolarizing neuromuscular blockers. However, with increased dosage, cholinesterase inhibitors can cause a depolarizing block as a result of elevated ACh concentrations at the endplate membrane. If the neuromuscular blocker has entered the ion channel, cholinesterase inhibitors are not as effective in overcoming blockade.

   b. **Halogenated hydrocarbon anesthetics:** Drugs such as *desflurane* act to enhance neuromuscular blockade by exerting a stabilizing action at the NMJ. These agents sensitize the NMJ to the effects of neuromuscular blockers.

   c. **Aminoglycoside antibiotics:** Drugs such as *gentamicin* and *tobramycin* inhibit ACh release from cholinergic nerves by competing with calcium ions. They synergize with *pancuronium* and other competitive blockers, enhancing the blockade.
d. Calcium channel blockers: These agents may increase the neuromuscular blockade of competitive blockers.

B. Depolarizing agents

Depolarizing blocking agents work by depolarizing the plasma membrane of the muscle fiber, similar to the action of ACh. However, these agents are more resistant to degradation by acetylcholinesterase (AChE) and can thus more persistently depolarize the muscle fibers. Succinylcholine [suk-sin-il-KOE-leen] is the only depolarizing muscle relaxant in use today.

1. Mechanism of action: Succinylcholine attaches to the nicotinic receptor and acts like ACh to depolarize the junction (Figure 5.12). Unlike ACh, which is instantly destroyed by AChE, the depolarizing agent persists at high concentrations in the synaptic cleft, remaining attached to the receptor for a relatively longer time and providing constant stimulation of the receptor. [Note: The duration of action of succinylcholine is dependent on diffusion from the motor endplate and hydrolysis by plasma pseudocholinesterase. Genetic variants in which plasma pseudocholinesterase levels are low or absent lead to prolonged neuromuscular paralysis.] The depolarizing agent first causes the opening of the sodium channel associated with the nicotinic receptors, which results in depolarization of the receptor (Phase I). This leads to a transient twitching of the muscle (fasciculations). Continued binding of the depolarizing agent renders the receptor incapable of transmitting further impulses. With time, continuous depolarization gives way to gradual repolarization as the sodium channel closes or is blocked. This causes a resistance to depolarization (Phase II) and flaccid paralysis.

2. Actions: As with the competitive blockers, the respiratory muscles are paralyzed last. Succinylcholine initially produces brief muscle fasciculations that cause muscle soreness. This may be prevented by administering a small dose of nondepolarizing neuromuscular blocker prior to succinylcholine. Normally, the duration of action of succinylcholine is extremely short, due to rapid hydrolysis by plasma pseudocholinesterase. However, succinylcholine that gets to the NMJ is not metabolized by AChE, allowing the agent to bind to nicotinic receptors, and redistribution to plasma is necessary for metabolism (therapeutic benefits last only for a few minutes).

3. Therapeutic uses: Because of its rapid onset of action, succinylcholine is useful when rapid endotracheal intubation is required during the induction of anesthesia (a rapid action is essential if aspiration of gastric contents is to be avoided during intubation). It is also used during electroconvulsive shock treatment.

4. Pharmacokinetics: Succinylcholine is injected intravenously. Its brief duration of action results from redistribution and rapid hydrolysis by plasma pseudocholinesterase. Therefore, it is sometimes

Figure 5.11
Onset and duration of action of neuromuscular-blocking drugs.
given by continuous infusion to maintain a longer duration of effect. Drug effects rapidly disappear upon discontinuation.

5. Adverse effects:

a. Hyperthermia: Succinylcholine can potentially induce malignant hyperthermia in susceptible patients (see Chapter 13).

b. Apnea: Administration of succinylcholine to a patient who is deficient in plasma cholinesterase or who has an atypical form of the enzyme can lead to prolonged apnea due to paralysis of the diaphragm. The rapid release of potassium may also contribute to prolonged apnea in patients with electrolyte imbalances who receive this drug. In patients with electrolyte imbalances who are also receiving digoxin or diuretics (such as heart failure patients) succinylcholine should be used cautiously or not at all.

c. Hyperkalemia: Succinylcholine increases potassium release from intracellular stores. This may be particularly dangerous in burn patients and patients with massive tissue damage in which potassium has been rapidly lost from within cells.

Study Questions

Choose the ONE best answer.

During an ophthalmic surgical procedure, the surgeon wanted to constrict the pupil of the patient using a miotic drug. However, he accidentally used another drug that caused dilation of the pupil (mydriasis) instead. Most likely, which of the following drugs did he use?

A. Acetylcholine.
B. Pilocarpine.
C. Tropicamide.
D. Phentolamine.
E. Bethanechol.

Correct answer = C. Muscarinic agonists such as ACh, pilocarpine, and bethanechol contract the circular muscles of iris sphincter and cause constriction of the pupil (miosis), whereas muscarinic antagonists such as atropine and tropicamide prevent the contraction of the circular muscles of the iris and cause dilation of the pupil (mydriasis). α-Adrenergic agonists such as phentolamine relax the radial muscles of the iris and cause miosis.
Sarin is a nerve gas that is an organophosphate cholinesterase inhibitor. Which of the following could be used as an antidote to sarin poisoning?

A. Pilocarpine.
B. Carbachol.
C. Atropine.
D. Physostigmine.
E. Nicotine.

Correct answer = C. Sarin is an organophosphate cholinesterase inhibitor. It causes an increase in ACh levels in tissues that leads to cholinergic crisis by the activation of muscarinic as well as nicotinic receptors. Most of the symptoms of cholinergic crisis are mediated by muscarinic receptors and, therefore, the muscarinic antagonist atropine is used as an antidote for sarin poisoning. Cholinergic agonists such as pilocarpine, carbachol, physostigmine (indirect agonists), and nicotine will worsen the symptoms of sarin poisoning.

Atropine is one of the ingredients in the antidiarrheal combination diphenoxylate/atropine available in the United States. Which of the following effects is produced by atropine that contributes to its antidiarrheal effect?

A. Increase in gastrointestinal motility.
B. Reduction in gastrointestinal motility.
C. Increase in salivation.
D. Increase in acid secretion.
E. None of the above.

Correct answer = B. Muscarinic agonists produce an increase in gastrointestinal motility, salivation, and acid secretion. Atropine is a muscarinic antagonist and therefore causes a reduction in gastrointestinal motility that contributes to its antidiarrheal effect.

A patient with chronic obstructive pulmonary disease (COPD) was prescribed a β2 agonist for the relief of bronchospasm. However, the patient did not respond to this treatment. Which of the following drugs or classes of drugs would you suggest for this patient as the next option?

A. β1 Agonist.
B. Muscarinic agonist.
C. Physostigmine.
D. Ipratropium.
E. Phenotolamine.

Correct answer = D. Major receptors present in the bronchial tissues are muscarinic and adrenergic-β2 receptors. Muscarinic activation causes bronchoconstriction, and β2 receptor activation causes bronchodilation. Therefore, direct or indirect (physostigmine) muscarinic agonists will worsen bronchospasm. Ipratropium is a muscarinic antagonist that can relax bronchial smooth muscles and relieve bronchospasm in patients who are not responsive to β2 agonists. α1 and β1 receptors are not commonly present in bronchial tissues and, therefore, β2 agonists or α antagonists (phenotolamine) do not have any significant effects on bronchospasm.

Which of the following drugs would be the most effective anti-motion sickness drug for a person planning to go on a cruise?

A. Atropine.
B. Tropicamide.
C. Scopolamine.
D. Darifenacin.
E. Tiotropium.

Correct answer = C. All muscarinic antagonists (anticholinergic drugs) listed above are theoretically useful as anti-motion sickness drugs; however, scopolamine is the most effective in preventing motion sickness in practice. Tropicamide mostly has ophthalmic uses, and tiotropium is used for respiratory disorders (COPD). Darifenacin is used for overactive bladder.

Which of the following is correct regarding ganglion-blocking drugs?

A. Blockade of sympathetic ganglia could result in reduced blood pressure.
B. Blockade of parasympathetic ganglia could result in reduced heart rate.
C. Nicotine is a nondepolarizing ganglion blocker.
D. Atropine is a nondepolarizing ganglion blocker.

Correct answer = A. Selective blockade (in theory) of the sympathetic ganglion causes reduction in norepinephrine release and therefore reduction in heart rate and blood pressure. Selective blockade (in theory) of the parasympathetic ganglion causes reduction in ACh release and therefore an increase in heart rate. Receptors at both sympathetic and parasympathetic ganglia are of the nicotinic type. Nicotine is an agonist at nicotinic receptors and produces a depolarizing block in the ganglia. Atropine is a muscarinic antagonist and has no effect on the nicotinic receptors found in the ganglia.
Which of the following is correct regarding the neuromuscular blockers (NMBs)?
A. Nondepolarizing NMBs are administered orally.
B. Cholinesterase inhibitors reduce the effects of nondepolarizing NMBs.
C. Nondepolarizing NMBs affect diaphragm muscles first.
D. Effects of depolarizing neuromuscular blockers can be reversed using cholinesterase inhibitors.

Correct answer = B. Nondepolarizing NMBs such as cisatracurium and vecuronium are highly polar compounds and are poorly absorbed from the GI tract. Therefore, they are administered parenterally, not orally. Nondepolarizing NMBs are competitive antagonists at nicotinic receptors. Therefore, increasing the levels of ACh at the neuromuscular junction reduces the effects of these agents. Cholinesterase inhibitors increase the levels of ACh at the neuromuscular junction and reduce the effects of nondepolarizing NMBs, but may enhance (not reverse) the effects of depolarizing NMBs. Nondepolarizing NMBs first affect rapidly contracting muscles seen in the face and eyes and affect the diaphragm muscles last.

Correct answer = C. Halogenated hydrocarbon anesthetics such as desflurane enhance the effects of nondepolarizing NMBs by exerting a stabilization effect at the neuromuscular junction (NMJ). Acetylcholinesterase inhibitors increase the levels of ACh at the NMJ and reduce the effects of nondepolarizing NMBs. Aminoglycoside antibiotics increase the effects of nondepolarizing NMBs by reducing the release of ACh from the cholinergic neurons. Calcium channel blockers increase the effects of nondepolarizing NMBs, possibly by affecting ion transport at the NMJ.

Correct answer = A. There are two types of NMBs: depolarizing and nondepolarizing NMBs. Depolarizing NMBs are agonists at the nicotinic receptors, whereas nondepolarizing NMBs are antagonists at the nicotinic receptors. Both types of NMBs affect the rapidly contracting muscles (face, eye, etc.) first and diaphragm muscles last. However, cholinesterase inhibitors such as neostigmine increase ACh levels in the NMJ and reverse the effects of nondepolarizing NMBs, but not those of depolarizing NMBs. Therefore, the NMB administered to this patient is most probably rocuronium, which is a nondepolarizing NMB. Tubocurarine is also a nondepolarizing NMB, but it is not used in practice. Succinylcholine is a depolarizing NMB, and diazepam is a benzodiazepine that does not cause paralysis of skeletal muscles.

Correct answer = B. Depolarizing NMBs cause muscle fasciculations before causing paralysis, and their effects cannot be reversed using cholinesterase inhibitors such as neostigmine. Nondepolarizing NMBs do not cause muscle fasciculations, and their effects can be reversed using cholinesterase inhibitors. Therefore, the NMB used in this patient is succinylcholine, which is a depolarizing NMB. Cisatracurium and tubocurarine are nondepolarizing NMBs, and diazepam does not cause paralysis of skeletal muscles.

Which of the following is correct regarding drug interactions with nondepolarizing neuromuscular blockers (NMBs)?
A. Desflurane reduces the effects of nondepolarizing NMBs.
B. Cholinesterase inhibitors increase the effects of nondepolarizing NMBs.
C. Aminoglycosides increase the effects of nondepolarizing NMBs.
D. Calcium channel blockers reduce the effects of nondepolarizing NMBs.

A patient was administered a neuromuscular blocker (NMB) prior to a surgical procedure to produce skeletal muscle paralysis. This NMB drug affected small, rapidly contracting muscles of the face and eyes first and diaphragm muscles last. The effect of this drug was easily reversed with neostigmine. Which of the following neuromuscular blockers was most likely administered to this patient?
A. Rocuronium.
B. Succinylcholine.
C. Diazepam.
D. Tubocurarine.

A patient was administered a neuromuscular blocker (NMB) prior to a surgical procedure to produce skeletal muscle paralysis. This NMB drug caused initial skeletal muscle fasciculations before the onset of paralysis. The effect of this drug could not be reversed with neostigmine. Which of the following neuromuscular blockers was most likely administered to this patient?
A. Cisatracurium.
B. Succinylcholine.
C. Diazepam.
D. Tubocurarine.